# The Eleven Pictures of Time

## *The Physics, Philosophy, and Politics of Time Beliefs*


C.K. Raju

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प्रणम्य शिरसा कालमभिवाद्य सरस्वतीम
कालज्ञानं प्रवक्ष्यामि...

*Saluting Time and the Goddess of Learning, Saraswati,*
*I now begin my discourse on the knowledge of Time....*

*Ṛgveda Vedanga Jyotiṣa*

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# Preface

Time is where science meets religion. The interaction between science and culture is mediated by time beliefs: changing time beliefs changes scientific theory on the one hand, and values on the other. Mapping time beliefs thus provides a way to understand and *to demonstrate* how culture has influenced science, and how science is influencing culture. This science-culture interaction through time beliefs is inevitably enmeshed with politics, for cultural values govern the behaviour of very many people, and attempts to influence human behaviour by manipulating cultural values have ended up manipulating time beliefs. Such a theme naturally demands the widest possible audience.

Some seven years ago, when I set out to write this book as a sequel to my first book on time in physics, my aim was to present to a lay audience the science-culture interaction through time beliefs. Further, I aimed to emphasize a non-Western perspective which considered science in relation to time beliefs in various religions, rather than 'religion' alone. To reach a large readership, I thought of presenting this book as a sort of rejoinder to books like Stephen Hawking's *A Brief History of Time*.

As the book developed, the enormity of the task that I had undertaken started becoming apparent. I found the book moving from the interface of science and religion to eschatology, to church history, to current politics, to the sociology of science, to physics proper, to the philosophy and history of science, to sociology, to comparative religions, to ethics. The movement was unavoidable, since time impinges on so many aspects of our life and thought that all these subjects had necessarily to be involved in the attempt to understand that single term—time—from a fresh perspective. It seemed worthwhile to attempt to understand all this, since so much of our way of life depends upon what we believe about the nature of time. Indeed, writing this book has been a richly fulfilling experience, just because of the clarity and understanding that I acquired in the process. But it was not easy to present this understanding in a way that would be intelligible to someone with no technical background.

Thus, the final result seems like a book which, in its entirety, will demand some persistence from an entirely lay reader; but it does not assume any specialised knowledge, and so remains accessible to the non-specialist. While the linkages of science and culture are intrinsically complex, and confusing, I have tried hard to make this book as easy as possible. I hope, therefore, that much, if not all, that I have to say, would still get across to almost everyone.

**P.S.** Given the recent events in India, of rising violence in the name of religion, a postscript to this preface is essential. This book should not be misconstrued as being slanted for or against any particular religion. I believe that those who seek to attain or retain state power through religion are undoubtedly the worst enemies of the religion, whatever be the religion they claim to represent: Christianity, Islam, or Hinduism.

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## Notes

- Do feel free to read this book in bits and pieces, starting with the most interesting bits, and moving backward or forward for more details.
- To skip a chapter, read the summary at the end of that chapter.
- Chapter summaries are collected together at the end of the book, under *The Argument*, to help link chapters and parts.
- Do check under *Glossary* and *Persons* not only for details on unfamiliar words and names, but also for some familiar words used in a specific sense.
- Page numbers in brackets are cross-references to pages in this book.

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# Prologue

# Time, Science, and Religion

There is an old story of a fisherman who saw a mermaid and instantly fell in love with her. Afraid she would disappear, he told her he loved her. The mermaid first laughed, and then cried. The puzzled fisherman asked why, and she explained that she had laughed because she was happy, for she had surfaced because she loved him. And she cried because they couldn't marry. 'To marry me', she said sadly, 'you will have to lose your soul.' So the fisherman rushed to the priest to ask how he could lose his soul. The priest refused to oblige. 'Never part with your soul', he warned, 'your soul is more precious than all the gold in the world!' But the fisherman did not heed the warning for he was madly in love. Instead, the thought of gold gave him an idea. 'The merchant will surely want it then', thought the fisherman, 'and he will find a way to relieve me of my soul.' So the fisherman ran to the merchant. But the merchant laughed. 'I will gladly pay for your body', he said, 'but your soul is of no use to me!' In the modern ending to this story, the dejected fisherman went to the scientist for help. But the scientist pooh-poohed him. 'You don't have a soul, so how can you lose it?' he asked. 'Besides, there are no mermaids', he admonished. (As if to prove the scientist right, by the time the fisherman returned, the mermaid had vanished.)

The Priest, the Scientist, and the Merchant are the principal characters in this story of the eleven pictures of time. The Fisherman remains a bystander, a bit like you and me, trying hard to reconcile his experiences and emotions with their weighty sayings that concern the core of his being: the soul.

What has the soul got to do with time?

# PART 1

# TIME AND ESCHATOLOGY

What does the soul have to do with time?

The soul relates to time through life after death: there is life after death, in a simple literal sense, if time is quasi-cyclic. (Quasi-cyclic time should not be confused with eternal recurrence.)

Belief in life after death has tended to decide conduct in everyday life *before* death. The belief in 'cyclic' time was also used to promote equity. But equity became unacceptable to the church after its marriage to the state: for rejecting the church now meant rejecting the state. To reject equity, the church cursed cyclic time. In terms of life after death, the church changed the belief in *reincarnation* (repeated lives after death) to the belief in *resurrection* (life after death just once, and for ever, after the apocalypse). The church now taught that the end of time would see not the equitable union of all souls, but their permanent separation into heaven and hell. Conduct in everyday life changed with the changed belief about life after death.

Cultural lineages are long lived. The changed time belief has persisted down the ages, and is incorporated also in current physics: Stephen Hawking's entire theory of time hinges on a postulated rejection of 'cyclic' time. Both Augustine and Hawking ultimately rely on the same invalid argument which confounds quasi-cyclic time with eternal recurrence, by supposing that there are only two pictures of time—'linear' and 'cyclic'.

Strangely enough, this link between science and religion, via time beliefs, has been strengthened by current politics. After the Cold War, an attempt is on to consolidate power and create a unipolar world: a process now called globalisation. To achieve this goal, a key strategy is to enhance the 'soft power' of the West by globalising culture and values, and establishing a universal church in the sense of Toynbee. This requires globally standardised 'appropriate' values, a prerequisite also for the globalisation of information capitalism.

The difficulty is that neither 'religion' nor science can, by itself, provide a compelling basis for the 'appropriate' global values. Despite the earlier harmony of science and 'religion', the later image of a quarrel between science and 'religion' has led to *(a)* a loss of credibility for the church, and *(b)* the truce that science is value-free. Hence, the authority of a particular religion is sought to be restored by stressing the congruence of its key beliefs with science. This congruence has less to do with the nature of the physical world, and more to do with the fact that both science and 'religion' have for long been instruments of the state. The linkage of science to the requirements of profit and war has created 'information poverty': reducing most people to a state of scientific illiteracy, or semi-literacy, where they have little choice but to rely on the opinion of socially recognised specialists. Under these conditions, the authority of science and scientists can easily be misused by the state to promote values and a religion of its choosing.

Time remains the link between science and religion; so this attempt to restore the authority of 'religion' through science once again seeks to mislead people by manipulating time beliefs in science. Creation (beginning of time) and immortality (end of time) are the two key points on which the new harmony of science and 'religion' is founded. Thus, the attempt is to relate (1) the doctrine of creation to the beginning of the cosmos (using the big-bang cosmology and Hawking's singularities to establish a beginning of time), and (2) the doctrine of immortality (resurrection) to the long-term future of the cosmos, again relying on the theory of Penrose and Hawking.

# 1

# Life after Death

> 'When a man dies, there is this doubt: Some say, he is; others say, he is not.
> Taught by you, I would know the truth…'
> 'Nay' replied Death, 'even the gods were once puzzled by this mystery.
> Subtle indeed is the truth regarding it, not easy to understand.'
>
> ***Kaṭha Upaniṣad*[1]**
> **1.1.20–21**

Belief in life after death is basic to many religions. The belief is that one's 'soul' continues to exist, in some sense or the other, after death. Non-believers reject this belief as firmly as believers accept it, but both have this tiny residual doubt: what, after all, is the truth about life after death? Doubts cannot be dispelled without first airing them; but airing such doubts would be considered a little indecent, because after-death is taboo.

Some people respect the taboo for a different reason. They think the very thought of life after death is a sign of weakness, for they are convinced that it is the fear of death that causes one to hope for life after death. This way of thinking is not particularly new. Indeed, the belief in life after death has been related to fear of death at least since Julius Caesar: he explained that he lost to the Celts because their belief 'that souls do not become extinct' made them fearless! Wasn't the great Caesar only making excuses? For is this way of thinking correct?

A *correlation* there is—belief in life after death lessens the fear of death—but can one say that fear of death is the *cause* of the belief in life after death? Can one say, 'psychology favours this belief, *hence* the belief can have no physical basis'? There is a strange difficulty here: in speaking of psychological causes of a belief, we involve the notion of *cause*. This notion of *cause* relates to the nature of time as does the belief in life after death! This strange difficulty makes any scientific re-examination of life after death very tricky, for one must first sort out the problem with time beliefs in science. But the difficulty has gone unnoticed—few scientists have tried to re-examine life after death, for everyone knows that after-death is the province of religion.

Now, a taboo is a practical matter. Whatever the reasons for observing it, the practical endorsement of the taboo about after-death definitely helps the priest to continue to make a living, for in most societies a priest is traditionally indispensable when someone dies. So long as no one else talks about death and after-death, religious organisations can continue to earn large sums of money by claiming life after death as their special province, by social sanction. Religious personages can continue to claim that tradition, and their authority within a religious organisation, is sufficient proof of their special knowledge about life after death. And they can use this authority to guide people along channels consonant with their own political interests. The doubts, therefore, need to be aired, even if at first it does seem a bit indecent to talk about life after death.

What actually happens after death? When someone dies and, say, the body is burnt, memories of the person may linger in our minds. But what else remains of the person apart from the ashes? Is there an intangible residue? Even the believers believe that the notion of the soul will never be explained clearly. In 1981, a Gallup poll[2] found that about 67 per cent adult U.S. citizens believe in life after death, but only 20 per cent of them think the belief will ever be 'scientifically proved'. (But that 20 per cent is an influential minority hard at work as we shall see in Chapter 3.)

Actually, nothing can ever be 'scientifically proved'; ideally, the scientist's first concern is with *refutability*, that is, with identifying circumstances under which the belief could *conceivably* be false. A refutable belief is one that is testable in theory. The next concern is to design a practical test and carry it out.

Some 2500 years ago, Pāyāsi, a chieftain from Bihar, in India, did exactly that. He performed some macabre experiments with condemned felons to try to catch a glimpse of the soul. He described how he ordered his men to

> '…throw this man alive into a jar, close the mouth of it and cover it with wet leather, put over that a thick cement of moist clay, put it on to a furnace and kindle a fire.' They saying 'Very good' would obey me and…kindle a fire. When we know that the man is dead, we should take down the jar, unbind and open the mouth and quickly observe it, with the idea: 'Perhaps we may see the soul of him coming out!' We don't see the soul of him coming out!…'Weigh him alive; then strangle him with a bowstring and weigh him again.'[3]

After some 30 experiments of this kind, Pāyāsi concluded that the soul did not exist. He had a long debate with the boy-wanderer Kassapa, who disagreed with this conclusion, and argued that the soul could not be seen or weighed.

Now it may be that the soul is an abstraction that cannot be seen or weighed—but that does not do away with the requirement of testability. Abstraction is acceptable, but lack of testability is not: a 'soul' whose existence cannot be tested would be, for the scientist, a word, a *meaningless* noise, devoid of empirical content. If Pāyāsi's tests are unacceptable, how, then, should one test the existence of the soul?

The requirement of testability forces us to be as clear-headed as possible about the notion of the soul. What is this mysterious *ātman* or 'soul'? Setting aside both the taboo against death, and the association of after-death with pseudo science, let us examine afresh the varied answers to this question, to locate an answer that is clear, meaningful, and testable.

Let us start by asking questions that try to pin down specific *details* of the belief in life after death: when? where? in what form? how often? for how long? is there an intermediate stage? is there an end even to life after death? what is the purported empirical evidence? etc. Diverse answers to these questions show that there are varied forms of the belief in life after death. A convenient threefold classification is the following:

**(i) The naive view.** A person dies and is born again in a different body immediately or shortly after death.

**(ii) The early view.** A person is periodically reborn, possibly with some alteration, after a long time, in recurrent phases of the cosmos.

**(iii) The post-Christian view.** A person is resurrected precisely once, in the flesh, for an eternity of time, in heaven or hell, after universal apocalypse, due any time now.

The differences between these three views are shown in more detail in Table 1.

**Table 1**
Three Different Views of the Soul

| *Question* | *Naive View* | *Early View* | *Post-Christian View* |
|---|---|---|---|
| *When* is a person reborn? | Almost immediately after death, the soul leaves one body and occupies another. | Periodically, a long time (several billion years) after death, when the cosmos recurs. | Exactly once, on the Day of Judgment, around the corner. |
| *What* is the soul? | Astral body, something which can perhaps even be seen or weighed. | An abstraction that relates an individual in one cycle of the cosmos to a similar individual in another cycle of the cosmos. | Made of soul substance. But resurrection will be in the flesh. |
| *Where* is the soul located? | Somewhere in the body, in the heart perhaps. | In the innermost part of one's being. (Abstractions have no location.) | In the third eye (pineal gland) according to Descartes. |
| Can one recall one's previous lives? | Yes. (Some people can.) | ?* (Memory must also commence afresh.) | Yes. (One must remember one's past sins!) |
| Does life after death end? | Don't know. | Yes. | No. |
| Do animals have souls? | Yes. | Yes. | No. |

*There are diverse views. The idea that identity may continue without memory is novel in the West, but Buddhism permits memory to continue without any continuation of identity! (See Chapter 11, p. 371.)

Of these three views about life after death, the post-Christian view is postponed to the next chapter, and it will soon be clear that the naive view is indefensible. This chapter will focus on the early view, as it appears in myth, symbol, and tradition from around the world.

## *The Butterfly's Dream*

The soul has been visualised as a tiny winged creature. The Greek word for soul is *psyche* which also means butterfly—the soul was depicted by a butterfly in early Greek art. Salvador Dali explained that the butterfly recurs also in his paintings not 'because it is in itself a thing of beauty…' but because

> the butterfly was the symbol of the soul. The ugly, ungainly caterpillar, our body, enters a form of the grave, the cocoon. Out of this death emerges the butterfly—beautiful, free, no longer earthbound…the soul of man.[4]

After death, it was supposed, the butterfly-soul emerged from some orifice in the body and flew away; on a tomb in Italy is engraved a butterfly issuing from the open mouth of a death mask. Rituals still incorporate this belief—the ritual of plugging the nose of the dead person, or saying 'God bless' when someone sneezes, for example. In medieval Christian art, the souls of the dead were depicted as angels, and it takes but a little imagination to see how butterflies may have evolved into angels with gossamer wings. In Scottish Gaelic, one of the names of the butterfly is *teine de*, 'fire of God', another is *dealan de*, 'brightness of God'. The butterfly was regarded as a symbol of fertility and of the soul in pre-Columbian Mexico.[5]

The butterfly was also related to the soul in China. There is the famous story of the Chinese philosopher who dreamt that he was a butterfly and awoke to find to his astonishment that he was Chuang Tzu. It was hard for him to be sure whether he really was Chuang Tzu and had only dreamt that he was a butterfly, or he really was a butterfly and was only dreaming that he was Chuang Tzu. The connection with the butterfly-soul is in the last part of the story, which is not so well known: 'Between a man and a butterfly there is necessarily a barrier. The transition is called metempsychosis.'[6] But only the simple-minded will take the butterfly metaphor literally.

## *Remembering Past Lives*

If the soul is not a tiny, winged creature which escapes from one body to occupy another, what connects the two bodies in question: memory? If the present life is not the last, it is presumably also not the first. But most of us, at any rate, do not remember any former life—as the Old Testament acknowledges (Eccl. 1:9–11), 'there is no remembrance of former things'. Nevertheless, in Indian traditions, it was believed that the actions (*karma*) of the previous life decided the dispositions (*saṁskāra*) in the present life. It was believed that through special effort one could remember one's past life; for example, the *Jātaka* tales represent the Buddha's memories of the chain of his past lives.

Socrates claimed that anyone could recollect his past lives: and the proof was that an untutored slave boy had an innate knowledge of geometry. (Socrates' claim made quite a stir, for Greek philosophers held geometry in high regard, while Greek democracy envisioned typically five slaves to every free man.) Socrates put forward his theory in a little speech.

> The soul, then, as being immortal, and having been born again many times and having seen all the things that exist, whether in this world or in the world below, has knowledge of them all; and it is no wonder that she should be able to call to remembrance all that she ever knew about virtue and about everything; for as all nature is akin, and the soul has learned all things, there is no difficulty in her in eliciting or as men say learning out of a single recollection all the rest, if a man is strenuous and does not faint; for all enquiry and all learning is but recollection.[7]

Briefly, Socrates' argument was that a memory of past lives was buried inside one in the form of an innate knowledge of the world, that learning was but the recollection of this innate knowledge, and that this recollection could be aided by the questioning of a philosopher who played the role of a midwife. The speech was followed by a practical demonstration of the existence of the soul: Socrates asked the right questions to elicit the slave boy's knowledge of geometry. At any rate, Socrates demonstrated that the slave boy's 'mathematical intuition' was not too far removed from that of Euclid!

Proclus of Alexandria, a key expositor of 'Euclidean' geometry, and its first actual source, not only subscribed to the doctrine that all learning is recollection, he hence advocated the teaching of mathematics as a religious practice for the good of the soul.

> Pythagoreans recognized that everything we call learning is remembering…although evidence of such learning can come from many areas, it is especially from mathematics that they come, as Plato also remarks. 'If you take a person to a diagram' he says [Phaedo 73b], 'then you can show most clearly that learning is recollection.' That is why Socrates in the Meno uses this kind of argument. This part of the soul has its essence in mathematical ideas, and it has a prior knowledge of them…[8]

This is the thought with which Proclus concludes the first part of his prologue to the *Elements*:

> This, then, is what learning [mathesiz] is, recollection of the eternal ideas in the soul, and this is why the study that especially brings us the recollection of these ideas is called the science concerned with learning [mathematike]. Its name thus makes clear what sort of function this science performs. It arouses our innate knowledge…takes away the forgetfulness and ignorance [of our former existence] that we have from birth…fills everything with divine reason, moves our souls towards Nous…and through the discovery of pure Nous leads us to the blessed life.[9]

For Proclus, mathematics was not a 'secular' activity, but the key means of propagating his fundamental religious beliefs about life after death.

The poet Shelley went for a thoughtful walk after reading the above passage from Plato. On the way, he grabbed a baby and earnestly asked its mother, ' "Will your baby tell us anything about pre-existence, madam?"…"He cannot speak, sir", said the mother seriously. "Worse, worse", cried Shelley with an air of disappointment…"But surely the babe can speak if he will…He may fancy that he cannot, but it is only a silly whim. He cannot have forgotten the use of speech in so short a time. The thing is absolutely impossible…" Shelley sighed [and] walked on. "How provokingly close are these new-born babes! but it is not the less certain, notwithstanding the cunning attempts to conceal the truth, that all knowledge is reminiscence." '[10]

The debate on the idea of soul as memory has continued. In this century, Ducasse argued, '…if absence of memory of having existed at a certain time proved that we did not exist at that time, it would then prove far too much; for it would prove that we did not exist during the first few years of the life of our present body…'[11] Leibniz had defended the idea that identity can meaningfully continue only with memory: 'Of what use would it be to you, Sir, to be born King of China on condition that you forgot what you had been? Would it not be the same as if God, at the same time that he destroyed you, created a king in China?'

Raymond Moody has tried to dispel this philosophical confusion by empirically investigating near-death experiences—taking the metaphor somewhat literally in supposing that those at the door of death are the most qualified to speak about what lies beyond. Others have diligently investigated stories of persons claiming to recollect a past life, but the evidence they have found hardly meets the standards of even moderate sceptics.

## *Sceptics and Believers*

From the earliest times, sceptics have disbelieved life after death. Ajit Keśakambali ('Ajit-the-one-whose-hair-is-like-a-blanket'), a contemporary of the Buddha, strongly disavowed life after death.

> A human being is built up of the four elements. When he dies the earthly in him returns and relapses to the earth…The four bearers on the bier as a fifth take his dead body away; till they reach the burning-ground men utter forth eulogies, but there his bones are bleached, and his offerings end in ashes…Fools and wise alike, on the dissolution of the body, are cut off, annihilated, and after death they are not.[12]

In the *Mahābhārata* epic, a sceptic rejects the belief: 'there is no being-again nor any deliverance from it', since neither is manifest, and the 'people's philosopher' refuses to accept anything unmanifest.

Ingenious replies have been given to sceptics. The boy Kassapa responded to Pāyāsi's scepticism (p. 23) by saying that the soul could not be seen either when it left the body during dreams.

Pāyāsi asked why, if they really believed in life after death, did ascetics not kill themselves to obtain their reward in the next life. Kassapa responded with an allegorical anecdote. A man died leaving behind a pregnant widow, and an elder son who claimed the inheritance. The widow begged him to wait until it could be ascertained whether the child in her womb was male or female. But the elder son was adamant. So she went inside and slit open her womb to ascertain whether the child was male, and killed herself and the unborn child in the process.

A constant number of souls seemed opposed to the empirical observation of a growing population. The answer was provided by transmigration: one had also to count the souls of, say, insects reborn as humans. Unlike Western Christian theology, in Islamic theology the number of souls need not be constant, for creation has been interpreted as a continuous process. The belief in transmigration (rebirth in forms other than human) as a systematic upward progress towards deliverance was developed by Islamic Philosophers (*Falāsifā*) like Ibn Sīnā (Avicenna),[13] who thought of the soul as 'the principle of self-direction and growth in a body'.[14] Hence, everything inanimate and animate has a soul; inanimate matter also has a measure of creativity 'akin to that of the First Cause, for it is an emanation of that cause.'[15] In Ibn Sīnā's theory of evolution, the soul evolves from vegetable soul to animal soul to human soul which alone can be described as a rational soul. There is a famous poem by the Persian mystic Jalāl u'D Din Rūmī:

> I died as mineral and became a plant,
> I died as plant and rose to animal,
> I died as animal and I was Man.
> Why should I fear? When was I less by dying?
> Yet once more I shall die as Man, to soar
> With angels blest; but even from angelhood
> I must pass on…[16]

A slightly different idea comes out in an anecdote about the Sūfī Abu Yazīd of Bistami. Abu Yazīd was walking with his disciples; the road narrowed, and a dog approached from the other side. Abu Yazīd retired, giving the dog right of way. A disciple wanted to know why, when God had honoured man above all creatures, Abu Yazīd 'the king of the gnostics', with such a large following, had made way for a dog. Abu Yazīd's answer was that the dog mutely asked him: 'what was my shortcoming, and what merit did you acquire [in your previous life], that I am clad in the skin of a dog, but you are robed in honour as the king of the gnostics?'[17]

There were those like Ibn al-Fārid who poetically ridiculed this theory: 'Have nothing to do with one that believes in *naskh* (the transmigration of soul into human bodies)—for his is a case of *maskh* (the transmigration of souls into the bodies of animals) ... And let him alone with his assertion of *faskh* (the transmigration of souls into plants)—for if *raskh* (the transmigration of souls into minerals) were true, he deserves to suffer it everlastingly *in every cycle*.'[18]

In more recent times, the theory of genetics has created another problem: bodily characteristics are genetically inherited from one's ancestors. If there is any relation at all between personality and inherited characteristics, how are soul and body matched to respect this relation? In answer, the Cambridge philosopher McTaggart[19] likened the inherited body and 'mental tendencies' to a hat, and the soul to the head; though the head was not made for the hat, nor, usually, the hat for the head, the hat fits the head by a process of selection. But how does one test this vision of disembodied souls shopping around for an appropriate foetus in which to be reborn?

Whatever it is that is asserted to survive death—memory, personality, or body—there are manifest difficulties. But if none of these survives, that creates another difficulty: for if neither memory, nor personality, nor body is reborn, what is left to be reborn? A solution to this problem is surely not beyond human ingenuity.

The falsity of the belief in the 'soul' has not been readily conceded, but the scientist would *hence* dismiss the notion of 'soul' as meaningless, since *irrefutable*—because the believer refuses to admit any conceivable circumstance in which the belief might be false. The belief is not testable, because the believer holds on to the belief, whatever the outcome of the test.

This deadlock between sceptics and believers seems a pity, because there *are* ways in which life after death is possible according to physics, as we understand it today.

## *Cosmic Recurrence*

Current physics has opened up many new possibilities for life beyond death: using a time machine one may perhaps be able to travel to the past before one's birth, or to the future after one's death. But the key insight which illuminates the mystery of life after death, and connects early forms of the belief to current physics is this: *the belief in the soul originally presumed the physical context of a quasi-cyclic cosmos or 'cyclic' time*—not only individuals but the entire cosmos was believed to recur approximately.

What does cosmic recurrence mean? Imagine an English tea party.[20] There is a table set out under a tree in front of the house, and Marjorie and Dame Thatcher are having tea at it, Dartmouth sitting between them fast asleep. 'Take some more tea', Marjorie says to Alice very earnestly. Cosmic recurrence means that billions of years later the same scene is going to repeat: the same house, the same tree, the same table, the same characters, the same conversation, the same joke! Everything need not be *exactly* the same.[21] There could (and presumably would) be some differences: the teapot might have moved to a different spot, or it might have a different pattern on it, as in the parlour game in which we are asked to specify six differences in detail between two pictures which seem strikingly alike.

We have seen a number of difficulties raised by sceptics about the belief in life after death; these difficulties evaporate in the context of cosmic recurrence. *What* is reborn? In the context of cosmic recurrence people are reborn in the sense that their bodies approximately repeat. *When?* After a cosmic cycle, which takes a long time.[22] Why don't we remember our previous lives? Because memories commence afresh!

What happens in-between lives? Nietzsche answers eloquently:

> You fancy that you will have a long rest before your second birth takes place,—but do not deceive yourselves! Between your last moment of consciousness and the first ray of the dawn of your new life no time will elapse,—as a flash of lightning will the space go by, even though living creatures think it is billions of years, and are not even able to reckon it. Timelessness and immediate re-birth are compatible...[23]

While traditional sceptical arguments are easily met, cosmic recurrence will not resolve all philosophical difficulties. In what sense are the two bodies or persons 'approximately' the same? There *is* a philosophical problem here: but this is the familiar problem of explaining to a computer how to 'recognize' a given face or person which may change from day to day in everyday life but still remain the same! My body cannot remain *exactly* the same between two instants, for otherwise the passage of the instant would not register. Nevertheless, there is a sense in which my I-ness continues from the beginning of a sentence to its end, from the beginning of life to death.[24] So these familiar philosophical difficulties need not distract us from noticing the way cosmic recurrence clarifies the question of life after death.

The belief in life after death in the context of cosmic recurrence is a *physical* belief, because cosmic recurrence is logically refutable: one may conceive of a cosmos which is *not* recurrent. The belief is also empirically refutable, and possible experiments which can be used to test cosmic recurrence will be considered later on. If one agrees that cosmic recurrence is the *only* context in which the notion of the soul is meaningful, then the refutability of cosmic recurrence makes the soul a *physical* entity, though it remains an intangible and formless abstraction.

Life after death in the context of cosmic recurrence is certainly not open to any *logical* objection. In fact, it is known[25] that, under a wide variety of circumstances, recurrence must necessarily take place, whichever the equations of physical evolution one uses—whether those of Newton, or Hilbert and Einstein, or Schrödinger, or Markov. The mundane observation of asymmetry between past and future does not refute cosmic recurrence because mundane time-asymmetry is not quite reconciled with the time-symmetry of physics, also based on observation. Moreover, cosmologically speaking, mundane observation is a local matter; it is hardly an argument against large-scale time-symmetry of the cosmos: the earth *seems* quite flat though we *now* know it is round. Complex physical theories may eventually be needed to decide whether or not the cosmos actually recurs.

Cosmic recurrence is the sort of experience one does not clearly remember! One can try to grasp it by relating it to other mundane experiences, but one must remember not to confuse the cycle of the cosmos or the cycle *of* time with cycles *in* time. The two notions, though analogous, are not identical. In the first case, the arrow of time must have different orientations in different parts of the cosmos: for a cycle *of* time, there must be, so to say, some time when time runs backward! This is not needed for a cycle *in* time, like that of day and night. Keeping this difference in mind, the most natural way to explain cosmic recurrence is through the analogy with natural cycles. Day and night are the natural cycles used in the Bhagvad Gītā (8.17–20):

> There is day also…and night in the universe…day dawns and all those lives that lay hidden asleep come forth and show themselves, mortally manifest: night falls, and all are dissolved into the sleeping germ of life. Thus they are seen, O Prince, and appear unceasingly, dissolving with the dark, and with day returning back to the new birth, new death.[26]

The time-scale of cosmic recurrence is an easy way to distinguish cosmic cycles from the usual cycles such as that of day and night. One cosmic cycle requires a very large number of the usual cycles. This was also the case in early myth. One cosmic day and night (of Brahmā) lasted 8.64 billion years according to the *Viṣṇu Purāṇa* amplification of the calculation.[27] Such a long time-scale of cyclicity makes very precise the analogy of a round earth which only seems flat because of its large size. The figure $8.64 \times 10^n$ is not confined to any one culture, though the value of $n$ varies; that is, the significant digits 864 are common, though different cultures may put a different number of zeros after these digits. For example, 60 seconds make a minute, 60 minutes make an hour, and 24 hours make a day, so that the number of seconds in a day and night on Earth is $60 \times 60 \times 24 = 86{,}400$ according to the Western notion. The sequence of metals and colours associated with the (invariably) four ages (*yuga*-s) in a Great Age also varies: for example, in Mexico the first age was silver rather than golden as in Greece.[28]

## *Eternal Return vs Deliverance*

It is beyond doubt that the early view of the soul was embedded in the (believed) physical context of cosmic recurrence. But two aspects of the early view need to be clarified.

(1) Life after death was regarded as a matter of physical fact; but it was *not* considered desirable.

(2) The cycles in question, whether of time or in time, were only approximate: the cosmos was believed to be only *quasi*-recurrent. Each day was much like the preceding, but not exactly like it. Hence, deliverance from life after death was believed to be possible.

Many early symbols of recurrence show the belief in the possibility and the desirability of deliverance from life after death.

The Wheel of Ages or the Wheel of Fortune or the Wheel of Time (*kālacakra*) provides another analogy for a quasi-recurrent cosmos: the Ashoka Chakra on the Indian flag and currency refers to this symbol of 'cyclic' time in Buddhist architecture. The belief is articulated also in the *Śvetāsvatara Upaniṣad* (1.6):

> This vast universe is a Wheel. Round and round it turns and never stops. Upon it are all creatures that are subject to birth, death and rebirth. It is the Wheel of Bṛhman. As long as the individual self thinks it is separate from Bṛhman it revolves upon the Wheel in bondage to the laws of birth, death and rebirth. But when it realizes its identity with Bṛhman, it revolves upon the Wheel no longer. It achieves immortality.[29]

Al Rāzī (Rhazes), the tenth century medical authority, asserted that the soul was addicted to the material world, and could be released from the 'wheel of birth' only through the therapeutic effects of philosophy.[30]

The serpent is another symbol: its hibernation is like the 'long night of the soul [when it is between two bodies]' and 'it verily passes through the throes of death',[31] to shed its skin and appear renewed. The mathematical symbol ∞ (infinity) comes from the 'circle of infinity': a serpent symbolising cosmic recurrence by swallowing its own tail. The serpent as a cosmic symbol refers to no ordinary cycle in time: one finds in the *The Egyptian Book of the Dead*: 'I am the serpent Sata. I die and am born again each [cosmic] day. I die and am born again and…grow young each day.'[32] Deliverance usually requires a bird (e.g., Garuḍa) which devours the serpent. Bird and serpent are fused together in the Central American plumed serpent.[33]

The Butterfly, the Wheel, the Serpent, all show that there was no belief in *exact* or *eternal* return of the kind attributed to the Stoics, and symbolised by beads on a string which repeat exactly and endlessly. In a Greek myth, Sisyphus is condemned to push a stone up a hill from where it rolls down. He repeats the task endlessly—without the hope that he will succeed some day. The myth of Sisyphus provides an image of hell, not of the actual world. With *exact* or *eternal* recurrence,[34] even death would provide no escape:

> There was a young man whose essence
> tended to Poincaré recurrence;
> so often was he born
> that, one day, forlorn,
> he decided to end his existence!

Perhaps the easiest way to distinguish eternal recurrence from *quasi*-recurrence is to ask: what would one do if the cosmos were like that? Nietzsche thought that science compelled the belief in eternal return. So he asked:

> What if some day or night a demon crept after you into your most singular solitude and said: 'This life that you now live and have lived, you will have to live it again and countless times again; and there will be nothing new about it; and every pain, every joy, every thought, every sigh, and everything unspeakably great or small in your life will have to return to you, everything in the same progression and sequence—even the spider I see, the moonlight filtered through the trees, even this moment and I myself. The eternal hourglass of existence will be inverted over and over again; as will you, you speck of dust!' Would you not cast yourself to the ground, grinding your teeth together, cursing the demon who spoke to you thus?[35]

The best one could do under these circumstances, perhaps, would be to bear things stoically. Nietzsche thought one needed to become a superman to bear this truth about the world.

The situation is quite different with quasi-recurrence. Except perhaps for the singular and not very influential case of (views attributed to) the older Stoics, time was widely believed to be only *quasi*-cyclic: recurrence was *in*exact and *non*-eternal. The Orphic Mysteries, or the Pythagorean school, and early Christians like Origen propagated similar beliefs in the West. Deliverance (*mokṣa*, *nirvāṇa*) from the cycle of life-death-and-rebirth was not only possible, it was held to be the ultimate goal of the whole sequence of lives.

## *Summary*

- The different views about life after death are: the naive view, the early view, and the post-Christian view. The naive view is indefensible, the post-Christian view is postponed.
- In the early view, life after death took place in the context of cosmic recurrence: not only are individuals reborn, the entire cosmos approximately repeats.
- Cosmic recurrence is a physical belief since it is refutable.
- Cosmic recurrence is not contrary to logic, nor is it already refuted by observation, or current physical theory.
- In the early view, cosmic recurrence was neither exact nor eternal; the early view regarded the cosmos as quasi-recurrent, and time as quasi-cyclic.
- Deliverance from the cycle of life-death-and-rebirth was believed possible, and was held to be the ultimate goal of the whole sequence of lives. This is emphasised by symbols like the Butterfly, the Wheel, and the Serpent.
- *Q. Is there life after death?* A. That depends upon the nature of time.
- *Q.* What is the nature of time? *Is time linear or cyclic?*

# 2

# The Curse on 'Cyclic' Time

The date: 5 May 553. The place: the Church of St. Sophia at Constantinople, newly rebuilt 'with incomparable magnificence'[1] twenty years after the riots of 532 which set the city ablaze.[2] Then the Emperor Justinian had been ready to flee from the crowds—the imperial residence had direct access to the sea and the boats were ready—but the Empress Theodora was determined that those who had donned the purple must die in it, saving Justinian his throne. This was the same Theodora who, orphaned in early childhood, had eked out a living by playing the buffoon on the streets of Byzantium, and had inevitably grown up to become a prostitute, but so attractive that, according to Gibbon,[3] the Romeos of Byzantium fought over her, the stronger ejecting the weaker already inside the door, so to say!

Theodora had accomplished the impossible—it would be easier for a black woman to become president of the US today. Justinian had to amend Roman law to marry her, and his first act on ascending the throne was to make her Empress with equal and independent powers, hence Mother of the Church. The laws in the Roman empire were against equity, but the *practice* of equity prevailed, just as today it is the practice of inequity that prevails over the formal equity declared in the US constitution. The marriage of the extraordinary commoner Theodora to the aristocrat Justinian accurately reflected all the tensions that one can expect from the marriage of equity to hierarchy. Formally, Justinian and Theodora differed only in their sectarian orientation, but so close was the Church to the State that the cleft at the apex of the empire bred political machinations intertwined with theological difficulties.

The Fifth Ecumenical Council, assembled to resolve one such difficulty, pronounced a curse on 'cyclic' time, a curse that would cloud Western thought about time for centuries to come. To be fair, it is very unlikely that any of the 166 assembled Bishops had the slightest idea that the reverberations of the curse would escape from the dome of St. Sophia into modern physics and shape, say, Stephen Hawking's theory of time—all were preoccupied with the immediate political controversy which concerned the Palestinian Origenists[4] rather than the person of Origen.

Origen[5] (ca. 185–ca. 254) had taught some kind of 'cyclic' time, found also in the Bible saying that 'there is nothing new under the sun.'[6] He was widely respected, and called 'immortal genius' and 'the greatest teacher of the Church after the apostles' by Jerome who first translated the entire Bible into the Latin (the *Vulgate*), using Origen's notes. Origen's beliefs, like those of many others from Alexandria, were similar to the doctrine of *karma*. He believed:

> Every soul…comes into this world strengthened by the victories or weakened by the defeats of its previous life. Its place in the world…is determined by its previous merits or demerits. Its work in this world determines its place in the world which is to follow this…The hope of freedom is entertained by the whole of creation…[7]

Origen quite explicitly related 'cyclic' time to equity and justice:

> In which certainly every principle of equity is shown, while the inequality of circumstances preserves the justice of a retribution according to merit.[8]

He thought that equity lay in the equal beginning of all souls, at the time of creation. Exactly analogous[9] to the *karma-saṁskāra* theory, he thought that good deeds were rewarded by birth in better circumstances in the next cycle of the cosmos, while bad deeds were punished by worse circumstances. In this manner, thought Origen, God demonstrated the operation of the two key principles of equity and justice.

The equity of souls was believed to be an eternal mathematical truth by Neoplatonists, including Proclus, another great teacher of Origen's Alexandrian school, who defined mathematics as the study of the soul: the theorems of 'Euclid's' *Elements* hence focus on equality. Accordingly, the present inequality of circumstances was only superficial and transitory, and equality would again be restored at the end of the world. This belief in 'eternal' equality *in the future* was similar to the Indian belief in *mokṣa* or ultimate deliverance. In Origen's account of things, on the day of deliverance all people would again become equal, as they were on the day of creation.

## *Condemning 'Cyclic' Time*

In 542, ten years before the Fifth Council, Justinian ridiculed and cursed Origen:

> (I) Whoever says or thinks that human souls pre-existed…and had been condemned to punishment in bodies, shall be anathema…(V) If anyone says or thinks that at the resurrection, human bodies will rise spherical in form and unlike our present form, let him be anathema…(IX) If anyone says or thinks that the punishment of demons and impious men is only temporary, and will one day have an end…let him be anathema. Anathema to Origen…[10]

Justinian thought that life in heaven or hell was no temporary interlude between lives on earth, but lasted for ever, and hence occurred only once. Hence, also, the present life was the first. Justinian wanted people to believe that there would be a future life, but that there was no past life. Many Christians still believed in reincarnation in a sequence of lives gradually leading up to deliverance. Justinian wanted them to believe in resurrection: life after death exactly once.

By Justinian's time, Christianity had become so imperial and urbane, and had moved so far away from equity that it referred to Neoplatonists as 'pagans'. The pagans thought that one may have different bodies in different lives, but that, on the final day of deliverance, there would remain only the soul which, since perfect, was spherical in form; they visualised drops of water losing their identity and merging back into the ocean. Since all merged back into 'the One and the same', the distinction between one perfect sphere and another was not critical—in fact, they thought this distinction to be mathematically impossible. Justinian wanted to make this very distinction to help God send some to heaven and others to hell. Hence, he urged that resurrection would be in the flesh; one would maintain one's present body in the life after death, despite all the fires of hell. Justinian, however, neglected to specify whether the 'present form' referred to the form of the body at birth, or at death, or at some age in between!

## *The Moral Dichotomy*

The foundation for Justinian's curse was laid c. 400. In Origen's time, the Roman empire was 'pagan' and tolerant towards all faiths, notwithstanding church propaganda to the contrary;[11] Origen held out the hope of freedom not only for all humanity but for all creation. But Christianity changed. After Constantine, the church aspired to religious monopoly. Laws were passed to take over temples; pagan shrines were desecrated[12] to prove the impotence of pagan gods, and Christians who dared disagree with official dogmas were excommunicated, exiled, and deprived of their property.

In this situation, the use of physical force, even in matters of belief, seemed so natural that Augustine adduced scriptural evidence favouring the use of force, especially state power, in propagating beliefs.[13] Augustine's impatience with debate is understandable because in Thagaste (Timgad) in North Africa, when he became bishop, there were 47 pagan priests, and the majority Donatist Christians regarded themselves as pure wheat in a field in which the Catholics were the weeds—surviving only with the constant help of the hated imperialist from Rome.

How could the church prosper when Origen's picture of quasi-cyclic time promised deliverance to all, with no special benefits to the flock of the church? The fear was clearly articulated by Jerome who turned[14] 180° to join those whom he had earlier called 'baying dogs' for denouncing Origen:

> Now I find among the bad things written by Origen the following: that there are innumerable worlds, succeeding one another in eternal ages…that in restitution…Archangels and Angels, the devil, the demons and the souls of men whether Christian, Jews or Heathen will all be of one condition and degree [i.e., they too will be saved], and…we who are now men may afterwards be born women, and one who is now a virgin may chance then to be a prostitute.[15]

While denouncing Origen, Jerome also misrepresented him. For Origen, previous worlds were a way to eliminate accidents due to birth: a virgin could not 'chance' to become a prostitute, 'for no one chooses of himself either where, or with whom, or in what condition he is born'.[16] Indeed, for Origen, pre-existence explained both equity and justice: all were created equal, but they behaved differently and were justly rewarded or punished in this world for their previous deeds.

Jerome's real difficulty was with equity—with the idea that the hope of freedom was entertained by the whole of creation—for the state could not be run on this doctrine of universal love. For the state, morality was synonymous with inequity: a person who rejects the state has no place in the state. A church aligned with the state had to adapt its notion of morality to suit the state.[17]

To encourage pagans to accept the values it propagated, the state-church felt it was necessary to limit deliverance to a chosen few. To limit deliverance to a chosen few, it was necessary to discriminate between the 'good' believers and the 'bad' non-believers. According to then-existing popular beliefs, heaven and hell were where the soul went *between* lives. Origen thought of heaven as a university and hell as a *temporary* reform school for souls. Similarly, in the *Mahābhārata*, it was possible for the villainous Duryodhana to go initially to heaven, while it was equally possible for the saintly Yudhiṣṭhira to go initially to hell (p. 359). Not only were heaven and hell temporary interludes between lives, it was possible to be transferred from one place to another. Finally, there was this third category of deliverance, available to all. All this allowed shades of grey inconvenient to Augustine in his competitive circumstances; he rebuked Origen.[18] Augustine wanted a sharp and lasting division between good and bad—a doctrine of sin, in short, according to which the good would go to heaven, the bad to hell, and both would stay in their respective places for ever. To create a sharp and lasting division between the good and the bad, heaven and hell, Augustine, in his *City of God: Against the Pagans*, made heaven and hell *eternal.*

## ***Confusing Different Pictures of Time***

The key which permitted this move from reform school to eternal damnation was confusion about time. Origen's picture of quasi-cyclic time was confused with the Stoic picture of supercyclic time:[19] an *exact* and *eternal* repetition, an inflexible causal chain of events. The two pictures are quite different.

> As for the 'conflagration' [at the end of the world]...Origen, as is well known, follows the Stoics in teaching...that there will be a series of world orders. But whereas Greek [Stoic] philosophy could admit no prospect except a perpetual repetition of the same alternate evolution and involution, a never-ending systole and diastole of the cosmic life, Origen holds that there is a constant upward progress. Each world-order is better than the last...The conflagration is really a purifying fire...All Spirits were created blameless, all must at last return to their original perfection.[20]

But Augustine was unconcerned with the difference between the two pictures of time. Instead of a sequence of lives in various bodily incarnations, as depicted in, say, the Buddhist *Jātaka*, instead of a 'stairway of worlds' ascending to perfection, Augustine saw a single sequence of events, in a single body, repeating mindlessly. In this picture of eternal return, there was no possibility of deliverance (*nirvāṇa*, say), which was the ultimate goal of the whole sequence of lives with quasi-cyclic time. By bunching quasi-cyclic time with supercyclic time, in the general category of 'cyclic' time, Augustine was able to argue that this (confused) picture of 'cyclic' time meant that deliverance, instead of being universal, was actually available to none!

In poor light, the single spiral groove of a gramophone record looks like a number of unconnected concentric circles (Fig. 1), but the difference is audible—the needle spiralling to the still centre regenerates harmony, but when stuck in a circle it produces cacophony. With the 'Stoic' idea of 'fatalism' the cacophony was everlasting: the record could not be switched off! Augustine amplified the cacophony using an image of Christ being repeatedly crucified. Eternal return meant that Christ was unable to save humanity, for his crucifixion would repeat like any other event. Sisyphus' nightmare applied to Christ on the cross suggested a destruction of morality so unbearable that Augustine's confusion went unnoticed, and he was able to propose a novel theological solution. The solution was to cut the supposed circle of time and unroll it into a line: 'Heaven forbid that we should believe this [supercyclic time], for

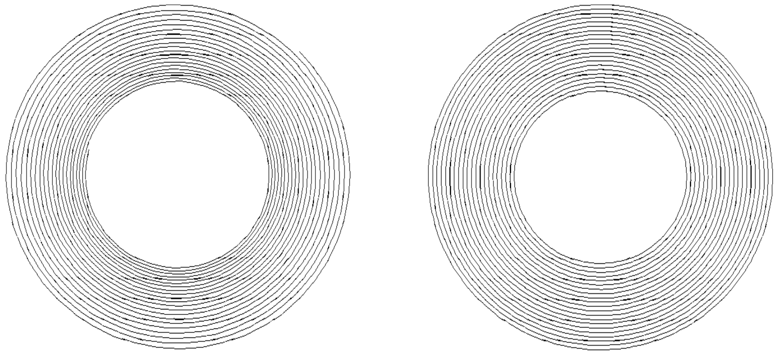

**Fig. 1: Confusing Quasi-cyclic with Supercyclic Time**

Quasi-cyclic time may be mistaken for supercyclic time just as a spiral may be mistaken for a number of concentric circles; actually the two are as far from each other as harmony is from discord.

Christ having died *once* for our sins, *rising again*, dies *no more*.'[21] A note of finality was introduced: everyone was resurrected, but this happened exactly *once*, on the day of judgment. Heaven and hell stretched out for an eternity after that.

## *Residual Difficulties*

Even with an eternal heaven and hell at the end of time, some residual difficulties remained for the doctrine of sin. To pagans, accustomed to the picture of cosmic recurrence, the end of time came after a large (even if finite) number of cosmic cycles, each of which lasted for an enormous time. This made the day of judgment *seem* infinitely remote: one could sin *now* for there was time enough to repent before the day of judgment. Augustine's answer was to resort to the old trick of dramatising by compressing the time-scale, but with the motivation of frightening people: repentance was an urgent matter because the day of resurrection was round the corner. (It still was round the corner as we approached the end of the second millennium.[22])

The pagan belief in the end of time after a number of cosmic cycles also made it difficult to understand the idea of a judgment passed on the last day. Across various cycles, the face and body might change beyond recognition, so that even God would find it puzzling to decide exactly who had sinned, and the 'sinner' could persuade himself that someone else would go to hell! On the other hand, if it were not the body that survived but some incorporeal soul-substance, separate from the body, then how could this incorporeal soul-substance feel the pain and pleasures of the body? Resurrection in the flesh was the answer. The sinner could not escape identification because life after death meant the continuation of bodily identity. When pagans asked how the body could survive the fires of hell, Augustine invented salamanders.

## *The Story of the Moral*

Augustine's efforts produced a new picture of the world. Instead of quasi-cyclic time, one now had apocalyptic time. Instead of the series of lives with quasi-cyclic time, one now had just two—one life in this world, and one life in the world that was to follow. The short life in this world was a unique opportunity. Though all would be restored in the flesh on the day of judgment, only the select few went to heaven: the rest went to hell, *for ever*, without any possibility of a transfer from one place to the other. Neither did anyone get a second chance: divine mercy did not come in the way of divine retribution, and the doors of the 'City of God' were not open to those who died unrepentant sinners or unbelievers. The ultimate objective of life now was to obtain the reward and avoid the punishment, and not deliverance from both. Hence one ought to behave morally. This long chain of consequences was founded on a confusion about time.

Eventually, Augustine's solution was officially approved[23] by the Fifth Ecumenical Council in its anathemas of 553, similar to Justinian's.

> IF anyone asserts the fabulous pre-existence of souls…let him be anathema…(XIV) IF anyone shall say that all reasonable beings will one day be united in one…let him be anathema. (XV) IF anyone shall say that…the end and the beginning shall be alike, and that the end shall be the true measure of the beginning: let him be anathema.[24]

The quasi-cyclic series of world-orders was eliminated by forcibly establishing an asymmetry between a unique beginning and a unique end to the one world before eternity. The original physical context of the belief in life after death was lost. The only reason to continue believing in life after death now was moral.

Moving time from the physical to the moral plane seemed legitimate to Augustine, since time was to him a subjective matter: there was no past, present and future, but only 'a present of things past, memory; a present of things present, sight; and a present of things future, expectation'.[25] But this created an enormous difficulty for Augustinian theology. Long before the advent of Christianity, other traditions had rejected quasi-cyclic time; but, like Ajit Keṣakambali (p. 28), they rejected also the associated notions of heaven, hell, and life after death. Western Christianity was unique in retaining the notions of heaven, hell, life after death, and the soul, while rejecting only their physical basis in the picture of quasi-cyclic time! These notions were left hanging in mid-air, in limbo so to say—they became irrefutable and untestable.

But the difficulty also provided an opportunity. Unlike Ajit Keṣakambali, who believed only in the empirically manifest, Western Christianity rejected both the manifest and inference as a means of arriving at the truth: it placed metaphysics above physics, and faith above reason. It advocated reliance on authority as the sole route to truth. Hence, as we will see in Chapter 11, unlike earlier rejections of quasi-cyclic time, the curse on cyclic time benefited the state, by strengthening hierarchy. We will also see later on how the revised notion of time serves the interests of the powerful by legitimising the unequal distribution of credits and resources in this world. The rejection of Origen signified the rejection also of the equity and justice that he advocated. The interests which it served helped sustain the new theology.

## *The Temporal Dichotomy: 'Linear' vs 'Cyclic' Time*

Though motivated by a desire for a moral dichotomy—a sharp distinction between good and bad—the curse against 'cyclic' time had a strange longer-term consequence. It created a belief in a *temporal* dichotomy: a belief that there are exactly two conflicting pictures of time—'linear' time vs 'cyclic' time. As propagated by Western theologians, 'linear' time symbolises the Christian view, 'cyclic' time the primitive pagan view; 'linear' time represents progress, human freedom, and so on, while 'cyclic' time represents stagnant societies, fatalism, etc.

This chronic confusion in Western thought suffers from three disabilities. First, there are many pictures of time, as we shall see; so the terms 'linear' and 'cyclic' refer to categories rather than individual pictures of time. Second, the categories are not exclusive, for pictures across categories may be compatible with each other. For example, a picture of time which is locally 'linear' need be in no conflict with a picture of time which is globally 'cyclic'. The earth, though round, *seems* flat because of its large size. And we have seen that, even in 'primitive' myth, the time scale of cyclicity is enormous, so that the same geometry applies to that picture of time.

Third, the categories are not well-defined, for pictures in the same category may be incompatible. With exactly two conflicting categories, even vaguely similar notions must be treated as identical (for they must go into one or the other category). So the dichotomy reflexively reinforced the Augustinian confusion that any kind of 'cyclic' time means supercyclic time—which should therefore be rejected for the same reason, namely because it conflicts with 'free will' or 'causality'. To summarise, the categories of 'linear' and 'cyclic' time are spurious: forcibly packing many pictures of time into these two categories invites incoherence. Originating in medieval theology, this spurious categorisation has deeply infiltrated science, from the time of Newton.

Another example may help to clarify the disabilities of this 'linear' vs 'cyclic' view. This example pertains to the 'linear' category. In everyday life, one believes the past is fixed, but that one's choices now partly decide the future: one philosophises about the past while agonising about the future. This past-linear, future-branching, mundane time (Fig. 2) is incompatible[26] with the 'superlinear' time of physics—which explains how the world evolves without any reference to human choices. But the two incompatible pictures of time—mundane and superlinear—are both categorised as 'linear', hence treated as identical. Thereby the choice available with mundane time is treated as compatible with the deterministic laws of physics. When the incompatibility is noticed, a facile solution is quickly accepted—some of these facile solutions are exposed in Chapter 6. (A serious solution is blocked by the perception of compatible pictures of 'linear' and 'cyclic' time as contradictory.) This particular example of the temporal dichotomy—the confusion between mundane time and super-linear time—also illustrates how the curse on cyclic time has infiltrated science through, say, Stephen Hawking's theory of time.

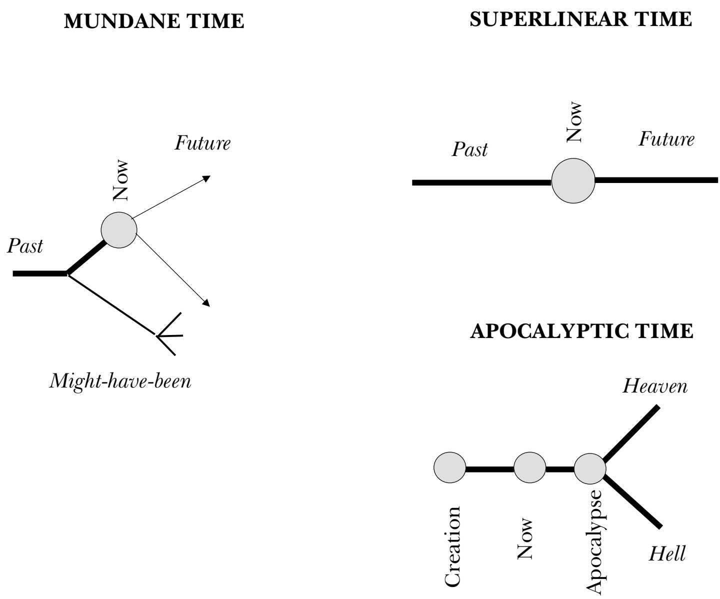


**Fig. 2: Types of 'linear' time**

## *The Reappearance of 'Cyclic' Time*

Despite the theological efforts to ban it, 'cyclic' time has reappeared phoenix-like in general relativity and quantum gravity in the form of closed loops in time—called closed time-like curves. A time machine going to the future and returning to the present executes a loop in time. Conversely, given a closed time-like curve one can, in principle, make a 'rocketship' which follows the closed time-like curve to 'travel' to the past via the future before returning to the present! The difference is this: the time machine obeys the will of the driver and supposedly goes to whenever at the flick of a dial, but the rocketship on a closed time-like curve, like a falling body, obeys only the laws of physics, and remains on the curve.

Where Augustine asked Heaven to forbid cyclic time, Stephen Hawking[27] forbids closed time loops by a *postulate* called the chronology condition. Augustine adopted a God's-eye view to see Christ being repeatedly crucified. In their celebrated book,[28] *The Large Scale Structure of Spacetime*, Hawking and Ellis (H&E) stand with Augustine, in a time outside the universe, to watch Sisyphus' nightmare applied to a 'suitable rocketship', which repeats its history in travelling around a closed loop in time. Augustine's moral revulsion is substituted by logical revulsion: travelling back in time could lead to logical paradoxes, for 'arriving back before one's departure, one could prevent oneself from setting out in the first place'.

There are many naive features to this paradox. In H&E's view, when one returns to *exactly* the same time, one retains a memory of the 'previous' same time! This is inconsistent, for if the time is exactly the same, everything, including one's memory must be the same. Consider an imaginary character on a film; the plot does not change each time the film is replayed. Our hero trapped on celluloid repeats exactly the same mistake, to the dismay of the audience, without the slightest recollection of previous shows, even as the film runs into its silver jubilee. Like our hero, the pilot of the rocketship would once again set off on an expedition, intending to return before his departure to prevent himself from setting off. If the pilot recollects the previous trip, at least one thing would have changed so that the time would be only approximately the same. In that case, certainly, no paradox would be involved if a different future were to ensue from this different 'present'. Let us overlook these naive features.[29]

H&E's fiat confuses two different pictures of 'linear' time: mundane time and the superlinear time of physics. With superlinear time, the present decides the future (independently of one's will) according to the laws of physics: it is like falling off the roof—one must crash to the ground, whether or not one is willing. Given that the present decides the future, if the present repeats so must the future. (Else H&E's paradox disappears, for a new future could well follow, each time the pilot returns to the same present.) If this superlinear time were bent into a circle and future joined to past, no one would notice the difference. But the same thing cannot be done with mundane time. In everyday life we believe the future is partly decided by our choices though the past is not. So future cannot be joined to past unless we allow either *(a)* that the past is open like the future, or *(b)* that the future is closed like the past. With mundane time the past is linear, so that joining future to past destroys future branching. The mistaken identification of the two pictures of time that went in at the beginning of the argument now emerges as a loss of branching hence choice.

H&E are aware that the notion of closed time loops is not in itself contradictory: that 'there is a contradiction only if one assumes a simple notion of free will'. Augustine could hardly reject human freedom because his system of morality would otherwise collapse, for only an unreasonable God would punish a person who had no choice. H&E suggest that science too would collapse, since 'the whole of our philosophy of science is based on the assumption that one is free to perform any experiment.' H&E realise that this apparent contradiction between 'cyclic' time and 'human freedom' actually depends upon a certain Augustinian hair-splitting between 'fatalism' and 'determinism'.

Augustine thought that his God, to be more powerful than pagan gods, must already know[30] the future—which is, therefore, determined—but he quibbled that *such* pre-determination did not curtail human choices, unlike 'fatalism'.[31] Likewise, H&E must distinguish between the 'determinism' of the equations of general relativity, which they need, and the 'fatalism' of closed time loops which they want to reject. This retreating chain of arguments having arrived at so weak a link, it can proceed no further, and H&E summarise their conclusion, changing the church's proscription into the postulate: 'that space-time satisfies…the *chronology condition*: namely, that there are no closed time-like curves'. H&E then proceed to derive a long chain of consequences, principally the idea of a 'singularity', that time itself had a beginning—without which one could hardly hope to write its brief history!

Hawking's is not the only case. Others, even more ambitious, have attempted to promote the curse from condition to 'theorem'. A singularity may also be the end of time. And if time has a beginning or end, it can't be 'cyclic', can it? So argues Tipler,[32] in his technically unconvincing 'no-return theorem': singularities located in the primordial egg mark the beginning or end of time for some material particles, so that return ought not to be *exact* or *eternal*. (We will see in the next chapter why singularities need not mark the beginning or end of time for even a single material particle.) More recently, Tipler has written a full book[33] claiming that current physics implies Augustinian theology, complete with resurrection in the flesh in purgatory, heaven, and hell.

The Wheel has turned full circle; despite all the progress of science, scientific arguments still remain identical to medieval theological arguments which sought to infer the large-scale nature of the cosmos from local political considerations

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## *Summary*

- Quasi-cyclic time was advocated in early Christianity by Origen, to explain how equity and justice both prevailed in this world.
- Equity became unacceptable to the church after its marriage to the state. Hence the church cursed 'cyclic' time and accepted Augustine's eternal heaven and hell at the end of time.
- *Q. Why bother about this medieval curse? Can't science straightaway tell us whether time is linear or cyclic?*
- The mistaken belief that there are exactly two pictures of time—'linear' time vs 'cyclic' time—is a consequence of the curse. Through this dichotomy, the curse has infiltrated current science.
- An example is Stephen Hawking's *chronology condition*—a fiat against 'cyclic' time—that he used to try to prove that time had a beginning. While Augustine's argument confused different types of 'cyclic' time,

Hawking's argument confuses different varieties of 'linear' time.

- *Q. Is this link between theology and current physics accidental, or are there deeper reasons for it?*

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# 3

# Creation, Immortality, and the New Physics

The *conflict* between religion and science is what naturally occurs to our minds when we think of this subject…When we consider what religion is for mankind, and what science is, it is no exaggeration to say that the future course of history depends upon the decision of this generation as to the relations between them.

**A. N. Whitehead**[1]

And what if the creationists win? They might, you know, for there are millions who, faced with the choice between science and their interpretation of the Bible, will choose the Bible and reject science, regardless of the evidence. This is not entirely because of a traditional and unthinking reverence for the literal words of the Bible; there is also a pervasive uneasiness—even an actual fear—of science…For one thing, science is uncertain…Second, science is complex and chilling… Third, science is dangerous…So why might they not win?

**Isaac Asimov**[2]

Has the famous story which stands at the beginning of the Bible really been understood—the story of God's mortal terror of *science*?…It has not been understood. This priest's book begins, as is only proper, with the priest's great…difficulty: *he* has only one great danger, consequently 'God' has only *one* great danger…

…man learn[ed] to taste the tree of knowledge.—What had happened? A mortal terror seized on the old God…God had created for himself a rival, science makes *equal to God*—it is all over with priests and gods if man becomes scientific!—*Moral*:

> science is the forbidden in itself—it alone is forbidden. Science is the first sin, the germ of all sins, original sin. This alone constitutes morality.—'Thou shalt not know' —the rest follows…The old God invents war…(—priests have always had need of war…). War—among other things a great mischief-maker in science! — Incredible! knowledge, emancipation from the priest, increases in spite of wars. —And the old God comes to a final decision: 'Man has become scientific—there is nothing for it, he will have to be drowned!'…
>
> **Friedrich Nietzsche**[3]

# The Remarriage of Science and Religion

A thousand years after the curse on 'cyclic' time, when Galileo bowed before the authority of the church, and said that the earth did not move round the sun, he is reported to have murmured, 'but it *does* move'. Over the centuries, that little gesture of defiance has crept into scientific folklore; that puzzled, almost inaudible murmur has turned into a roar of disapproval: truth cannot be decided by authority. 'Unthinking respect for authority is the greatest enemy of the truth', wrote Einstein.[4] Ultimately, a few years ago, the church withdrew its strictures against Galileo.

Why did the church make this small but significant gesture *now*? Why withdraw the strictures[5] against Galileo in 1992, after 349 years? To understand this we must probe into the changing relations between science and religion.

## *Science vs Religion: The Case of Creationism*

From Nietzsche to Asimov, it was the *conflict* between science and religion which seemed natural—God was mortally afraid of science. This conflict continues today, creationism being one of the best-known examples. The creationists maintain that the world was created by God, some 4004 years before the start of the Christian era, or some 6004 years ago. In Europe, this was the standard belief for over a thousand years: it persisted until the last century, barring isolated speculations. Newton, for example, believed this. In the previous century, the study of geology suggested larger estimates of the age of the earth, estimates that were supported by later studies of the half-life and distribution of radioactive elements. Thus, according to current scientific theories, the earth is some 4.5 billion years old, and the cosmos is a lot older than that. Creationists reject this. Moreover, creationists are offended by Darwin's theory of evolution which puts man essentially on par with other animals: they claim that man is not just an animal descended from the apes, but has a special relationship with God who directly created him. They deny that fossils are evidence of evolution, and maintain that fossils were simply put there by God to test one's faith. In support of all their beliefs they cite the authority of the Bible.

Even today, Biblical authority cannot be brushed aside, because Protestantism replaced the religious authority of the pope by the authority of the Bible.[6] In a democratic polity, like the USA, this Biblical authority easily translates into political authority through organised, and well-funded pressure groups. Thus, instead of the pope, it was the state authority of the legislature that now intervened in the conflict between science and religion.

Fundamentalists,[7] who believe in a literal interpretation of the Bible, thought the theory of evolution threatened Biblical authority; they got instituted a law prohibiting the teaching of the theory of evolution. In a key trial of 1925, a school teacher, John T. Scopes, was found guilty of breaking this law in Tennessee, and fined (this was later overruled). The creationist controversy resurfaced in the 1960s. This time the state of Arkansas passed a law, in 1982, to ensure that schools gave equal time to teaching evolution and the account of creation in the Bible. Though this law was later overturned, in 1981 a judge ruled in California that a disclaimer must be published in school texts that evolution was not 'the ultimate cause of origins'.

Having failed in prohibiting the teaching of the theory of evolution, and having failed to get 'equal time' for the Biblical account, the creationists are currently pursuing the strategy of 'equal neglect'. The Kansas state board ruled on 11 August 1999 that teaching of the theory of evolution should *not* be a compulsory part of the school science syllabus. The hope presumably is that most schools will, in practice, neglect to teach whatever it is not compulsory to teach.

Creationism is not restricted to the USA. In Australia, Ian Plimer, a Professor of Geology at the Melbourne University, winner of the 1995 Eureka prize, and author of *Telling Lies for God—Reason versus Creationism*,[8] has been ruined through a prolonged legal battle with the creationists.

## *Science vs Religion: The Three Stages of Harmony, Truce, and Conflict*

Creationism is also not the only point of conflict between science and religion. The conflict between science and religion has ranged far and wide, and the classical story of this conflict,[9] from the time of Copernicus, makes for very amusing reading. But the relation between science and religion has *not* always been one of conflict. In Galileo's time, it was the *harmony* of science and religion that was taken for granted: it was thought 'the Bible is the word of God and Nature is the work of God'. Copernicus began his book[10] with a lengthy preface addressed to Pope Paul III, citing in his support various religious authorities, including one Cardinal, two Bishops, and a previous pope. Similarly, Galileo initially obtained the Pope's permission for his book by saying that mathematics was the language in which God had written the Book of Nature. Even about a century later, in Protestant England, Newton spoke of the 'Laws' of physics for he thought that the Laws of God had been revealed to him.

But then relations between science and religion got a bit strained, as Protestant reformers systematically used the authority of science to attack the authority of the pope. So it was the *truce* between science and religion which came to seem natural at the time of Hume and Kant. It came to be believed that science and religion operated in disjoint spheres—science concerned inanimate matter, while religion concerned human ethics, science concerned facts, while religion concerned values. It came to be believed that any attempt to connect facts and values involved the 'naturalist fallacy'—physics could not hope to decide metaphysics, the handmaiden of the priest.

Whatever the merits of this truce, as the creationist controversy demonstrates, religious authority has not readily withdrawn from a variety of spheres, like education, that it once completely controlled. So why withdraw the strictures against Galileo? Clearly, religious authority has no intention of capitulating, so the withdrawal of the strictures only signals the desire to re-establish a harmonious and cosy relationship with science. In this post-modern world, there is an expectant new harmony in the air—between the new theology and the brave new physics. It is now beginning to seem as if theology and science can again work together; theology can accommodate the age of the world, provided science confirms that the world was created—as the big-bang theory and Hawking's singularities suggest. Theology can welcome quantum mechanics, provided quantum mechanics confirms theological views of free will and the mind.

Having passed through the three stages of harmony, truce, and conflict, the renewed attempt to establish harmony suggests that the relation between science and religion has gone through a complete cycle. But the new harmony must be carefully distinguished from the earlier naive belief in the consistency of all knowledge—the idea that science and religion represent different facets of the same truth. It is possible for two people to meet, to fall in love, and to get married without knowing very much of each other. But after getting to know each other better, after accepting their incompatibility, after undergoing a prolonged separation and a painful divorce, if they again seek to get together, it is hard to imagine that they have suddenly regained a lost freshness. This sounds more like a case of remarriage precipitated by practical concerns. So what practical concerns motivate the remarriage of science and religion?

## *Marriage as an Exclusive Relationship*

*Which* religion does the harmony of science and 'religion' concern? Science is one, though religions are many.

Another thing about the remarriage is puzzling, and most 'authorities' who have commented on the question of science and religion remain silent[11] on this point: *which* is the religion in 'science and religion'? There is some justification to regard science as one: of two competing theories, one will eventually be eliminated. But many different religions have coexisted for thousands of years, and this situation could conceivably continue indefinitely. The perception of a conflict between science and religion has been used to set up a dichotomy—with science on one side, and all religions indiscriminately lumped on the other side. This dichotomy certainly ceases to be meaningful when we move from the picture of conflict to the picture of a revived harmony between science and religion; for science, being one, cannot harmonise with more than one religion.

Proofs of God's existence, typical of the alleged harmony of science and 'religion' in the West, are contrary to Buddhism. On the other hand, creationism is no ground for conflict between science and Buddhism.

Consider, for example, a typical claim that some new scientific speculation (the anthropic cosmological principle, say) provides a proof of the existence of God. Of what use would such a claim be to Buddhists who do not believe in 'God', and could reject the very logic of the 'proof'.[12] The Buddha is not known to have taught the existence of either God, or heaven, or hell. Like him, his distinguished followers denied God or any other creator of the universe—with increasing vehemence as theories of creation gained currency later on. Thus, Buddhists in the 7th century CE argued *against* creationists as follows:

> Entire denial of him [Puruṣa; Creator] as in the case of Īśvara [God] should be stated. For why would this [Puruṣa] perform activity of this kind (i.e., creation of the world, etc.)? If because of being prompted by another, then Puruṣa would not have independence. If out of compassion, then He would make a purely pleasant world… If He acts from sport, then He would not be the master of that sport, for like a child, He needs accessories with which to sport…If…due to his own nature, just as…burning…belongs to fire…due to nature alone…, everything would be originated from Him at the same time, because the cause with the power to originate them would be existing.[13]

Thus, the moment one takes other religions into account, establishing creation as a scientific truth does not establish the harmony of 'science and religion'.

Indeed, if one takes other religions into account, the very conceptualisation of science vs religion as a case of reason vs faith fails. Thus, this 'faith' is faith in religious or scriptural *authority*, while Buddhism rejects authority, and advocates scepticism about all authority including the teachings of the Buddha. As the means of right knowledge, Buddhism accepts only the empirically manifest, and inferences from it.[14] Thus, all this grand talk of 'science and religion' has appealed to the perception of a conflict between science and 'religion' to tacitly erase the fundamental incompatibilities between one 'religion' and another, by incorrectly supposing that one particular religion can represent or replace all religions.

There can be no matching claim of harmony between religion and religion. Hence the new equation between science and 'religion'.

Does 'religion' in 'science and religion' then refer to a common denominator of humanism? Not at all: humanism comes naturally, and the case for it is not bolstered by bracketing it with science. The real thesis lies in the new equation between science and religion: the revived harmony of science with one particular religion, *and its continued conflict with all other religions*. Accordingly, there are no humanistic visions here of the pope embracing Khameini; no dons from Cambridge or Oxford or Harvard or Princeton or Yale to claim that the latest scientific thinking establishes the correctness of Khomeini's theology.

## *Religion as a Public Belief*

Harmony with science would make 'religion' an item of public belief, like science.

Private beliefs need no public justification. The diversity of religious beliefs in a country like India, and the requirements of peaceful coexistence, make it very easy to regard religion as an item of private belief that should not be publicly discussed, and Christianity has peacefully coexisted in India for the last 1800 years. But, in fact, there is no sign even of this liberal vision of peaceful coexistence, for the 'authorities' who are today talking of science and religion, are not ready to accept religion as an item of personal belief:

> So the story goes…science is allocated its role in a public domain of fact, whilst theology is relegated to a private domain of opinion. ('True for me' is the best that it can aspire to.) Leslie Newbigin has eloquently warned us of the dangers of such a compromise.[15]

That is, the concern of the 'authorities' is that the particular religion they advocate should become an item of public belief like science: as with scientific theories, it would have to be publicly agreed that there is one 'right' religion, and all others are wrong.

Thus, the proposed remarriage of science and 'religion', like any marriage, makes a public statement: it seeks to elevate a particular set of religious beliefs to public beliefs. After the remarriage, science and 'religion' would have the same status, so that religious beliefs would be on par with scientific truths. This proposed remarriage seeks to establish an exclusive relationship: it would make illegitimate any flirtation between science and any other religion—there would be no more frights from flings of the sort in Capra's *Tao of Physics*. By implication, the proposed remarriage would make illegitimate all religious beliefs (and values) which do not *thus* harmonise with science. Whether or not creationism is in, Buddhism would be out. And this would be the case even though Buddhism, like science, in principle, rejects authority, and accepts inference based on the empirically manifest as the sole means of right knowledge.

Legitimately, therefore, we may publicly ask: what are the particular features of this particular religion which make possible such an *exclusive* claim of harmony with science? Why is one particular religion the natural partner for science? This is a big question; before answering it let us first attempt an easier one.

## *The New Strategic Doctrine*

The easier question concerns the date of the remarriage. Why is *now* the auspicious occasion? What *current* political and cultural necessity prompts the revived claims of harmony between science and 'religion'?

This current necessity concerns perceptions of the situation prevailing after the Cold War—the end was marked by the collapse of the Soviet Union. During the Cold War, it was easy to think of the world as split into two opposing camps. How should we understand the world *now*? Is it a unipolar world? or is it a world fragmented into 180 nations, more or less? Does victory in the Cold War signify the ultimate triumph of the West? Or is it a local peak in an irregular general pattern of decline?

New strategic doctrines have been propounded to meet the new situation. Gone are the days when strategic analysis concerned mainly nuclear policy, and strategic analysts were either in the Mutually Assured Destruction (MAD) camp or were Nuclear Use Theorists (NUTs). No longer is it the function of strategic doctrines to ensure the victory of one nation over another: the very concept of a nation is being abandoned. Economic globalisation is erasing the economic importance of national boundaries. National boundaries, it is being argued, are artificial constructs, often drawn hastily during the retreat of colonialism, and the world is naturally divided along cultural and religious lines. Accordingly, strategic doctrines now focus upon the victory of one culture, and one religion over others. These strategic doctrines are rooted in certain historical theories, a very simplified account of which follows.

## *The Decline of the West*

Spengler thought that Western Culture would end with the century.

Oswald Spengler was a German school teacher, who abandoned even that job because he was bursting with something to tell the world. In 1917, he published an influential historical tract called *The Decline of the West*. Spengler[16] rejected as '*the Ptolemaic system*', the then-prevalent Eurocentric scheme of history, and announced 'the *Copernican discovery* in the historical sphere…that it admits no sort of privileged position to the Classical or the Western Culture as against the Cultures of India, Babylon, China, Egypt, the Arabs, Mexico…'. It is impossible to draw a curve through a set of observed points if one looks at the particulars of just one point individually, and ignores the rest: a pattern emerges only when all the cultures are seen together. This shift in perspective from Euro-history to world history enables Spengler to identify periodicity and polarity in history: the events that are common and those that are unique to a given Culture.

Spengler regards these Cultures as organic;[17] like live organisms they are born, they grow, and they die. Cultures being living forms, mathematics, appropriate to the study of inert nature (physics), is inappropriate to study Cultures: 'The means…to understand living forms is Analogy.'[18]

Spengler now finds a deep analogy between the state of the world in his time (when he was writing, i.e., just before World War I) and the Hellenic world in its state of decline, when it was overtaken by the Roman empire. He concluded that the West was in a state of decline, and the end would come some time around the end of the millennium (i.e., around now), with the barbaric use of brute force displacing money as the source of power.

Unlike Marx, Spengler thought the next phase would be militarism rather than socialism.

In part, Spengler was responding to Karl Marx's historical analysis, and the resulting projection of the future. Spengler agreed that money-power (capitalism) would be violently replaced. But where Marx thought that socialism and a utopian rule of the people would follow a revolutionary change, Spengler thought that gross militarism and dictatorship would replace money-power.

## *Spengler vs Toynbee*

Toynbee responded that all civilisations were declining except the West.

In response, Arnold Toynbee rattled off *A Study of History*, in ten volumes. Some of Spengler's criticism cannot be validly refuted but Toynbee's anxiety lies elsewhere, and he changes the categories to suit his concerns. Toynbee points out that nation-states and political boundaries are ephemeral on the historical time-scale, so that 'civilisations' are the proper subject matter of history. These 'civilisations' Toynbee identifies by affiliating each with a universal state; he contends that any such universal state must also be associated with a universal church. This universal church, he claimed, is formed as a creative response to the disintegration of an earlier universal state. As a supposedly generic example, Toynbee considers the birth of Christianity at the time the Hellenic world was disintegrating. (Additionally, there is a universal narrative, involving a 'time of troubles', an 'interregnum', and a 'heroic age'.) To condense ten volumes into ten sentences, Toynbee[19] concludes that most of these civilisations, or their remnants, are in a state of decay and decline, barring only the 'Western civilisation' associated with Western Christianity (as distinct from, say, the Eastern Orthodox Christianity practised in Russia).

Apocalypse now?

In his final volume, published after the Second World War, Toynbee goes on to discuss the qualifications that the USA has of leading this future universal state. In short, Toynbee provides an optimistic response to Spengler's *Decline of the West*. In Toynbee's projection of the future, everyone else is declining while the West is in the ascendant—and he regards this as true also of the associated Western Church.

Toynbee thought he was opposing Spengler's 'cyclic' view of time in history with the 'linear' apocalyptic view.

Toynbee's conclusions relate to his view of time, which is inevitably influenced by the temporal dichotomy. Toynbee regards Spengler as an advocate of the 'cyclic' view of time in history, of the periodic rise and fall of civilisations. As for himself, Toynbee champions the linear, 'apocalyptic' view of the Western church. He sees history heading for a climax. The practical meaning of this apocalyptic climax is, however, a little curious.

## *The Clash of Civilisations*

> In the nineteenth century the idea of 'the white man's burden' helped justify the extension of Western political and economic domination over non-Western societies. At the end of the twentieth century the concept of a universal civilisation helps justify Western cultural dominance of other societies and the need for those societies to ape Western practices and institutions. Universalism is the ideology of the West for confrontation with non-Western cultures.[20]

In the light of these historical theories, let us examine the events of the past century. (The aim of this examination is *not* to arrive at the theory which gives the best estimate of the future. Instead, the aim is to understand the political perceptions which motivate the new strategic initiatives for the remarriage of science and religion.)

At first it seemed that Marx was right.

The publication of Spengler's book was immediately followed by the Bolshevik revolution, and the formation of the Soviet Union. There was a revolutionary change also in China, and the two together covered a large part of the people and the land of the world. For a time it seemed as if Marx was right. The Second World War definitely led to partial decolonisation. Britain was compelled to retreat and to withdraw direct control over its far-flung colonies. The USA wanted to take its place, but could not continue the colonial process of loot and exploitation as easily because in its way stood the two post-revolutionary giants: USSR and China.

Then it seemed that Spengler was right.

To prevent the further spread of 'communism' as the only hope for people in the former colonies, the USA had to invest heavily in various 'frontline' states like Taiwan, Korea, Vietnam…. For a time, the Cold War looked like a losing battle for the USA; but following so quickly after the Second World War, it did succeed in militarising the Soviet Union, and subverting its socialism. It began to seem as if Spengler was right. But now an unsuspected polarity asserted itself: advances in the technology of war made (global, nuclear) war impossible. Orwell's visualisation[21] of Spengler was ruled out: there could only be a protracted and dangerous stalemate, where the slightest spark might escalate and spell doom for both parties, if not the end of the human species. The Soviet Union gave in without resistance, like Greece gave in to Rome.

But now it seems as if Toynbee was right: it is now the West against the rest. Which would be the future universal church?

The Cold War has now ended, and the USSR has disintegrated, while China wants to integrate in the 'global village'. How will history continue? Historians in the eschatological tradition, from Hegel, have pleased the vanity of the rulers by announcing their present as the end (*eschaton, telos*) of history; since history has obviously continued, these announcements need not concern us. But, it is now beginning to seem as if Toynbee was right. The war in Iraq has left no one in doubt of the intent of hegemony: it is now the West against the rest. Which universal church would be affiliated with this candidate universal state? Toynbee thought that the associated universal church would be Western Christianity.

Huntington argues that conflict has not ended with the Cold War. Conflict will now assume the form of a clash of civilisations or religious war.

We may be inclined to doubt Toynbee; perhaps he too was wrong like earlier historians. But his vision of a universal state is very attractive to those who today are seeking to build a unipolar world. So, Toynbee's theory has already moved into the practical realm of state politics. A leading US strategic analyst, Huntington, has warned against the danger of euphoria: this euphoria derives from a two-world Cold-War perspective. The victor of the Cold War will not rule happily ever after; instead, conflict will assume a different form. Which form would it take? The many-civilisations perspective of history can be applied also to current politics: for values and beliefs demarcate human groups much better than head shapes, skin colours, or national boundaries. The conclusion is that the post Cold-War world would be marked by a clash of civilisations, not unipolarity—by religious war, not class war.

The power of the West has been irregularly declining.

In this scenario, victory in the Cold War has produced exhaustion, not triumph for the West. The West was much more powerful at the beginning of the century when colonialism was at its peak. The power of the West is, in fact, declining as predicted by Spengler, but so slowly and irregularly that the decline is not easily perceptible.

What is power? Economic and military force equals *hard power*, used to force another person to behave as one wants. Religion represents *soft power*, used to make the other person want what one wants.

Power is the ability to influence the behaviour of another person or group. One might make the other person behave as one wants through some form of *force*: economic, military, or institutional—this has been called hard power. Or one might make the other person *want* what one wants—this has been called soft power.[22] The soft power of the West seems to have declined: the non-West is no longer unanimous in seeing Western culture and attitudes as the route to success; despite television, there is increased assertiveness among non-Western cultures.

The hard power of the West has also declined since decolonisation. It may be difficult to reverse this decline. Today, science and technology, rather than people, have become the basis of hard power. Thus, the ultimate basis of hard economic and military power is, now, a monopoly of accumulated information—for example, information about how to make an atomic bomb, or a missile, or a medicine. A monopoly of information is a precondition for profit and power: information, like land and labour, has been transformed into a commodity. On the other hand, this information is generated through scientific research and technological innovation, a precondition for which is the free sharing of information. It is now beginning to become clear that this process of profiting by claiming ownership of commonly generated information—for example, by rewriting the history of science—goes all the way back to the beginning of colonialism in the scientific revolution, which was triggered by the massive import of information along with spices. Copernicus, who translated Arabic heliocentric theories from Byzantine Greek to Latin, is a clear case[23] in the point.

More people are becoming aware of this process of profiting by competing for ownership of information that was earlier generated cooperatively. Awareness of the process may enhance the desire to compete, but it surely diminishes the willingness to cooperate. Once they understand this process, this time around, people may be reluctant to share information with those who wish to monopolise it. Similar tensions arose under feudalism, for example. The aristocracy needed peasants to produce from the land, though it claimed ownership of the produce. This led peasants to revolt. The fundamental contradiction of information capitalism—the need to simultaneously share and monopolise information—may also be resolved in a revolutionary way and not through a comfortable dialectical synthesis.

There are other levelling forces at work. Information, though now commodified like land and labour, remains more abstract. Hence, information is difficult to monopolise, for it tends to 'leak'—and information leakages level the hard power derived from information monopoly. With advancing technology, even small leakages of information could cause havoc. What if an Iraqi terrorist were to get hold of the blueprint of a lethal, genetically engineered, new organism? The possibility of information leaking into the hands of disgruntled elements is the present-day nightmare of the West, and its greatest security threat. The only way to prevent information leakage is by instilling a sense of commitment into people—that is, by an expansion of soft power. Therefore, despite having won the Cold War, the West remains besieged; its hard power is under a variety of subtle but serious threats, so that it may never again reach the peak of hard power it attained during the age of colonialism.

There is another way of looking at things. Perhaps the West is not declining. Perhaps, after the Cold War, it is poised for hegemony. Perhaps 'soft' power is only a contemporary euphemism for supreme power—making the other person want what one wants. Perhaps Huntington's talk of decline is intended only to counteract euphoria; what he advocates is that victory in the Cold War must be quickly consolidated. A victory is one thing; a stable rule another. But this way of looking at things makes absolutely no difference to the course of action he suggests. Whether the West is inching towards hegemony or declining, any future expansion in its power can come only by expanding its soft power.

There are many other reasons for the West to seek an expansion in its soft power. Investment in hard power has reached a saturation point. Investing hundreds of billions of dollars annually in nuclear weapons and missiles will not now increase the power of the West; better nuclear weapons will not help to change the behaviour of any more people. But even if a fraction of that money is diverted to the fields of culture, that is cause for the non-West to worry: what would be the cumulative effects of such systematic investments in culture over, say, 15 years? It is not difficult to imagine the havoc that an International Cultural Fund could wreak!

Again, for the West to achieve supreme power, or lasting security, economic globalisation is not enough; there must be cultural globalisation—another name for the expansion of soft power. Economic globalisation has helped to break down national barriers to capital, but cultural barriers remain in place. Cultural barriers impede economic globalisation. Banks cannot function smoothly if charging interest is seen as culturally wrong. Cultural barriers are particularly awkward in an age of information capitalism. Bill Gates would not be rich if private ownership of cooperatively generated information were seen as ethically reprehensible (as Marie Curie saw it). So people must be taught to admire Bill Gates and not Marie Curie.

For all these reasons the West seeks to expand its soft power. What exactly does an expansion of soft power entail? It entails investment in the propagation of 'appropriate' values. Values decide what one wants, and how one behaves. So, one can make the other person want what one wants by modifying his values. Modifying values is not easy. To propagate values successfully, they must be universally credible. The obvious difficulty is that the religion in which Western values are anchored has lost credibility because of its perceived conflict with science. Hence, its credibility can be restored if that religion is seen to harmonise with science, which is universally credible today. The right time to make this investment is *now*, immediately after the end of the Cold War, when the West is at a local peak of its power and influence.

To summarise, the West is threatened with decline which, however, is not inevitable. Its hard power is under the long-term threat of information leakage. How should the West respond? Toynbee suggests that a creative response is required. But in regarding Western Christendom as the future of humanity, Toynbee is not being faithful to his own vision: a mere continuation of the old church can hardly be a 'creative' response. If Toynbee's vision is consistently applied, it would seem that the old church can rejuvenate itself only through a creative synthesis with a universal young science. The auspicious occasion for the remarriage is *now*: The end of the Cold War marks the beginning of a new clash of civilisations; a clash in which the remarriage of science and religion can play a creative role—it can perhaps arrest the decline of the West.

To move on to the other question, what exactly makes Western Christianity the natural partner of science in this enterprise of constructing a future universal church?

## *The Candidate Universal Church*

The West having won the Cold War, it seems natural enough for Western Christianity to partner science in making a future universal church. But the curse on cyclic time suggests some other answers. Time beliefs are fundamental to both science and religion. The time beliefs resulting from the curse have penetrated science so deeply that, even today, people can write books claiming that Western Christian theology is a branch of physics. Science has come to resemble theology, and the basis of this resemblance is examined in more detail in the next part (of this chapter and book). It is this similarity between science and 'religion' which makes them natural partners.

The curse provides another sense in which this partnership of science and 'religion' is 'natural'—a sense which relates to soft power. The political function of a universal church is to promote values that suit the state. Among the major religions, only Western Christianity now propagates values that are the most acceptable to the state and to industrial or information capitalism (as we shall see in more detail in Chapters 10 and 11). This acceptability is not an accident—these values have nothing to do with the original doctrine of universal love that one identifies with Jesus. Instead, these 'religious' values relate to the political role of the church: the church has systematically adapted its doctrine to meet the changing requirements of the state. The curse shows how the church—an institution unique to Western Christianity—has systematically reinterpreted key aspects of the doctrine to inculcate values suited to the state. Close association with the state for over sixteen hundred years is the key which distinguishes official Christianity from other religions—the distinction which gives it the privilege of attempting an exclusive harmony with science.

While a more detailed comparison of official Christian values with those propagated by other religions is postponed till Chapters 10 and 11, a quick historical review of some special features of official Christianity is in order. (Christianity was so substantially transformed after Constantine and Justinian that we need a new name for it: official Christianity.)

## *The Official-Christian Doctrine of Religious War*

Official Christianity differs fundamentally from other religions—including Christianity. What is the chief distinguishing feature of its doctrine? What is the main innovation that it introduced? Early Christianity was like various other religions that then existed, and the teachings of Origen were similar to the doctrine of *karma*, and to common Neoplatonic beliefs in Alexandria. At a sufficiently abstract level, there is no doubt a similarity between, say, Buddhist compassion and early Christian love.[24] The early Christian traditions of community, missionaries, equity, and monasticism, though not identical with the corresponding Buddhist traditions, still retain discernible similarities.

Pre-Christian religions lacked the concept of religious war.

What Buddhism and early Christianity both lack, however, is the idea of religious war, which must be regarded as the principal innovation introduced by later-day official Christianity. War is not concomitant with religion. Jains, for example, are not known to have ever engaged in religious war: they are so extremely averse to explicit violence that orthodox Jains do not even eat tubers, for they are the roots of the plant, so eating them kills the plant. Buddhism did not spread through warfare—the Emperor Aśoka renounced war and turned Buddhist after the horror of war was brought home to him by his victory in Kalinga. Though he sent out his own daughter as a 'missionary', he did not send an army before her. In fact, there is no record of any Buddhist army, nor any case of a martial victory identified with the propagation of Buddhist or Jain beliefs

Christianity invented religious war.

But all history books[25] seem to agree that the superstitious association of the cross—a religious symbol—with martial victory was the key to the conversion of Constantine. This fraud, as Gibbon called it, first enabled the church to acquire a share of state-power. As is well known, religious war remained an important principle with the church for the several centuries during which the church played a pivotal role in organising crusades to the Middle East. In Gibbon's words,[26] 'The Church of Rome defended by violence the empire which she had acquired by fraud.'

Religious disputes certainly existed before Christianity, for example between Buddhists and Jains—but they ferociously attacked each other's philosophical positions, and not the persons holding those positions. The same thing is true of early Christianity: Origen debated with the 'pagans', he did not fight wars with them. War, too, most certainly existed earlier, though it concerned other disputes. The innovation introduced by official Christianity was the use of war to resolve religious disputes; the use of coercion to decide the ultimate truth.

It would be facile and disingenuous to dismiss intolerance and religious war as purely an aspect of the church's pre-modern history. Religious war did not end with the crusades; it provided the impetus for colonial expansion. The search for Prester John—the legendary Christian king in Africa—was a key motivation for early colonists: the hope was that the religious war could be won through a strategic alliance with him. The first military spy to Prester John, and Africa and India generally, was a priest—Pedro Covilhão. Jesuit priests sent to India and China regularly doubled as military spies, sending back military information in their periodic reports back to Rome. The strategic–military objectives of the church were no secret. Thus, in an attempt to repeat its acquisition of the Roman empire through Constantine, the church sent several missions to India, in 1580, hoping to win all of India by converting one person—Akbar, the Moghul emperor. Though this plan did not succeed, the church did succeed in converting a few minor potentates, and it did retain its representatives in the court of succeeding Moghul emperors.

This strategic-military role of the church, of course, continued after colonisation, two centuries later, with the notorious 'civilising mission'—a war against all non-Western cultures. During the Cold War, the church fought a feverish war against communism—it convinced millions of people that communism was something bad, even though these people did not know the meaning of the term 'communism' well enough to distinguish it from socialism.[27] Huntington's current strategic perspective of a clash of civilisations is only a shade different from the perspective of religious war, and that shade of difference may be only in the terminology. (In strategic analysis, it is customary to make harsh thoughts more palatable by, for example, calling a fusion bomb a 'strategic device'.)

Unlike normal wars, religious war is fought both within and outside the boundaries of the state. Militarised Christianity fought its first religious war with the 'pagans' in the Roman empire. Pagan temples were taken over and desecrated (p. 40),[28] dissenters were exiled, and the Great Library of Alexandria was burnt down. Stones from the temples were used to build new Christian churches. For these great tasks, and also for personally commanding troops sent to destroy Origenist monasteries in the desert, Theophilus of Alexandria was declared a saint. The revised ideas of saintliness were confirmed by his nephew and successor, Cyril of Alexandria, who led the mob of Christian monks that murdered Hypatia, a beautiful and brilliant mathematician and philosopher. She was 'torn from her chariot, stripped naked, dragged to the church' where 'her flesh was scraped from her bones with sharp oyster-shells and her quivering limbs were delivered to the flames'.[29] 'After this', adds Bertrand Russell, 'Alexandria was no longer troubled by philosophers.'[30] The brutal church policy of liquidating disaffected people had the following benefit for the state: the Roman empire survived long after it had lost its original military clout.

The church policy in Alexandria was no temporary aberration. A similar policy of eliminating disaffected people was repeated in Goa, a thousand years later, with similar consequences. Before the arrival of the Portuguese, Goa was part of the prosperous Vijaynagar empire. The Muslim potentates of the Deccan coveted the wealth of Vijaynagar (which dazzled Vasco da Gama) and waged a constant war against it. In 1473, Adil Shah of Bijapur captured Goa on the fringes of Vijaynagar. Though he did not interfere with the religious beliefs of the people, he levied heavy taxes on them to finance his constant wars. This made the people of Goa very unhappy. They approached the king of Vijaynagar, asking him to recapture Goa, and he deputed the task to an admiral, Timayya. Being unsuccessful, Timayya suggested to Afonso de Albuquerque, the Portuguese viceroy, to take over Goa, which he did with the ample support he had from within. Adil Shah recaptured it, but Albuquerque regained it, again with the support of the people of Goa. By 1520, the Portuguese were established in Goa, and on 12 January 1522, Bishop Dume wrote to the king of Portugal advising that the temples in Goa island be demolished, and churches erected on their sites. This meant rendering service unto God. Those who wanted to live on the island had to convert to Christianity, and those who refused had to leave. By 28 June 1541, all Hindu temples in Goa island were demolished; this task was carried out by Miguel Vaz, who was blessed for it by St Francis Xavier.[31] This process was repeated in other parts of Goa, and the Inquisition, imposed in 1560, dealt with any deviations in its well-known way. As a result of this policy, Goa stayed with the Portuguese long after the Portuguese had ceased to be militarily important in the Indian ocean. In fact, Goa's liberation from the Portuguese came 14 years after India's independence from the British!

Conversely, despite its military might, the collapse of the Soviet Union came about exactly due to the presence of disaffected people, and the key role that the church played in creating this disaffection is too well known to go into here. To give just one example, the Solidarity movement in Poland was transparently spearheaded by the church, and a Polish cleric was subsequently appointed pope. The church has not, of course, forgotten its other enemies: there is an easily noticeable correlation between fluctuating Western political fortunes in the Middle East, and fluctuations in the crusading spirit against Islam: in Iran after the fall of the Shah, in Iraq after the revolt of Saddam Hussain, and in Afghanistan after the victory of the Taliban. In short, the strategic-military role of the church must be discussed in the present tense. The popularity of this idea of religious war, and its evergreen appeal in Western culture cannot however be fully understood without going into the changes in church ideology that accompanied the innovation of religious war.

## *The Changed Face of God*

In the transition from Origen to Augustine, the two key changes in church ideology were *(a)* the rejection of equity, and *(b)* the acceptance of force as morally valid (p. 40).[32] An even more fundamental ideological change was *(c)* the willingness to adapt ideology to suit the concerns of the state.

Along with the switch from equity to inequity, the official church switched its allegiance from the people to the rulers. Helping the rulers to rule, by 'guiding' the beliefs and behaviour of the people, became its chief function. To facilitate its role as a moral guide, it not only destroyed philosophers, the church extolled faith—faith in its authoritative interpretation of the scriptures, hence, ultimately, faith in its own authority. To ensure a perennial base for its authority, it systematically indoctrinated young children. Where the state ruled the arm which wielded the sword, the church guided the mind which moved the arm.

The Bible tells us that God created man in his own image, and the rationalists assert that man created God in his own image, but the fact seems to be that the church created God in the state's image!

The changed face of God that accompanied the curse on 'cyclic' time ensured the requisite change of values among people by modifying the picture of afterlife—it is often overlooked that hellfire-and-brimstone arguments would not have been possible without this changed picture of God, heaven, and hell. Augustine's depiction of *eternal* heaven and hell enabled a carrot-and-stick management policy—heaven was the carrot, hell was the stick, and the people were the donkeys to be managed with this policy. These changes of doctrine were so powerful that their consequences persist to this day: opinion polls[33] have consistently shown that a substantial majority of adult US citizens still believe in such a heaven and hell.

The problem is that many people today reject these beliefs as unscientific. Consequently, they also reject the accompanying value system. Is there any way to make them accept it? After the demise of the Soviet Union, Toynbee's vision of a world ruled by the West now seems more likely. But who will now rule the mind of man? Was Toynbee right in supposing that Western Christianity would be the universal church associated with the future global state? Strangely enough, Western Christianity's main rival for the role of the future universal church in the future universal state seems to be science, for only science is universally acceptable today.

## *Science and the State: The Third Role of Science*

Science is universally acceptable because it is regarded as a quest for truth. But the idea that science is simply a quest for truth is naive, for most scientific research today is carried out under state patronage. Why does the state patronise science? Surely not to promote truth! The state is mainly interested in promoting itself. The state extends its patronage to science and technology largely because these are perceived to be useful for trade, or for war and other coercive aims of its expansionist policies. Not only is the bulk of the scientific research in the USA today supported by the

Department of 'Defense', this has all along been the case as Bertrand Russell points out:

> Archimedes was respected for his scientific defence of Syracuse against the Romans; Leonardo obtained employment under the Duke of Milan because of his skill in fortification, though he did mention in a postscript that he could also paint a bit; Galileo similarly derived an income from the Grand Duke of Tuscany because of his skill in calculating the trajectories of projectiles. In the French Revolution, those scientists who were not guillotined devoted themselves to making new explosives.[34]

From the 16th to the 18th century in Europe, the Spanish, Dutch, and French governments, followed by the British, systematically patronised astronomy and mathematics by offering huge cash rewards to people like Galileo, Huygens, Newton, Leibniz, etc., because astronomy and mathematics were seen as the key to navigation—then a matter of the greatest strategic and commercial importance to Europe.

Earlier, Roger Bacon had called this diminutively '"the third role of science"...that power is assured to those who possess it...'. He wanted that 'the Church should take it into consideration in order to spare Christian blood in the struggle with the infidel'.[35] In the USA, this realisation struck home with the making of the atomic bomb during the Manhattan Project.

Science and technology help the state become universal by physically eliminating the opposition. It is not the atom bomb, but technology *per se* which is genocidal. The genocide of the north-American Indian and the Australian aborigine did not require any atomic weapons. Genocide is premised on racism which rests on the technology gap more than the colour of the skin. The first European explorers (or traders, or pirates, or would-be-conquerors) came back with glowing accounts of the physique of the African, and the riches of India and China. It was three hundred covetous years before Europe picked up a stable lead in technology. Intoxicated, the newly 'discovered' civilisations were *then* ranked by the use of technology.[36] This procedure of measuring men by the machines they used put Chinese at the top, Indians next, Africans after that, and the North-American Indian and the Australian aborigine at the bottom. Those at the bottom of the technology ladder were eliminated. The Africans were seen as fit to be enslaved and the Indians and Chinese as fit to be colonised. (Today, Africans and Indians are the two at the bottom of the ladder, and in imminent danger of being tribalised, with consequent massive depopulation and possible extinction. Africa, particularly, is waiting for genocide through epidemics arising from engineered viruses, say, and the enforced polarity in society which ensures that the poor are always the worst affected.)

For his attempted genocide, Hitler has been regarded as the embodiment of evil. But that was perhaps only because he failed in his attempt, for successful genocide is seen as a triumph, and is largely celebrated rather than condemned to this day in the USA and Australia—as in 'Western' stories, and the Australian 'Bicentenary' celebrations. The reason for celebration is clear enough: the prosperity of USA is built on the loot of a continent enabled by genocide and slave labour. After the Second World War, the USA signalled its superpower status by demonstrating its ability and willingness for mass murder by dropping atomic bombs on Hiroshima and Nagasaki. Technological progress builds prosperity by enabling genocide and mass murder. Subsequent technological progress has brought us to the point where the entire human species can easily be extinguished. A universal state would be impossible without the ability and willingness for genocide.

## *Science as a 'Higher Religion'*

Those lacking scientific knowledge, rely on the *authority* of scientists.

Such past triumphs of science, and the association of technology, hence science, with the state, have vested the scientist with an authority that the priest (and the social scientist) envies. If a scientist says that a comet is going to crash into Jupiter, everybody believes this. People believe what the scientist says, though they may have never used a telescope to look at Jupiter, and may know nothing about the dynamics of comets or planets, and so may be quite unable to cross-check the calculations on which this prediction is based—calculations which they have not, in any case, seen. Reliance on scientific authority has been reinforced by the general lack of scientific knowledgeability.

Most people lack scientific knowledge because innovation has outstripped education.

Spengler noted the general lack of scientific knowledgeability as one of the causes of the inevitability of the decline of the West. He pointed out that education would not keep pace with scientific and technological advance, so that the society at large would remain scientifically and technologically illiterate, as we find it now.[37] One person in three in the USA today has access to a computer. How many of them can fix a software bug or troubleshoot hardware? In a pathetic SF story, all persons on Earth suddenly become unintelligent: though they could continue to drive cars, no one knew how to fix a breakdown. A similar thing happens if people are uninformed instead of unintelligent. Most people cannot say for sure whether the roadside mechanic is telling the truth; they have to rely upon a general feel for the trustworthiness and competence of the mechanic.

There is a generic reason for widespread scientific illiteracy. Force is needed to maintain social inequity and expand profit. Both needs drive constant technological innovation, so a significant proportion of available resources are readily allocated to produce technological innovation. Education, on the other hand, only produces the scientists who will produce the innovation—this is a more indirect and a longer-term process. So it is always more profitable to devote resources to the production of scientific innovation, rather than education which only reproduces the scientific labour force.[38]

Scientific illiteracy is not confined to non-scientists. Among scientists, overspecialisation (a form of semi-literacy) is common: a physicist is not expected to know biology or chemistry, any more than an eye-specialist is expected to know neurology. The generic reasons for specialisation are the same: the function of scientists is to produce innovations, and the hope is that, as in the production of any commodity, more narrowly focused resources will increase the efficiency with which technological innovations are produced.

This widespread scientific illiteracy, among non-scientists as well as scientists, has encouraged the process of deciding truth by authority to infiltrate science itself. Being scientifically illiterate, most people can only decide the validity of a scientific theory by trusting authority. Very often the only way to distinguish between a crackpot speculation and a serious one is to judge from the social *authority* of the scientist or of the institution to which he is affiliated. This is justified on the grounds that it may take years of study to understand the theories on which the scientist's judgment is based.

The difficulty is that scientifically illiterate or semi-literate people are often incapable of accurately assessing the intrinsic worth of the authorities on whom they rely. They tend to fall back on the naive belief that the existing social order is close to a utopian one in which the state and media confer social authority on a scientist roughly in proportion to intrinsic worth. But the state decision-makers—those who decide on *what* science should be supported—are themselves uninformed. These uninformed decision-makers cannot avoid reliance on the authority of experts—even to decide *who* are the experts.[39] They tend to trust the media, which trusts them in return, for newsmakers are typically those in positions of authority! We are familiar with the maxim 'Familiarity breeds sales' for authors and cinema-actors turned politicians; for science in a scientifically illiterate society, this familiar phrase acquires an unfamiliar twist: 'Familiarity breeds truth'!

State- or media-conferred authority has become the popular test of knowledgeability, hence truth. In the herbal fuel hoax, for example, the press in India did not approach organic chemists in the local universities; it sought out top bureaucrats, nuclear engineers, and astrophysicists. Neither the journalists who wrote these reports, nor the people who read them, seem to have realised that their primary superstition was to suppose that state-conferred authority is the de-facto test of the truth.

One reason for this identification of scientific knowledge with state-conferred authority is that scientific innovation is no longer something that can be produced by hand: it requires expensive gadgetry, and big money. Money on this scale is available only with the state; but where the state extends its patronage, it also extends its control. Hence, in practice, only that sort of science is do-able which is approved by those with state-conferred authority. Naturally no professional scientist wants to be left out in the cold, attempting what is not do-able. Consequently, the seriousness with which a new scientific speculation is received is directly proportional to the authority of the scientist proposing it. This becomes a professional habit which infiltrates also the process of peer review, virtually the ultimate guide to the social acceptance of scientific theory.

Like any other form of authority, scientific authority is surrounded by a paraphernalia of rituals: publication in a socially reputed journal is not only a means of disseminating information, it is a ritual test of truth and validity. Science has thus acquired the trappings of a primitive religion. As Arnold Toynbee points out in his *Study of History*:

> The pith of primitive religion is not belief but action, and the test of conformity is not assent to a creed but participation in ritual performances. Primitive religious practice is an end in itself, and it does not occur to the practitioners to look beyond the rites that they perform for a truth which these rites might convey. The rites have no meaning beyond the practical effects which their correct execution is believed to produce.[40]

Who can honestly say that this does not apply to scientists who feel quite content to pursue career advancement in the implicit belief that Adam Smith's hidden-hand of God has so nicely arranged things that the society at large is bound to derive practical benefits from the papers they write and the conferences they attend, provided only that they go on executing these rituals correctly? The scientist who personally benefits from these rituals may not see in himself an analogue of the priest who benefited from *his* rituals—the practical benefits of those rituals could not be demonstrated, they were mere rituals! The state adds its weight by allocating resources to support scientific rituals.

These rituals are fast becoming global. One quick indication is that science and computers have induced more people to learn English than the British empire could! Even the Germans and the Japanese now recognise English as the *lingua franca* of the sciences.

To summarise, science today is not a quest for truth. It is a quest for the sort of understanding needed for technological innovation, which confers on its possessors a military or economic advantage. Resources, therefore, are focused on innovation. Consequently, there is widespread scientific illiteracy, and over-specialisation, so that scientific truth is usually decided by recourse to authority and ritual. Science provides the technological means to make a universal state possible; it provides a universal belief in what is true, and a universal language in which to express this truth. Science is now more than a primitive religion: it has become a higher religion in the sense of Toynbee—possibly part of the creative response to a Western civilisation that is actually disintegrating!

## *Science as a Candidate for Universal Church-hood*

Science, in its manifestation as a higher religion, can hardly be ignored as a candidate for the universal church of the future universal state. Nevertheless, there is one reason why science cannot yet fulfill the role of the universal church. This major lacuna derives from the initial conflict between science and 'religion', and the subsequently accepted truce hammered out by visionaries like Kant. Science must limit its universality: science must leave alone the domain of ethics to 'religion', though it could have every other intellectual province. 'Pure reason' must not be mixed with 'practical reason'. Scientific and religious authority operate in different domains. Today, this truce is expressed through the formula: science is concerned with facts, it is value-free. The essence of the truce is that *science cannot pronounce on questions of good and bad*.

Of late, this truce has been coming under increasing pressure, as science shifts its focus from the inanimate to the animate, and scientists study more of animal behaviour and the human brain, or think more carefully about the longer-term environmental impact of, say, genetically engineered mutations. We will see later why this truce must eventually break down on the question of the nature of time. Nevertheless, the fact remains that scientific authority, today, can hardly provide moral guidance with the same organisation, reassurance, and aplomb as the church. And of what *use* is a universal church if it cannot provide the 'soft power' needed by the universal state?

Scientific authority is supremely credible, but it cannot provide values. Religious authority can provide values, but it lacks credibility among non-believers. In this situation, scientific *and* religious authority together would provide an irrefutable combination for the universal church.[41] If, however, science were to continue to expand its domain to include ethics, this would provoke an open war with 'religion'.

## *Harmony of Science and Religion as a State Objective*

Since science is the source of hard power and 'religion' is the source of soft power, a war between science and religion would damage the interests of the universal state, just as an open war between two important princes could damage the interests of an empire.

But hard power, by itself, is not enough. Consider the Western response to Iraq as an example, an ideogram. The universal state extends coercion so far and so frequently that it not only impoverishes people on its margins, it internalises them by constantly trying to control them. And any state which relies solely on coercion to control large numbers of its own poor people is likely to be unstable.

Loyalty becomes critical especially when technological sophistication is the basis of hard power; for this hard power is controlled by people who lack scientific and technological competence, and so is very susceptible to sabotage from within. The state propaganda machinery can temporarily disinform; it cannot win over loyalty. The state may use technology to impose its will externally, but propaganda is inadequate to make it cohere internally, as the case of the Soviet Union shows. As the case of the Soviet Union further shows, in the absence of loyalty scientists may sell their knowledge to the highest bidder—the current possibility that nuclear secrets of the former Soviet Union may leak to the Middle East in this manner is a major nightmare for the West. The benefits of technological progress can quickly evaporate if scientists stop valuing loyalty to the state and start maximising profit.

Even a truce between science and religion can be damaging to state interests. Such a truce would provide space for the individual's ethical perception to differ from that of the state—but for the universal state to work, ethical perceptions must cohere. The universal state cannot function without uniformising ethical perceptions for the same reason that the mass market cannot function without standardising demand. For instance, R. P. Feynman wondered whether it was morally right to work on the atomic bomb. In Feynman's case, the persuasive authority of J. von Neumann was available to settle these moral doubts. (He said Feynman was not responsible for the world.) But moral doubts can arise over innumerable issues, and they may not be so easy to settle, as in the case of Karl Marx who refused to recognise the authority of capital as legitimate. History shows that such moral doubts may even eventually overthrow the state.

To ensure moral coherence, therefore, it is convenient for the state to have an organised agency which can make authoritative moral pronouncements, in harmony with 'state interests'. How convenient it would be if moral pronouncements had the persuasive force of scientific truths! Feynman's doubts could have been better settled by proving the morality of war, by generally propagating the need to fight 'evil' with sophisticated weapons (as in children's 'comics'), and then, at suitable times, particularly identifying the forces of evil with the heretic, with Hitler, with communism, or with Islamic fundamentalism, etc.

Conflict between science and religion is damaging to Western interests, and so is truce. But is a renewed harmony between science and religion feasible today? The personal conflict within the believing scientist shows that religious belief, once implanted in childhood, can stay alive and kicking. And if belief can remain alive within a scientist, why can it not be kept alive within the society?

The prevailing conditions are conducive to a revival of harmony between science and 'religion'. There is widespread scientific illiteracy, and people at large believe what scientific authorities say is true. These scientific authorities are entirely dependent on the state and on private capital for their authority, their livelihood, their pet projects, and their awards. Dependence makes it easier to persuade them to exert the authority of science *for* 'religion' and not against it. The state has many ways of persuasion; for example, it can reward and confer authority on those willing to do its bidding.

To achieve harmony, the form of religious belief may, of course, have to undergo a change; for, today, the interests of the state no longer *coincide* with those of the church as they did at the time of Constantine and Justinian: teaching creationism to children in school may dampen the rate of technological innovation.[42] The church is not at liberty to attack the roots of technological innovation, for that would run counter to the interests of the state.

If the church ideology goes against current state interests, the church is prepared to modify its ideology. It is already doing so.

But it is not difficult to persuade a church accustomed to relying on authority. Such attacks on science, flowing from overconfidence, may soon become a matter of the past. The church has chosen between obsolete beliefs and a share of state power. In response to the changed global situation, the church has indicated a change of policy. It is now ready to accept a diminished role. It is ready to concede that education is no longer its exclusive preserve, and that education may be linked to the needs of the state or of industrial capital. The church can change; it can evolve in response to new political realities, and innovate doctrine, as it did in the past. The pope has now accepted that evolution is not merely a hypothesis. The church can further harmonise with science by changing science, for example. The religion of progress may progress to cope with progress! If the strictures against Galileo represented progress, the withdrawal of these strictures represents further progress.

To summarise, harmony between science and 'religion'(= Western Christianity) is a mutually desirable objective for both the state and the church in the West today; and one can understand why this objective seems feasible.

It does not, of course, follow from this conclusion that *every* attempt to harmonise science and religion is necessarily state- or church-sponsored. The objective conditions are there for a major state-and-church-sponsored systematic political attempt to harmonise science with religion. But there could be personal reasons as well. There surely are many persons who may not be directly aligned with the state or the church, but who may yet be interested in the harmony of science and 'religion'. They may want to resolve the tensions within themselves arising from a fractured identity—from an inability to reconcile the culture imbibed in childhood, with later-day training in science. This is part of a wider cultural problem, which has claimed as its victims even rebels and intellects like Newton and Nietzsche.

Whether or not the above arguments conclusively establish an actual attempt to build a unipolar, unicultural world, the objective conditions are very much there for such an attempt. So, it is prudent to act on the assumption that there is such an attempt. How would the plot proceed? How would the state pursue this objective of amplifying its power by harmonising science with religion? The infiltration of authority into science has made it an excellent tool for marketing those religions that are based on faith and authority, where the adherents are supposed to believe rather than think and question; to obey rather than experiment and find the truth for themselves. But authority cannot be used brazenly, not at least for so subtle a political enterprise concerning morality.

## *Demarcating Areas of Harmony*

> What does a priest care about *science*! He is above it!—And the priest has hitherto *ruled*!—*He has determined* the concept 'true' and 'untrue'!
>
> **Friedrich Nietzsche**[43]

Authority works best where experience is least likely to refute it. Complete irrefutability worked for centuries. Today, however, irrefutability would defeat the purpose, for every scientist now knows that it would make for non-science. Ideally, *some* experiments should be possible; preferably, they should not be feasible for the next hundred years or so that are likely to be politically critical. (As shown by the forged 'Donation of Constantine',[44] subsequently establishing the falsity of a theory or document does not help to recover lost political ground—in that case the Vatican.) At the very least the experiments should be very difficult and expensive to perform. Also, these experiments should only have so indirect a bearing on the theory that (through a process of interpretation by 'experts') the underlying metaphysics should be maintainable, regardless of the outcome of the experiment. (Examples are the debate on the foundations of quantum mechanics, or Tipler's Omega Point, examined below.) In short, the harmony of science and religion should be sought in areas where theories *seem* refutable but are not. Prime examples of these areas are the beginning of time (creation), and the end of time (apocalypse).

This entirely suits the church, and even the Catholic church which was traditionally anti-science has publicly proclaimed a new policy. While insisting that faith and science can coexist, Pope John Paul II exerted his authority and cautioned that the church and the faithful must remain firm on two points: (1) creation itself is the work of God, and (2) human beings have another dimension, they have an immortal component.[45] The authority of the church derives from its alleged proximity to God, and the authority of God is legitimate because the scriptures say God created man. Hence to deny belief in creation is to deny the authority of the church and scripture. The other requirement concerns the value-system, which, we saw, is the reason why the state is happy to solemnise the remarriage of science and 'religion'. So far as this religion is concerned, the value-system flows from the doctrine of sin, which requires an everlasting heaven and hell. Hence, the church regards belief in immortality as essential to restore the requisite values.

These, then, are the terms for the new compromise: short of denying creation and immortality, scientists can do what they want. The route to this new compromise has been opened up through the 'new physics'.

## ***Summary***

- The current *conflict* between science and 'religion' was preceded by *harmony*, and *truce*. Now 'religion' and science propose to remarry.
- The *remarriage* has become strategically important to globalise culture by propagating convenient values.

- The state is happy to solemnise the remarriage, because science is the source of 'hard power' whereas religion is the source of 'soft power'; science is credible while religion is the source of values. So, together, the two can yield credible values, and guide human behaviour.
- The remarriage would make certain religious beliefs public and universal, like scientific beliefs. It would exclude all 'non-approved' religious beliefs.
- Which religion would remarry science? Western Christianity.
- Why *now*? To consolidate victory in the Cold War. Further expansion in the power of the West requires an increase in its soft power.
- Why Western Christianity? Because it happens to be the religion of the victors in the Cold War; but also because it propagates convenient values, due to its long and close association with the state.
  - — The idea of religious war first united church and state, and then kept them together for the next 1500 years through Crusades, colonial exapansion, and Cold War.
  - — Western Christianity internalised its linkages to the state by reinterpreting its doctrines to help 'persuade' the people, through intimidation. Augustine accepted the use of force as morally valid. By rejecting cyclic time, he adapted the ideas of heaven, hell, God, and immortality to suit this doctrine of coercion and inequity.
  - — The church propagated these beliefs by encouraging 'faith' or reliance on its authority.
- Scientific truth, too, is today largely decided by authority, since most people are scientifically illiterate, and most scientists are overspecialised. Scientific authority is dependent on the state and so can be manipulated by it.

- Since both 'religion' and science now rely on authority, and both have close links to the state, harmony between the two is possible as a matter of state policy.
- As articulated by the pope, this renewed harmony should leave intact two key beliefs propagated by the church: belief in (1) *creation* (to legitimise its authority), and in (2) *immortality* (to legitimise values flowing from the doctrine of coercion).
- This new harmony is reflected in the way the Brave New Physics treats *creation* (beginning of time) and *apocalypse* (end of time).

∞

# Brave New Physics

> …in 1981 my interest in questions about the origin and fate of the universe was reawakened when I attended a conference on cosmology organized by the Jesuits in the Vatican. The Catholic Church had made a bad mistake with Galileo when it tried to lay down the law on a question of science, declaring that the sun went round the earth. Now, centuries later, it had decided to invite a number of experts to advise it on cosmology. At the end of the conference the participants were granted an audience with the pope. He told us that it was all right to study the evolution of the universe after the big bang, but we should not inquire into the big bang itself because that was the moment of Creation, and therefore the work of God.
>
> **Stephen Hawking**[46]

The new physics may well be on its way to becoming obsolete.

The 'new physics', incidentally, is now about a century old, depending on how one looks at it. But the 'new physics' still provides a philosophical opening. Any new theory calls for some philosophical readjustment: in this case the philosophical readjustment may have been slow in coming because the older

Newtonian theory is still taught in schools and in early courses in physics, so that the physicist's intuition is still based around the old theory. This is done on the strength of a facile philosophical predisposition that the two new theories are relevant only at very high velocities (the 'relativistic domain'), or in microphysics (the 'quantum domain'). So strong is this predisposition that neither Bohr nor anybody else since then actually cared to carry out the relevant calculations.[47] This author did exactly that, and the results are quite surprising.[48] A few more such surprises, and the new physics may well soon become obsolete, as is anyway likely to happen to any physical theory, or technology: phlogiston and aether are no longer thinkable, yesterday's gleaming car is today's junk, and yesterday's prized computer is today's embarrassment.

But the point in question here is not the ultimate validity of the new physics—its ultimate invalidity is almost surely a foregone conclusion—the point in question is how the new physics has provided a new respectability to old theological terms of critical importance: *God, mind (soul), creation, apocalypse, 'free will', immortality.* A review of the theological literature would be largely irrelevant here. Our immediate concern is with the way in which science has been influenced by stale theological arguments, which have been revived by the new harmony between science and religion. One may therefore restrict oneself to the literature by scientists.

It would be a good plan to choose one scientist as the representative of the popular thinking on each of the five themes above. The rough, and not necessarily unique, correspondence with the popular literature is as follows. Stephen Hawking on creation and apocalypse, especially in *A Brief History of Time*; Paul Davies on God, especially in *God and the New Physics*; F. J. Tipler on immortality, especially in *The Physics of Immortality*, and on God's purpose in J. D. Barrow and F. J. Tipler, *The Cosmological Anthropic Principle*; R. Penrose on mind (soul), especially in *The Emperor's New Mind* and in *Shadows of the Mind*, and Ilya Prigogine on reconciling 'free will' and God's foreknowledge, especially in *Order out of Chaos*. It is, however, not possible to cover all the arguments of so many books in a part of one chapter. Nor does it seem worth the effort to go into the details of the arguments if the fundamental ideas are seriously faulty. Those who wish to do so are welcome to pick up the threads from here and follow them. This chapter will take up, in a preliminary way, only some sample arguments concerning creation and apocalypse, since these have been identified as the two key fixed points of the new harmony.

## *Creation in Theology*

Let us begin with creation. In Augustinian theology, the focus on creation is meant to prove the existence of a God. It is clear enough that if one believes in a God who created the world, then one must necessarily believe in a world which is created. But the other way round, the argument is a bit wobbly. The argument goes as follows. Everything has a cause, and God is the uncaused first cause. The world itself cannot be the uncaused first cause because its existence is contingent, while God does not need another creator, a God number 2, because the existence of God is necessary. In other words, creation (in the sense of a beginning in or of time) proves the existence of God, provided one has assumed that the existence of God is necessary! Not every religion believes in a God, and not every religion accepts the logic of 'proof' used here, as we have already seen, but we shall return to these inconvenient details later.

So, let us set aside this theological argument, and its difficulties, and move on to the central question: does the 'new physics' show that the world was created? The big bang theory and the singularity theory of Hawking and Penrose have been used to argue that the world was indeed created. The first question here is one of correspondence, which is usually glossed over in a facile way. Assuming that the big-bang theory provides a description of creation, does this description agree with the description in the Genesis? or does it agree with the description of creation in other religions? We have earlier seen the context of this question: the harmony between science and 'religion' excludes the harmony between science and other religions, and the harmony between 'religion' and religion. As Davies[49] notes, 'Christian cosmology, for example, has differed radically from Oriental cosmology. At least one must be wrong.'[50] If this is so, which is wrong here? It seems necessary to recall a great many brutal details that have been brushed under the carpet.

Let us begin with the question of the description of creation in the Bible.[51] As Isaac Asimov points out, 'Of all the prescientific descriptions of beginning, the account of the first chapter of the Genesis seems to us to be the most majestic and rational. Perhaps this is a matter of cultural prejudice…we cannot help but absorb a certain awe concerning it from childhood…'[52] As Asimov further points out, the only astronomical bodies specifically mentioned here are the Sun and the Moon, created on the fourth day, along with the stars which are 'dismissed as a matter of small importance'. He goes on to quote from the New English Bible (Genesis 1:1–19):

> 'God said, "Let there be light", and there was light; and God saw that the light was good, and he separated light from darkness. He called the light day, and the darkness night. So evening came, and morning came, the first day.
>
> 'God said, "Let there be a vault between the waters, to separate water from water." So God made the vault, and separated the water under the vault from the water above it, and so it was; and God called the vault heaven. Evening came, and morning came, a second day…
>
> '…God said, "Let there be lights in the vault of heaven to separate day from night, and let them serve as signs both for festivals and for seasons and years. Let them also shine in the vault of heaven to give light on earth." So it was; God made the two great lights, the greater to govern the day and the lesser to govern the night; and with them he made the stars…'

Compare this with the 'Creation Song' of the Ṛgveda (X.129).

> Neither non-being nor being[53] was then. Neither air nor the sky beyond. What stirred? where? and within what? was there an unfathomably deep void?
>
> Neither death nor non-death was then. Nor any sign to divide night from day. That one breathed, without breath, by itself; there was none other whatever.
>
> Darkness there was, at first lost in greater darkness. All was undifferentiated water. In that formless void, devoid of creative impulse, that one arose by the strength of warmth.

> Desire engulfed that one in the beginning, desire the seed of mind. Only poets steeped in wisdom have found in the depths of their hearts what binds non-being to being.
>
> The umbilical line of separation stretched across. What was below it? and what above? Begetters and creative powers, impulses below and a giving forth above.
>
> Who really knows? who will here declare it? whence it was born and whence came this creation? Even the gods came later. Who, then, knows whence it has arisen?
>
> Perhaps it created itself, perhaps it did not. He who sees it from the highest heaven only he knows—or perhaps he knows not.

The second is a description of creation *ex nihilo*—before this universe came into existence, nothing whatever existed.[54] Without a wise poet's imagination, one cannot hope to imagine or describe 'nothing'. There are points of similarity between the two descriptions, but there are differences. The 'umbilical line' does create a difference between above and below, but this line of differentiation is not identified with anything as concrete as the sky as it appears from earth. Why did the universe come into existence? No one ever will be able to say for sure, neither the gods nor any God.

Both agree that the universe came into existence with light, but the 'oriental' description is a bit more specific on this point: the universe had a radiant birth (*hiranyagarbha*, 'golden egg') (p. 33).[55] Also, the Vedic description does not specifically mention any God who created the world.

These are certainly not the only two descriptions; there are many others. The Buddhists would, as we have seen (p. 57), deny any truth in both accounts, saying that both rely on scriptural authority, which cannot be considered as valid. But two descriptions suffice for the following.

## *Creation vs Big Bang: The Extreme Youth of the World*

With at least two descriptions before us, we can now compare in more detail the different religious accounts with each other and with current scientific theory. In both religious accounts, the world has a beginning, but only in one account does it have a creator.

Therefore, even if the world had a beginning in time, one cannot infer from this that it was created by a Creator, whether one represents this creator in a concrete[56] or abstract way. Somewhere along the line, someone seems to have made a theological mistake in deciding to root for the big-bang theory; for the steady-state theory, with its hypothesis of continuous creation, offers more room for divine intervention (just as providence provides more room for divine intervention than rationality)! We shall see later on why Augustine's vision of the end of time impelled theologians like Aquinas to rebut continuous creation (and an immanent God) as, for example, accepted in Islamic theology by al Ghazālī.

The second puzzling feature of the alleged harmony of the Biblical description with the big bang theory is this. In the big-bang theory 'creation' is supposedly instantaneous, a great deal of action takes place in the first 0.0000000000000000000000000000001 second. But in the popular Bible description it takes six days. In this instance the harmony is pre-established! This difficulty was already known, for the Genesis account speaks also of 'the day' in which 'the Lord God made the earth and the heavens'.

> Serious difficulties were found in reconciling these two views, which to the natural mind seem absolutely contradictory; but by ingenious manipulation of texts, by dexterous play upon phrases, and by the abundant use of metaphysics to dissolve away facts, a reconciliation was effected, and men came at least to believe that they believed in a creation of the universe instantaneous and at the same time extended through six days.[57]

The key difference, however, concerns the time elapsed since creation. When did the universe come into existence? According to official Christianity, this was some 6000 years ago. According to current beliefs, the age of the universe from the time of the big bang is of the order of 10 billion years. In 'pagan' or 'oriental' cosmologies, the time from creation *ex nihilo* is so much larger that even staunch orientalists could not resist taking a dig at the numbers. But the relevant time for comparison is the time elapsed from the latest 'golden egg' which is only of the order of a fraction of the 8.64 billion years duration of a cosmic cycle (p. 33), some 10 times *too small* by present standards.[58]

**Box 1: The big bang**

The main lines of evidence for the big bang cosmology are as follows.

**1. Olbers' paradox**. The stars appear as bright pinpoints of light against a dark background. Why are the stars visible at all? why is the background dark? why isn't every point in the night sky as bright as every other? The background to this question was the Newtonian belief that the cosmos was infinite (else it would collapse). The infinity (hence necessity) of the cosmos was considered theologically objectionable. So the argument was advanced that an infinity of stars would make every point of the night sky as bright as the sun. Olbers' paradox cannot be resolved *only* by assuming that light from the stars is absorbed by an intervening medium, for the medium would absorb and re-emit light, and would soon become as bright as the stars; but an intervening absorbing medium which is itself invisible (because the cosmos is not static, see redshift below) will do. The paradox can be resolved by assuming a finite 'age', i.e., a finite lapse of time from the last moment of extreme disequilibrium. (Most cosmologists implicitly assume, with facility, that this state of extreme disequilibrium naturally means nothing but the moment of creation.) The paradox can also be resolved by supposing that the distribution of stars is non-uniform, though we would have to explain why this seems so or why we occupy a special location in the cosmos.

**2. The cosmological redshift.** The spectrum of light from the stars shows the patterns characteristic of elements found in the sun, though all patterns are shifted a little towards the red-end of the spectrum. The amount of the redshift is the same for all elements in a star, and statistically very nearly the same for all the stars in a distant galaxy. Between galaxies, the redshift seems to vary systematically, and Hubble's law says that the redshift increases in direct proportion to the distance. The constant of proportionality is called Hubble's constant, and its exact value is disputable because it must be admitted that we cannot too well judge the distance to the distant stars and galaxies. One way to judge distance is by the faintness

*(continued on p. 94)*

(apparent luminosity) of a star or galaxy. The redshift can be regarded as a Doppler shift: the phenomenon of the drop in the pitch of any sounds (e.g., a car horn) coming from a receding object. Thus, Hubble's law says that the more distant a galaxy is, the faster it is receding from us. The familiar picture of galaxies as mutually receding dots on the surface of the expanding Hubble-Bubble shows how every point in an expanding universe can see itself as the centre of the expansion, so that our location is not particularly privileged. The redshift due to cosmological expansion provides the invisible means of absorption needed to resolve Olbers' paradox. One might say that the energy lost by the light fuels the expansion of the cosmos.

**3. Relativistic cosmology.** Relativistically, a static cosmos like that of Gödel or de Sitter is quite possible, but it was unclear to Einstein how to obtain a static cosmological solution without introducing by hand a term (cosmological term) into the equations of general relativity. After Hubble announced his law, this term, which Einstein called his 'greatest blunder' was dropped, and a picture of the cosmos as expanding was accepted. There are clearly three possibilities for any initially expanding cosmos: it may eventually recontract, it may expand for ever, or it may reach an intermediate state where the expansion becomes imperceptible but recontraction does not commence. (Analogously, a stone thrown upwards may fall back, or escape into space, if thrown hard enough, or, if thrown with just the right energy, it may reach a stationary location.) These possibilities are called the Friedmann models—recontracting, ever-expanding, and intermediate. Which model best describes the cosmos depends upon the amount of matter in the cosmos. One can decide this, in principle, by measuring the amount of matter (density parameter [a hopeless task]) or measuring the rate at which the expansion of the cosmos is slowing down (deceleration parameter). These conclusions could also be drawn classically, but relativity introduces the additional feature of linking these three models to geometry. Imagine a geodesic triangle, the three vertices of which are three distant galaxies, and the three sides of which are the paths of light particles travelling between the vertices. The sum of the interior angles is less than $180^{\circ}$ for

*(continued on p. 95)*

the recontracting model, and greater than $180^{\circ}$ for the ever-expanding model, being exactly equal to $180^{\circ}$ only in the intermediate model.

**4. The microwave background radiation**. Combining the supposedly purely empirical Hubble's law with relativity theory leads to the big bang cosmology: that the cosmos started expanding from a point at a finite (proper) time in the past, roughly given by the inverse of the Hubble constant. Cramming all the galaxies in the cosmos into a space smaller than a pinhead would generate a lot of heat and radiation. Since every line of sight stretching back into the past would at some time intersect this fireball, we should still be able to see this radiation, coming quite uniformly from all directions—as we seem to do in the form of the cosmic microwave background radiation. The observed radiation also seems to be roughly at the right temperature, though it does have some very small non-uniformities. The names 'big bang' and 'fireball' are a bit misleading, for neither fire nor sound can exist in vacuum, and one may more aptly name this event the 'golden egg', except that this terminology has the wrong pedigree in various 'pagan' cosmologies, and, therefore, cannot be acceptable terminology to scientists.

Therefore, one must conclude that *the big-bang model, though sanctioned by the pope, definitely refutes the account in the Genesis.* None of the authorities who have opined on the big bang in the context of 'science and religion' have expressed an opinion on this key issue. The silence is palpable. It seems clear that everyone implicitly and tacitly agrees that the question of time-scale is unimportant, or that the 'days' in the Genesis account must be differently interpreted. Some 'non-official' branches of Christianity can legitimately maintain that this is what they have been saying all along. But for the last one and a half thousand years, since Augustine, official Christianity has subscribed to the millenarist view that human history is brief—it had a short past, and will soon have an end.

The short time-scale was politically critical for the following reason. Pagan cosmology also allowed for a beginning and end of the world. But the beginning and end were interspersed with numerous cycles of 'incidental' creation and destruction. This made the beginning and end of the world *seem* infinitely remote; a physical picture unsuited to sustain the doctrine of sin, and unsuited to maintain the urgency of repentance[59]—hence unsuited to maintain the political authority of the priest.

Both pagans and Christians had an account of the creation of the world, but the point specific to official Christianity was that the world was very young: Augustine ridiculed the pagan idea of creation a billion years ago. He opined[60] that the cosmos was no more than 6000 years old. For fifteen hundred years, theologians followed Augustine's example. They fixed the time elapsed since (the day of) creation ever more accurately, finally arriving at the polished figure of 6004 years. It is incorrect to suppose that there is anything medieval about the primary motivation of frightening people and heaping ridicule on all 'pagan' systems of cosmology (p. 90).[61]

Therefore, only one intellectually honest course is open to anyone who maintains a positive connection between the big-bang theory and Genesis—to accept first that official Christianity has been consistently and emphatically wrong in its interpretation of a critical section of the scriptures for the last one and a half thousand years. No one is obliged to reconcile this interpretation of Genesis with the big-bang theory; but if one does so, one must also accept that those who claimed to have a special authority in interpreting the scriptures were wrong in a sustained way (and reaped material benefits from this 'mistake'); one must accept that they were fundamentally wrong, for they are today asking us to accept as true that on which they heaped ridicule just because they could not then materially benefit by it. What, then, will guarantee that they will not be equally wrong in other matters for another fifteen hundred years?

As an important corollary, it follows that 'creation' may refer *not* to some unchanging scriptures, but to a time-varying theological disambiguation of the scriptures. In that case, what is being talked about is not the relationship between a new science and an old scripture, but only the relationship between the new science, and the latest and politically most convenient meaning that can be assigned to the scriptures. (Such a 'most convenient meaning' can always be found, regardless of the physical ideas about the world; because it goes on changing with time, such a meaning is metaphysical, not refutable, and hence not open to comparison with science. It can, however, most certainly continue as an item of private belief.)

Equating the big bang model with the Genesis account can, thus, only be regarded as a most irrational and illegitimate act of appropriation of science by a particular religion.[62] This is not the first time we have witnessed such acts of appropriation.

> A few years since one of the most noted professors of chemistry in the city of New York, under the auspices of one of its most fashionable churches, gave a lecture which…was to show that science supports the theory of creation given in the sacred books…A large audience assembled, and a brilliant series of elementary experiments with oxygen, hydrogen, and carbonic acid was concluded…[and] the audience…burst into rapturous applause…Thereupon a well-to-do citizen…moved the thanks of the audience to the eminent professor for 'this perfect demonstration of the exact and literal conformity of the statements given in the Holy Scripture with the latest results of science.'[63]

## *The Beginning of Time: Singularities vs Creation*

The big bang is distinct from the beginning of time.

The next question is this: can one identify the big bang with the *creation* of the world *ex nihilo* or *ex deux*? Many cosmologists take this for granted in their writings. For example, Harrison[64] says, 'Through the starless gaps of the night sky…we see what our immediate forebears feared to see: the creation of the universe written across the heavens.' Just raise your eyes and look at the sky: you can see God at work, for the dark gaps tell us that the world was created. One is tempted to quote Newton,[65] 'Ye Hypocrites ye can discern the face of the sky but can ye not discern the signes of the times?' More seriously, this kind of religiosity inhibits the questions that one must ask. Specifically, what makes one exclude the possibility that the big bang may be only the other side of a big crunch? Apart from the religious beliefs of the concerned scientist, what reasons are there to regard the big bang as elemental rather than incidental creation? In short, was the big bang also the beginning of time?

One may speak meaningfully of an intrinsic beginning of time.

One must first of all explain what is meant by the beginning of time. Is it not paradoxical to speak of a beginning *of* time? In what time did the time in question have a beginning? Fortunately, this is only one of those verbal paradoxes, because of the structure of time implicit in the tense-structure of the language. One can get around this paradox quite easily. If time is regarded as given by a (temporal) ordering of events, a beginning of time is the least element, if it exists, in this ordering. The point here is only that the notion of least element is intrinsic to any ordering, so one does not need another time to be able to speak of the beginning (or otherwise) of our time.

But is a 'singularity' a beginning of time?

A purely logical explication of the idea of a beginning of time cannot tell us anything about whether or not time really has a beginning; for that, one must turn to physics. In physics, the closest thing to a beginning of time is the notion of a singularity,[66] or an exceptional point in spacetime. What exactly is a singularity? Here is how Stephen Hawking describes it.

> Perhaps then the current expanding universe resulted not from a big bang singularity, but from an earlier contracting phase...Does general relativity predict that our universe *should* have had a big bang, a beginning of time? The answer...Penrose's theorem had shown that any collapsing star *must* end in a singularity...[my] argument showed

> that…[our] universe *must* have begun with a singularity…The final result…at last proved that there must have been a big bang singularity provided only that general relativity is correct…There was a lot of opposition to our work, partly from the Russians because of their Marxist belief in scientific determinism…The proof showed that general relativity…predicts that all physical theories, including itself, break down at the beginning of the universe.[67]

To bring out the religiosity underlying this passage, let us try to understand it from four angles: those of physics, theology, mathematics, and the physical interpretation of the mathematics. We recollect that for a theory to have *any* physical content, it must be refutable. Is there any way to test this idea of a beginning of time? Does Hawking's theory help us to distinguish between a world in which time has a beginning and one in which it does not? Does it help us to identify the circumstances in which the belief in a beginning of time could conceivably be false? Hawking has not articulated any such test; instead, he speaks grandly of the breakdown of *all* physical theory.

A singularity is NOT necessarily a simultaneous beginning or end of *all* time. It is *perhaps* the beginning or end of time for a potential path of an imaginary material particle.

Perhaps we need to understand a little better the physical interpretation of the mathematical result that has been proved. Is a singularity the same thing as a beginning of time? Really speaking, a singularity is not a beginning of time in the sense of being a beginning of *all* time. At best, it is the beginning of time for at least one material particle or a photon. Strictly speaking, it is not even quite that; it is the beginning or end of a geodesic in spacetime. (The equator or the meridian of Greenwich are examples of geodesics on the surface of the earth.) A geodesic in spacetime is a *possible* evolutionary path[68] of an *imaginary* material particle or a photon. Thus, a singularity may be, at best, the beginning or end of time for at least one of an infinity of possible paths that a material particle or photon might follow; but it need not be the beginning or end of time for even a single actual particle.

Face-to-face with a singularity should one kneel down and pray?

What *happens* at a singularity? An SF writer[69] attended a lecture where Stephen Hawking was persistently asked this question. Hawking's answer was that the laws of physics, as we know them, would fail.[70] But what *exactly* happens? Anything at all could happen (since the laws of physics, as we know them, would fail), was the reply. According to the SF writer, Hawking would not budge from this position, and the questioner gave up. But the SF writer had to describe to this untutored audience what a singularity was. So he thought: what would he *do* if he came face to face with a singularity? Well, if anything at all could happen, then what was there to do but to go down on one's knees and pray! And, indeed, there is a touch of God about these singularities. If a particle reaches the end of time, we could say it is destroyed; if it is at the beginning of time we could say it is created. Stephen Hawking himself concludes as much in his popular exposition.

> At the big bang and other singularities, all the laws would have broken down, so God would still have had complete freedom to choose what happened and how the universe began.[71]

Thus, the theological content of Hawking's thesis is rather more apparent than its physical content. But let us probe its physical content a bit further. Let us *assume* for the moment that (a) singularity theory has validly proved the existence of singularities, and that (b) a singularity involves creation or destruction of matter, since (c) the laws of physics fail at a singularity. Does it then follow that the big bang was the big event of creation of the cosmos?

Friedmann singularity distinguished from Hawking–Penrose singularity.

At this stage it is best to make a distinction between two types of singularities. There is the common garden variety of singularity, found in the Friedmann models. This singularity may be understood as follows. The universe, as we see it, seems to be expanding. But (if matter is conserved) this means that yesterday it must have been a little smaller, and still smaller the day before. So there must have been a time, long long ago, when all the matter in the cosmos, all the billions of stars and galaxies with all the dust between them, would have been squeezed into a space smaller than a pinhead. That would have caused an almighty explosion—the big bang. At the very beginning of this big bang is the Friedmann singularity, which seems rather like a common instant of creation for the entire cosmos, localised within the 'golden egg' or dense initial configuration. But this Friedmann singularity is easily avoided, if the universe rotates, for example (p. 243).[72] The Hawking–Penrose kind of singularity is supposedly unavoidable. But one doesn't know *where* or *when* it occurs. All one can say is that a singularity exists somewhere, and it is a speculation that one such singularity may be found in 'our' big bang and involves creation, while another during the big crunch involves destruction. It could be that the singularity in question is approached chaotically through a series of 'bounces', and that our own big bang is one such bounce, with no singularity within it. Even if there is a singularity within it, it could still be that the big bang is only the other side of a big crunch, so to say, so that the singularities within the 'golden egg' may involve both creation and destruction—because it would be an 'end of time' seen from one side, and a 'beginning of time' seen from the other.

While there is only one Friedmann singularity, there can be any number of Hawking–Penrose singularities in the cosmos; for example, every black hole supposedly has in it a Hawking–Penrose singularity. The Hawking–Penrose singularity theorems do not tell us the number of such singularities there are; the theorems do not even tell us whether this number is finite or infinite. It is only by confusing the two types of singularities that one may imagine, as many people do, that the entire world emerged from a single singularity, to be found in the big bang, or that it would be destroyed in another such singularity in the big crunch. Perhaps this is so, but Penrose–Hawking singularity theory has not proved anything of the kind. The cosmos could merrily go through a series of oscillations. At each big bang/crunch some matter might be destroyed, while something else might be created, as Hawking himself once speculated.[73] Hawking's conception is not quantitative, so we have no way to tell *how much* matter would be destroyed, nor how much of something else would be created. In short, no test today can tell us whether a big bang—a dense early state for the cosmos—was indeed a beginning of time or the creation of the world.

Does a singularity actually involve *any* creation or destruction? This is the idea put forward by Stephen Hawking and Roger Penrose. Penrose and Hawking, and many people subsequently, have apparently proved the existence of some sort of singularity. But there is a gap between what has been mathematically proved, and how it is to be physically interpreted. We saw one gap above: no actual material particle or photon need be created or destroyed; what begins or ends is only one or more of an infinity of possible paths that such particles might follow.

To visualise this, imagine the surface of a sphere with a small hole in it. The hole corresponds to the singularity.[74] A ball used for bowling will do (though the opening in it is rather large). Place the ball on the ground so that the opening is to one side. Now balance a ball-bearing on top of the big ball, and displace it by stamping on the ground. Any great circle through the top is a geodesic and a possible path along which the ball-bearing may start falling to the ground. If the ball-bearing falls into the opening one might consider it to have been destroyed. As one can see, this may or may not happen. Thus, to every geodesic there does not necessarily correspond an actual material particle which moves along that geodesic. An actual material particle need not follow any specific geodesic: it has an infinity of geodesics to choose from. There is a further caveat which we can ignore as unimportant: a timelike geodesic is the path of only an *imagined test particle*. An actual particle need not follow any geodesic at all. If the actual particle is 'small enough', the geodesic hypothesis is that it will approximately follow a geodesic. Thus, there is a gap between what has been demonstrated, and what is being claimed.

## *Fear of Infinity*

But the bigger gap concerns the question of just what happens at the singularity. We have seen various sorts of claims about what happens. To re-state the momentary assumptions (b) and (c) given earlier, the claim is that (b) some matter is created or destroyed at a singularity, since (c) (Hawking believes that) the laws of physics fail at a singularity. The Hawking–Penrose singularity is defined, and was explained earlier, in *geometric* terms. How does one move from this geometric description to a *physical* description in terms of matter? The connection of geometry to matter is provided by the very same 'laws' of physics that are alleged to fail at a singularity. So, if one believes that the laws of physics fail at a singularity, one cannot claim anything about matter being created or destroyed at a singularity.[75] It would be more accurate to say that one does not know what will happen because the laws of physics fail.

But do the 'laws' of physics really fail at a singularity? This belief is based on a certain fear of infinity in Western mathematics: a singularity is roughly associated with an infinity of some sort, and the appearance of this infinity shows that the 'laws' of physics fail. Of course, there *are* examples of singularities that are not associated with an infinity of any sort, and Hawking is aware of this, but he opines that these examples are not 'generic'.[76] So, let us consider a singularity of the kind that Hawking approves of, which is associated with an infinity of some sort. Do the 'laws' of physics fail at *this* singularity? This belief involves further caveats and assumptions. A particular mathematical assumption is the smoothness assumption: Hawking simply assumes that spacetime may well develop a singularity, but it ought not to develop the slightest kink or discontinuity.[77] Such a kink or discontinuity would only mark the end of Penrose and Hawking's geometric techniques—it would mark neither the end of the world, nor the end of time, nor even the end of physics. Analytic techniques to handle such kinks could take us across the end of Plato's geometric world; but such a kink would block the interpretation of singularities as a place where physics fails.

Consider the flow of air around a firecracker which has just exploded. Certain characteristic[78] paths associated with the fluid particles[79] collide, just like the analogous possible photon paths (null geodesics in spacetime) near a singularity. These paths come to an end at the point of intersection in exactly the sense of Penrose–Hawking singularities: there is no (unique) way to extend the lines beyond the point of intersection. Analogously, in the continuum approach (the only one available to general relativity), there is no unique way to theoretically calculate the flow of air beyond this point of intersection. The non-uniqueness is heralded by the appearance of infinities in the equations describing the flow of the fluid. The 'laws of fluid flow' (which are just the 'laws of physics') do not break down, however; they are mathematically reinterpreted. The fluid particles do not cease to exist, but a discontinuity develops in practice. The appearance of infinities only signifies that the smoothness assumption used in the theory breaks down: the state of the air changes abruptly across a thin region called a shock wave. One hears the sound of a firecracker as a sharp burst, and not as a sound gradually rising and fading away. The bursting of the firecracker generates a shock wave. If, on the other hand, one assumes that all sounds may only rise or fall gradually, then, in the general relativistic description of a firecracker, one arrives at the conclusion that a firecracker is a singularity. In short, a singularity, instead of being God, may be only a loud noise! Needless to say, the existence of singularities has no particular empirical consequences,[80] so that there is no way to decide whether, in fact, a singularity is God or a firecracker. That depends upon one's theological beliefs.

Instead of hearing it, one can *see* this smoothness assumption involved in Hawking's interpretation of singularities. A wave moving towards the sea-shore moves into shallower water. This forces the wave to become taller, but it cannot grow beyond a certain point, at which stage the wave 'breaks', and falls over itself. This is also the kind of situation that cannot be properly described if one sticks to the idea of smoothness.

In the mathematics used by Penrose and Hawking, this idea of smoothness is closely linked to the idea of infinity. We have already seen (Box 1: Olbers' paradox) an example of a theological argument linking God to infinity. Today, Newton's way of handling infinity seems to us to be naive; we believe he was wrong in supposing that making the universe infinite could stave off gravitational collapse.

The moral of the story is that infinity need not be the end of the world—or its beginning! Today we have many ways to handle infinities (see Box 2). Infinities can be managed as in quantum field theory, for example, and, though it is not widely known, the

**Box 2. Types of infinities**

**1. Cantor's infinities: Hilbert's hotel.** Cantor suggested how to count the number of elements in a finite or infinite set. This intuitive method using counters is counter-intuitive. Hilbert's hotel has an infinity of rooms, but is full when an unexpected guest arrives. The caretaker has no difficulty providing a room as follows. He shifts the occupant of room number 1 to room number 2, 2 to 3, 3 to 4, and so on *ad infinitum*. He then asks the unexpected guest to move to the vacant room number 1. It is clear what the caretaker must do if ten unexpected guests arrive instead of 1; unfortunately, an infinity of unexpected guests arrive. Still the caretaker does not have much difficulty. He moves the occupant of 1 to 2, 2 to 4, 3 to 6, 4 to 8.... He now accommodates the infinity of guests in the infinity of vacant rooms numbered 1, 3, 5, 7.... If guests are counted using rooms as counters, half of infinity is the same as infinity.

**2. Non-Standard infinities: Archimedean property.** Cantor's infinities are the only kind described in the popular literature, but they are good only for counting and not for calculations. One may want to multiply infinities, divide them, or subtract them. In the usual kind of (real) numbers there are no infinities because of the Archimedean property, which is as follows. Take two positive numbers, one might be very large, say 1 million, and the other might be small, 1 say. One added to itself a million and one times produces a number larger than the first. The smaller number added to itself sufficiently many times exceeds the bigger number. This remains true no matter how large the first number and no matter how small the second number. But, one can construct systems of numbers in which the Archimedean property fails. (In fact, the Archimedean property

*(continued on p. 106)*

fails in any system of numbers [ordered field] properly larger than the usual [real] number system.) That means there would be numbers larger than 1 added to itself any (finite) number of times. An infinite number would be larger than any number one could name in the usual way: it would be larger than a million, a billion, a quadrillion, a zillion, a zillion times a zillion.... The inverse of a large number is a small number; the inverse of an infinitely large number is a very small number called an infinitesimal. A positive infinitesimal would be greater than zero but smaller than 1 part in a zillion....

**3. Limits and infinities: the Calculus.** One can understand the calculus better if one locates its origin in methods of approximate calculations. The calculation of tables of sines and cosines, needed for astronomical and navigational purposes, was done using a method of successive approximations from the 5th to the 16th century. In this Indian ('algorismus') method of calculation, a leftover quantity, too small to be of any practical consequence, and requiring too much effort to compute, was called *sūnya* (non-representable) and discarded. In the 16th c., this concept of 'zero' already was, for several centuries, an object of suspicion in Europe. Further, in the Indian approach, the successive approximations arose from the ever-finer subdivision of the circumference of a circle, for example, which was seen as a *physical* process that would terminate, when the subdivisions reached the level of indivisible atoms. When introduced into Europe, by the Jesuit Cavalieri, this notion of 'indivisible' (later infinitesimal) was regarded as scandalous, for Europe could then accept neither a physical basis for mathematics, nor the physics of atomism. Infinitesimals remained objects of suspicion, so that Newton (unsuccessfully) devoted much effort to the concordance of this method with exactitude and rigour in the geometric tradition associated with 'Euclid'. This required infinitesimals to be smaller than 1 part in $n$, where $n$ might be as large as one liked. Like mathematicians of the 17th century, physicists to the present day use these notions. Though the notion of infinitesimal was revived in the 20th century, the 19th century mathematicians firmly bid good bye to this confusing notion of infinitesimal, and replaced it with the notion of limit: if something were non-negative but

*(continued on p. 107)*

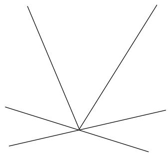

**Fig. 1**
Two possible tangent lines at the bottom of the V.



**Fig. 2**
Discontinuous rate of change along the V.

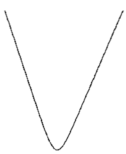

**Fig. 3**
Smoothened V.

**Fig. 4**
Velocity along smoothened V.

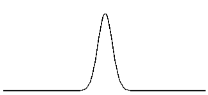

**Fig. 5**
Acceleration along smoothened V.

smaller than 1 part in $n$ with $n$ as large as one liked, then that something had to be zero.

**4. Infinities in finite jumps: Dirac and Heaviside.** A tangent to a curve is a straight line which best approximates the curve near a point. If the curve happens to be a circle the tangent line will touch it at exactly one point. In Europe, one of the first uses of the calculus was to draw a tangent at any point to a curve. This was done by drawing a chord between two points on a curve and making the distance between the two points infinitesimal (in a practical or theoretical sense). Suppose we apply this procedure to a curve in the shape of a V (Fig. 1). At almost any point of the V, the tangent line will coincide with the arm of the V. But at the bottom, there is no unique answer. Any number of 'tangent' lines could be drawn which touch the V exactly once at its pointed bottom, and it is hard to say which fits best. Imagine now the V being traced out by an ant as it moves. (Suppose the ant to have been dipped in ink, or, if this seems cruel, suppose that smell has been transformed into sight, by tracking the ant's chemical trail, and using a computer.) At the bottom of the V we would say that the ant suddenly changed its direction. The change was sudden, not gradual, so one is unable to calculate at what rate the change took place. The rate of

*(continued on p. 108)*

change of position, when plotted, looks like Fig. 2, a curve called signum and similar to the one named after Oliver Heaviside. Velocity is the rate of change of position, while acceleration is the rate of change of velocity. To calculate the acceleration of the ant, we must calculate the rate of change along this new curve, which has a finite (as opposed to infinitesimal) jump at 0. This rate of change is infinite. If we smoothen the bottom of the V, to get Fig. 3, then the new version of Fig. 2 will look like Fig. 4, and the acceleration of the ant will look like Fig. 5. In the limit, in place of Fig. 5, we obtain the Dirac delta function—this new curve cannot be drawn at all because it is infinite in an infinitesimal neighbourhood of zero and infinitesimal elsewhere.

Because physicists did not know how to calculate with sudden changes, they made a rule that nature does not allow sudden changes—it is always gradual. This is the postulate used by Hawking to interpret singularities as the beginning of time. A shock wave is a physical example of a sudden change: temperature and pressure have finite jumps across a shock wave. The infinities that arise in the study of shocks are closely related to quantum infinities.

**5. Quantum infinities.** The final truth about singularities, according to Stephen Hawking, must come from a quantum theory of gravity. But such a theory does not exist because of the inability to handle infinities. From its very beginning, quantum theory has involved not only quantum jumps, but also infinities closely related to manipulations with the Dirac delta function. Eventually, a method to handle these infinities was evolved by Abdus Salam, Freeman J. Dyson, and others. This method works neither for shocks, nor for the case of quantum gravity. Whether to fault the method or the theory is not a question that can be discussed here, but the basic difficulty may be illustrated with an example. The Thompson lamp has a common kind of switch which turns the lamp off if on, and on if off. Suppose one jabs the switch at ever shorter intervals of ½, ¼, ⅛…seconds. At the end of one second, there are an infinity of jabs; after an infinity of jabs is the switch off or on?

infinities arising in shock waves are exactly the same kind of infinities that are encountered in quantum field theory.[81] Hence, physical 'laws' need not fail in the presence of such infinities.[82] Indeed, it is rather inconsistent to suppose, as Hawking does, that the infinities of quantum gravity can be managed some day, while those of classical gravity cannot be—for the same mathematics may be used to handle the infinities in both contexts.

So much for the conclusions of singularity theory, and how they should be interpreted. But what of the physical assumptions used to derive these conclusions? Historically, singularity theory actually commenced with a number of other assumptions which are questionable. One assumption is the absence of closed timelike curves. We have already gone through Hawking's arguments in favour of this assumption in Chapter 2, and seen how they merely replicate Augustine's incorrect arguments against 'cyclic' time. (For a quick review, see Box 10, p. 457, and summary of Part 1.)

A closed timelike curve is very much like a closed causal chain, which we will examine in more detail in Chapter 7. In the present context, a closed causal chain is of special significance, for it provides an example of a situation where everything has a cause, but there is no first cause! The moral of the closed causal chain is that even if one finds everything to have a cause, one cannot infer from that the existence of a First Cause, without first abolishing closed causal chains by fiat. Hawking and Ellis' chronology condition abolishes closed causal chains by fiat.

Some of these assumptions have been substituted with others by later workers,[83] and we will have more to say on the question of positivity of energy and closed loops in time in Chapter 7, in the context of time travel.

## *Stephen Hawking's Singularity-God*

The bottom line of Stephen Hawking's first book is this:

> …the actual point of creation, the singularity, is outside the scope of the presently known laws of physics.[84]

This conclusion about 'creation' from a physics book is made clearer in the lay literature:

> In the Beginning, the Big Bang emitted Chaos; and the Chaos was without form, and void, for it was homogeneous and isotropic. And the singularity moved upon the face of the Chaos and emitted light; and the Universe was no longer homogeneous, for the light was divided from the darkness.[85]

The SF writer was right in supposing that singularities have a touch of God about them. But theologians rushing to identify singularities with God have overlooked that they may end up damaging their theology in two ways. The first is that *the singularity-God is really a god-of-the-gaps*. In medieval Europe, preachers used to interpret lightning striking church towers as a sign of divine wrath. The statement 'May heaven strike me down if I am lying' was a common test of the truth. There was a gap in our knowledge about lightning: when the gap was filled, and lightning conductors were installed, God was squeezed out of the gap.

The same thing could happen with singularity theory. Hawking's position is that the laws of physics break down at a singularity. At best, this means that we are today ignorant of what happens at a singularity. But this ignorance may be removed some day; the gap in our knowledge may be filled, leaving no space for God to occupy. The gap in our knowledge about mathematical infinities has almost closed.

The second danger is this. Suppose the gap remains in place. Consider our SF writer who decided that if he came face to face with a singularity, he would go down on his knees and pray. This writer was appealing to a cultural reflex. One must remember that '*anything at all can happen at a singularity*'. Why should the singularity-God be appeased by his ritual act of prayer? The point is not that the singularity-God might turn out to be one of the much defamed pagan gods who would demand that the SF writer cut off his arm: *the singularity-God need not be the rational God of theology*. If one goes about looking for God in every crevice of scientific theory, one cannot expect that this God will automatically satisfy the complex expectations built up by two thousand years of politicised theology.

Therefore, Hawking himself seems now to say something different.

> I still believe that the universe has a beginning in real time, at a big bang. But there's another kind of time, imaginary time, at right angles to real time, in which the universe has no

> beginning or end. This would mean that the way the universe began would be determined by the laws of physics. One wouldn't have to say that God chose to set the universe going in some arbitrary way that we couldn't understand. It says nothing about whether or not God exists—just that He is not arbitrary.[86]

Hawking is here responding to 'savage attacks' on him for having introduced 'imaginary time'. People who had welcomed the singularity God were upset that his existence might be challenged. Hawking is, here, soothing such fears in a lay audience. Leibniz would have approved of Hawking's view, for Leibniz believed that God had created a perfect cosmos in which He need not intervene.[87]

This 'imaginary time' involves the famous 'no-boundary condition' put forward by Hawking along with Jim Hartle. It is pointless to debate the correctness of this proposal here, because there is no proper theory of quantum gravity as yet. (One of the reasons why there is no such theory is that one does not quite know how to handle the infinities that arise in the theory!) The motivation for introducing 'imaginary time', etc., is mainly this: 'It is only in this case [of the no-boundary condition] that the known laws would determine how the universe should behave.'[88]

The political fallout from the no-boundary condition is this: it provides a picture of the cosmos where there can be another truce between science and religion. In this truce, science would describe all phenomena within the cosmos, and religion would be relegated to metaphysics—all 'how' questions belong to science, and all 'why' questions to religion. As Hawking asks: 'What is it that breathes fire into the equations and makes a universe for them to describe?…Why does the universe go to all the bother of existing?' The novel feature of this new truce is that it leans towards a harmony through an ambiguity built into physics: one can believe both that the universe has a beginning and that it does not have a beginning!

## *Summary of Arguments*

To summarise the arguments so far, the current claim of harmony between science and 'religion' involves three things. First, it is implicitly an exclusive claim: the harmony of science and a particular religion implies that other religions are wrong or inferior in some sense, as theologians of a particular brand have been explicitly claiming for long. Second, it involves the elevation of religious beliefs to the domain of public knowledge, like scientific knowledge—all those who do not subscribe to these beliefs are superstitious or worse.

Third, the claim of harmony between science and religion concerns hegemony. In Toynbee's vision of the future, the logical corollary to the disintegration of the Soviet Union is the formation of a universal state with a universal church—religious globalisation, in short. Strategic analysts like Huntington have adopted Toynbee's vision of Western Christianity as most suited to this future role of the universal church, which will control the thoughts of the people in the universal state. For this position, the main rival of 'religion' is science, which too is closely allied to the state, and has turned authoritarian. Not only do appropriately positioned scientists today command a certain authority regarding the truth—an authority that priests no longer have—this truth aspires to be a public and universal belief. Re-establishing the lost harmony of science and religion, it is hoped, would pave the way for the public and universal acceptance of Western Christian religious and moral beliefs.

In the light of the preceding, we examined the claim that the big-bang theory harmonises with the account of creation in Genesis. Actually, the exact opposite is true. The big bang theory conclusively disproves the interpretation of Genesis advocated by official Christianity for the last fifteen centuries. The key difference between the pagan account and the official Christian interpretation was not the occurrence or non-occurrence of creation, but the politically critical claim of the extreme youth of the world. Therefore, the alleged harmony of the big bang and Genesis cannot proceed without accepting that the priests of official Christianity have been persistently mistaken, for fifteen hundred years, despite their claims to special authority in the form of sainthood, papal infallibility, etc.

The big bang cannot as readily be identified with elemental creation, or the beginning of time, as so many cosmologists have supposed without justification. Even the identification of a singularity with an event of creation or destruction for even one material particle is speculative and questionable. The absence of 'cyclic' time was initially assumed to 'prove' the existence of a singularity. A closed causal chain is a kind of cyclic time which provides an example of a situation where everything has a cause, but there is no first cause. Whether or not the world starts or ends in singularities, Hawking's theory starts with theological premises and ends in theological conclusions! Finally, the singularity-God is ultimately a god-of-the-gaps, depending upon a (possibly non-existent) gap in our knowledge of mathematical infinity. The singularity-God need not even remotely correspond to the rational God of theology.

## *Apocalypse*

> Will there be sex in Heaven, Mr Tipler?
>
> **Anon**[89]

Having examined the creation of the world, let us saunter across to the other side to look at the end of the world: for this is the other point at which the 'other world' of religion meets this world of science. Right away, one must acknowledge that this is a very very speculative domain. There are too many loose ends, and not a single reliable observation to go by. The way to proceed is illustrated by Freeman J. Dyson, Templeton prize winner and a well-known physicist, who rejects the closed (Friedmann) model of the cosmos on the explicit ground[90] that it gives him claustrophobia!

Other speculations have proceeded in even more interesting directions. Particularly, let us consider Tipler's *Physics of Immortality*. Frank Tipler professes mathematical physics at the Tulane University. The book subtitled, 'Modern Cosmology, God, and the Resurrection of the Dead', begins as follows:

> It is quite rare in this day and age to come across a book proclaiming the unification of science and religion. It is unique to find a book asserting, as I shall in the body of this book, that theology is a branch of physics, that physicists can infer by calculation the existence of God and the likelihood of the resurrection of the dead to eternal life in exactly the same way as physicists calculate the properties of the electron. One naturally wonders if I am serious.

'I am quite serious', continues Tipler, in writing a book which

> ...purports to show that the central claims of Judeo-Christian theology are in fact true, that these claims are straightforward deductions of the laws of physics as we now understand them. I have been forced into these conclusions by the inexorable logic of my own special branch of physics...the area of global general relativity...created...by the great British physicists Roger Penrose and Stephen Hawking.

Frankly, it would be cruel to the trees that are cut down to make paper to waste it elaborating on the difficulties with Tipler's claims as physics.[91] It is more fruitful to analyse the political and theological dimensions of the claim. The interesting theological point related to Tipler's work concerns the Rational God of theology. The singularity-God need not be the Rational God of theology. Tipler wants to remedy this difficulty.

What can be more infuriatingly rational than a machine? Nothing. Anyone who has ever written a computer programme knows this. Even if one has not written a computer programme, one has only to play chess with a computer to understand this. If one does not play chess, then one ought to know Bobby Fischer's story.

## *Bobby Fischer's Frustration*

Bobby Fischer, as everyone knows, was formerly a world champion in chess; the first American to have wrested that crown from the Russians. The essence of Fischer's artistry was psychological play. Though people who play chess at the grandmaster level are not necessarily[92] the cold calculating types, no one had thought chess itself to be anything other than a game of cool calculation. Fischer brought in and forcefully employed the element of psychology, the art of creating a strategic illusion, the art of subtly damaging the concentration of his opponent. Before the end of his much publicised world-championship match, his psychological onslaught left his opponent Boris Spassky bewildered, and reduced him to a nervous wreck.

The Russians naturally realised what was happening, and within four years prepared a new challenger, Anatoly Karpov, who was temperamentally the epitome of coolness. Fischer refused to play against Karpov, losing the world title, but remaining unbeaten!

More recently, there has come up on the horizon a still more serious challenger: the computer programme. Here is a contender against whom psychological tactics simply do not work. No psychological illusion is possible because the computer obtains its strategic insights by brute-force calculation. In complete frustration, Fischer recently suggested that the rules of chess should be modified, to make it more difficult for computers to play: this is the only way in which the computer could be psychologically upset at the very first move! This presupposes that man makes the rules. Will this always remain so?

## *Tipler's Machine-God*

To return to the Rational God of theology, what can be more rational than a machine? In this industrial age, when machines and factories have become the focus of so many lives, when machines have virtually become God, what is more reasonable than to suggest that God should be a machine? This is exactly what Tipler has suggested: God is a machine, a very advanced supercomputer made in the future. According to Tipler, mechanically obedient to rational theology, this supercomputer-God will resurrect man in a virtual reality which reconstructs Augustine's heaven and hell. In short, Tipler's claim is that the end of time will find man resurrected in a machine's dream.

One can find precursors to this Frankensteinian idea in science fiction, in what must be one of the shortest SF stories.[93] Eons of time, and all the knowledge of all the ninety-six-billion populated planets of all the galaxies goes into building this supercomputer of the future. Eventually, the time comes to ask it the Big Question: 'Is there a God?', and the machine answers, 'Yes, NOW there is a God.' In a flash of realisation, the questioner tries to switch off the machine, but is struck down by a bolt of lightning from the blue sky, which also fuses the switch shut.

This story, like that of Frankenstein, suggests that the machine, particularly the computer, is the ultimate invention spinning out of control. Spengler[94] pointed to a 'truly Faustian danger': from the days of Roger Bacon, 'man has felt the machine to be devilish, and rightly', for the machine 'would wrest the almightiness from God…It signifies in the eyes of the believer the deposition of God'.

It suggests that the Devil 'was leading them in spirit to that mountain on which he promises all the power of the earth'.

'Faustian man', continues Spengler, has become *'the slave of his creation'*; it is therefore natural for him to deify his master, and to turn the machine into God as Tipler does. Tipler promises all the other world of theology in this one. Augustine said the future is subjective, and politicians have always understood that one can hence 'suitably' mould the future: politicians have always known that one can trade-off present-day political advantage against false promises about the future. The machine-God, which Tipler calls the 'omega point', is full of promises for the future politically-correct heaven.

> 'Will there be sex in heaven?'…the answer has to be yes, sex will be available to those who wish it…However, the problems which sex generates in our present life will not occur in the afterlife…it would be possible for each male to be matched not merely with the most beautiful woman in the world…who has ever lived, but…whose existence is logically possible…it would be easy to ensure that said male is also the most handsome (or desirable) man to this most beautiful woman (provided the man has spent sufficient time in Purgatory to correct personality defects)…[for] the Omega Point the wishes of men and women count equally.[95]

Is the Rational God of theology the same as the Devil then? This is a problem best left to theologians to sort out. My concern is with science. If this is what physicists can today claim to 'infer by calculation', then physics itself needs to be re-examined, from its beginnings, for surely, Lysenko's inferences were relatively more credible, and far less dangerous.

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## ***Summary***

- Q. Does the account of the beginning of time (*creation*) and end of time (*apocalypse*) in current scientific theory match the theological account?
- The big bang conclusively disproves the interpretation of creation in Genesis officially approved by the Western church for the last fifteen centuries.

- The big bang differs from singularities which supposedly correspond to the beginning of time.
- Singularities are not necessarily the beginning or end of *all* time. Neither need they be the beginning or end of time for even a single material particle. The laws of physics need not fail at a singularity. The singularity-God is a god-of-the-gaps whose existence depends upon a possibly non-existent gap in our knowledge of mathematical infinity.
- The singularity-God has no resemblance to the rational God of theology. Hawking's 'no boundary' condition tries to eliminate the singularity-God's potential for arbitrariness. The condition is not even meaningful until the previous gap in our knowledge of mathematical infinity is closed.
- Tipler tries to remedy this by modelling the rational God of theology as a machine—a parallel supercomputer—at the 'end of time'. He claims this machine would dream (simulate) a politically correct version of Augustine's heaven and hell as virtual realities. Tipler claims that the dream of his machine-God is a necessary and calculable consequence of present-day physics.
- *Q. Did the original marriage of science and religion similarly influence ideas of time in physics?*

∞

# PART 2

# TIME IN CURRENT PHYSICS

The linkage of science and 'religion' cannot be undone simply by ignoring the cruder manifestations of the present-day attempts to link science and 'religion': the linkage has been built into science from the time of Newton who chose linear time, to be able to formulate the 'laws' of physics (as differential equations). He thought God had revealed to him these 'laws' which men perforce had to obey. This belief in causal 'laws' led eventually to the conclusion that God had decided all things, leaving nothing to man.

Relativity partly corrected the conceptual confusion about time in Newtonian physics, which it replaced; but this replacement did not quite undo the linkage of 'religion' and science. A subtler aspect of this linkage is the following. Augustine's theology required that God must reward and punish individual human beings. This presupposes that the nature of time must be such that causes *can* be located within individuals, so that God need not be arbitrary in allocating reward and punishment. This belief is reflected in the social practice of glorifying scientists, for example Einstein as the originator of the theory of relativity. But this religious and social time-belief (that causes can be located in individuals) is incompatible with the time beliefs in relativity, according to which no one can do something novel and not already decided by the equations of relativity.

Most scientists have interpreted this last problem as exactly the problem of 'free will' in Augustine's theology: if God has decided everything why should man be punished? Hence, the answers to this question are similar to the answers in theology, which sought to wriggle out of the difficulty without compromising God's powers. Thus, scientists have sought increasingly complex ways to establish 'free will' without changing an iota of the deterministic 'laws of physics'. These attempts involve chance, chaos, complexity, and computability. If one is not frightened or enamoured by the underlying technicalities, these quibbles are as unconvincing as those of the classical theology they mimic.

The only way out is to abandon this mimicry of theology in science. Relativity permits time travel, which sharpens the classical theological paradox of 'determinism' vs 'free will'. The paradoxes of time travel force one to abandon the classical philosophical idea that everything must have a cause. Time *machines* are hence impossible, though time travel remains a possibility.

# 4

# Newton's Secret

On Christmas Day, 1642, Isaac Newton was born, a little prematurely, three months after the death of his father, Isaac Newton. The day of his birth must have been significant for Newton as he grew up, though today we may say that Protestant England had rejected, as popestant, the Gregorian Calendar used in the European Continent, where it was 4 January 1643.

Following a little too soon after the trauma visited upon the expectant mother, baby Newton was so tiny he could be put in a 'quart pot' and his life swung in balance. Pre-colonial England was poor, and underweight infants rarely survived even if their family owned many sheep! Two women going to fetch something for the newborn, 'sate down on a stile by the way & said there was no occasion for making haste for they were sure the child would be dead before they could get back'.[1] The business of using miracles to prove the existence of God was common then. Did Newton ever see his own survival as one such miracle? We can only speculate; but he did remember and recount the story even at the age of eighty.

Hannah Newton left the child Newton, aged three, to marry a wealthy widower aged sixty-three, and had three more children in the next ten years. The unhappy boy Newton, who grew up with his grandmother, once threatened his stepfather and mother Smith, 'to burne them and the house over them', in a confrontation which was serious enough for him to repent solemnly nine years later.

## *The Secret Theologian*

Newton remained celibate, or at least unmarried, all his life; even the God of Love seems to have left him alone, except for a possible adolescent romance.[2] In short, the love of God was the only love

Newton knew, and the intensity and passion[3] with which Newton pursued theology has generally been markedly underestimated. Such underestimation has been greatly facilitated by the shroud of secrecy surrounding Newton's theological writings.

Says Richard Westfall,[4] Newton's biographer, 'Newton concealed his views so effectively that only in our day has full knowledge of them become available.' But Newton surely cannot be blamed if his theological writings lay concealed for centuries after his death. Newton's theological writings stretched across more than 50 years of his life, from early youth to old age; more than 50 per cent of what Newton physically wrote was on theology: it has been estimated that his theological writings would occupy some 15 books the size of this one. Why write at all if the object was to conceal it even after his death? Newton wrote because he felt it his moral duty to write.[5] He did not think it immoral to conceal what he wrote, perhaps because the prophecy of the scriptures was at the core of his religious belief, and concealing his writings, during his lifetime, only mimicked the idea of prophecy kept closed and sealed till the time was right for it to be known.

Newton judged his times correctly. His successor, Whiston, lost the Lucasian chair for speaking out his theological opinions. Newton's strategy was the more successful: while Whiston has faded into obscurity, neither Newton nor his theological writings can be so easily dismissed today, 275 years after his death.

Four of Newton's theological works were published posthumously: *The Chronology of Ancient Kingdoms Amended* (London, 1728), *Observations upon the Prophecies of Daniel, and the Apocalypse of St. John* (London, 1733), a 'Dissertation upon the Sacred Cubit of the Jews and the Cubits of the several Nations'(1737),[6] and two letters to John Locke, concerning the doctrine of the Trinity, *Two Letters to Mr LeClerc* (1743). These represent only a small fraction of Newton's actual works on theology, vast amounts of which still exist as unpublished manuscripts.

## *Newton's Box*

Why did these manuscripts remain unpublished? When Newton died, a large box of his theological works was given to the Royal

Society, of which he had long been the President. The Royal Society returned the box telling the family to keep it secret. Many years later the family asked their minister who returned the same advice. David Brewster, Newton's biographer in the 19th century, repeated the advice.[7] The Earl of Portsmouth, Lord Lymington, inherited the secret box early in the 20th century. He tried to give it to Cambridge University and then the British Museum, both of which refused it.

It was only after the death of Newtonian mechanics was confirmed, and Newton's authority started declining, that the secret started leaking out. Newton's papers with the Earl of Portsmouth were auctioned by Sotheby and Co. in 1936. Many libraries and private collectors acquired these papers, the full extent and location of which is still not quite mapped. Among the major collectors, one was ironically the economist John Maynard Keynes, and the other was one A. S. Yahuda 'a wealthy Palestinian Jew…and a refugee scholar in America from 1940 until his death in 1951.'[8] When Keynes died, his collection of Newton's theological manuscripts passed to the King's College, Cambridge, along with his papers, and was soon published.[9]

As for Yahuda, in 1935 he published a book called *The Accuracy of the Bible*: 'Albert Einstein was present when Yahuda first stated his theory in a lecture, and…Einstein wept with joy when he realised that one might be able to prove that the events in the Bible were accurately and factually described.'[10] Though Yahuda's theory was quickly rejected by scholars, he enlisted the support of his close friend, Albert Einstein, to try and place the Newton manuscripts at Harvard, Yale, or Princeton. Harvard refused saying that a war was on; Yale felt they lacked the space; and Princeton said the material was not scientific.[11] On his deathbed, Yahuda, a former Zionist, willed the manuscripts to the Jewish Library in Jerusalem. The will was contested, and the manuscripts were eventually sent to Jerusalem only in 1969, and are yet mostly unpublished. Indeed, as late as 1980, we find Westfall[12] lamenting that Newton's long theological manuscript with the Martin Bodmer Library, Geneva, perhaps 'is a connected history of the church…Unfortunately, the Bodmer Library…chooses to withhold its possession from scholarly use'.[13] A more detailed chronology of Newton's secret box is in Box 3.[14]

**Box 3: Chronology of Newton's box**

- 7 April 1727. Newton dies and is buried in state with honours and accolades never before accorded to any scientist.
- c. 25 April 1727. It publicly emerges for the first time, in a statement by John Craig (d. 1731), that Newton was more interested in religion than in science, but did not state his religious opinions during his lifetime to avoid disputes.
- May 1727. Dr Thomas Pellett, Fellow of the Royal Society, appointed to examine Newton's papers and to decide what should be published. Dismisses Newton's lifework with comments such as 'foul papers relating to Church matters', and 'not fit to be printed'. Permits publication of an innocuous text.
- Late 1727 (title date 1728). John Conduitt, Newton's amanuensis publishes Newton's *Chronology of the Ancient Kingdoms Amended,* edited by Thomas Pellett and Martin Folkes, FRS. An abstract had been printed earlier.
- 1733. Newton's *Observations upon the Prophecies of Daniel and Apocalypse of St. John*, edited and published by the son of his half-brother, who hopes thereby to make something for himself. This work, too, does not reveal Newton's real opinion.
- 26 January 1737. Catherine Conduitt, née Barton, Newton's favourite niece, who married John Conduitt, made a will stating that, after her death, Dr Arthur Ashley Sykes should see Newton's papers on Divinity and decide what should be published. (Sykes was a staunch supporter of Samuel Clarke, the well-known Arian.) She adds that the papers should not in the meanwhile be copied for printing, and that Sykes should consult the papers at her house. She

*(continued on p. 127)*

specifically mentions a) *The Historical Account,* b) *Paradoxical Questions Concerning Athanasius,* c) *A History of the Creed,* and d) *A History of the Church.*

- 23 May 1737. John Conduitt dies. 20 January 1739, Catherine Conduitt dies. Their only child, a daughter, Catherine Conduitt marries John Wallop, Viscount Lymington, son of the first Earl of Portsmouth, and Newton's papers pass to the Portsmouth family.
- 1744. Giovanni Castillione writes to the Royal Society, seeking to know the whereabouts of Newton's biblical papers.
- 29 March 1748. Edward Gibbon vainly seeks Newton's papers on early church history.
- 12 November 1755. Fifteen years after her death, Catherine Conduitt's will is formally executed, and Newton's papers are sent to Sykes, virtually on his deathbed. Sykes dies of paralysis a year later on 23 Nov 1756. Probably he never saw the papers.
- Lady Lymington passes on some of Newton's papers to Jeffrey Ekins, the executor of her will.
- October 1777. Bishop Horsley, editor of Newton's 'complete' *Works*, sees all the papers, and prepares a catalogue. Comments that Newton had left behind a cartload of papers on religion which he had examined and found unfit for publication. Publishes a couple of innocuous letters, while suppressing a third.
- 1795. Charles Hutton, FRS, publishes a rough catalogue of Newton's papers. Expresses astonishment at the 'care and industry' shown in 'upwards of four thousand sheets' in possession of the family of the Earl of Portsmouth.
- 1831. Sir David Brewster publishes his *Life of Newton*, apparently written without any knowledge of the

*(continued on p. 128)*

manuscripts. Affirms that Newton was a believer in the Trinity. This is picked up by many later authors.

- 1837. Brewster starts examining the manuscripts. Sees also the manuscripts with The Rev. Jeffrey Ekins, rector of Sampford, in 1855. Thinks that 'Dr Horsley exercised wise discretion in not giving other manuscripts formally to the world'. Prints a few more innocuous papers that do not at all represent Newton's real religious beliefs.
- 1855–60. Brewster publishes *Memoirs of Isaac Newton*. States that Newton's orthodoxy is not proven, but that he should be given the benefit of doubt, in the absence of evidence (that Brewster suppressed).
- 1872. The Ekins family donates the Newton manuscripts with them to New College, Oxford. They consist of four volumes of about a thousand folios.
- 1934. L. T. More publishes a comprehensive biography of Newton. Concludes that Newton was an Arian.
- July 1936. The Sotheby sale of Newton's papers.

Why the need for secrecy about a three-hundred year old theological manuscript? After all even secret military documents are declassified after 40 years. What was so explosive in these manuscripts that they cannot be revealed even to this day, when theology has, by some accounts, ceased to be relevant? *Who* has been keeping them a secret? Why are they so mortally afraid of Newton's researches? Is it because those who preach morals themselves stand accused, and the only way to answer these accusations is to hide them? What is the mystery surrounding Newton's theology?

## *The Ordainment Crisis*

The beginning of the mystery probably dates back to 1675, when Newton's career faced a crisis: he had to be ordained in the

Anglican church or resign his fellowship. This was one of the few points on which Trinity College was strict, and three fellowships had been terminated in the previous decade, for refusal to be ordained.[15] Very few fellowships were exempt, and meant for those who wanted to retain the income while pursuing a career elsewhere; apparently Newton tried and failed to obtain such an exempt fellowship. The other route was a royal dispensation against ordainment; but Isaac Barrow, then Master of Trinity, had cogently presented the college's case against it in a letter of 3 December 1674: 'It would destroy succession and subvert the principal end of the college which was the breeding of clerics.'[16] Newton started making preparations to resign his fellowship. In January 1675, he wrote requesting the Royal Society to excuse him from payments as earlier promised, '"For y$^{e}$ time draws near y$^{t}$ I am to part w$^{th}$ my Fellowship, & as my incomes contract, I find it will be convenient that I contract my expenses."'[17]

In itself ordainment did not entail any duties, and Newton, a deeply religious person, intended to stay on celibate in Cambridge, and pursue his studies. Why then was he against ordainment to the point of giving up a lucrative fellowship of 60 pounds per annum and inviting ostracism and social wrath? The only answer seems to be that he refused ordainment because it offended his religious sentiments. What were Newton's religious sentiments? To obtain his Bachelor's and Master's degrees in 1665 and 1668, he signed his belief in the Thirty-Nine Articles of the church as required. On becoming a Fellow of Trinity College, in 1668, he vowed to embrace the true religion of Christ with all his soul, as statutorily required. In 1669, when he took up the Lucasian Professorship, he took an oath of allegiance to the Church of England, as required by the 1662 Act of Uniformity of every master and head, fellow, tutor, etc., of a college, and every public professor and reader in the university. Apparently, between 1669 and 1675 his religious sentiments changed: we now know that he had come to believe that the church and belief in the Trinity was the work of the devil, and he was ready to give up his fellowship, his career, and perhaps even his life, rather than invite the wrath of God. Even on his deathbed, 'Newton refused to receive the sacrament of the church'.[18]

## The Heretic

In the nick of time, Newton's career was rescued by a royal dispensation, perhaps arranged by his mentor Barrow, for unknown reasons, exempting the Lucasian Professorship from ordainment. Newton was able to stay on in Cambridge and pursue his theology and alchemy well before he started writing the *Principia*. He said nothing to anyone about his views on the church, and people noticed only that Newton's hair had turned prematurely grey at the age of 30, that he lived a reclusive life keeping his windows shuttered, and never going to church. The unhappy boy had grown up into an unhappier man.

It would be a hopeless task to try and summarise here 50 years of Newton's poorly accessible writings on theology.[19] Nor is it relevant what exactly initiated Newton's serious theological study—whether the examination he would have given for ordainment, or, for example, the difficulty that the uninitiated have in distinguishing *homoousios* from *homoiousios*, like Tweedledum from Tweedledee. The key point of relevance is only this: that Newton eventually went deep into the history of the church, to its foundations. 'He set himself the task of mastering the whole corpus of patristic literature.'[20] In his notebooks, Newton cited 'Tertullian, Cyprian, Eusebius,…Origen, Basil, John Chrysostom,… Epiphanius, Hilary, Theodoret, Gregory of Nyssa, Cyril of Alexandria, Leo I,…Rufinus,…and others. He seemed to know all the works of prolific theologians such as Augustine, Athanasius, and Origen.'

## The Arian Controversy

What secret did Newton uncover? As the natural fruit of this scholarship, Newton was able to judge for himself the debate at the Council of Nicaea or the First Ecumenical Council. (Of the two points on the formal agenda, one concerned the dispute between Arius and Athanasius, and the other the non-uniformity in the date of Easter.) In what was perhaps his opening insight, Newton concluded that Athanasius had deliberately misrepresented the writings of earlier church Fathers,[21] and the declaration of the earlier synod of Serdica,[22] in order to win the debate with Arius. Newton's successor, the outspoken Whiston, succinctly summarised Newton's position by calling Athanasius a 'liar and a forger'. What troubled

Newton the most was that Athanasius and his followers were ready to distort even the scriptures, the very word of God, towards their worldly ends: 'That is, when the Fathers were not able to assert the position of Alexander[23] from the scriptures, they preferred to desert the scriptures than not to condemn Arius.' Newton called them *homoousiosians*, for their use of the term taken 'not from tradition but from Eusebius's letter…yet they chose it for it's being opposite to Arius'. After rejecting the papacy, the scriptures were regarded as the ultimate religious authority; but what if they were not quite authentic? Newton scanned various early versions of the Bible and Jerome's translation to correct the distortions that had crept in as a consequence.

## *The State-Church as Antichrist*

A politically literate person today may see the Council of Nicaea as a struggle involving state power. Mutual distortions of the teaching of one another were alleged, and personal allegations adduced even before the Emperor Constantine came to know of the division in the Eastern Church, and sent his emissary Hosius of Cordoba to reconcile the feuding parties and ensure religious peace in the empire. At the Council of Nicaea these allegations reached such a pitch that, in front of the assembled Bishops, Constantine reportedly burnt as unread the numerous parchments containing such allegations. Today one might see this sort of thing not as a 'distortion' but as a characteristic feature of the ecumenical councils: one could point to, for example, the 'Robber Synod of Ephesus', or the 'questionable diplomacy' and manipulations used by Cyril of Alexandria to have the outspoken Nestor branded a heretic.[24]

From the point of view of a politically literate person, today, Newton's insight was that the Church married the State at Nicaea, and changed the scriptures to suit its new role. It is unlikely that Newton thought in terms of 'State',[25] but he clearly realised that he was dealing with a general process rather than with individual aberrations. Newton held that this process was not only aided and abetted by the pope in Rome, but that the entire clergy became 'covetous and ambitious': 'It's plain therefore that not a few irregular persons, but y[e] whole clergy began at this time to be puft up, to set their hearts upon power and greatness more then upon piety & equity, to transgress their Pastoral office & exalt themselves…'[26]

For Newton the locus of religious authority had shifted from the pope to the scriptures; so it was intolerable that the clergy had tampered with the scriptures for political gains. Newton, who regarded the church as apostate, was not far from an understanding of the church itself as the embodiment of the antichrist.

For a believer, such an understanding, backed by Newton's scholarship, would be devastating even today. For Newton himself, this understanding was shattering, and became the basis of an obsession that would preoccupy him for the next fifty years of his life. One must remember that Newton was brought up in a culture in which for centuries the mechanism of sharing power was that the state ruled the arm which wielded the sword, and the church ruled the mind which controlled the arm. One can only speculate whether Newton grew up thinking that the church was father and mother to those who had none: but religious figures must have been significant role models for him. Saints were people to be revered, not people who had got sainthood in a *quid pro quo* for increases of church revenue and influence. Saint Athanasius a liar and a manipulator? *Athanasius*, the founder of the church? Clearly, Arius seemed morally superior, for even his enemies agreed that he had charming manners, an ascetic way of life, was knowledgeable and a good speaker, and he was no hypocrite, for he was ready to bear exile rather than compromise his views.

The church is even now bound to treat Arians as heretics, and to excommunicate them. We have seen how, even in this century, Cambridge University, the British Museum, Harvard, Princeton, and Yale, all refused to accept Newton's theological papers. Three centuries ago, in Cambridge, not only was an Arian and anti-Trinitarian understanding of Christianity a psychologically shattering matter for Newton, it was socially very dangerous, and any articulation of this understanding would have definitely endangered livelihood, if not life. Newton's patron, and master of the college, Isaac Barrow, composed a *Defence of the Blessed Trinity*, while Barrow's successor, Roger North, 'let it be known that he intended "to batter the atheists and then the Arians… ". Since any discussion was fraught with the danger of ruin, Newton chose silence.'[27]

Newton had no confidante—no one at all with whom he could share his startling insights. Nevertheless, all his life he secretly pursued his conviction that 'a massive fraud, which began in the fourth and fifth centuries, had perverted the legacy of the early church'.[28] He started (and presumably completed) writing an eight-volume history of the church. He was impatient with his correspondence on optics and mathematics because he was preoccupied with writing this history.

Newton held that Athanasius and his followers introduced pagan elements in order to encourage conversions and increase their political strength. One of the signs of the apostate church, wrote Newton, was the use of sorcery and false miracles to deceive people. He pointed to the superstition that the sign of the cross could drive away devils or produce beneficial spiritual effects. The corruption of doctrine resulted in idolatry: the introduction of 'consecrating Images Pictures Holy water, Agnus Dei's, Psalters, rings, Beads wooden crosses, & y$^{e}$ like…is a superstition of y$^{e}$ same kind w$^{th}$ y$^{e}$ Charmes & spells of y$^{e}$ old Heathen, & even w$^{th}$out a figure may be truly called enchantment and sorcery…'.[29]

The church had come to identify its implicit goals squarely with state power. The Protestant reformation clearly did not more than scratch the surface: though it rejected papal authority and the flourishing trade in divine forgiveness, it remained bound by the decisions of the Ecumenical Councils, including the one at Nicaea. In short, Newton had 'committed himself to a reinterpretation of the tradition central to the whole of European civilization'.[30]

## *Hope in Newton's Box*

Was there hope in Newton's shattered world? An indication is provided by 'one of the most revealing sketches of Newton'[31] drawn by Newton's senior colleague and theologian, Henry More, when he found how the thought of the apocalypse put Newton in a state of ecstasy: '…after his reading of [my] Exposition of the Apocalypse…, he came to my chamber, where he seem'd…(by the manner of his countenance which is ordinarily melancholy and thoughtfull, but then mighty lightsome and chearfull, and by the free profession of what satisfaction he took therein) to be in a manner transported'.[32] Newton thought that the central message of the Bible concerned the second coming of Christ at the seventh trumpet, 'y$^{e}$ great mystery of God to be fulfilled at y$^{e}$ voice of y$^{e}$ Seventh Angel when he shal begin to sound',[33] when the apostate church would come to an end, and 'at w$^{ch}$ time ceases & y$^{e}$ mystery of God is finished (Apoc 10.6, 7) & y$^{e}$ Kingdoms of y$^{e}$ world become y$^{e}$ kingdoms of Christ for ever & y$^{e}$ dead are judged & saints rewarded…'.[34] Newton's involved calculations fixed the time of the second coming in the 19th century, some two hundred years later.

Newton believed the future to be known and predictable. He believed in prophecy, and regarded Christ as a prophet; indeed he believed that the future had already been prophesied in the scriptures, and that the meaning of the prophecies would become clearer as apocalypse approached. This idea of prophetic revelation in the scriptures was the core of his religious belief. As a historian, 'It was Newton's intention to establish the exact correlation of prophecy and history'.[35] The difficulty was that he had to be sure of the content of the prophecy, and he was sure only that the Bible had been corrupted by trinitarianism, the 'fals infernal religion', brought about by 'Idolaters', 'Blasphemers & spiritual fornicators' who pretended to be Christians but were actually 'y$^{e}$ most wicked wretched sort of people…the worst sort of men that ever reigned upon the face of y$^{e}$ earth'.[36] He examined 1 John 5:7 in his Bible and noted, 'It is not read thus in the Syrian Bible…Not by Ignatius, Justin, Irenaeus, Tertull. Origen, Athanas. Nazianzen Didym Chrysostom, Hilarius, Augustine, Beda, and others. Perhaps Jerome is the first who reads it thus'.[37] This was a maze from which there was no exit.

The gods may have laughed when they put Hope in Pandora's box, but the story of Newton's box too would be incomplete without it. Where Newton the honest theologian could see through the manipulations of the first four ecumenical councils, Newton the historian fell a victim to the machinations of the fifth ecumenical council, which cursed 'cyclic' time. This was Newton's error, a theological error which infiltrated his physics and became the reason why his theory could not be sustained beyond a point, and so it is important to understand this error. To synthesise afresh the amalgam of theology, history, and physics that formed in Newton's mind, it is necessary to recognise time as the bridge connecting these disciplines.

Newton had before him two views of historical time: the view of Herodotus about history repeating itself, and the apocalyptic view of history as progress towards the goal of eternity. The latter view represented, as we saw above, the only bright spark in his life; it provided meaning not only to history, but also to his life. Newton's faith in prophecy was welded to his physics through apocalyptic time.

## *Even Tenor and the Temporal Dichotomy*

Newton's teacher, Barrow, had devoted much thought to time, the topic with which he commenced his lectures on geometry.[38] He opened his comments on time with an ironic reference to Augustine's 'very trite Saying' ('What, then, is time?'): *'If no one asks me I know; but if any Person should require me to tell him, I cannot.'* He thought this escape route was not available to 'Mathematicians' since they 'frequently make use of Time, they ought to have a distinct Idea of the meaning of that Word, otherwise they are Quacks'!

He then introduced the even-tenor hypothesis, 'whether things move…or stand still; whether we sleep or wake, Time flows perpetually with an equal Tenor'.[39] Barrow's argument was that a quantity has a reality independent of the means used to measure it.[40] His other argument was that the imperceptible need not be non-existent: '*When we wake we cannot perceive or tell how much Time has passed during our Sleep*; which is certainly true: But it cannot be justly inferr'd from thence. *We do not perceive the Thing, therefore there is no such Thing,* that is a false Illusion, a deceitful Dream, that wou'd cause us to join together two remote Instants of Time'.[41] [Italics original.]

Since time flows in 'an equal Channel, not by Starts', it could be measured only by a special class of motions, called 'equal motions', such as those of the Sun or Moon, adapted for that purpose by 'the divine Will of the Creator'. Was there any reason, apart from 'divine Testimony', to call this an 'equal motion'? Barrow appeals to the principle of sufficient reason: these motions could be compared using clocks, 'as, for Instance, an Hour-Glass…because the Water or Sand contain'd in it remain entirely the same as to Quantity, Figure and Force of descending, and the Vessel that contains them, as likewise the little Hole they run thro' don't undergo any Kind of Mutation, at least in a short Space of Time, and the State of Air much the same; there is no Manner of Reason for us not to allow the Times of every running out of the Water or Sand to be equal.' In short, Barrow's formula for equal intervals of time is that the same causes take the same time to produce the same effects.

Since the even tenor of time was measured by equal motions, time was similar in all its part, and had length alone.[42] Time could, therefore, be represented by *'a strait or circular Line'* [emphasis mine]. Barrow concluded, 'We therefore shall always express Time by a right Line'.

Whether or not he ever attended Barrow's lectures, a scholar like Newton could hardly have written his *Principia* without consulting Barrow's thoughtful *Lectures on Geometry*. In his *Principia*, Newton stated that he did 'not define time, space, place, and motion, as being well known to all',[43] but proceeded to remove 'certain prejudices' amongst 'common people'. Without ado, he restated the even-tenor hypothesis: 'Absolute, true, and mathematical time, of itself, and from its own nature, flows equably without relation to anything external, and by another name is called duration…'

He distinguishes between absolute and relative time in astronomy to conclude that solar motion could not be used to measure equal intervals of time, 'For the natural days are truly unequal, though they are commonly considered as equal, and used for a measure of time.' What are 'equal motions' then? The universality of gravitation makes Newton doubt their existence: 'It may be, that there is no such thing as an equable motion…All motion may be accelerated and retarded…' This does not make any difference, for the flow of time has a reality independent of the means used to measure it, for things endure all the same, 'whether the motions are swift or slow, or none at all'.

Unlike Barrow, Newton does not state the dichotomic representation of time as a 'strait or circular Line'. His mind is already made up, he has no residual doubts in the matter, hence no need to state any alternative possibility. Newton and subsequent physicists took it for granted that time must be represented by a straight line. We have already seen that 'linear' time was the hope in Newton's box, and that circularity would have destroyed Newton's apocalyptic view of history, which implicitly accepted the dichotomy of linear and cyclic time.

But from the point of view of physics, the choice of linear time was unnecessary. Newtonian physics is 'instantaneous': Newton's second law of motion relates the force at an instant of time with the acceleration at that very instant. A Newtonian force does not take any time to act. On the other hand, the 'linear' or 'cyclic' nature of time is a global property: it depends on the way the instants are strung together, whether or not the 'string of instants' eventually curls back upon itself.

It should be clearly understood that we are speaking here by hindsight, so that the assertion that Newton's theological error led to the error in his physics is not meant to be derogatory to Newton. Even the keenest mind can hardly hope to escape the stamp of the time. As Westfall says, 'Newton could no more have leapt out of his time than we can.' Poincaré put matters even more forcefully: 'Descartes used to commiserate the Ionians. Descartes in his turn makes us smile, and no doubt some day our children will laugh at us. Is there no way of getting at once to the gist of the matter, and thereby escaping the raillery which we foresee?'[44]

## *Time Measurement and the Physical Content of Newton's Laws*

Consider, for example, the difficulty that many people, today, have in understanding that Newton's laws of motion are not physics. It is surely relevant to this difficulty that these people were brought up to regard 'Newton's Laws' as the beginning of physics. Newton's laws of motion, by themselves, are not physics because they are not *refutable*. The second law defines force as mass times the acceleration (or the rate of change of velocity). The second law is not even a good definition of force, for acceleration is not well-defined. A body accelerates if it covers unequal distances of space in equal intervals of time. But what are equal intervals of time? We cannot put two time intervals side by side to compare them; we must rely upon a 'proper' clock. That is, one must have an 'equable motion', and Newton conceded that this may not exist. There is, therefore, no way to show experimentally that Newton's laws of motion are false.

This does not mean that Newton's theory had no physical content. The most significant success of Newton's theory was the ability to calculate planetary orbits. Newton achieved this by combining the law of universal gravitation with the laws of motion. The *combined* laws are clearly refutable: for instance, they imply that the path of a projectile is an ellipse rather than the parabola that Galileo took it to be, though a small portion of the one approximates a small portion of the other very closely. (And in the trajectory of the projectile we see only a small portion of either.)

Today one might say Newton's achievement was that he was able to establish for elliptic orbits the inverse square law that many others believed[45] to be the case for circular orbits. To put matters in another way, Newton was mathematically able to back-calculate the force law that would give Kepler's 'observation'[46] that the planetary orbits are ellipses with the sun at one focus. This may seem a small detail, just as the difference between the Keplerian ellipses and the Copernican circles is nearly insignificant. But seemingly insignificant details which inconveniently do not fit into a facile general pattern are the stuff that the achievements of scientific theories are anchored upon. Merely looking at the planets as they appear in the sky gives absolutely no indication that their positions can be calculated with such elegance.

## *Providence, Prophecy, and Rationality*

Why are Newton's laws called 'laws'? Laws are made by authorities—kings, parliaments, etc.—and imposed on individuals. In the current understanding of physics, physical theories can never quite grasp the truth; there is no guarantee that the sequence of theories will ever converge to the truth, or that successive theories will approximate each other more closely, or even that there exists anything like a timeless truth about the physical world. Therefore, there are only theories that are either false or in the process of being falsified, and there can be no 'laws' of physics that can be broken or violated. But Newton had an image of Solomon's temple with a central fire surrounded by seven lamps. He thought that God was to be worshipped in the temple of nature, in which the central fire was the sun and the seven lamps were the planets. He thought that he had understood the correct plan of the temple of Solomon, and also of the temple of nature. He thought that God had revealed this plan to him, and not to others before him, because the prophecy of the scriptures became easier to understand as the time came near when the seventh trumpet would sound. Newton believed in miraculous providential interventions, but thought that miracles must, by definition, be rare; the rest of the time the world evolved according to God's plan. Hence he cancelled *'Hypothesi'* and wrote *'Lex'*, while preparing the draft of his *Principia*.

Many people who, today, rush to disavow Newton perhaps need to be reminded that it was not Newton alone who believed he had found the ultimate 'Laws of God'. It was after Newton's death that a poet (Alexander Pope) wrote,[47] 'Nature and Nature's Laws lay hid in the Night/God said *Let Newton be*! and All was *Light*'. Even today, physicists continue to speak of the 'laws' of physics.

The matter is perhaps more easily understood in the framework of theology. Rational theology took its inspiration from Aristotle who thought that everything needed a cause. If an archer shoots an arrow, the archer is the cause. But this locates the cause in the past which Aristotle thought had ceased to exist. *At this instant* why does the arrow fly through the air? why doesn't it fall down? Can one locate a cause of the arrow's flight at the *immediately preceding* instant?

The theologian John Duns Scotus and his followers maintained that the arrow continues to fly because of providence. This providence is like continuous creation. At every instant, God intervenes in the world. The arrow remains aloft as a result of this intervention. This doctrine (which continues today to be an aspect of Islamic theology) was a matter of serious dispute amongst Islamic philosophers and theologians like al-Ash'arī, and al-Ghazālī who preceded[48] Duns.

In Islamic theology, the dispute concerned rational theology (*aql-i-kalām*) versus providence. Rationality (Aristotle's) was advocated by a group known as Mut'azilites, and later by another group known as the Philosophers (*falāsifā*). Both groups were opposed by al-Ghazālī who granted that Allah was bound by the 'laws' of logic. But he maintained (correctly) that causal necessity was not logical necessity. Hence, he maintained, Allah was not bound by any 'laws of cause and effect'; He might intervene as He liked. Hence, Allah was the sole cause of the arrow remaining aloft.

Whatever happened was the will of Allah, and it was *logically* possible for Allah to intervene, if He so chose, at any instant. At every instant the world was created afresh, though this new world *could* be very similar to the preceding one. Al-Ghazālī's point was that inanimate things could not be agents. But Western theologians interpreted this to mean that animate beings could also not be agents: a man did not will to write, the hand did not move the pen, nor was the pen the cause of the mark on the paper; the correct description was that God simultaneously created the will to move the hand, and the mark on the paper.

Hence, in Christian theology, this point of view fell into disrepute, and the followers of Duns came to be known as Dunsmen or Dunces, with the latter word having the same connotation as it does now.[49] The reason was not a disbelief in miracles but a belief in the need of punishment: if God created the will to move the hand that wrote, then what sense did it make for God to punish the person whose hand it nominally was? If someone forcibly puts a gun in your hand, and forcibly makes you pull the trigger, why on earth (or in Hell) should you, the person to whom the hand was attached, be held responsible? The opposite viewpoint was that of rational theology, which maintained that God directed the world through 'laws of cause and effect', and not through direct intervention.

Today, this contrary point of view is usually taken to be that represented by Wilhelm of Ockham who rejected the idea of continuous divine intervention: *in the absence of any intervention*, the arrow would continue to fly. It was not necessary to explain why the arrow continued to fly; rather it was necessary to explain why the arrow fell down where it did. This is a very interesting point of view, because it separates good answers from bad by separating good questions from bad. This point of view is embodied in the law of inertia, which we know today under the name Newton's first law of motion: in the absence of external forces, a body continues in its state of rest or uniform motion. From this point of view, all that this law states is this: uniform motion needs no explanation, departures from uniform motion do and are 'explained' by the application of an external force.

Restrictions on divine intervention were also supported by the theological belief in prophecy. God had already prophesied what was to happen, and this prophecy was written down in the book. (Newton thought this prophecy would be progressively unveiled as one neared the apocalypse.) It seemed ludicrous to imagine God running around at the last minute, like a harried hostess, arranging things to make sure that everything is perfect. Instead, the image of God as the divine watchmaker was better suited to the idea of grand prophecy. The world was like an intricate clock (the one at Strassbourg) which once set into motion did not require any further intervention. Along with the world, God created rigid and immutable laws to govern it. The motion of the clock was controlled by its mechanism, and that of the world by the laws of God. Newton cancelled '*Hypothesi*' and wrote '*Lex*' in his draft of the *Principia* probably because he thought he had received a divine revelation into the laws of God.

As the thought of divine revelation suggests, Newton did not rule out providence altogether. The divine Watchmaker might intervene now and then, adding a spot of oil here, tightening a screw there, and winding up the watch as needed. In particular, Newton thought that planetary motions needed to be 'wound up' from time to time.

Time destroyed Newton's physics; but will it resurrect his insights into theology?

∞

## *Summary*

- Barrow stated Augustine's dichotomy about 'linear' and 'cyclic' time using the geometric line and the circle to represent time.

- Barrow defined equal intervals of time as follows: equal causes take equal times to produce equal effects.

- Newton's choice of 'linear' time is not relevant to his physics, which is instantaneous.

- Newton was more a religious historian—he spent most of his life obsessively wrting a history of the church, which has remained suppressed to this day.

- Newton the physicist chose linear time because Newton the historian believed in apocalyptic time—a progressive unfolding of God's plan, culminating in universal apocalypse.
- Newton referred to the 'laws' of physics because he thought the laws of God had been revealed to him.
- In addition to these laws, he thought that God made occasional providential interventions.

∞

# 5

# In Einstein's Shadow

Einstein's early life was hardly as unhappy as that of Newton. But he had his anxious moments. His general lack of respect for his teachers got him into trouble in school and later on at the Polytechnic. His mathematics teacher, Hermann Minkowski, called him a 'lazy dog'. His physics teacher, Jean Pernet, warned him, 'in his own interest' to study medicine or law instead.

Of the four people who successfully graduated in his batch of August 1900, he was the only person to remain unemployed. He tried desperately to obtain the position of 'Assistent', under Heinrich Weber whose 'masterly lectures' he had earlier admired; but Weber preferred to employ two engineering students from elsewhere. Einstein remained jobless for eight months, and having to rely on his (not well-off) parents at the age of twenty-one made him feel a complete failure. His father, Hermann Einstein, wrote pathetic letters to Albert's former teacher, begging him to employ Albert or at least to write to him. There was no response. On 14 April 1901 Einstein wrote to his friend Marcel Grossman that he could have found an Assistant's position long ago, but for 'Weber's underhandedness'. But he promised to keep trying and not to give up his sense of humour; 'God created the donkey and gave him a thick hide'.

## *E=MC?*

It is conceivable that Nature has created a sex without brains!

**A. Einstein**[1]

Here E denotes Einstein, and MC

'So, what will become of your Dollie now?' asked his mother. 'My wife', Einstein replied.

is an abbreviation of MCP.

He went on to describe the resulting scene, in a letter of July 1900 to 'Dollie'.

> Mama threw herself on the bed, buried her head in the pillow and wept like a child. After regaining her composure she immediately shifted to a desperate attack: 'You are ruining your future and destroying your opportunities.' 'No decent family will have her.' 'If she gets pregnant you'll really be in a mess.' With this last outburst, which was preceded by many others, I finally lost my patience. I vehemently denied that we had been living in sin and scolded her roundly…[2]

'Dollie' was Mileva Marić, the fifth student in his class, an intelligent young woman whom the examiners chose not to pass, at a time when women physicists were virtually unknown. In the event, when Dollie informed him that she had become pregnant, he was not too perturbed. She had also to give an examination. He continued with his work. He wrote to her in a letter dated to 28 May 1901: 'I have just read a wonderful paper by Lenard on the generation of cathode rays by ultraviolet light. Under the influence of this piece I am filled with such happiness and joy that I must share it with you. Be happy and don't fret…you just have to be patient!'

Einstein soon wrote a letter to Paul Drude, editor of the *Annalen de Physik*, 'to point out his mistakes' in his electron theory of metals. Einstein thought his arguments were irrefutable, and that his brilliance would be rewarded with a job; he made it clear in his letter that he needed one. As the scientific giant of the day, Drude snubbed him; he rejected Einstein's objections offhand. Einstein felt hurt. Drude whom he had called 'a brilliant man' in April, he now called 'a sad specimen'. He wrote to a friend that he would 'make it hot for Drude', by publishing his criticism in a humiliating article. (He didn't: in his 1905 paper on light quanta, for which he got the Nobel prize, Drude led all the rest in the list of references, and Einstein did not criticise Drude's methods.)

Reeling from Drude's snub, he reformulated his career objectives. He wrote to Mileva that he had made an 'irrevocable decision' to accept any job, and give up, if necessary his 'personal vanity' and scientific goals. 'After suffering a humiliating reverse, he wanted Mileva at his side in his battle against the philistines.'[3] Mileva cautioned him to be sensible, since 'a really bad position' would make her 'feel terrible…I couldn't live with it'. Ultimately, he managed to get a temporary job, to coach one student at a private boarding school (in Schaffhausen). The temporary job was so poorly paid that Einstein asked to be paid enough to be able to eat out, hoping to save some money in this way; on being refused, he threatened to quit! Considering the trouble he had had in getting any kind of job, this was an absolutely empty threat. But he got his way, and wrote to Mileva, 'Long live impudence! It's my guardian angel in this world.'

Just before he left this job in December 1901, he heard from his friend Marcel Grossman that Grossman's father had spoken to Haller, the head of the Swiss Patent Office, and Einstein was likely to get a position which would be advertised soon. Einstein wrote that he was 'dizzy with joy'. He suddenly discovered that Professor Kleiner was not such a bad fellow after all, and decided to follow his advice and publish his ideas before he was bogged down by the responsibilities of his future job.

As for Mileva, who was soon due to have her baby, whom she called Lieserl, he wrote to her that 'the only problem that still needs to be resolved is how to keep our Lieserl with us'. Disingenuously referring to himself as 'impractical Johnnie', he advised her 'ask your Papa; he is an experienced man'. Lieserl was born towards the end of January 1902.[4]

No one knows what happened to her. Einstein never saw her. He never again mentioned her publicly, and no other mention is found of her in the vast bulk of his papers. Her existence came to light only in 1986, but she herself seems to have disappeared as completely as Theodora's illegitimate son.

In 1933, a woman claiming to be Einstein's long-lost daughter showed up with a son. Some friends of Einstein were persuaded. One friend (Frederick Lindemann) sent a telegram to Hermann Weyl, who was asked 'to question the professor personally…It appears that Einstein disavowed all knowledge…'. Another (Janos Plesch) wrote 'a tactful letter', but to his 'great mystification, Einstein showed no proper interest'. 'It amused Einstein greatly', and he responded jocularly,

> All my friends are hoaxing me
> —Help me stop the family!
> Reality's enough for me…

Privately, however, Einstein engaged a detective to get the claim investigated over eight or nine months.

## The Origin of Relativity

Given Einstein's constant philandering, Lieserl was probably not the only illegitimate child Einstein had.[5] But the story of how Einstein handled the difficult social situation of an illegitimate child is only a preparation for a more difficult question. Children are not illegitimate, though the social order or parents may be. Was Einstein illegitimately declared the father of relativity? Einstein's private life is of no interest here except in so far as it has a bearing on this question.

Aim.

This question about priorities itself would be somewhat pointless, except that (1) brushing aside this question has not only obscured the true foundations of relativity theory, in questions about the nature of time; it has also obscured the true nature of relativity theory. (2) The question helps to illuminate the principles underlying the distribution of credits in science—principles which also underlie the distribution of resources in society at large. (3) Finally, there is the question of the time beliefs underlying the principles used to distribute social credits: are these time beliefs compatible with the nature of time in relativity?

## Einstein's Version

Here is how Einstein described the origin of the theory of relativity.

> By chance a friend of mine in Bern (Michele Besso) helped me out. It was a beautiful day when I visited him with this problem. I started the conversation with him in the following way: 'Recently I have been working on a difficult problem. Today I came here to battle against that problem with you.' We discussed every aspect of this problem. Then suddenly I understood where the key to the problem lay. Next day I came back to him again and said, without even saying hello, 'Thank

> you. I've completely solved the problem'. An analysis of the concept of time was my solution. Time cannot be absolutely defined…With this new concept, I could resolve all the difficulties completely for the first time.
>
> Within five weeks the special theory of relativity was completed. I did not doubt that the new theory was reasonable from a philosophical point of view…[6]

That is Einstein's version. Poof. He had an inspiration. Time was the problem. Within five weeks the theory was ready.

## The Text-Book Version

Let us look at the text-book version. What is the velocity of light (*in vacuo*) coming from a moving source? Does the velocity of the source get added on to the velocity of light? Suppose it does, then the speed of light coming from a moving source will vary, being highest in the direction of motion of the source, and the least in the opposite direction. In the old picture it was supposed that the earth is moving in absolute space (aether). Suppose we measure the speed of light in two directions: one along and one perpendicular to the earth's motion. In one direction the speed of the earth would be added on; in the other direction it wouldn't be. Michelson and Morley performed this experiment, which aimed to measure a difference in speed in the two cases.

Nobody had the foggiest idea what the absolute speed of the earth might be. But it was supposed that this might be the same as the speed of the earth around the sun, or its speed in relation to the fixed stars. Since the speed of the earth in its motion around the sun is very small compared to the speed of light, this is a very difficult experiment to perform. The aim was to measure the difference in the round trip time for light along two paths of equal length; one path being along the direction of the earth's motion, and one being transverse to it. Since nobody knew what this direction might be, all possible directions were tried.

The principle of the experiment is simple. Whether the wind blows from the echo point to the hill, or the other way around, the echo takes *longer* to return. In one direction the sound is speeded up, in the other direction it slows down. Since it travels at a slower speed for a longer time, the average speed is reduced. Hence, the time taken for the return trip is increased. In exact analogy, the round trip time would be *longer* for the light travelling in the direction of the earth's motion than it would be for light travelling perpendicular to this direction. No difference was detected by Michelson and Morley. The experiment was later repeated by Miller who reported a small positive effect, which was largely disbelieved. (This last part is not mentioned in text books to avoid confusing students.)

It follows from the Michelson–Morley experiment (ignoring Miller's experiment) that the speed of light is a constant independent of the speed of the source. The rest of special relativity may now be derived by modifying Newtonian physics, to accommodate the peculiarity that the speed of light is a constant, hence a limiting speed.

How can the two preceding versions be reconciled? In Einstein's 1905 paper on the special theory of relativity,[7] there is only a vague mention of the 'unsuccessful attempts to discover any motion of the earth relatively to the "light medium"'. In his later years, Einstein was repeatedly asked about the influence of the Michelson–Morley experiment on his work. He gave contradictory answers.[8] When informed about Miller's results he simply disbelieved them saying 'God is subtle but not malicious', or some more poetic translation to that effect. We will see a little while later what was the exact influence of the Michelson–Morley experiment.

## *Whittaker's Version*

In 1953, E. T. Whittaker published the second volume of his history of the theories of aether and electricity,[9] while Einstein was still alive. Chapter 2 was called 'The Relativity Theory of Poincaré and Lorentz'. In this he pointed to works on relativity prior to Einstein. The principle of relativity was formulated and so named by the French mathematician Henri Poincaré. Though Poincaré believed in the principle of relativity from the earlier century, stating in 1899 that it was 'very probably true', Whittaker[10] maintains that 'Poincaré gave to a generalised form of this principle the name "The Principle of Relativity"' for the first time during his lecture of 24 September 1904 to a Congress of Arts and Science at St. Louis, USA. Whittaker[11] mentions that during this lecture Poincaré spoke of 'a new mechanics, where, the inertia increasing with the velocity, the velocity of light would become a limit that could not be exceeded'. (In fact, Poincaré stated, 'no velocity could surpass that of light any more than any temperature could fall below absolute zero'.) Whittaker points out that Poincaré's article[12] giving the mathematical details of his new mechanics appeared in June 1905, while that of Einstein appeared only in September 1905:

> In the autumn of the same year,…Einstein published a paper which set forth the relativity theory of Poincaré and Lorentz with some amplifications, and which attracted much attention.[13]

A number of biographers of Einstein found the similarity between the two papers to be strong enough to have to state that Einstein did not know of the contents of Poincaré's 5 June paper, when he submitted his own paper at the end of June 1905. Einstein's paper was received by *Annalen der Physik* on 30 June 1905; had Einstein known of Poincaré's 5 June paper, that would have given him at most three weeks instead of five to complete his own paper on relativity. But Poincaré's ideas were circulating informally, for a number of years *before* June 1905. Did Einstein know of the contents of Poincaré's St. Louis talk of 1904? (This talk was published in 1904, and an English translation in January 1905.[14]) Was it ever discussed at the University at Berne? Was Einstein present when it was discussed?[15]

## *Whittaker*

Before proceeding, a few preliminary questions are in order. Who was Whittaker? who was Poincaré? and who was Lorentz?

Sir Edmund Whittaker, a mathematician, is most widely known for the first volume of his *History of Aether and Electricity* which was published more than forty years before the second volume. The first volume is widely acknowledged as a masterpiece. He was also the joint author of a relatively less noticed but equally splendid book on computing before computers.[16] In both these books, there are numerous attempts to correct popular attribution of credits. To take a random example, volume 1 points out that the force law usually attributed to Lorentz was actually stated earlier by Oliver Heaviside. The other book similarly goes into questions such as the origin of what is today known as the Newton–Raphson method. In carrying out these corrections, animosity towards Lorentz or Newton was probably the farthest thing from Whittaker's mind.

Usually, for a scientist, the focus is on accurate handling of the technique or the equation; accuracy in attribution is unimportant. Hence, any attribution soon becomes conventional, no matter how inaccurate. For most physicists, it was quite enough that someone of the stature of Max Planck attributed the theory of relativity to Einstein. As a historian of science, Whittaker seems to have thought it his duty to systematically attack inaccuracies in such attribution. Usually, for scientists unwilling to consult archives, Whittaker's authority suffices. In the case of Einstein, however, Whittaker's authority was not only rejected, it was disparagingly dismissed. Poincaré is rarely mentioned, and then only to be dismissed. In the latest best-seller on relativity, Kip Thorne a well-known relativist, describes the reactions of the scientific community

> faced with the…triumphs of Newtonian physics, triumphs grounded firmly on the foundation of absolute time, nobody was willing to assert with conviction that time really does dilate. Lorentz, Poincaré…waffled.[17]

So who were Lorentz and Poincaré? Did they really waffle?

## *Lorentz*

H. A. Lorentz was a Dutch physicist, awarded the Nobel prize in 1902 jointly with Zeeman. Everyone including Lorentz is agreed that he came very close to discovering relativity, but waffled. He took the Michelson–Morley experiment seriously,[18] and suggested (in 1895) that there was only one way to explain why there was no observed change in the speed of light in the direction of the motion. This way was to suppose that the measuring rod itself contracted in the direction of motion: 'The length of a meter rod would change…by about 1⁄200 micron.[19] One could hardly hope for success in trying to perceive such small quantities…' Lorentz thought that the length reduced because the space between the particles composing the body was compressed because of the pressure of the aether. Later on he thought that the particles themselves were reduced in length. The reduction of length would exactly compensate for the longer time taken by light in carrying out a round trip along the direction of the earth's motion. This idea was anticipated by Fitzgerald, and led to the famous caricature in a limerick.

> There was a young man named Fisk
> Whose fencing was exceedingly brisk.
> So fast was his action,
> The Fitzgerald contraction
> reduced his rapier to a disk.

In 1904 Lorentz also introduced a new mathematical variable, which he called 'local time', to which he did not attach much significance. Lorentz's theory was that no effect was observed by Michelson and Morley because things behaved *as if* length contracted, *as if* time dilated, *as if* the speed of light were a constant. Later on he admitted, 'The chief cause of my failure was my clinging to the idea that…my local time…must be regarded as no more than an auxiliary mathematical quantity'.[20]

## *Poincaré*

Henri Poincaré was a French mathematician and mathematical physicist. His citation for the Bolyai prize called him

> at the present moment unquestionably the most powerful investigator in the domain of mathematics and mathematical physics…With his brilliant creative genius is combined the capacity for sharp and successful generalization, pushing far out the boundaries of thought in the most widely different domains, so that his works must be ranked with the greatest mathematical achievements of all time.[21]

Not many informed persons will disagree with this assessment even today. It is a sign of Poincaré's genius that ninety years after his death, his work still has a contemporary flavour. He was repeatedly nominated for the Nobel prize, receiving 34 nominations in 1910. The nominators included Marie Curie, Lorentz, Michelson, and Zeeman. But Poincaré did not get the prize on the grounds that his work was in mathematics rather than physics. (Nobel was allergic to mathematicians.) This is the same Poincaré who appears in the limerick in Chapter 1, and we shall encounter him again in the next chapter. Poincaré addressed in great depth all the issues in relativity ranging from the philosophical to the mathematical. To start with he formulated and so named the principle of relativity.

Whittaker suggests that while Poincaré believed in the principle of relativity even in 1899, he so *named* it only in his St. Louis lecture of 1904. There is a key point here. Though it does not refer to any of Poincaré's works, Einstein's 1905 paper uses not only the same ideas but also the same name of the 'Principle of Relativity'. Afraid that this point may have been missed, Whittaker repeated it two years later in his biography of Einstein:

> Einstein…adopted Poincaré's principle of relativity, using Poincaré's name for it…[22]

If Whittaker is right on this point, Einstein must have seen Poincaré's 1904 paper; and anyone who believes that Einstein wrote his 1905 paper on relativity after seeing Poincaré's 1904 paper, but without citing it, and without ever acknowledging this, cannot but draw unhappy conclusions about Einstein.

This 1904 paper was not simply a shot in the dark. Poincaré had been working on this theme for some time, and had earlier written a book, *Science and Hypothesis*, which was published in 1902 (which Einstein had certainly read and discussed extensively). This book enunciates what Poincaré then called the principle of relative motion:[23] 'the movement of any system whatever ought to obey the same laws' whether these laws refer to a fixed observer or to an observer moving with constant velocity. No doubt there is still an 'ought' here, which disappeared only in 1904. Why did Poincaré want to regard this as a fundamental principle of physics?

Velocity is relative, but acceleration is absolute. Hence the principle of relativity.

The reason for this is fairly clear. Newton's second law of motion *defines* force as mass (a constant) times the acceleration. But acceleration is the same[24] whether seen by a fixed observer or by an observer moving with a constant velocity: velocity may be relative, but acceleration is absolute. Acceleration involves the *change* in velocity; adding a constant velocity does not change this change: whatever the numbers $a$, $b$, and $c$, the difference between $a + c$ and $b + c$ is the same as the difference between $a$ and $b$. If the speed is 2 now and 3 one second later, the change is $3 - 2 = 1$. Suppose we add the constant number 5, so that the speeds are 7 now and 8 a second later, but the change in speed in one second remains 8 – 7 = 1. Hence, the two observers will agree on the acceleration experienced by any body, hence also they will agree on the forces acting on that body. Electromagnetic forces, however, seemed to depend upon velocity. This led Poincaré to ask: can one have a law of motion using *velocity* rather than acceleration?[25] In *Science and Hypothesis*, Poincaré considers this possibility in great detail and rejects it for compelling reasons.

But Poincaré goes much deeper. The above argument subtly assumed certain Newtonian notions of space and time. Anyone seeking to change Newtonian physics must, therefore, examine both the notions of space and time afresh, as Poincaré does in separate chapters in *The Value of Science*. Here we consider his examination of the notion of space. It is characteristic of Poincaré that this involves rethinking of the most mundane observations.

> I am seated in my room; an object is placed on my table; during a second I do not move, no one touches the object. I am tempted to say that the point A which this object occupied at the beginning of this second is identical with the point B which it occupies at its end. Not at all; from the point A to the point B is 30 kilometers, because the object has been carried along in the motion of the earth. We can not know whether an object, be it large or small, has not changed its absolute position in space, and not only can we not affirm it, but *this affirmation has no meaning*...[26]

Poincaré concludes that there is no absolute space. Position and displacement are relative.

> Many experiments have been made on the influence of the motion of the earth. The results have always been negative...we might expect to find accurate methods giving positive results. I think that such a hope is illusory...I do not believe, in spite of Lorentz, that more exact observations will ever make evident anything else but the relative displacement of material bodies.[27]

Velocity too can only be relative. There is no absolute motion or absolute velocity.

> Optical and electrical phenomena…might reveal to us not only the relative motion of material bodies, but also what would seem to be their absolute motion…Will this ever be accomplished? I do not think so…[28]

The absence of absolute motion is repeated later on explicitly in the context of Michelson's experiment.

> Michelson has shown us, I have told you, that the physical procedures are powerless to put in evidence absolute motion; I am persuaded that the same will be true of the astronomic procedures, however far precision be carried.[29]

The laws of motion cannot depend upon absolute motion just because absolute motion does not exist. This is exactly the principle of relativity, which Poincaré stated later on.

> The Principle of Relativity.—…the principle of relativity…not only is confirmed by daily experience,…it is irresistibly imposed upon our good sense…[30]

The reason for the initially expressed hesitation was this: Lorentz's theory of the interaction between electric charges and magnets led to forces which seemed to depend upon absolute velocity. How could this be reconciled with the principle of relativity?

Poincaré was not inclined to reject the principle of relativity. He was unhappy with 'that extraordinary contraction of all bodies' though he was not inclined to dismiss Lorentz's theory.

> The Lorentz theory is very attractive. It gives a simple explanation of certain phenomena which the earlier theories… could only deal with in an unsatisfactory manner…[31]

Or again,

> Look at the ease with which the new Zeeman phenomenon found its place, and even aided the classification of Faraday's magnetic rotation, which had defied all Maxwell's efforts. This facility proves the Lorentz's theory is not a mere artificial combination which must eventually find its solvent. It will probably have to be modified, but not destroyed.[32]

Poincaré's basic difficulty with the Lorentz theory was that it accumulated hypotheses,[33] in addition to requiring the notion of aether and absolute space. Refutability and simplicity were the guiding principles of Poincaré's philosophy. Accumulation of hypothesis went against both. Therefore, he sought a simple and more natural hypothesis. He already had a clear idea of this in 1902.

> The most satisfactory theory is that of Lorentz…it still possess a serious fault…it must take into account the action of the aether on matter and the reaction of the matter on aether. *Now, in the new order, it is very likely that things do not happen in this way.*[34]

It must be remembered that Poincaré was also a mathematician (and French), and mathematicians are accustomed to very conservative standards of rigour. A mathematician who believes something to be true, but lacks a rigorous mathematical proof states his belief as a conjecture. This is the significance of the qualification 'very likely' in the above quote.

By the time of his 1904 St. Louis lecture, Poincaré almost surely had a proof; he had found the 'new mechanics', a key component of 'the new order' in physics. His remarks reveal an awareness that he had a grand new theory. He placed the dilemma of the relativity principle and the Lorentz theory in the context of a wider historical movement, a crisis in physics: a confrontation with Maxwell's unified theory of electromagnetism leading to a revision of Newton's acclaimed laws of motion. He commenced the lecture by suggesting they were 'about to witness a profound transformation…', a revolution in physics.

> yes, there are indications of a serious crisis, as if we might expect an approaching transformation. Still, be not too anxious: we are sure the patient will not die of it, and we may even hope that this crisis will be salutary, for the history of the past seems to guarantee us this.

Poincaré opined that the first crisis in physics had destroyed the Newtonian physics of central forces and replaced it with the physics of principles. He identified five or six general principles: (1) the conservation of energy or the first law of thermodynamics, (2) the entropy law or the second law of thermodynamics, (3) Newton's third law of motion, (4) the principle of relativity, (5) the conservation of mass. As a sixth possible principle, he continued, 'I will add the principle of least action'. (Thermodynamics and entropy is discussed in the next chapter.) In the context of Whittaker's point about the name 'principle of relativity', it should be pointed out that Poincaré's elevation of the principle of relativity to rank with the established (but threatened) pillars of physics is done so subtly, that anyone reading Poincaré in the above context is likely to get the illusion that the principle of relativity had for long been regarded by physicists on par with the other principles which are all much older. (I learnt this by making the mistake.) The crisis arose because each of these older principles was under attack.

Consider, for example, the Lorentz theory. As an immediate consequence of his theory, Lorentz was forced to abandon the constancy of mass: in his 1904 paper he supposes that there are two masses, a longitudinal mass (in the direction of the motion), and a transverse mass (perpendicular to the direction of motion).

> These quantities...may therefore properly be called the 'longitudinal' and 'transverse' electromagnetic masses of the electron. I shall suppose *that there is no other, no 'true' or 'material' mass*. [Emphasis original.][35]

(In his 1905 paper, Einstein dropped the adjective 'electromagnetic', but used the same names, 'longitudinal' and 'transverse' masses,[36] for the same numerical quantities without the quotation marks and without any explanation. In the later reprint of his paper, in 1923, he added a note about Lorentz's 1904 paper,[37] 'The preceding memoir by Lorentz was not at this time known to the author.') Poincaré argued that 'mechanical masses must vary in accordance with the same law...they can not, therefore, be constant'.[38] The constancy (conservation) of mass was a key principle, named after the chemist Lavoisier. Poincaré continues,

> Need I point out that the fall of Lavoisier's principle involves that of Newton's? This latter signifies that the center of gravity of an isolated system moves in a straight line; but if there is no longer a constant mass, there is no longer a center of gravity, we no longer even know what this is.

What is the remedy? Poincaré continues,

> From all these results, if they were confirmed, would arise an entirely new mechanics, which would be, above all, characterized by this fact, that *no velocity could surpass that of light,*[1] *any more than any temperature can fall below absolute zero*. [Original footnote 1: Because bodies would oppose an increasing inertia to the causes which would tend to accelerate their motion; and this inertia would become infinite when one approached the velocity of light.][39]

Poincaré continues that the inability to surpass the speed of light would be true also for an observer moving with a uniform velocity (which he would have no way to detect).

> No more for an observer, carried along himself in a translation he does not suspect [i.e., moving with a uniform velocity that he cannot detect], could any apparent velocity surpass that of light; and this would then be a contradiction, if we did not recall that this observer would not use the same clocks as a fixed observer, but, indeed, clocks marking 'local time'.

We see here the culmination of years of hard thought by a brilliant creative genius working on an extremely difficult problem. Poincaré's lecture breaks off at this point, though he returns once again, at the end of the lecture to remind the audience about

> the new mechanics…where…the velocity of light would become an impassable limit. The ordinary mechanics, more simple, would remain a first approximation, since it would be true for velocities not too great, so that the old dynamics would still be found under the new.[40]

But how has the mystery been resolved? For this we must go back to an 1898 work of Poincaré, on 'The Measure of Time'.[41] What do we mean by equal intervals of time? To compare the heights of Deepa and Nanda we can put them side by side and compare them. But how do we put two time intervals side by side? and if we can't put them side by side, how do we compare them? This can only be done by convention. Hence Poincaré's question and reply,

> When I say, from noon to one the same time passes as from two to three, what meaning has this affirmation? The least reflection shows that by itself it has none at all. It will only have that which I choose to give it, by a definition which will certainly possess a certain degree of arbitrariness.[42]

Poincaré objects to Barrow's idea (p. 136)

> Instead of saying: 'The same causes take the same time to produce the same effects', we should say: 'Causes almost identical take almost the same time to produce almost the same effects.'

We must recall in this context that the relativistic time dilation effect, or the use of Lorentz's 'local time', may lead to a difference so small, under everyday circumstances, that we have here exactly the situation where time intervals declared very slightly unequal by relativity theory are called exactly equal according to Newtonian mechanics.

Poincaré's conclusion is that

> Time should be so defined that the equations of mechanics may be as simple as possible.[43]

In other words, it does not intrinsically matter whether one uses a pendulum clock or Lorentz's 'local time'. The choice is decided by the form of the equations that result. Lorentz's 'local time' leads to a simpler form for the equations of physics, hence that is the time that must be used.

The next step is crucial. Poincaré points out that while the notion of equal intervals of time had attracted much attention earlier, the related notion of *simultaneity* had not. What is meant by the simultaneity of events that are spatially separated? There is the famous problem of determining longitude at sea (Chapter 10). The practical way to tell Paris time at sea is to carry a chronometer set for Paris. This is also the theoretical way. The notion of simultaneity depends upon the measurement of time. Which notion of simultaneity should one use? Poincaré illustrates with an example concerning the velocity of light.

> Could not the observed facts be just as well explained if we attributed to the velocity of light a little different value from that adopted, and supposed Newton's law only approximate? Only this would lead to replacing Newton's law by another more complicated. So for the velocity of light a value is adopted, such that the astronomic laws compatible with this value may be as simple as possible.[44]

Whether it is the velocity of light, or the notion of equal intervals of time, or the notion of simultaneity, the guiding rule is simplicity:

simplicity of the equations of physics. We note here, for reference elsewhere, that this aesthetic guiding principle is *explicit* in Poincaré.

The simplest set of equations is obtained by supposing that the speed of light is a constant independent of the source. This is so by postulate, and not because of any experiment (see, e.g., the quote on p. 154, about Michelson's experiment). This postulate gives a definition of equal intervals of time as follows. Set up a pair of parallel mirrors, and bounce a photon (or a light pulse) between them. The time intervals between the bounces are equal (by definition). *The speed of light cannot be experimentally measured independently of a defined measure of equal intervals of time.* (This is why Poincaré is 'persuaded' that experiments will always show a null result, however far precision be carried.) This definition of the measure of equal intervals of time ensures that the speed of light will turn out a constant, whether the observer is at rest or in uniform motion. (No observer can distinguish between these two states.) These equal intervals of time correspond to a clock which, Poincaré pointed out, marks Lorentz's local time. The increase of mass with velocity follows mathematically, *without the need for any further assumption*, so that the speed of light becomes an impassable limit.

What about the contraction of length? The key step is to understand the need of a clock for measuring length; this step shows that space and time are not separate. Suppose the length is represented by a rod AB. We observe the position of the ends A and B, and calculate (or read on a ruler) the distance between these points. But suppose the rod is moving. We observe that point A is at the origin O, and that point B is also at the origin O a little while later. Should we conclude that AB has zero length? No; because we did not observe the positions of A and B *at the same time*. To get the length of rod, we must observe the positions of A and B *simultaneously*. But deciding simultaneity needs a clock. The clock we use is decided by simplicity, i.e., it is Lorentz's 'local time' obtained by supposing that the velocity of light is constant. Thus, there is no longer any need to accumulate hypotheses, and everything follows from a simple and more natural hypothesis about how to go about measuring equal intervals of time.

Recall Poincaré's closing remarks (p. 157) about the new mechanics in his St. Louis lecture. For those accustomed to the current-day techniques of hard-sell it may still be necessary to point out that for a cultured Frenchman in those days this claim about the new mechanics, repeated twice in such a historical context, was direct to the point of nakedness. For a mathematician to state anything more, without at the same time offering a proof, would have amounted to undignified chest thumping.

## Summary of Arguments so Far

Whittaker's case against Einstein looks pretty bad. The *entire* philosophy of the theory of relativity, including the crucial insight about time, had been *published* by Poincaré prior to Einstein, between 1898 and 1904. Most of the mathematical formulae *and terminology* of Einstein's September 1905 paper can be found in these papers, and in Lorentz's 1904 paper. The remaining can be found in Poincaré's paper which *appeared* in print on 5 June 1905. (Einstein's paper was submitted on 30 June 1905.) Einstein appears almost as an expositor of Poincaré's view; and it seems as if scientists at large have mistaken the expositor for the originator, because of an initial mistake made by W. Kaufmann[45] and then Max Planck, who declared Einstein as the originator of relativity.

## Dukas' Defence

The priority of Poincaré's claim to relativity was debated in a desultory fashion in the subsequent years. Holton[46] sought to refute Whittaker, while Scribner,[47] in 1964, tangentially supported Whittaker, inviting a refutation from Goldberg in 1967.[48] All these articles miss out essential points in Poincaré. For example, Scribner incorrectly maintains that Poincaré believed in the aether. But, compared to the standard biographies published before[49] Whittaker, the biographies published later[50] show an awareness of Poincaré's existence.

Here is how Banesh Hoffmann and Helen Dukas (Einstein's secretary and companion) defend Einstein.

> In June 1905, almost simultaneously with Einstein, Poincaré sent two papers…They leaned heavily on Lorentz's 1904 paper…Einstein, of course, did not know of Poincaré's not-yet published papers when he wrote his own. Nor did he know of the paper of Lorentz…Practically all of the basic mathematical formulas of Einstein's 1905 paper on relativity are to be found in the 1904 paper of Lorentz and the two papers of Poincaré…The presence of often-identical formulas was almost inevitable…Indeed, the mathematical transformation that is fundamental to relativity—…to which Poincaré gave the name Lorentz transformation—had already been found by the Irish physicist Joseph Larmor.[51]

The logic of this argument seems to be the following. Why bother to mention Poincaré's St. Louis talk?—that was only a matter of philosophy. The real stuff, the mathematical formulae, were in the scientific papers. Mathematical formulae cannot but be the same; one can't possibly write 2 + 2 = 5 for the sake of variety; hence the mathematical formulae in Einstein's papers coincide with those in the papers of Poincaré and Lorentz. But the mathematical formulae do not constitute relativity; after all these formulae were known earlier; the new thing was the derivation of these formulae from new philosophical principles. (And why bother to mention that Poincaré's paper was published in June, while that of Einstein was sent at the end of June, and published in September? Publication dates are merely a matter of luck.) Q.E.D.! (Larmor is just a red herring.) We will return to the real motivation for this unsustainable argument later.

## Pais' Hypothesis

Abraham Pais brought out a biography of Einstein roughly coinciding with the Einstein centenary. In the first place Pais confronts Whittaker's objection about the name, 'Principle of Relativity' by abusing Whittaker, and pointing out that Einstein was aware of Poincaré's *Science and Hypothesis*. Einstein had a study group along with a couple of friends in Berne. One of them, Solovine, maintained a list of the books they read. Against Poincaré's *Science and Hypothesis* he noted that this book 'profoundly impressed us and kept us breathless for weeks on end'.[52] Pais states that Einstein was also aware of Poincaré's 1898 essay on the measure of time. (None of this answers Whittaker's naming objection.) Specifically, Pais remains silent on the key question of Einstein's knowledge of Poincaré's 1904 St. Louis lecture and paper, or his *The Value of Science*, which first appeared in 1905. (Einstein knew French.)

As for Poincaré's claim as the originator of relativity, Pais puts forward the hypothesis that Poincaré needed a third hypothesis, about the aether. Pais' hypothesis is possibly the basis of Kip Thorne's statement that 'Poincaré…waffled': the only hope for Pais' hypothesis is that people, after reading Pais, will not read Poincaré. (This is a good hope.) What did Poincaré actually say about the aether in his 1904 St. Louis lecture and paper?

He starts with his pet example. Take two static electrical charges. Though they seem to us to be static, they are carried along in the motion of the earth. A moving electric charge corresponds to an electric current, so the two charges correspond to parallel currents. Parallel currents attract each other.

> In measuring this attraction, we shall measure the velocity of the earth; not its velocity in relation to the sun or the fixed stars, but its absolute velocity.
>
> I well know what will be said: It is not its absolute velocity that is measured, it is its velocity in relation to the ether. How unsatisfactory that is! Is it not evident that from the principle [of relativity] so understood we could no longer infer anything? It could no longer tell us anything just because it would no longer fear any contradiction. If we succeed in measuring anything, we shall always be free to say that this is not the absolute velocity, and if it is not the velocity in relation to the ether, it might always be the velocity in relation to some new unknown fluid with which we might fill space.
>
> Indeed, experiment has taken upon itself to ruin this interpretation of the principle of relativity; all attempts to measure the velocity of the earth in relation to the ether have led to negative results…[53]

Poincaré clearly used the principle of refutability (championed by Popper later on) to reject the aether. The appeal to experiment is only meant to persuade others. Is there any ambiguity here? Is this waffling? This is exactly the decisive argument with which Einstein's 1905 paper begins, though the example is different, and the argument is simplified, omitting the middle paragraph on refutability.

Pais repeatedly quotes Poincaré out of context, as I have shown elsewhere.[54] For instance, Pais quotes Poincaré,

> 'Clocks regulated in this way will not mark the true time, rather they mark what one may call the local time',

omitting the next sentence,

> It matters little, since we have no means of perceiving it,

and pretending as if Poincaré was unaware of the principles of refutability and simplicity.

While most such quotes obviously misrepresent Poincaré, there is one small point on which there could be a genuine misunderstanding. In his St. Louis lecture, which concludes by saying 'we are not yet there', Poincaré talked of *two* new things: 'the new mechanics' and a new order in (mathematical) physics. The new mechanics was a part of the expected new order; the new mechanics was there, the new order was not. Someone who looks for only *one* revolution (or none) in Poincaré's paper, may easily confuse one with the other.

Looking back, Poincaré's remarks seem prophetic:

> the savants of a hundred years ago…if someone had asked them what the science of the nineteenth century would be… would have thought themselves bold in their predictions, and after the event, how very timid we should have found them. Do not, therefore, expect of me any prophecy.[55]

The two key features of the new physics are relativity and quantum mechanics: relativity was there, quantum mechanics was not. Indeed, Poincaré's vision goes far beyond special relativity; his talk is far bolder, and he talks of electrons and spectra, and the possible statistical character of future physical law as part of his broader canvas. (Are we there yet?) In his concluding paragraph, Poincaré argues that there should be a place for the physics of principles in the new order, just as there is a place for the old mechanics within the new (see quote on p. 157). Clearly, Poincaré is definite about the new mechanics; he is uncertain only about the new order. If this is waffling, so be it.

We will see later on (Chapter 9) that the exact opposite of Pais' hypothesis is true. The term aether has two meanings. Poincaré rejected the aether in both senses, and it was Einstein who did not reject aether in the Cartesian sense of action by contact. Till the end of his life, Einstein regarded action at a distance as 'spooky', and remained happily unaware of the mathematical complications introduced into relativity by rejecting the aether.

## *The Origin of the General Theory*

> I was under the impression that, simultaneously with Einstein, Hilbert also found the now accepted equations of general relativity. Is this correct? If so, is there a reason no one seems to mention this now? I realize that the basic idea was due to Einstein but it is interesting that, even after the promulgation of the basic idea, it took a rather long time to find the correct equations incorporating that idea—even though both Einstein and Hilbert seemed to have worked on it.
>
> **Eugene Wigner**[56]

But isn't all this a bit unfair to Einstein's capabilities? Isn't it true, as Stephen Hawking says,[57] that 'Einstein was almost single-handedly responsible for general relativity…'? Couldn't the originator of the general theory of relativity have worked out the special theory of relativity on his own? Alas, the situation with regard to the general theory is no different! I will only summarise below the key points, since this has been the subject of several researches, and there already exists a book length study of this question.[58]

Ironically, it was only for the general theory of relativity that Einstein acknowledged Poincaré's inspiration. Poincaré's idea, expressed in his *Science and Hypothesis*, was to try and view physics as geometry. From a mathematician's point of view there is nothing terribly novel about this idea; it flows naturally from the principle of least action. The real novelty arises from the mixing of space and time in relativity. Could the earlier approach to physics as geometry be adapted to the new theory?

But Einstein, unlike Poincaré, and contrary to popular belief, was no mathematician. As David Hilbert once remarked, 'Every boy in the streets of Göttingen knows more about four-dimensional geometry than Einstein.'[59] Einstein sought the help of his friend Marcel Grossman, who was a mathematician. (This was the same Grossman who helped him to get a job in the Swiss Patent Office.) He learnt differential geometry from Grossman, and in 1913 the two came up with a system of equations for the general theory, which proved to be faulty. Einstein presumably realised that he needed higher-order help with mathematics.

After Poincaré's death, the star mathematician of the time was David Hilbert at Göttingen. When Hilbert invited Einstein to present his ideas at Göttingen, Einstein was overjoyed. He travelled to Göttingen, and wrote in July 1915 that 'I had the great joy of seeing in Göttingen that everything [about relativity] is understood to the last detail. With Hilbert I am just enraptured. An important man!'[60] Hilbert was equally keen to learn about the new theory of relativity which had become very famous by that time.

At Göttingen, Einstein's ignorance of mathematics soon became painfully obvious, and gave rise to various remarks of the kind cited earlier.[61] Hilbert even concluded that Einstein discovered the special theory of relativity just *because* of his ignorance—not only of mathematics but also of philosophy!

> Do you know why Einstein said the most original and profound things about space and time in our generation? Because he learned nothing at all about the philosophy and mathematics of time and space.[62]

On his part, Einstein remarked in exasperation with mathematicians, 'The people at Göttingen sometimes strike me, not as if they want to help one formulate something clearly, but as if they only want to show us physicists how much brighter they are than we.' The two parted in mutual respect, and continued to correspond with each other. Hilbert later nominated Einstein for the Bolyai prize.

A few months later, on 14 November 1915, Hilbert wrote to Einstein that he had found a solution of 'your grand problem'. Hilbert had derived the equations of general relativity from an action principle, as was to be expected in any view of physics as geometry. He enclosed a draft of his paper, and invited Einstein to attend a lecture on the subject which he planned to give on 16 November. On 20 November 1915, Hilbert submitted the paper to the Göttingen Academy, publicly stating, for the first time, the correct form of the equations of gravitation. Einstein was, then, at the Prussian Academy, giving lectures on the theory of relativity. In the first three lectures of 4, 11, and 18 November 1915, he continued to use his older (wrong) version of the equations. In his talk of 25

November 1915, he had changed over to the new (and correct) form of the equations, though he disagreed with Hilbert on the representation of matter in the new theory. We have once again a disagreeable coincidence.

There was a slight tiff between the two. Einstein wrote to Hilbert on 20 December 1915, 'There has been a certain pique between us…It is really a shame if two real fellows who have freed themselves to some extent from this shabby world should not enjoy each other.'[63] Till today, the general theory of relativity remains a mathematical theory. The representation of matter in it is the one forced by geometric considerations, and no one has as yet found a way to connect it to, say, the atomic theory of matter. Unlike Hilbert, Einstein was not fully convinced, and continued to experiment with the equations, adding a cosmological term as a matter of physical expediency, and later dropping it, calling it his 'greatest blunder'.

Einstein, of course, did not solve the resulting system of equations. The first solution, and one of the most important, was found by Karl Schwarzschild. The three crucial tests of the general theory all lean heavily on the Schwarzschild solution, though Einstein had tried to carry out the calculations differently earlier. Nevertheless, when various newspapers flashed headlines about the general theory having passed the experimental tests, it was only Einstein's name they carried. As the originator of the special theory of relativity, hadn't he earned the right to full credit for the general theory?

## *Einstein's Formula for Success*

Examining the origin of the general theory only seems to make the case against Einstein worse. From an expositor, he seems to have turned into an appraiser: someone who quickly understood the worth of a new idea and claimed it as his own to the extent possible. The special and the general theory of relativity are by no means the only two cases. It is little known that during the period 1902–1905 the to-be discoverer of relativity, passing through a difficult phase in his life, had started auspiciously by independently rediscovering statistical mechanics, and also the kinetic theory of gases.

> Not acquainted with the earlier investigations of Boltzmann and Gibbs, which had appeared earlier and actually exhausted the subject, I developed the statistical mechanics and the molecular-kinetic theory of thermodynamics which was based on the former.[64]

These examples are not exhaustive. Einstein predicted the existence of Brownian motion 'without knowing that observations concerning Brownian motion were already long familiar'.[65] Whittaker was presumably aware of these additional examples when he wrote his biography of Einstein in 1955. The point is now to decide whether Einstein read little and thought much, or did little and claimed much.

What is the worst that can be said? That he learnt the art of appraising at the Swiss Patent Office. That living on a meagre salary in an expensive city, and finding it difficult to bring up a family on seemingly shattered dreams of fame and fortune, he could not resist the thought of claiming as his own some already worked-out idea from among the many that constantly came to his notice. That working in the Patent Office, he knew that this could be done legally—for he was surely aware of the legal aspects of priority and patenting. For example, here is the certificate that he gave to Besso, to prevent Besso's dismissal in 1926.[66]

> Everyone at the Patent Office knows that one can get advice from Besso on the difficult cases; he understands with extreme rapidity both the technical and the *legal aspects* of each patent application… [Emphasis mine.]

(Besso's weakness, according to Einstein, was his inability to reach a quick decision.)

Granting that Einstein was aware of the contents of Poincaré's 1904 lecture (and paper[67]), and also of Lorentz's 1904 paper,[68] would Einstein's 1905 paper have legally amounted to plagiarism? Would it have legally amounted to plagiarism if he had read even Poincaré's June 1905 paper? I don't think so. Ideas cannot be patented. As a clerk in the patent office, Einstein certainly knew that. Copying ideas is not plagiarism, so long as one expresses these ideas in one's own language. Scientists make use of each other's ideas all the time; the *customary* thing to do is to acknowledge the source. But, while writing a scientific paper, there is no *legal* compulsion to acknowledge one's predecessor's. There cannot be; one may have arrived independently at the same conclusions as another scientist. Usually, it is the established scientist who unethically neglects to acknowledge another scientist, more obscure. In Einstein's case things were unexpectedly the other way around; Einstein was obscure, Poincaré was not. If Einstein read Poincaré and did not acknowledge him that would have been decidedly impudent; it would have implied a disrespect for authority, but it would still not have been illegal. Reproducing, and claiming as one's own, a series of ideas from the foremost intellects of the time—Boltzmann, Gibbs, Poincaré, Hilbert—would have been a novel *modus operandi*, a desperate short-cut to fame, but it would not have been illegal. Patent laws do not protect ideas—Einstein surely knew this. Given the law of evidence, there is no way to conclude that one has read this or that article. One must be given the benefit of doubt.

An uncomfortable string of such 'didn't read' cases no doubt increases the doubt, and tilts the balance of probabilities. The correlation of such a string with a career crisis, and an economically and emotionally trying time, is there. But couldn't one claim to be a super-genius? And wasn't Einstein one? (And so what if his genius and creativity were not manifest in his youth, and suddenly dried up later in life?) Whittaker understood that credits accumulate around fame: he consistently disregarded the present accumulation of credits in his attempt to arrive at the truth. He thought this truth was important; that science being a search for truth, one could not refuse to articulate such deep suspicion surrounding the allegedly greatest scientist of the century. To understand Whittaker, one must ask counterfactually: would Einstein be regarded today as a super-genius if he hadn't, in the first place, got the credit for the special theory of relativity? And without credit for the special theory, would Einstein's career have progressed at all? Would Hilbert or any of Einstein's later collaborators have collaborated with him?

Would Einstein's quiet acceptance of the credit that others conferred on him have legally amounted to fraud? I don't think so, though it could be pointed out that Einstein (humorously) gave the following formula for success: 'If $A$ is the success in life, then $A$ is the sum of $x$, $y$, and $z$; $x$ being work, $y$ play, and $z$ is keeping your mouth shut!'[69]

Nevertheless, no one has denied him credit for his work on the photoelectric effect, for which he got the Nobel prize. Or for his lifelong pursuit of the general theory of relativity. Only this would result in a figure much more human, and much less titanic than the headlines of the London *Times* and *New York Times* led us to believe. Would such an assessment of Einstein today be accepted? I don't think so, and I will elaborate on the reasons later on.

Naively, everything seems to depend upon whether Einstein was more truthful or acquisitive: it seems as if the truth of E=MC decides the truth about $E = mc^2$! But it is not of interest here to assess the personality of Einstein.[70] Whether or not Einstein should get some credit for relativity, it is unfair that Poincaré has been completely eclipsed.[71]

Why should one bother about this? One reason, explored further in Chapter 9, is that, in his haste to publish, Einstein made a mistake in understanding the new theory of relativity. That is, a wrong allocation of credits may lead also to a wrong physical theory.[72] The other reason is the following.

The point of bringing up the unfairness in the distribution of credits in relativity is to understand the dynamics of unfairness. The real questions are these. How are credits distributed? How ought credits to be distributed? These are not questions about how one ought to do the history of science in the heroic mode. Neither are they questions about what name we should give to this or that equation or theorem or theory. So far as distribution of credits is concerned, the scientific community follows society. Unfairness in the distribution of credits among scientists is merely a reflection of the unfairness in the distribution of credits in the society at large. That is undeniably a very serious problem.

It is, moreover, a problem that should concern relativists; for time is the key to the theory of relativity, but the notion of time in the theory of relativity is *not* the one used by scientists when it comes to the distribution of credits. Social and cultural beliefs about time are used instead.

What have beliefs about time got to do with the distribution of credits?

## *Summary*

- Newton's physics failed exactly because of confusion about time.
- Poincaré rejected Newton's (and Barrow's) ideas of time in 1898. He later defined equal intervals of time in such a way that the speed of light is constant by definition. (By this definition, a photon bouncing between parallel mirrors takes equal intervals of time between the bounces.)
- Poincaré announced the key ideas of the theory of relativity, *and so named it*, in a 1904 lecture *and publication*, encapsulating the results of a five-year effort. The mathematics of the theory appeared in print in 1905, three weeks ahead of Einstein's submission.
- Einstein stated that he needed only five weeks to work out the theory. He used the same formulae as in Poincaré's 1905 paper, *and* the same name for the identical 'principle of relativity'; but he claimed he had not seen either of the 1904 or 1905 papers, though he had closely read Poincaré's 1902 book and his 1898 paper.
- A similar 'coincidence' exists about the equations of general relativity, communicated to Einstein, and publicly reported by David Hilbert five days ahead of Einstein's claim to have independently discovered them.
- Unlike Poincaré and Hilbert, and contrary to the popular image, Einstein was no mathematician. Hilbert ascribed Einstein's originality [in discovering special relativity] to Einstein's ignorance of mathematics and the philosophy of time. Till the end of his life, Einstein missed a key mathematical difficulty with relativity, anticipated by Poincaré.

- Einstein also claimed to have independently reinvented the statistical mechanics of Boltzmann and Gibbs, published earlier.
- As a clerk in the patent office, Einstein was thorough with patent laws, hence knew that restatement of an idea did *not* constitute plagiarism.
- *Q. With the relativistic notion of time, can causes, hence credits, be located in individuals, as required by patent laws and Augustine?*

∞

# 6

# Broken Time: Chance, Chaos, Complexity

> Einstein was almost single-handedly responsible for general relativity…
>
> **Stephen Hawking**[1]

What have beliefs about time got to do with the distribution of credits? We saw one example in Chapter 2. Augustine changed beliefs about 'cyclic' time, in order to ensure that God would be able to distribute credits and blame on the Day of Judgement. Augustine needed two things.

First, Augustine required the world to be such that individual humans were clearly identifiable, despite any changes over time. The idea of the unchanging core of a human being as a perfect soul, reborn each time in a new body, made things very confusing for Augustine's God who wanted to distribute eternal credits and blame; so Augustine required that, even in resurrection, individuality would be preserved in the present bodily form, in the flesh as he put it. (Augustine didn't say anything about the exact age of that flesh, nor of the bundle of memories that went with it.) God should be able to recognize the person without any pagan ambiguity about all souls being like perfect spheres.

Second, Augustine required the world to be such that individual humans were clearly identifiable as *causes* of events. If this were not the case, God would be unable to judge; he would be unable to apportion credit and blame. Accordingly, Augustine adapted the physical world to suit his moral prejudices. (Why God, or society, should want to pass judgment and distribute credits and blame is altogether another question.)

## Credits, Cause, and Becoming

Unequal distribution of credits requires the notion of cause, a notion which relates naturally to the notion of time. What was Augustine's notion of time?

Subjectivity of equal intervals of time according to Augustine.

For Augustine, past and future did not quite exist; only the now existed. Past and future existed in the now as memory and expectation. Augustine raised the same question about equal intervals of time: 'for the time past that was long, is it long when it is now past, or was it long when it was yet present?' But Augustine's answer to this question differs from the one given by either Isaac Barrow or Poincaré. Measurement of different intervals of time was only measurement of different expanses of memory, for the past had ceased to exist, and only a memory of the past now existed.

The relation of cause to mundane creation of the future, and how Augustine modified it.

With the everyday idea of time, the idea of individual humans as the cause of events is the following. The future comes into existence, and the choice that one makes now decides *which* future comes into existence. This coming into existence, and passing out of existence is fundamental to the mundane notion of cause; this belief is the basis of action in everyday life. Augustine modified it so that theological considerations carried greater weight than everyday experience. The mundane notion strongly suggests that humans *create* the future, and Augustine would not allow this, for he thought that God alone had created the world—past, present and future—down to the last detail.

## God's Prescience and Human Culpability

Thus, Augustine had a little problem with God's omniscience; as creator, God already knew what was coming. He knew, when he made the world, what choices we were going to make.

But Augustine had to argue that these choices themselves were free, not decided by God. God knew about these choices when he made the world, but he did not make these choices for us. We made these choices ourselves, else there would be little point in Augustine's elaborately constructed heaven and hell. Why should anyone be punished for choices that God made on his behalf? A God who punished people for choices he had made on their behalf would become a laughing stock among the pagans. To avoid this difficulty, Augustine invented a quibble about fatalism being different from God's foreknowledge (Chapter 2). God had authored the book of the universe, but the characters in this little drama were, in some strange way, not compelled to choose as they did because this was what the author decided.

## *The Block Universe of Relativity*

Relativity reproduces this problem for the mundane notion of cause. Newtonian physics still had a place for God (in the form of providential intervention). At least this was true until Laplace reduced the world to all clockwork and no clockmaker. But that was something that one could avoid taking seriously, in the hope that Laplace's demon would be exorcised (see Box 4). Within Newtonian mechanics, one could at least continue with the belief that the future came into existence and passed out of existence every instant.

**Box 4: Newton, providence, and Laplace's demon**

Newton thought that he had found the laws of God, but he was unable to prove the stability of planetary motion. So he thought that God also made direct providential interventions in the world from time to time, as necessary. The analogy was to a mechanical clock, which periodically needs to be wound up. Presumably, he thought that human beings, too, could make interventions from time to time.

Laplace, was able to prove the stability of planetary motions. He did not need providential interventions. But when writing

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a voluminous tome on mechanics, he did not acknowledge many persons whose work the book used. Napoleon, who once was Laplace's pupil, twitted his former teacher, by telling him that he had written a book without once acknowledging God as the author of the universe. Laplace retorted that he had no need of God in his system.

In the preface to his book on probability theory, Laplace tried to explain that chance was due to ignorance. He explained this by imagining a superior being who could overcome the limitations which the ordinary scientist faced, and would have no need of the theory of probability. This being, being a super-scientist, knew all the laws of physics; being a super-observer, it knew the exact state of all the molecules in the world and all the forces which acted between them; being a supercomputer, it could use this knowledge to calculate the state of all the molecules at any other time: 'past and future alike would be before its eyes'. Since Laplace did not need God, and since this being eliminated the need for providential intervention, it has since come to be known as Laplace's demon.

My 'now' may be your past, and someone else's future. Hence if 'now' exists, so do the past and future.

After relativity, it is difficult to hold on to this belief. Relativity, we recall, changed the notion of simultaneity. The key point of relativity was that simultaneity is relative: different observers could disagree about the simultaneity of two events. The 'now' consists of all events that are simultaneous with this one. So different observers could have different notions of 'now' (see Fig. 1). What is 'now' for one could be future for another, and past for a third. Many people would grant that the 'now' exists. But then so must the future and past, for it may be 'now' for someone else.

No doubt there is something (see Fig. 1) that could be called the absolute past and absolute future. But it would be exceedingly odd to suppose that the absolute past has ceased to exist,

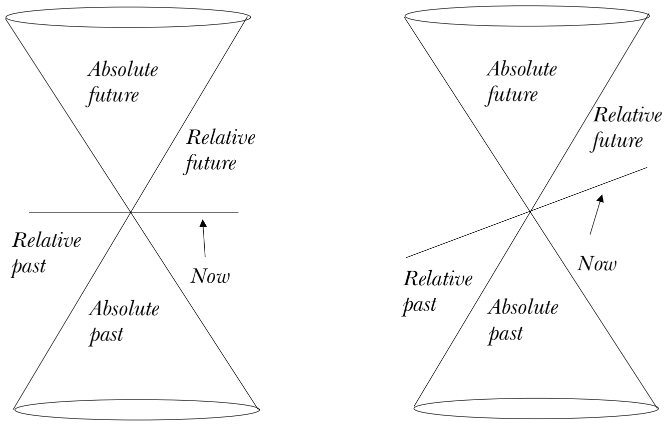


**Fig. 1: The Relativity of Simultaneity**

for what is 'now' for me may involve events that are 'absolute past' for someone else who is 'now' located at a different place. Why should existence be tied to spatial location?

The block universe of relativity.

All this is very confusing, and the simplest solution is to suppose that the entire world, past, present, and future, exists; the world 'simply *is*, it does not happen', in the much-quoted words of Hermann Weyl. In short, after relativity, one may not use the everyday idea of future coming into existence at the present, and passing out of existence into the past. So, on the face of it, after relativity, we should also abandon the mundane idea that our actions somehow create the kind of future world that will come into existence. But in the absence of creativity, what happens to the notion of 'cause'? And in the absence of cause, what happens to the distribution of credits in society?

## *Contact, Instantaneity, and Time-Symmetry*

Time symmetry of relativity.

In fact, there are two further difficulties. The first is this. The notion of 'cause' presupposes *some* notion of past and future. But, there isn't even a clear distinction between past and future in relativity. (The absolute past and future mentioned above presupposed this distinction.)

Aether in the original sense of action by contact is retained in relativity.

The reason for the absence of a distinction is this. Relativity gave up the term aether and the associated notion of absolute motion. But *relativity did not give up the Cartesian aether in the sense of action by contact*.[2] The essence of the idea of action by contact has been that causes have always been sought here and now. It is common enough to explain the motion of the arrow by appealing to the action of the archer. The objection to this was that the action of the archer was in the past which had ceased to exist, and how could something that had ceased to exist affect something now? With action by contact, the motion of the arrow must be explained by the motion of the arrow at the infinitesimally preceding instant. This means that the future state of the universe, at a moment infinitesimally later, must be uniquely decided by its state now, and physical law expresses this unique relationship. In a word, physical law is a differential equation.

Chain of causes.

In the frame of action by contact, the full explanation of the motion of the arrow is given by appealing to a *chain of causes*. The state of the arrow now is decided by its state at the preceding instant, and its state at the preceding instant by its state at the instant preceding that. Ultimately, we arrive at the initial instant when the archer pulled the bowstring and released the arrow. This initial condition becomes like the first cause of the entire chain.

Hume thought that the same kind of relation through an intermediate chain of causes must be sought whenever a causal relationship between distant objects, such as the moon and the tides, presents itself to observation.

Instantaneity, hence, time symmetry of physics.

The difficulty is this. The idea of physical law as an asymmetric relation between moments that are infinitesimally earlier and later is illusory; what the differential equation does is to relate two entities *now*, where this now extends infinitesimally and symmetrically into *both* future and past. In Newton's law, for example, acceleration at an infinitesimally later moment is not caused by force applied infinitesimally earlier; this is merely a mental image, a fiction; the law actually relates force now to acceleration now; we have mentally decomposed the infinitesimally extended now into one infinitesimally earlier, and one infinitesimally later. By a mere reversal of perspective, one can see this as a relation between force applied infinitesimally later and acceleration which occurs infinitesimally earlier. If the future state of the universe at a moment infinitesimally later is decided by its state now, then the past state of the universe at a moment infinitesimally *earlier* is also decided by its state now. One can now extend the 'chain of causes' backward in time, instead of forward. The chain may terminate on a final condition instead of an initial condition.

In current physics, this instant decides all past and future history.

The differential equation may be solved forward in time; with equal facility it may be solved backward in time. There is a certain illusoriness in this talk of initial and final conditions. Actually, the present condition can be treated as both the initial and the final condition. One can extend the chain of causes towards both past and future. The present condition is the initial condition for chains of causes extending towards the future, and the final condition for chains of causes extending towards the past. *The present decides both past and future*.

The relativistic notion of instant.

Though relativity changed the notion of the present, and made it relative, it did not change this belief that past and future are decided by the present. This is true of both the special and the general theories of relativity. The difference between the Newtonian 'now' and the 'now' of special relativity is shown in Fig. 1. (The 'now' of general relativity, if it exists, goes under the more imposing name of a 'Cauchy hypersurface in spacetime'; though technically more complicated, the solution process by extending chains of causes into future or past is not fundamentally different here.)

Relativistically, the entire past and future exists and is already decided.

Something seems a little peculiar here, and the least peculiarity is that the thought can only be expressed ungrammatically. So many different 'present-s' or 'now-s' can be used to calculate past and future; what ensures that all these possibly different pasts and futures can be reconciled? What if A chooses to bring about a different future from one that B intends to bring about? The answer is very simple: neither has any choice. The whole theory is based on the idea that it should be possible to reconcile the observations made by different observers. The reconciliation is achieved by having, so to say, exactly one past and future, which only *seems* different to different observers. This 'real' past + future not only exists like the present, it is completely decided by the present, whether the present is that of A or of B. Hence, also, the past of A decides the present of B and vice versa. For both A and B, time is superlinear (Fig. 2).

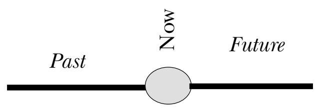


**Fig. 2: Superlinear Time**

## *Reconciling Mundane Time with Superlinear Time*

While there is no mathematical difficulty, there is another sort of difficulty here. The variety of possibly different pasts and futures are reconciled by excluding the possibility of choice. Neither A nor B can do anything novel at the present moment because each of their present-s is decided by their respective pasts. One could think of these present-s as being past for someone else, so both A and B have already done what they would do!

Are we complex automatons?

There is a close parallel here to Augustine's theological difficulty of reconciling God's foreknowledge with human culpability. The theological difficulty may not in itself be interesting; but one cannot so easily dismiss the socially prevalent ideas about time we still use to plan our lives. One may discard theology, but can one neglect everyday experience?

Consider. I am seated in my room; an object is placed on my table; during a second I do not move. The door of my room is locked, and no one else is in the room to touch the object. (But you may watch from a little porthole on the door if you want.) At the end of one second, will the object continue to be in the same position relative to the table? No one else may be able to say. But I feel I can. Our everyday beliefs about mundane time are sketched in Fig. 3. Whether or not the object moves at the end of one second seems to depend on the decision I make, either now or earlier. This is a simple empirical observation which I can repeat as often as I like. (If an earthquake occurs on the thousand-and-first trial, this is not of any concern; we are concerned here theoretically with physical

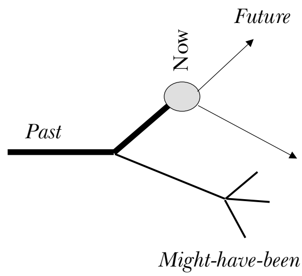


**Fig. 3: Mundane Time**

approximation, and empirically with things that happen *usually* or *often*, not with any deceptive notion of logical or absolute certainty.) What model does physics have to account for the possible motion of the object?

One possibility is to suppose that the belief that I make the decision is a hallucination. This is not a private hallucination; for I could compare notes with you, and you will (probably) agree that you feel the same. No doubt something goes 'click' in my mind, and the object moves; but the something that goes 'click' in my mind was itself decided by the past, in accordance with physical theory. The hallucination lies in our belief that we can control the things that go 'click' in our respective minds.

If we are complex automatons, then we are left with no reason to believe in the physical theory that tells us this.

Are we complex automatons, unaware of having been programmed? Suppose we admit this possibility. There is still a difficulty. This belief in complex automatons flows from the belief in the validity of relativity theory. But what does the belief in the validity of relativity theory flow from? It flows from belief in simplicity, refutability, and experiment; we have seen that. But, having accepted that we are programmed, we must make allowances for it. What if our programming does not permit us to conceive of some possibilities? What if it does not permit us ever to carry out some critical experiments? That is, the validity of physical theory, or any other theory conceivable by an automaton, is only an uncertain matter. But, if the validity of physical theory is an uncertain matter, why should we believe in the first place that we are complex automatons?

The alternative is to construct a physical theory better suited to living organisms.

The other option is to say that physical theory does not apply to human beings. This is not so simple either. As Ludwig Boltzmann once reportedly said, 'The most superficial observation shows that the laws of physics apply equally to animate matter.' Indeed, if a man jumps off a roof, the manner in which he falls to the ground is so slightly different from the manner in which a stone falls to the ground that we may neglect the difference to a first approximation. It is not as if divers defy physics—they use diverse physical principles like the conservation of angular momentum—a dive is just more complicated to describe.

So, if we want to hang on to this idea that physical theory does not apply to human beings, we must explain just *which* part of physics fails. It is not enough to say vaguely that physics might be wrong, because physics has produced many counter-intuitive results—like explaining lightning. Till now, it is always intuition that had to be updated. So we must pinpoint the alleged failure of physics. And it is not enough to say that something fails in some ultimate sense, for this is always true of physics. *The failure of a physical theory can be accepted only if one has a better physical theory, which corrects this failure.*

The main obstacle in the way of such a new physical theory is cultural. In the analogy to theology, abandoning the old 'laws' of physics to look for new physical models is like abandoning Augustine's idea of a transcendent Creator to search for a new vision of God—because the problem of determinism vs free will is otherwise insoluble. (We shall see later on that if living organisms are permitted to participate in creation, one may also need to abandon the related idea that causes can be located in individual humans, and along with it the theological justification for the unequal distribution of resources in society.)

Formerly alternatives could only be two; but a third alternative now presents itself: one can have one's cake and eat it too. To retain both determinism and free will, Augustine invented fatalism. Many attempts have been made, in exactly the spirit of Augustine's quibble about fatalism, to reconcile existing physics with everyday experience—to reconcile the superlinear time of physics with mundane time (Fig. 3). Are these attempts anything more than prolix apologias? Let us see.

## Chance

The first idea is this. Most natural processes, like aging, are irreversible; one can use this irreversibility to distinguish future from past. In physics this irreversibility is captured by the increase of entropy towards the future. It is believed that entropy increases because of chance. What is chance?

### *The Rolling Dice*

Take a pair of dice, shake them well and roll them on a table. There are two ways to describe what happens. One is to try to reason backward, using a chain of causes. The present state of the dice is caused by its previous state. The initial cause is the way the dice were thrown. (If instead of rolling dice, one were to spin a coin, the initial 'cause', related to the force with which the coin is flipped, could be controlled by training the appropriate muscles, as pointed out by Poincaré.[3]) But we do not *know* the initial state very well, because the dice were shaken well before the throw. We do not *know* the exact force with which the dice were thrown, nor the exact height from which they were released. (A slight variation in the way the dice are thrown could result in a different pair of numbers showing up.) Moreover, the motion of the dice is complex; it would take a long time to calculate which number would show on the face of the dice. That is, we believe that nothing miraculous is happening: the dice move in accordance with physics, and not because of our hopes and prayers. We could, if we really wanted it, carefully observe the dice as they are released, and calculate what numbers would show up; but this is a difficult task. In a normal game this difficult task would have to be repeatedly performed a large number of times. (Perhaps this task can be performed some day, but we could easily invent a more complex game.)

The other way to describe the dice is based on the following observation. Though a *single* throw of the dice is very hard to describe, it is easier to describe a *large number* of throws. In a large number of throws, we may suppose that all variations are equally likely to take place, so that all six possibilities of each die are equally likely. This allows us to describe, in a simple way, how *often* the numbers on the faces of the dice will total, say, 7. The larger the number of throws, the more accurate the estimate is. The laws of physics can be replaced by laws of large numbers.

A standard way of cheating is to have the dice loaded, so that the game *seems* fair, but is not. (A practical example of such a game is the market mechanism: it *seems* to provide equal opportunity to all but does not.) How will one make out whether or not the game is fair? There is no way to be certain, but one can make an informed judgment, one can draw inferences that may be almost certain. Instead of supposing all possibilities to be equally likely, one observes a large number of throws of the dice, and estimates which possibilities are more likely than others. (One such method of estimation, called the maximum likelihood estimate, is used in the Appendix.)

How large is large? In general, the answer depends upon how precise one wants to be. But there are some situations in physics where large numbers occur naturally. In a room full of air there are roughly an octillion (1E24) molecules, i.e., around 1,000,000,000,000,000,000,000,000 molecules. That seems large enough for any reasonable approximation that one might require. And, indeed, the theories of chance have been very successfully applied to the physics of heat and fluids, variously known as statistical[4] mechanics, thermodynamics.

There is little fear of the dice being loaded, because the molecules are constantly colliding with each other and moving about in a chaotic way called Brownian motion (see Fig. 4), after a botanist

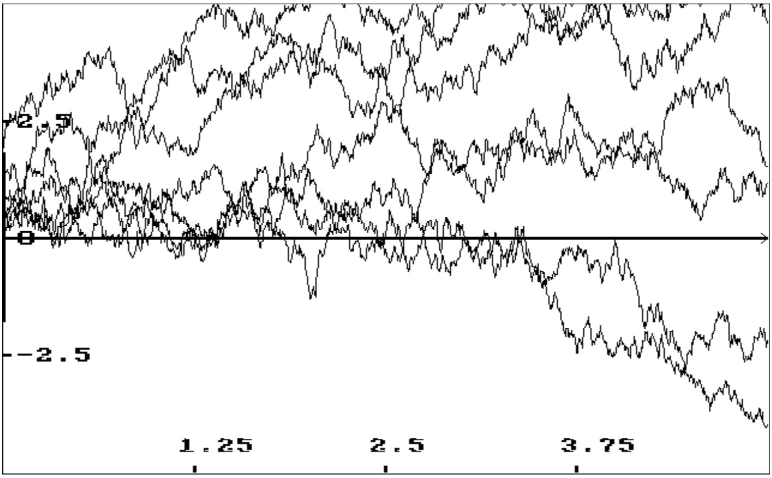


**Fig. 4: Brownian Sample Paths**

The figure plots possible paths of a Brownian particle as a function of time. (The *x*-axis is time, and the *y*-axis is the position.) The particle moves in an erratic way that is predictable only on an average.

called Brown who observed pollen particles randomly dancing about under a microscope. One of Einstein's early papers was on Brownian motion. The figure also gives one an idea of what Poincaré meant when he suggested that physical law might assume a statistical character, and relates to what Nietzsche meant when he talked of the eternal return.

## *Stochastic Evolution*

Statistical law of physical evolution.

In this model of physical evolution, of which Brownian motion is an example, we are concerned not with what happens *invariably*, but with what happens *usually*, or with what happens *often*. We are typically concerned not with individual cases or exceptions, but with typical cases. The theological significance of evolution by chance is this: moral law is not absolute for, even within a fair society, the better-off person is not necessarily or invariably more meritorious—someone may be accidentally better off; better off by chance. (To turn things around, the fairness of a society should be judged not by what is possible in it for exceptional persons, but what is possible in it for typical persons.)

The simplest form of a statistical law of evolution is provided by what is called a time series. To obtain an example of a time series, repeatedly throw a pair of dice, and record the numbers so obtained. A typical sequence is: 5, 8, 2, 11, .... The numbers from 2 to 12 constitute the 11 possibilities that can occur here; each of these possible outcomes can be called a *state*. Unlike a cause which is invariably or necessarily accompanied by the effect, each time the experiment of rolling dice is repeated, a different sequence is almost sure to result. We have here a chain, which is not a chain of causes: 8 does not invariably follow 5, any state can follow any preceding state. This chain is called a Markov chain, because (it is assumed that) the throw of the dice does not depend upon the past history of throws that materialised. It is called *ergodic* because any state is accessible from any other state, so every state is visited some time.

Though 8 does not invariably or necessarily follow 5, there is a certain regularity. We can ask: what is the *probability* that 8 follows 5? We can calculate the probability by assuming probabilities for each of the six faces of each die to come out on top, or by observing several sequences and estimating these probabilities. Probabilistic evolution differs from the usual physical law as follows. With probabilistic evolution one cannot be sure which state comes next; one is uncertain about the future.

No doubt one is also uncertain about the past. Given one term ('the present') of the above time series, one would be equally unable to calculate the preceding terms. But, one somehow believes that the future is *more* uncertain than the past. The entropy law expresses exactly this idea that the future is *more* uncertain than the past. What is entropy, and what is the entropy law?

## *The Entropy Law*

> The Entropy Law is something that needs to be felt as much as understood.[5]
>
> Economists have taken notice of the first law [of thermodynamics]...[and] explicitly recognized that we can produce neither matter nor energy; we can produce only 'utilities.'

> Modern economists, however, have failed to take notice of the Entropy Law; so none has come to ask how we can produce utilities.[6]

Entropy measures absence of information. Suppose one is doing a kind of crossword which looks like this. What is the letter in the

| | | |
|---|---|---|
| **p** | ? | **t** |

middle? Information about this letter is absent; though we know that it must be one of the vowels, *a*, *e*, *i*, *o*, *u*. Suppose that from the context we can exclude the vowel *u*; any of the remaining four vowels, hence any of *pat*, *pet*, *pit*, *pot*, might occur as a matter of chance. Which one could it be? Could it be *a*? Could it be *e*? The number of questions one needs to ask provides one rough way to judge the paucity of information. We can make this measure more precise by disallowing vague and repetitive questions, by eliminating bad questioning strategies, and allowing questions only of the yes–no type. The results of a possible attempt are shown in Fig. 5 below.

In the accompanying figure, one starts with the question 'Is the letter one of O or I?'. If the answer is yes, one asks, 'Is the letter O?'; if the answer is again yes, we know the letter to be O; if the second answer is no, we know that the letter is I. If the answer to the first question (OI?) is no, the letter must be one of A or E, and

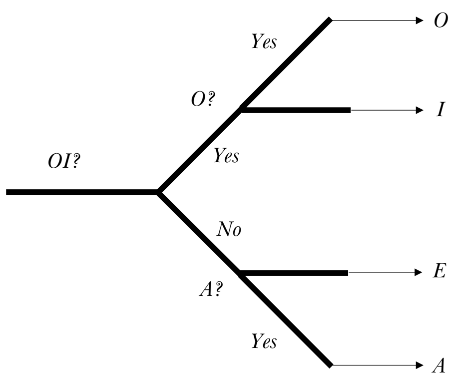


**Fig. 5: Entropy**

one more question decides. Thus, the number of questions one needs to ask is 2, which equals the entropy in this particular case.

In general, if the letters vary according to some rule of chance, or a given set of odds, the number of needed questions will also vary as a matter of chance. The minimum average number of such yes–no questions is the entropy. This average can be easily worked out using the usual mathematical formula for calculating averages. To summarise, entropy measures ambiguity, counted by the number of yes–no questions one must ask to remove all ambiguity.

**Box 5: Maxwell' s demon**

This demon was contributed by the physicist James Clerk Maxwell. A gas in a box is partitioned into two. The partition has a small aperture guarded by Maxwell's demon. The demon allows faster molecules to pass through the aperture, and stops the slower molecules. After some time, the faster molecules accumulate in one half of the box, raising its temperature. The two halves of the box are now connected from the outside, allowing heat to flow naturally from the hotter to the cooler half. The flow of heat drives an engine. This creates a perpetual motion machine, flouting the entropy law.

The demon was exorcised in this century by L. Szilard and L. Brillouin. The demon must know which molecules are fast and which are slow. It is this information that the demon uses to reduce the entropy of the gas. But how does the demon get this information? Suppose it gets this information by measuring the speed of the molecules. This process of gathering information will then generate more entropy than the demon reduces.

Let us now look at half a bucket of (cold) water. The water may seem crystal clear, but the physicist sees ambiguity there! For the physicist, the water consists of a large number (octillion or more) of water molecules, and the physicist lacks detailed information about the positions and velocities of these water molecules. If any two molecules were to be swapped, one could not tell the difference just by looking at the water; the water in the bucket would look just the same. The physicist would describe this by saying that a large number, say N, of microstates are consistent with the same macro-state (half a bucket of cold water). This large number N describes the ambiguity that the physicist 'sees'; the number of digits in the number N is the entropy of the water.[7]

Let us now gently add half a bucket of hot water to the bucket of cold water. I did this kind of thing in my childhood, only to discover half-way through my bath that the water at the bottom was cold. But if one churns the water so that the hot and cold layers of water get *mixed* (or if one adds cold water to hot), then the water soon has the same temperature throughout. This situation of uniform temperature throughout is clearly more ambiguous than if the water in the bucket is in two layers, one hot and one cold. Heat is due to molecular motion—the hotter the water, the faster on the average the molecules in it are moving—so in the case of two layers one at least knows that the faster molecules are more likely to be found in the hotter layer. The case of uniform temperature is the case where one has least information, and maximum ambiguity, hence maximum entropy. This state, also called the state of thermodynamic equilibrium, is naturally (i.e., in nature) the most preferred state. Heat flows from hotter to cooler bodies, until the two bodies are in equilibrium at the same temperature.

**Box 6: Entropy and economics**

Any economic article of any use-value involves creation of order. This process creates disorder elsewhere. One's attention tends to be focused on the product, and not on the waste; but the entropy law assures us that the amount of waste must exceed the amount of order so created: machines make waste, the article is a byproduct. The greater the production, the greater the waste; the greater the energy throughput, the greater the waste. Mining coal is more difficult than cutting trees; drilling oil is harder, and splitting atoms is harder still. Waste has increased with progress. When wood was used as fuel, it was only in a small country like England that forests started disappearing. Coal dirtied rooms, hands and faces, so that wood was reserved for the aristocracy. When oil came into use the

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pollutants lodged inside the lungs, making it difficult to breathe; radioactivity from nuclear fuel causes irreparable genetic damage and may change us inside out. Even the aristocracy would be unable to escape, unless they escape into space.

According to the entropy law, industrialisation must *inevitably* lead to environmental degradation. There is no escape; industrial progress will only hasten this process, which more efficient machines cannot avoid. The entropy law guarantees that no machine can be perfectly efficient. Catalytic convertors or anything else cannot provide a solution to pollution; they are, at best, a very temporary palliative which will eventually worsen the disease. (The solution, if one is interested, can only lie in less machines and not more.)

What is the logic in refusing to see the inevitable? What is the logic in the constant hope that the entire economy is a perpetual motion machine of the second kind? The only possible logic is this: someone gains by declaring that he has a perpetual motion machine of the second kind, for the effects of the entropy law may take a long time to become manifest, and much can be done in the meanwhile. The acceleration of natural degradation by the economic process takes a long time to become apparent. On the other hand, the logic of industrial capitalism discourages thinking about the longer term except in Keynesian terms! One must think and plan ahead: but only for the short term, for what is manifestly undesirable in the long term may seem desirable in the short term.

The state of maximum ambiguity is also the most probable state: this is one way to understand the entropy law, also called the second law of thermodynamics: *entropy never decreases*. (The first law of thermodynamics simply says that energy cannot be produced from nothing.) One must distinguish between the two cases, 'never decreases', and 'increases'. The second law of thermodynamics, as stated, permits the possibility that the entropy never increases as well, and simply stays a constant. One expects, however, that entropy *increases* towards the future. Entropy represents the absence of information, so increase of entropy represents loss of information as time increases. That is, entropy increase towards the future simply means that future is *more* uncertain than past: expectation is less certain than memory. The restated entropy law also means that heat flows from hotter to cooler bodies; it means that the universe progresses towards thermodynamic equilibrium. More accurately, it means that the world is regressing into chaos.

This decline into chaos is irreversible: information once lost cannot be regained—not without violating the entropy law. This is a restatement of the process of aging. A violation of the entropy law would allow one to construct a perpetual motion machine of the second kind—there have been many claimants, but no such machine exists. Supposing one tidies up a disordered room, hasn't one restored order? The answer is yes. One has restored order in the room; but this is only at the expense of creating disorder elsewhere in the universe. One has only redistributed the disorder in the universe; and this process of redistribution has created more disorder. The entropy law says that the amount of disorder that one so creates will always exceed the amount of order. One can cool a room using an airconditioner, but only by a process which not only heats the outside, but generates a net amount of heat. The entropy law does not apply to little bits and pieces of the cosmos: it applies to the cosmos as a whole, which is the only truly isolated system we know of.

The thermodynamic arrow of time.

The increase of cosmic entropy towards the future means that one has less information about the future than one has about the past. This asymmetry of information serves to characterise the difference between past and future, it permits us to say that future is more uncertain than past. This is called the thermodynamic arrow of time.

## *The Reversibility Objections*

The thermodynamic arrow of time captures at least one aspect of mundane time belief, viz., that the future is *more* uncertain than the past. But it is difficult to reconcile the thermodynamic arrow of time with the fundamental premise of current-day physics—that physical law connects future to present. For, if the present decides the future and the past, how can there be less information about the future than about the past? And therein lies the nub; everywhere, we observe entropy increasing; everyday, we get irreversibly older, whether that makes us happy or sad; no one has yet constructed a perpetual motion machine of the second kind, and we believe this to be impossible. For all that, the entropy law (in the sense of entropy *increase*) remains a semi-empirical law. Unlike the first law of thermodynamics, the entropy law does not have a simple and direct connection with the basic laws of physics. This led to a fierce controversy in the previous century, with Ludwig Boltzmann supporting the entropy law, and many others disbelieving it.

We could, of course, simply take the entropy law as an additional physical hypothesis. The difficulty is this: not only can the entropy law not be established from other physical principles, it is contrary to them!

Loschmidt's reversibility paradox.

This is further clarified by the paradoxes of Loschmidt and Zermelo. Loschmidt's paradox uses the time-symmetry of physical law which permits chains of causes to be developed towards both past and future. The paradox is this. Suppose entropy increases towards the future, and suppose this is in agreement with physical law. Then entropy must also increase towards the past, since physical law does not discriminate between past and future. Hence entropy cannot increase at all and must stay constant.

From the theoretical point of view this argument is entirely reasonable, and quite watertight. One can mathematically prove that entropy must stay constant. From a practical point of view the conclusion seems completely unreasonable. Physical law may be reversible, but reversing physical evolution would mean being able to get younger every day instead of older. That seems practically impossible. Neither can one use the constancy of entropy to avoid death by staying the same age all the time—that happens only in Wonderland. The actual debate took place in the context of molecular motions, and, practically, reversing the motion of an octillion molecules is equally impossible. In answer to Loschmidt's objection, that molecular motions were reversible, Boltzmann is reported to have remarked, 'Go ahead, reverse them!'

Boltzmann's actual answer to Loschmidt's paradox, which is also the current textbook answer, is this: physical law alone cannot lead to an increase of entropy, or explain the biological process of aging; one needs to introduce chance. Unhappily, this chance is not introduced by modifying physical law and asserting chance evolution; instead one tries to hang on to both chance and physical law. Chance is introduced in the fashion of Laplace: it is not intrinsic, but represents ignorance. This chance is compatible with physical law, though its origin remains obscure. Nevertheless, the introduction of this chance seems to lead to entropy increase, a conclusion not permitted by physical law.

Boltzmann himself was honest enough to admit that all this meant that entropy increase was illusory: a local matter in the cosmos. In other parts of the cosmos, entropy must be decreasing. For chance to be compatible with physical law, entropy must remain constant. Hence, entropy cannot increase everywhere—it must decrease somewhere else if it is to increase here.

## *Poincaré's Recurrence Theorem*

Zermelo's paradox. Poincaré recurrence theorem.

But there is a further difficulty: if entropy here does increase, it must eventually also decrease. This is Zermelo's paradox, based on a theorem due to Poincaré concerning recurrence. For a physical system such as a gas in a box, the theorem asserts that the present state of the system must recur after arbitrarily large times, hence infinitely often. Though this recurrence is only approximate, the approximation can be made arbitrarily precise. This means that the history of the gas-in-a-box, though not exactly cyclic, is very nearly so.

This is a very general theorem which does not depend on the assumption of any particular physical law such as Newton's laws of motion. The theorem is not *directly* affected, for example, by the transition from Newtonian physics to relativity (as currently understood). I have analysed elsewhere[8] the exact assumptions underlying this theorem. The proof of the theorem depends only on the assumptions of (1) a deterministic and instantaneous time-symmetric law of evolution, (2) a finite number of particles enclosed in a finite region. Assumption (1) may be called the *phase flow* hypothesis, which may be elaborated as follows: at any instant of time the system has a unique state, and this state has a unique successor *t* seconds later, and a unique precursor *t* seconds earlier. Assumption (2) states, for example, that the state of the system must be specifiable by a finite set of numbers, and each of these numbers can take on values only in a bounded interval.

If the entire cosmos satisfies these assumptions, then the cosmos must be nearly periodic. As a consequence of this theorem, we simply cannot associate *any* quantity with the physical system in such a way that this quantity will go on increasing with time. There is no way to escape the conclusion of this theorem for a gas-in-a-box without changing physics fundamentally, by changing either the evolutionary law of physics or the description of a particle in physics.

Boltzmann's idea was that the entropy law could be established by introducing a chance element into physics. He thought this chance element arose from (our ignorance of) the chaotic motion of atoms and molecules. After Boltzmann's tragic suicide, and after the acceptance of the atomic hypothesis, this idea was generally adopted, and may be found in many textbooks. The attempts, however, to relate this chance element to the motion of molecules led to chaos! The texts on statistical mechanics do not accept that physical law has a fundamentally statistical character, and the attempt is to show how chance behaviour arises naturally from deterministic physical laws. The production of time-asymmetric increase of entropy from time-symmetric physical laws amounts to sleight of hand and mathemagic, for it hides the additional time-asymmetric assumption in obscure corners of techniques of ever-increasing complexity. (A case in the point is the work of Ilya Prigogine and his group.)

## *Nietzsche's Proof of Markovian Recurrence*

But it is worth pointing out that even the introduction of chance does not do away with recurrence! This argument is the focal point of Nietzsche's philosophy. While Heidegger wants to move this point to the secure plane of metaphysics, in Nietzsche this argument is anchored in physics. (This reflects the change in attitudes towards science between Nietzsche and Heidegger.)

Nietzsche's argument proceeds as follows. As the first step, Nietzsche assumes the finiteness listed as assumption (2) above.

> we insist upon the fact that the world as a sum of energy must not be regarded as unlimited—we forbid ourselves the concept of infinite energy, because it seems incompatible with the concept of energy. [9]

Nietzsche has a point. We have seen (Box 2, Chapter 3) that half of infinity equals infinity. So, if an infinite amount of energy were available, one could consume half of it, and the amount remaining would equal the original amount. Like the inexhaustible pot of fairytale, one could draw as much energy as one liked, and the total energy would still remain the same. The conservation of energy (or the first law of thermodynamics) makes sense only if the total energy is finite.[10]

Nietzsche assumes that the world has existed for an infinity of time.

> We need not concern ourselves for one instant with the hypothesis of a created world…'create' is…but a word which hails from superstitious ages.[11]

In a finite world which has existed for an infinity of time, and which evolves through chance, every possibility must be realised, and must already have been realised.[12] If one tries to while away eternity by playing a card game such as Bridge for an infinity of time, then it is not clear that one can escape boredom, for every possible hand must already have been dealt, and must almost surely have been dealt infinitely many times.

> If the Universe may be conceived as a definite quantity of energy…it follows that the Universe must go through a calculable number of combinations in the great game of chance which constitutes its existence. In infinity, at some moment or other, every possible combination must once have been realized; not only this, but it must once have been realized an infinite number of times.[13]

As we understand things today, Nietzsche's argument is correct, given his assumptions.[14] Nietzsche clearly has the debate on the entropy law at the back of his mind, for he makes a direct reference to the heat death of the universe.

> Only when we falsely assume that space is unlimited, and that therefore energy gradually becomes dissipated, can the final state be an unproductive and lifeless one.[15]

Nietzsche thought that the heat death was a necessary consequence of the mechanical laws of physics,[16] and was unaware that recurrence was unavoidable whether or not chance evolution was assumed.

## *The Loophole with a Loophole*

What is the loophole? One does not actually see heat flowing back from a hotter to a cooler body. That means that recurrence must be a very improbable occurrence. The more improbable an event, the longer it would take, on an average, to recur. Exactly how long would it take before 'ashes heat the boiler, and a corpse revives to live its life in exactly the reverse of an earlier case'? It is part of physics folklore, found equally in textbooks and in statements by authorities, that the loophole is that the recurrence time is very large, say $10^{10^{137}}$ seconds (so that, tacitly, the cosmos will come to an end long before it recurs; why the cosmos must end is not stated, but we have seen earlier the political importance of the psychological fact that people tend to lose interest in very large intervals of time). I can think of only one reason why this figure is bandied about: few physicists are mathematically sufficiently well-equipped to know how to calculate the Poincaré recurrence time, and still less have they applied their minds to the philosophical question of what it means to speak of such a large time, especially when entropy itself is used to distinguish past from future.

Actually, recurrence-time estimates of the kind presented above simply correspond to the largest possible time in which recurrence can occur. Why should we believe this correspondence? Because otherwise one would, in general, not be able to calculate the recurrence time—for it may equal the maximum, it may be zero, or it may have any in-between value! Technically, the assumption needed here is that of *mixing*. The temperature of hot water poured into cold water quickly becomes homogeneous if the water is mixed. The same assumption (mixing, shuffling, shaking, rolling, tossing) ensures that it will take a long time for the water to un-homogenise through a chance fluctuation. A closely related name for this assumption is *ergodicity*. Roughly speaking, (quasi) ergodicity means that the cosmos must (nearly) visit every state it possibly can visit before it recurs. This explains why the recurrence time calculated this way is so large.

The value of even this largest possible recurrence time changes with exactly what is counted as a recurrence: the sharper the similarity one looks for, the longer it will take to recur. But how sharp is sharp enough? In the above calculation, mere un-homogenisation of water would not count as recurrence: each molecule would have to return to very nearly its original position with very nearly its original velocity. Tepid water may separate into hot water and cold sextillions of time before *that* happens. There are other difficulties as well.

The figure for the recurrence time seems impressive. But this is a psychological matter rather than a physical one. Any measurement whatsoever requires a state of non-equilibrium: the needle of the measuring apparatus is in one state to start with, and it moves to another state at the end of the measurement. The entropy law states that the cosmos progresses towards equilibrium. Suppose the entire cosmos has reached a state of equilibrium, its heat death. The movement of the needle, indeed the needle itself, not to mention the measuring apparatus, cannot exist in a state of homogeneous chaos. (Any identifiable object would mean un-homogenisation of the chaos.) So no measurement of time is possible in a state of equilibrium. *When the cosmos reaches equilibrium, time stops*. 'After' this there are two possibilities: either it stays in equilibrium, or it moves back into a state of non-equilibrium. We have already seen that it is naive to talk of 'how long' the cosmos stays in a state of equilibrium. But when it moves back into a state of non-equilibrium, we must count time as running backwards. (If the entropy law is used to define past and future, we have no choice here.) Boltzmann himself inclined towards the possibility that there would be different arrows of time in different parts of the cosmos, with time running forward here and backward there. So what does that impressive textbook figure for recurrence time *mean*? And how valid is the calculation which supposes, in addition to mixing, that a clock external to the universe keeps ticking away all the time?

## *Summary*

It is possible to make physical law statistical. This would break the necessary connection between future and present, replacing it with a probabilistic connection. So far this has not been done: in the existing approach, time is only epistemically broken. The point of introducing chance is only to allow increase in entropy, while hanging on to the physical laws which force it to remain constant. In the current understanding of physics, no matter how entropy is defined, entropy can either only *seem* to increase, or it can increase for some time before again decreasing. Neither possibility resolves the basic problem of reconciling superlinear time with mundane time. In the long run, the future, as defined using the entropy law, does not coincide with the mundane future (since entropy *must* decrease in the long run, so that the thermodynamic arrow of time must boomerang). What happens to Keynesian economics if we all come back to life in the long run?

# Chaos

Two things were used to make the entropy law compatible with other physical laws: (1) chance, and (2) mixing. This chance was compatible with physical law, not orthogonal to it: the introduction of chance did not truly break the invariable connection between future and present provided by physical law; chance merely expressed our ignorance of this connection—our inability to use this connection to calculate the future. The origin of mixing remains obscure.

## *Reconciling Determinism and Chance*

Theories of chaotic dynamical systems provide an answer to these two difficulties. The first example of a chaotic dynamical system was presented by Hadamard nearly a century ago, and the philosophical implications were analysed further by Poincaré in 1908 who also created the theory of dynamical systems. But there was a long gap before these ideas were taken up again.

To understand Hadamard's theorem, imagine a really old billiard (or pool) table, which has not been maintained so that its surface is twisted out of shape. (If you have difficulty in imagining this, you can think instead of billiards with convex obstacles as in Fig. 6. Alternatively, you can find such a table in the dungeons in the basement of the former Viceregal palace which houses the Indian Institute of Advanced Study in Shimla!) Hadamard proved that it would be very difficult to play billiards on such a table! On a normal billiard table, a slight error in hitting the ball would result in a near miss. On a twisted table anything at all might happen: Hadamard proved that anything at all that could happen *would* happen as a result of a slight error. The motion of the ball would be *(quasi) ergodic*: the ball would travel to practically every point on the billiard table. (Hadamard studied only the frictionless motion of the ball, and assumed that the table was twisted in a special way.[17])

The motion of the ball on the twisted billiard table depended very sensitively on the initial conditions—the slightest error would get enormously amplified.[18] Hence, Pierre Duhem called this an 'Example of a mathematical deduction forever unusable': knowing the solution to the problem of the motion of the ball on a twisted table was of little use, for there would always be some error in our

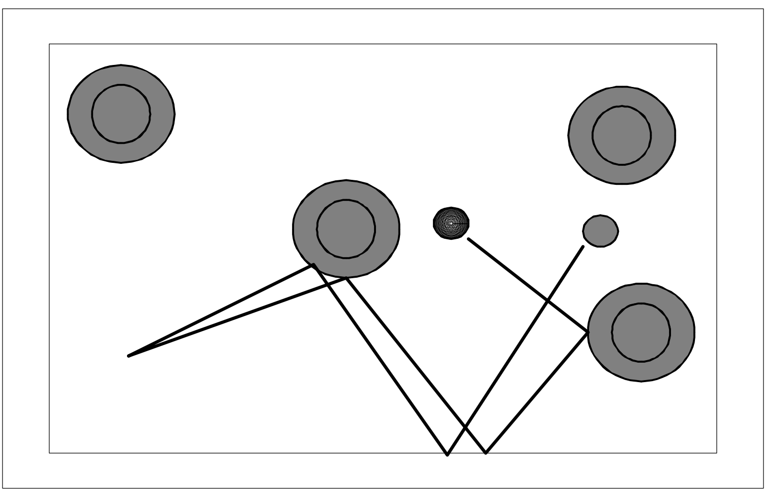

**Fig. 6: Billiards with Convex Obstacles**

There are two balls: one real and one imaginary. A small initial difference in direction grows very quickly, so that, after a while the balls may be travelling in completely different directions. The balls remain confined to the billiards table.

knowledge of the initial conditions, so that the future trajectory of the ball could not be predicted.

The acute Poincaré noted, however, that this unpredictability could be used to try to reconcile chance and determinism:

> A very small cause, which escapes us, determines a considerable effect which we cannot ignore, and then we say that this effect is due to chance.[19]

Poincaré prophetically argued that weather forecasts were unreliable for the same reason. It is generally supposed that he had no mathematical proof of this and was relying on intuition. The general phenomenon is that of sensitive dependence on initial conditions.

## *The Lorenz Model*

> 'It is, monks, for elementary, inferior matters of moral practice that the worldling would praise the Tathāgata…"Whereas some ascetics and Brahmins make their living by such base arts as predicting good or bad rainfall;…computing, calculating,…the ascetic Gotama refrains from such base arts and wrong means of livelihood." '[20]

So what exactly does 'sensitive dependence on initial conditions' mean? The simplified model of Edward Lorenz (not Lorentz) provided a really good excuse for the failure of meteorological forecasts! The Lorenz model (not realistic) describes convection in the atmosphere. The sun heats the earth, and the air closest to the earth gets warmer and lighter, and starts rising upwards. Cool dense air from higher up flows down to replace this. There is a convection current of the kind you might have seen in middle school. The Lorenz model provides a crude mathematical description.

Because it is so simple, one can easily solve the Lorenz model and plot the solution.[21] Two such solutions for different initial data are displayed in the Figs. 7 and 8, called phase portraits.[22] The difference in the initial conditions is so slight that it is not visible, and the general aspect of the two figures seems the same.

However, the two figures are different. Imagine that the two curves are made of stiff pieces of wire. Imagine a tiny bead which moves along the wire. The bead goes around the right 'ear' a certain

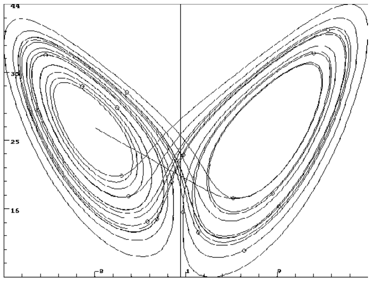

**Fig. 7: The Lorenz 'Butterfly'**

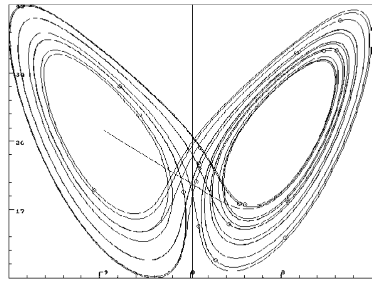

**Fig. 8: A Slightly Different 'Butterfly'**

number of times (twice); then moves to the left, goes round the left 'ear' a certain number of times (twice); and returns to the right and goes round thrice; returns to the left and goes round once, and so on…. The difference between the two figures is this: the number of circuits around each 'ear' has changed, though the change in the starting point is not discernible. How can we tell? This is clarified by the following three figures. The number of circuits is obtained by counting the number of cycles of the upper curve between successive points where the lower curve crosses the *x*-axis (Fig. 9). If

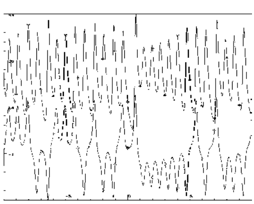

**Fig. 9**

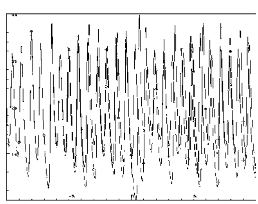

**Fig. 10**

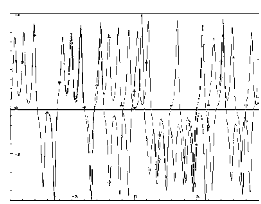

**Fig. 11**

The number of circuits around each 'ear' of the Lorenz butterfly is obtained from Fig. 8 by counting the number of cycles of the upper curve between successive points where the lower curve crosses the *x*-axis. The upper and lower curves are plotted separately in Fig. 9 and Fig. 10 respectively.

the initial conditions are changed, the upper curve (Fig. 10) does not change as much as the lower curve (Fig. 11) does.

Let us try to understand this a little more clearly. Today, weather prediction is carried out by simulating general atmospheric circulation on a supercomputer. Part of the data for this simulation may come from satellite observations of clouds. This is as close to the observational and computational powers of Lapalce's demon as we can get today. But the forecasts are valid only for a short period of time like a week. Medium-range weather forecasting is an important excuse for acquiring more supercomputers. (In Delhi, the centre which houses the Cray X-MP supercomputer—now obsolete—which, as the PM announced, was expected to tell every farmer whether or not it would rain on his farm, is called the National Centre for Medium Range Weather Forecasting.)

But long-range forecasts may be forever out of reach: howsoever sophisticated the model, it is unlikely to be able to take into account everything, like the flapping of a butterfly's wings in the Amazonian jungle. Weather is unpredictable because atmospheric circulation depends sensitively on initial conditions. The flapping of a butterfly's wings in the Amazonian jungles might cause an unpredictable cyclone off the coast of Andhra Pradesh, a couple of months later. Even sophisticated models cannot predict the long-term future, since any model neglects some details, but even the tiniest neglected detail may have a decisive bearing on the long-term future. For the want of a nail, a war may be lost.

## *Popper's Exorcism of Laplace's Demon*

The future course of a chaotic dynamical system cannot be easily predicted because it has very sensitive dependence on initial conditions, and there is bound to be some practical error in deciding these conditions. Popper[23] argued that this error could not, even in principle, be eliminated. This point was used by Popper to exorcise Laplace's demon.

The demon, said Popper, was a creature of classical mechanics, and should be exorcised within it (else one would be obliged to admit that classical mechanics was deterministic). Moreover, Popper felt it was only proper that the demon should be permitted all possible non-miraculous powers. Since the demon is a superior sort of being—a super-scientist, supercomputer, and super-observer rolled into one—the demon should be permitted all possible knowledge of science, he should be permitted to compute everything that can be computed, and observe everything that can be observed.

Nevertheless, it would be impossible for the demon to eliminate errors of observation altogether, for something like velocity or acceleration is an average quantity. To calculate this average, one must observe the position at different instants of time. The estimate (calculation) of the average deteriorates if the time interval is taken to be too small. One is not quite sure what it is an average of if the time interval is taken to be too large. Hence, there must be an optimum time interval and an optimum error. This is the minimum non-zero error that Laplace's demon can hope to achieve. But take a motion (Popper gives Hadamard's example) which is sensitively dependent on initial conditions. The slightest error would make it forever impossible to make long-term predictions. Hence Laplace's demon fails to predict the future accurately.

The last point of Popper's argument (a key point) is this. We have allowed wide latitude to Laplace's demon. We have endowed him with all possible non-miraculous powers that a scientist might possess now or in the future. If Laplace's demon is nevertheless unable to predict the long-term future, how can we say that the theory determines the future? What *meaning* would such an assertion have? Hawking[24] makes the same point more recently: 'the clearest operational test of an open future is this: can you predict it?' Hence, a future which is, in principle, unpredictable is indistinguishable from an open future.

## *Summary: Chaos, Unpredictability and Creativity*

To summarise, Boltzmann's account of irreversible entropy increase as due to chance evolution had two difficulties: the origin of chance and mixing. Chaos provides a solution: chaotic systems reconcile chance and determinism. Though deterministic, they have chance-like evolution. The future of a chaotic system is hence unpredictable, even by Laplace's demon. Chaotic systems are also ergodic (mixing). This last statement means the following.

Chaos does *not* undo the Poincaré recurrence theorem. 'Eternal return' (i.e., Poincaré recurrence) remains inevitable, so that irreversibility from reversible dynamics remains an illusion. Chaotic systems are *exactly* those for which this illusion of irreversibility persists the longest. That is, chaotic systems are 'complex' and 'irreversible' in the precise sense that the recurrence times for them are (likely to be) among the largest. Chaotic evolution of the cosmos does *not* avoid the difficulty with the meaninglessness of large cosmic recurrence times. Like drugs which cause hallucinations, chaotic systems, however, give the greatest value for money: the kick lasts relatively the longest with chaos!

Chaotic systems undoubtedly help to understand the unpredictability of the weather. Whether they help to understand mundane human creativity is not so clear. Indeed, chaotic systems do not answer the other reversibility objection either. Chaotic systems are equally chaotic towards the past. But can we say that unpredictability of the past means that we can bring about the past in the same mundane sense in which we can bring about a certain future? These and other objections to equating unpredictability with human creativity are examined in the section below on the 'Failure of Broken Time', and in the next chapter on time travel.

Chaotic time evolution has other limitations: chaos only makes long-term future predictions impossible. Short-term prediction remains possible for Laplace's demon. Atmospheric air-circulation is chaotic, and long-term weather prediction may be impossible, but a supercomputer can be used to make accurate weather forecasts in the short or medium term. Thus, chaos only serves to veil the distant future just as the curvature of the earth creates a horizon which prevents us from seeing distant objects. Someone might maintain that a ship coming over the horizon operationally comes into existence. But that is not very convincing—unlike mundane creativity, we have no control over the events that thus 'come into existence' over the future horizon, and the future horizon due to chaos keeps receding with every improvement in our computational capabilities.

# Computability: Man and Machine

To recapture the thread of the argument, credits are distributed among scientists in the same way as they are distributed in society. This appeals to notions of creativity and cause, both of which are *prima facie* incompatible with relativity. Chance may help restore compatibility; it may help to reconcile mundane time with the superlinear time of relativity, but this has not happened—as of today, physical law remains deterministic, and not statistical. Chaos helps to reconcile the determinism of relativity with the complexity that makes physical time-evolution seem as if it is due to chance. But chaos succeeds only in making the long-term future unpredictable in a rather weak sense. Is that the same as creativity?

Indeed, non-human automatons could also be chaotic, hence unpredictable. Are human beings then no different from complex automatons? Perhaps that is so, but this conclusion does not seem very palatable. So what, if any, is the difference between man and machine? We can try to argue that we are *not* automatons—that creativity involves something more than chance, chaos, and complexity.

According to Roger Penrose,[25] this 'something more' is uncomputability. While complexity due to chaos only makes it difficult for a machine to compute the future, uncomputability makes it impossible. The conclusion is that the human mind is good at certain arts—like proving mathematical theorems—that will forever remain beyond the reach of machines. This conclusion is quite acceptable, but the arguments leading up to it need not be: it is quite possible to arrive at a correct conclusion through an incorrect argument that may have other unacceptable implications. Therefore, the arguments need to be examined.

Penrose's arguments have subtle but unacceptable political implications.

For example, Penrose's arguments are loaded with Platonic metaphysics. According to this metaphysics, there are certain universal ideas of truth, beauty, morality, etc., existing independently, and these ideas are revealed to the human mind when the mind (soul) makes contact with the perfect Platonic world of universal ideas. This metaphysics may have unacceptable political implications, and universality is a key element of current strategic doctrine. But since we have already gone into these aspects in Chapter 3, we will not reiterate the political connotations in what follows.[26]

To unload also the emotional connotations, one can think of the problem as follows: is it possible to construct a machine, a robot-mind, which would be virtually indistinguishable from a human brain? This is a natural question to ask if human ability to create novelty is equated with the inability to predict the future.

Turing test.

What does 'virtually indistinguishable' mean? This is specified by the famous Turing test. Suppose one carries on a conversation for half an hour without suspecting that one has been conversing with a machine: then it would be reasonable to call such a machine virtually indistinguishable from a human being.

## *Does a Machine Need its Maker?*

The ability to behave in unexpected ways does not distinguish human beings from machines, in principle, for machines, too, may behave in unexpected ways: a car may break down when one least expects it to. The frequency with which a machine does unexpected things increases with the complexity of the machine: any good chess programme will surprise most people. A Bridge programme may be taught to deceive and bluff. But doesn't the programmer know all the secrets of the machine? To believe this is to be as egoistic as Pygmalion[27] (in the play/film).

> When a program grows in power by an evolution of partially understood patches and fixes, the programmer begins to lose track of internal details, loses his ability to predict what will happen, begins to hope instead of know, and watches the results as though the program were an individual whose range of behavior is uncertain.
>
> This is already true in some big programs…it will soon be much more acute…large heuristic programs will be developed and modified by several programmers, each testing them on different examples from different [remotely located computer] consoles and inserting advice independently. The program will grow in effectiveness, but no one of the programmers will understand it all. (Of course, this won't always be successful—

> the interaction might make it get worse, and no one might be able to fix it again!) Now we see the real trouble with statements like 'it only does what its programmer told it to do'. There isn't any one programmer.[28]

It is easy to find human beings who are unhappy because they do not possess this or that machine. We see everywhere that human beings are unable to live without the machines they make. But does a machine need its maker? A machine could be programmed to learn; such machines (programs which learn to recognise voice or handwriting) already exist and are being sold in the market.

How does a machine learn? By mimicking human beings. The basic nerve cells in the human body are called neurons, and the human brain may be regarded as a complex network of neurons. The learning machines try to imitate the human brain using neural networks, a notion mathematically equivalent to the notion of a Markov chain, which we encountered earlier in this chapter. A neural network moves between a finite set of states; the deterministic rules of movement between states are subsumed under probabilistic rules. Unlike the rolling dice where the Markov chain is *stationary*, the rules here may change with time. The key to the learning process is that the rules change with time: an expert is one who can do something much faster than a novice.

To know *what* a learning machine has learnt, we must know all that it has been exposed to. One could possibly hope to monitor that with present-day machines; but what of machines of the future, a hundred and fifty years hence? Would it not be the same as trying to monitor all that a human child learns? For all one knows, it may be more complicated!

Biologists today believe, somewhat dogmatically, that the great variety of life we see around us has evolved as a result of chance factors in the environment. If so much novelty can be due to mechanical 'chance', without the intervention of any creative process, then machines which can learn and respond to chance factors in the environment should be able to produce a surprising amount of novelty, given enough time.

Machines may accumulate a store of knowledge by learning also from other machines. We already have a situation of object-oriented programming, for example, where large repetitive chunks of machine code are written by the machine itself. One can visualise this process amplified a great many times; so that the programmes of tomorrow would be so complex that no unaided human mind would be able to trace their internal logic. We are accustomed to regarding machines as our prosthetic extensions, feeling superior about machines like cars or bicycles, which aid movement, and perhaps a little nervous about machines like computers, that aid thought. But why should machines remain *our* prosthetic extensions? Why shouldn't machines aid other machines as well? Why shouldn't machines programme and teach other machines? Possibly a learning machine may evolve a programme to generate random numbers which humans can only dimly understand. It may then teach this programme to other machines. Not only would it be impossible for human beings to predict the behaviour of all such machines, no one could claim even to understand the internal working of such machines.

We already have some examples before us. In chess, the case of king and two knights vs king (Figs. 12 and 13) was believed to be a draw till computation established that it was a win. We also have examples before us of machine-aided mathematical proofs. There is one such proof, a gargantuan result of collaboration between a

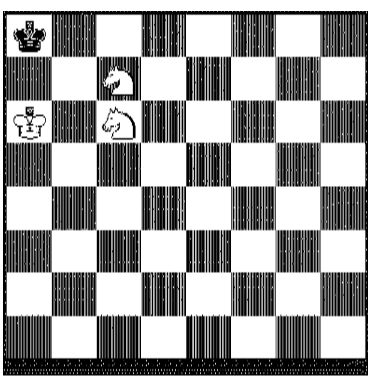

**Fig. 12**

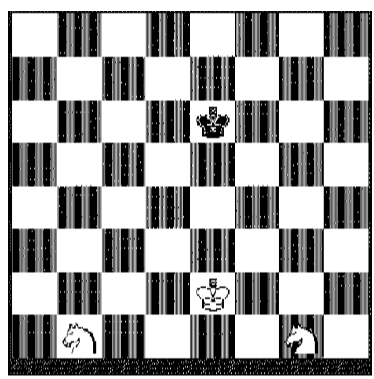

**Fig. 13**

The position on the left is a winning position for white. Starting from a general position, such as the one on the right, is it always possible to arrive at the winning position in, say, 45 moves? Books on chess stated, for many years, that the answer was 'No', until computers showed that the correct answer was 'Yes'.

group of mathematicians and machines, which runs into five *thousand* pages.[29] The map colouring problem was a famous unsolved problem, which had defied all the efforts of earlier mathematicians. It is as hard to solve as it is easy to state. The problem is to colour a map so that no two adjacent countries have the same colour. It is assumed that no country is in two pieces (as Pakistan formerly was). The countries are not regarded as adjacent if the boundaries meet at only finitely many points. The question is: do four colours always suffice? Four colours are always sufficient in practice; the point is to prove this. It took a number of years for people to verify the correctness of the machine-aided proof, after it was produced.[30]

Machines can, of course, reproduce. One does not have to worry about the complications of the self-reproducing machines proposed by von Neumann. The computer virus is the most primitive example of a machine which reproduces. Of course, it might be objected that the computer virus is only a programme, not a machine made of steel.

But the outer encasement of a machine—whether made of steel or plastic, whether it has two hands or four, whether it is attractively coloured or not—is quite irrelevant to the question at hand. The machines we are talking about are abstract machines, made for the purpose of running a programme. Such machines can be identified with the programmes they run—the programme is the closest thing to the mind of the machine (so the computer virus is like a mental parasite).

The general sort of abstract machine—basically an error-free computer with a potentially infinite memory—is commonly called a Turing machine. The most general sort of abstract machines, the so-called universal Turing machines, are abstract machines capable of imitating any other abstract machine. The machine moves from one state to another using a definite rule. Even when the machine moves to an unexpected state, even when the machine produces a list of numbers, which satisfy all our tests for numbers generated by chance, the machine produces these numbers using a rule. The defining attribute of a machine is that its time evolution is rule-based.

This sort of thing suggests a conceptual difficulty. Just what is a rule? We recognise a simple rule when we see it. But what is *not* a rule? Given complex behaviour—a chaotic system, say—can one decide whether or not this is mechanical or rule-based? Before examining the general rule for a mechanical or rule-based process, lets us consider a particularly important example of a mechanical process: the process of verifying the validity of a mathematical proof.

## *Hilbert and Gödel*

For many people, a mathematical proof is the last word in certitude. The modern idea of a mathematical proof originates in 'Euclid's' *Elements*. We do not know who this 'Euclid the geometer' was—the first and only reference to him is in a casual remark by Proclus of Alexandria, some 700 years later. Proclus may well have invented a Greek ancestry for the work of his own school, to deflect the religious persecution that he faced. [Hypatia (p. 72) was not an isolated case; at about the time he cursed Origen, Justinian closed the Alexandrian school at which Origen too had taught. Indeed, mathematics was, for Proclus, a key aspect of his (Neoplatonic) religion, a method of drawing the soul towards truth, a self-discipline which he explicitly recognised as leading to the religious goal of a blessed life (p. 27).] At any rate, the idea of the *Elements* was to so arrange the theorems of geometry known at that time that each subsequent theorem required an appeal only to preceding theorems, and to axioms and postulates which were made perfectly explicit. This enterprise produced a great work of such striking beauty and clarity that people were enraptured by it for over a thousand years. Anyone who did school geometry in the older way[31] will recall the seductive charm of 'Euclid'.

Though banished by Justinian, 'Euclid' returned to Europe via Islamic rational theology. While Islamic rational theology retained the Neoplatonic focus on equity—most theorems of the 'original' *Elements* concern equality—Christian rational theology rejected equity, and saw in the *Elements* only a form of persuasive discourse, which could be used to persuade the non-believers.

In the nineteenth century, however, the mathematician Dedekind remained unpersuaded. He was not persuaded by the very first theorem in the *Elements*. By Dedekind's time, the arithmetisation of geometry (initiated by Descartes) had proceeded to the point that Dedekind could locate the logical gap: there might be gaps in Euclid's circular arcs, and to correct them one must fill in the gaps in the (rational) numbers—gaps due to the existence of irrational numbers such as the square root of 2. To fill in the logical gap in Euclid, Dedekind filled in the gaps in the number system, giving a new foundation to the system of real numbers. This process was very fruitful, for it also cleared up the confusion related to the infinitesimal calculus in Europe.[32]

We have already met David Hilbert. By then, he had become famous for carrying forward the process initiated by Dedekind and removing all logical gaps in the *Elements*. For Proclus, a proof was important for the effect it had on the human mind: it turned the mind inwards and away from everyday concerns. For Hilbert, living in the heart of industrial culture, when that culture was at its peak, the importance of a proof was that it could be mechanically checked without fear of any psychological tricks—the certitude of a proof was underwritten by the trust that could be reposed in the mechanical process of checking the correctness of a proof.

**Modus Ponens**.
1. A
2. A implies B
3. Hence B.

What is a proof? This is not a question *in* mathematics, it is a question *about* mathematics, and is today answered as follows in the metamathematics initiated by Hilbert. A mathematical proof is a (finite) sequence of statements. A machine or any moron should mechanically be able to verify that each statement is (i) either a postulate or (ii) is derived from two or more preceding statements by means of a few simple rules of reasoning such as the rule called *modus ponens*.

Proof is as important for mathematicians, today, as experiment is to scientists. However, unlike experiment, which involves the empirical world, Hilbert's definition of proof makes absolutely no reference to the empirical. For Proclus, mathematics provided a path from the empirical world to the Platonic world of ideals, so Proclus was ready to admit appeals to the empirical at the beginning of the *Elements*. For Hilbert, any appeal to the empirical was disallowed, for it constituted a logical gap, and he closed this logical gap by changing a key proposition of the *Elements* (the side-angle-side theorem) into a postulate. For Proclus, diagrams were an important aspect of geometry, and he quotes[33] Plato to the effect that 'if you take a person to a diagram then you can show most clearly that learning is recollection'. For Hilbert, diagrams were irrelevant and deceptive, for had they not deceived so many people before Dedekind? Hence, for Hilbert, diagrams had no place in a mathematical proof. One might say that where Proclus sought to persuade human beings, Hilbert sought to persuade machines!

Indeed, Hilbert wanted to reduce mathematics itself to a mechanical matter. He had done this for geometry by listing out all the important theorems. Having also replaced the 'equality' in the *Elements* by 'congruence', Hilbert now turned his attention to the theory of numbers. He proposed a grand programme. He wanted to do for number theory what the *Elements* had done for geometry: correctly arrange all the important theorems, and prove them. This would reduce number theory to a mechanical matter. As in the case of his modification of 'Euclidean' geometry, he wanted to add as axioms any important results which could not be proved from the existing set of axioms. At that time, many mathematicians such as Russell were concerned with this question of foundations. Particularly, Cantor's study of infinities (Box 2) had led to recognisable paradoxes. Hilbert wanted to crown his grand programme with a proof that no such paradoxes would arise in his revised version of the theory of numbers: he wanted to prove the consistency of number theory.

What is consistency? Consistency simply means that a statement and its negation must not both be true; otherwise, every statement is provable in the mathematical theory, so that the theory becomes trivial.

Hilbert pursued his grand programme for over a quarter of a century from around 1900 to 1931. By way of comparison, his derivation of the equations of general relativity was almost a diversion. In 1931, in one of the most dramatic moments in the history of mathematics in this century, an unknown young man called Kurt Gödel put a full stop to this programme. He comprehensively shattered Hilbert's dream. Gödel proved that what Hilbert was attempting was not just a very difficult thing to do, it was impossible.

Gödel showed that number theory, or any larger (consistent) theory containing number theory, would contain an undecidable statement—a statement that could neither be proved nor disproved. What had been done for the *Elements*[34] would not work for number theory: it would not help to attach an undecidable statement as an additional axiom because the resulting theory, being larger, would again contain an undecidable statement. Hence, there cannot be *any* mechanical way to decide whether or not a given statement in number theory is a theorem. It is impossible mechanically to classify the statements of number theory as true and false.

The idea of Gödel's proof was to use a paradox[35] similar to the barber paradox: a barber shaves *exactly* all those people in his village who do not shave themselves. So who shaves the barber? If the barber shaves himself, then he is among those who shave themselves. Therefore, since the barber shaves only those who do *not* shave themselves, he cannot shave himself. But if he is among those who do not shave themselves then, being the barber, he must shave himself. 'To shave or not to shave' remains an undecidable question for the barber. The main technical difficulty in Gödel's proof is, of course, to construct the barber using number theory!

As a consequence of Gödel's theorem, there cannot be any finite set of 'rules' to decide the truth or falsity of number-theoretic statements. *There cannot be any mechanical way to decide whether or not a given assertion is a theorem.* Many people interpret this theorem as follows: mathematical theorems cannot be proved mechanically; mathematics requires ingenuity. *Checking* the validity of a proof is a mechanical process, but *generating* an (interesting) mathematical proof or theorem is a creative process.

Moreover, Gödel proved that the consistency of number theory could not be proved within the theory. This meant that the belief in the validity of number theory would require an appeal to a larger theory, to establish whose consistency would require a still larger theory…. Mathematics must forever remain doubtful.

(Many people will disagree with the last statement. They prefer to think of the second theorem as follows: a system cannot be understood within itself. The human brain cannot understand itself. This [fanciful] interpretation of Gödel's theorem can be summarised in a limerick.

> There was a young man called Gödel
> who came along to yodel,
> that it could be a pain
> to examine one's brain;
> and one would never do too well! )

## *Turing Machines and the Halting Problem*

Gödel's first theorem needs further elucidation. For we have still not explained what exactly a 'rule' is. So we still do not know the difference between man and machine. Gödel's idea of a rule-based or mechanical process is most easily elucidated using Turing machines. We recall from the previous section that a Turing machine (named after the metamathematician Alan Turing), is essentially an error-free computer with a potentially infinite memory. The operation of this machine is rule-based. Just what are these rules on which the operation of this machine is based?

A concrete example of a Turing machine is provided by a game which needs the following equipment. (1) Several rolls of toilet paper, (2) several black and white stones, (3) one coin (called 'the marker'), (4) one ordinary playing die. To start playing the game, roll out the toilet paper on the floor. Place the black and white stones, one to each square as follows. (a) One black stone on an arbitrary square, (b) two white stones to the right, (c) a black stone to the right, (d) a blank square, (d) a black stone to the right, (f) three white stones to the right, (g) a black stone to the right, (h) place the marker on the rightmost square occupied by a white stone. Place the die with 1 pointing upwards.

The rules of the game are given in the table. The marker must be moved according to the rules. If required to move beyond the right edge of the roll, attach a second roll to the first. Undoubtedly this seems a rather stupid game to play. But this game[36] is meant to be talked about, and not to be played!

The game corresponds exactly to a Turing machine which adds two numbers. The numbers on the die are called the *internal states* of the machine. The only difference between this Turing machine and the most general Turing machine is exactly this: the most general Turing machine may have more than six internal states; it may have any finite number of internal states. The state corresponding to 0 is called the *halting state*. The toilet roll corresponds to the old-style magnetic *tape*, each square on the roll is a memory location. The potentially infinite memory of the machine means that one can supply as many toilet rolls as the machine wants. The white stones correspond to 1's and no-stones to 0's. The black stones are separators: punctuation marks like brackets, etc. These constitute the *alphabet* of the machine. The initial arrangement of stones on the roll is the *input state* of the machine: the numbers of white stones between the first and last pairs of black stones are the two numbers to be added. When the machine halts, it has an *output state*, corresponding to the sum of the two numbers.

It is possible to make the *rules* of this game an input to another Turing machine. This is exactly what a computer does: it reads a programme, and also the data—the rules of the game correspond to a computer programme, and the input to the data. The computer then mimics the machine described by the program. (It is this ability to mimic many other machines that makes the computer such a supertoy.) There are, of course, many differences of detail, but these are not relevant here.

There exists a *universal Turing machine*: a machine which can mimic any given Turing machine. An error-free computer with potentially infinite memory is an example. Though rather slow and inefficient compared to a digital computer, a universal Turing machine can do everything that any machine can do. It defines what may be done mechanically—it defines rule-based behaviour. The simple and silly-sounding rules about moving one square to the left, or to the right, erasing a square and putting another alphabet on it, and changing the internal state, are all the 'rules' that one needs (though one may need a very large number of them). All the apparent complexity of the computer arises from a repetition of these rules, a very large number of times.

The term 'machine', without qualification, usually refers to a universal Turing machine. That is the general understanding: when Penrose says that it is possible for the human mind to do something that a machine cannot, he is referring to what a universal Turing machine can do. Something is 'computable' if a machine, in this sense, can compute it, and 'uncomputable' otherwise. Actually, of course, Penrose's argument fails at this very first step: this consensus about the meaning of the term 'computable' was reached among a few Western mathematicians during Hilbert's time, *but it is already out of date*. Notwithstanding Penrose's statements to the contrary,[37] there are already in existence some key ideas of parallel computation,[38] according to which a parallel computer can do things that are 'uncomputable' in this old sense! We shall explain a little later in this chapter, how such a computer may be engineered today. Penrose's response[39] to this argument is

**Table 1**
**Example Rules for a Turing Machine**

For each rule three things are to be done, as indicated.

(1) Turn the die.

(2) Change the stone on the marked square.

(3) Move the marker one square right or left.

The game ends when the player is asked to turn the die to 0.

For a general Turing machine the die is not restricted to six faces.

| *IF THE DIE READS* | *AND THE STONE ON THE MARKED SQUARE IS* | *THEN TURN THE DIE TO* | *REPLACE THE STONE BY* | *MOVE MARKER ONE SQUARE* |
|---|---|---|---|---|
| 1 | None | 3 | White | Left |
| 1 | White | 2 | No stone | Left |
| 1 | Black | 1 | White | Left |
| 2 | None | 2 | No stone | Left |
| 2 | White | 3 | No stone | Left |
| 2 | Black | 5 | No stone | Right |
| 3 | None | 3 | No stone | Left |
| 3 | White | 4 | No stone | Right |
| 3 | Black | 5 | No stone | Right |
| 4 | None | 4 | No stone | Right |
| 4 | White | 1 | Black | Right |
| 4 | Black | 6 | White | Left |
| 5 | None | 5 | No stone | Right |
| 5 | White | 1 | Black | Right |
| 5 | Black | 1 | White | Left |
| 6 | None | 0 | No stone | Right |
| 6 | Black | 0 | Black | Right |
| 6 | White | 3 | White | Left |

inadequate. Nevertheless, to arrive at a physical characterisation of the difference between living organisms and machines, taken up in the next two chapters, it is possible to start with the provisional definition of 'machine' as a universal Turing machine.

For a general Turing machine, there is no guarantee that it will stop once it has started. The halting problem for a Turing machine is to decide whether the machine will ever stop. In terms of Turing machines, Gödel's theorem says that there is a Turing machine for which the halting problem is undecidable. For, consider the machine which has the task of testing whether a given statement about natural numbers is true or false; by Gödel's theorem, the halting problem for this machine is undecidable. Since the universal Turing machine can mimic any machine, the halting problem for the universal Turing machine is undecidable. If one feeds in an arbitrary programme to the computer, it may or may not ever stop executing the programme. The situation is not as if the computer hangs because there is an infinite loop somewhere: for in that case one *knows* that the machine will never stop. The situation is that one cannot, in principle, decide whether or not the machine will stop.

## Machine Ingenuity

We now know what an automaton is (at least we have a definition we can later modify). But how do we know we are not one? Alarm bells should ring and warning lights should flash the moment someone tries to deduce from Gödel's theorem that human beings have ingenuity, since human beings do mathematics.

Gödel's theorem says *nothing at all* about human beings. It is a theorem about theorems concerning natural numbers. It does say something about machines: that if a machine is asked to decide whether a given statement about natural numbers is a theorem, there is at least one statement for which it will never reach a decision. It does *not* tell us how *many* such undecidable sentences there are, nor does it tell us how large is the class of theorems that can be mechanically proved. Gödel's theorem says nothing about man, and so nothing can be inferred from it about the relation between man and machine. Without a similar characterisation of man, or at least an additional (usually tacit) hypothesis about human beings, we can conclude nothing whatsoever about human beings from Gödel's theorem. If we do invoke an additional hypothesis, our conclusions would be only as good as the additional hypothesis.

The additional hypothesis in this case seems self-evident. Human mathematicians can prove theorems. But so what? Computers, too, can prove *some* theorems. We believe that the theorems proved by human mathematicians are ingenious, whereas the theorems that computers today can prove are of the obvious and trivial sort. But this is the conclusion that is sought to be established; to assume this would be to beg the question. Gödel's theorem does not tell us that the theorems actually proved by human mathematicians require ingenuity; it does not say anything about the class of theorems actually proved by human mathematicians.

Chess was once used to teach ingenuity to kings. More ingenious and more intelligent human beings often play better chess; but does the ability to play good chess guarantee ingenuity? Today, no one will concede this. Twenty years ago, people laughed at computer chess. Ten years ago, they smiled. Today, few people can defeat a computer—even the world-champion, Kasparov, recently lost to the IBM Deep Blue. And if chess is only second-rate mathematics (as a mathematician friend of mine used to say), isn't it true that mathematics is only first rate chess?

What guarantees that computers cannot produce first-rate mathematics? Is it impossible that all existing mathematical results can be proved by a (possibly future) machine? Gödel's theorem, at any rate, is quite *irrelevant* to this question, for we have seen that it says nothing at all about the class of theorems proved by human beings. In fact, one can give a very simple prescription to make such a machine: just load all existing mathematical results into it. (Remember, the machine has infinite memory!) The machine functions according to a look-up table. Just supply the machine with any statement, and it checks to see if this is amongst the list supplied to it. If it is, it simply recalls the proof from memory!

There seems to be some cheating here. The machine did not *do* any mathematics: it simply learnt everything by rote. Was it because we agreed to endow the machine with infinite memory? Not really. Our feeling of discomfort is given a precise expression by a form of the second law of thermodynamics: *machines cannot create order*. The output of the machine has only produced as much information[40] as was supplied in the input. The machine did not generate any new information; it did not create novelty.

*But what guarantees that humans can create order?* This, after all, is the crux of the question of man and machine; we cannot simply assume it. In the above instance, the input was supplied by us. But recall the earlier remarks about learning. For a learning machine we may have no control on *what* the machine learns; we need have no control over the input. What seems novel to us may just be a piece of novelty supplied by the environment!

If this seems hard to believe, consider the Darwinian model of the process of biological evolution. In this model, the process of evolution does not intrinsically create order; order only *seems* to be created because of chance variations in the input (environment) and a mechanical selection process.

We can easily mimic this process of mutation and selection on a computer. Here is a pseudo-algorithm for a theorem builder. Produce long proofs at random. (Remember it can be mechanically decided whether or not a chain of statements is a proof.) Ruelle[41] opines that the complexity of a proof depends on its *length*, after all redundancies have been eliminated. So we will retain only those proofs that are genuinely very very long. The final statement in these long proofs is a striking and not-at-all obvious theorem. (The complexity is inbuilt, and if you don't find the result striking it can be put down to your defective aesthetic sense!) If we can believe that all human beings could have been generated by this process of chance mutation and selection, why can't all theorems proved by human mathematicians be so generated? One can try various things to make this into a real algorithm: for example, start with a large store of existing proofs, and generate 'mutations' that are also proofs, or, instead of a random search, try a more directed search, etc. But the exact details of a theorem-prover are not relevant here, and these details may change rapidly over the next hundred years, say. The question is whether such a theorem prover will drive mathematicians out of their jobs.

One can, of course, object that even this mechanical process only *seems* to create order; it does not actually create order. But then the same argument could be applied to human efforts. So how can we assert human ingenuity?

The fact of the matter is this: if we accept that human beings are subject to physical laws, and if, further, we accept only a mechanical formulation for physics, there is no way that human beings (or any physical process) can create order. If we accept that human beings create order, we are back to the old problem of identifying just what part of physics must be changed.

But are physical laws mechanical? Doesn't quantum mechanics break the mechanical linkage of future to present?

## *Quantum Chance: Ontically Broken Time*

Most discussions of quantum mechanics gloss over the key fact that quantum chance is different from classical chance. This difference, concerning quantum logic, is considered in more detail in Chapters 8 and 9.

The main point here is that quantum chance is necessary, not introduced by hand; it is an essential aspect of the physical theory. Quantum chance governs the description of particles, not their time evolution, which continues to be rule-based, rather than stochastic. (People have tried to invert this, but without much success.) The wave nature of particles, or wave-particle duality, relates to the use of quantum chance to describe particles. Particles are not the geometric points one took them to be in Newtonian mechanics and relativity—they are distributed around in a way describable only by chance. (People have tried to describe this in other ways, but without much success.)

The hard part is this. Quantum chance represents reality, not our ignorance of it. Quantum chance is really the case. For all physical purposes, the particle behaves just as if it is really distributed around. Like a wave, the quantum particle can go around corners; if the quantum particle encounters an obstacle in its path, like a wave it can divide into two to go around the obstacle and interfere with itself; it can also tunnel through a barrier.

The harder part is this. Though the quantum particle 'really' does divide into two we cannot see this. What we see is always only a full particle, never parts of a particle. Suppose a coin is tossed. We do not know whether it has landed heads or tails. Looking at the coin leads to a net gain of information. After we have seen that the coin shows heads, the chance that it might show tails has vanished. This is quite all right: before looking there was a chance that the coin might show tails; we were ignorant of the state of the coin, and looking at it made this ignorance vanish. But if this chance represents reality and not just our ignorance of it, then some part of reality vanishes with the vanishing of chance. This vanishing of a part of reality is called the collapse of the wavefunction, and has been a source of great perplexity. People don't like the idea that something real can vanish. But they don't know what to do since nobody has yet come up with a better theory.

What is immediately relevant, however, is not the vanishing of a part of reality, but the *way* in which this reality vanishes. According to (orthodox) quantum mechanics, there is just no way to tell how this reality vanishes. In the classical case, the coin was really showing heads all along; we were ignorant of it till we saw what it showed. The quantum coin is really both heads and tails, until we see it; after which it becomes exactly one of heads or tails. Quantum mechanics describes only the probability of this process; it does not give a definite rule; God must play dice to decide what happens next. (People have tried to describe this as a mechanical linkage, without much success.)

We see that, according to our present-day theories, the process of seeing—the measurement process, as it is called—breaks the presumed mechanical connection between present and future. At this stage, time evolution in quantum mechanics becomes stochastic. In the classical case, the breaking of the connection between past and future concerned our ignorance: we did not know what would happen in the future, but God knew. In the quantum case, the breaking of the connection between past and future concerns reality: the future is undecided—even God does not know. Briefly, classical chance corresponds to epistemically broken time, and quantum chance to ontically broken time.

Against all this background, Penrose uses ontically broken time to distinguish as follows between man and machine. The human brain is made of real neurons, which are described by quantum mechanics. Accordingly, what the human brain does is not only unpredictable it is not mechanical or rule-based since it is non-computable in the Turing sense. Briefly, the human brain being quantum mechanical is not mechanical.

The weakness of this argument is immediately manifest. It relies upon an old definition of 'rule-based' or 'mechanical'. Turing's definition was appropriate to the technology of his times. But technology has changed, and Turing's definition will soon be obsolete. Today, it is possible to make computers based on the principles of quantum mechanics. Admittedly, such quantum computers are at a rudimentary stage—so far as marketing them is concerned—but quantum computing has been demonstrated in the laboratory. If it is quantum mechanics that makes humans creative, then quantum computers share this creativity. Indeed, if arguments of the sort given by Penrose were valid, quantum mechanics should also provide creativity and 'free will' to every electron, and by extension to all matter in the cosmos. The distinction between man and machine then breaks down in the other direction—man is no longer mechanical because machines are creative. Perhaps that is so, but does ontically broken time guarantee *any* creativity, for the key feature of quantum mechanics used by Penrose's argument is ontically broken time.

# Failure of Broken Time

## *Insufficient Indeterminism: Al-Ghazālī's Destruction of the Philosophers*

For those who find quantum mechanics difficult, there is a simpler example of ontically broken time. This example was provided by the medieval Islamic theologian and Sufi, al-Ghazālī.[42]Al-Ghazālī thought that every instant the world is created afresh by Allah. Allah is not constrained by the sequence of cause and effect. Hence, the linkage between past and future is not mechanical; for Allah could, at any instant, introduce a new creative element into the world.

Al-Ghazālī anticipated the objection that this makes everything *unpredictable*; if the world is created afresh each instant, no one could say what would happen in the next instant. He imagines an opponent who argues that one might have to say,

> 'I do not know what there is at present in the house. All I know is that I left a book there. Perhaps by now it has turned into a horse, defiling my library with its excrement.'

Or, upon meeting a stranger, one might say,

> 'It may be that he was one of the fruits in the market which has been changed into a man, and that this is that man.'[43]

In Indian traditions, such a state of affairs was called by a picturesque term (*yadrchchāvād*) which roughly translates to 'as-it-wishes-ism'. This state of affairs has also been called occasionalism (after Malebranche) or accidentalism: every time atom (or every instant) provides God with an occasion to create a fresh set of accidental properties. There could be some regularity, for these *could* be the same accidents as before: al-Ghazālī allowed that Allah may habitually create the same set of accidents. But a habitual sequence only *seems* mechanical, for one could break a habit. Apparent regularity does not imply predictability. Time seems continuous, but it could be broken.

Causal linkages between past and future break down with ontically broken time: an effect may or may not follow the cause. Al-Ghazālī's point was that effect followed cause habitually, *not necessarily*. Al-Ghazālī observed that logical necessity (in the sense of Aristotle) was different from causal necessity; hence causal necessity was no necessity at all, in the sense that Allah was not constrained by it. Al-Ghazālī argued that it was not *logically* necessary for cotton in contact with fire to burn. No doubt we always observe this to happen, but this is contingent, not necessary. Al-Ghazālī believed, as we do today, that an empirical observation pertaining to the empirical world is contingent; in al-Ghazālī's case the world was contingent upon the will of Allah. Today we would say that it is *conceivable* that cotton in contact with fire need not burn; al-Ghazālī said, Allah could create contact without burning, and burning without contact.

Planning is impossible in such an unpredictable or providential world because past and present would not decide future. There would be no rational way to judge the future consequences of one's present actions. Hence, rational choice between good and bad would be impossible, for any consequence may follow a given action.

Let us imagine a world in which time is completely ontically broken. We imagine, with al-Ghazālī's opponents, that there is not even any regularity, so the world evolves in such a way that there need be no connection at all between one instant and the next. A book may change the next instant into a horse, an apple might change into a man, and so on. Such a world would be completely unpredictable; it would be completely indeterministic. Yet there would be no place at all for voluntary action in this world, for voluntary action requires some planning, and planning would be impossible in a completely unpredictable world. One's decisions and actions now would have no connection with the future world that would come into existence. As in one of those 'miraculous' films, one might reach out for a necklace only to find that it has changed into a snake. In fact, one might reach out to find that one has changed back to an apple! In such a world it would be futile to speak about choosing rationally between different futures, for one could not bring about the future. It would be impossible even to understand such a world rationally. Conclusion: *Broken time destroys rationality without securing 'free will'*.

## The Chocolate–Ice Cream Machine

Recall that we started off with the basic problem of trying to reconcile physics with the human ability to bring about the future. The problem of reconciling mundane time with superlinear time is not solved through either epistemically or ontically broken time. *Mere unpredictability or mere indeterminism is inadequate*.

One can see this in another way. The chocolate–ice cream machine is operated by a coin. One does not insert the coin in a slot, however; the coin must be tossed. The coin may be tossed either classically or quantum mechanically. If the coin shows up heads, the machine gives you chocolates. If it is tails it gives you ice cream. What you eat is a matter of chance; there is no way anyone can predict it—it need not even be decided by physics. But one thing is certain: *you* do not decide what you will eat. You can hope and you can pray, but you have no way to influence which way the coin will land; and whether you like it or not, the machine will indeterministically ram either chocolates or ice-cream down your throat.[44] *Chance does not yield choice*. The entire discussion on unpredictability, in the literature, is quite useless for this purpose. (The only way out is to change physics so as to specify the role of the human being in this process. This presupposes a physical distinction between a human being and a complex automaton.)

## The Dancing Chief

There is yet another way to understand the inadequacy of unpredictability or mere indeterminism. *The argument from broken time applies only to the future, and not to the past*. Glance back to the picture of mundane time (p. 181). The single thick line represents the unique past that has occurred. But we may not *know* this past. Certain things about the past may remain forever doubtful. Did Einstein see Poincaré's June paper on relativity 3 weeks before he submitted his own? One can carry on the discussion for another hundred years. Even if it becomes generally accepted that he did see Poincaré's paper, there will be some people who believe otherwise. But whatever the doubt about the past we have no doubt that our efforts now cannot redo that past!

Or can we redo the past? Can we say that the picture of mundane time has not been drawn correctly? Let us apply the argument from broken time to the past. There is ignorance of the past. Moreover, we cannot retrodict it. What difference is there between this situation and that of a *really* open past?

Consider the case[45] of a tribe which has the custom that young men go to hunt lions to establish their manhood. The young men travel for two days to the lion country, hunt lions there for two days, and travel back for two days. As the young men set out, the chief of the tribe starts dancing, and he continues dancing for all of six days. He dances not because he believes that dancing has some miraculous properties, but because he wrongly believes that his dancing in this way *causes* the young men to be brave.

After four days have elapsed, we approach the chief and suggest to him that he should now stop dancing. The lion hunt must be over by now, and the party must be on its way back: the young men either have been brave, or they have not been brave, and nothing the chief does *now* can alter that. But the chief rejects our arguments. He says we will not *know* whether or not the young men have been brave until they return, and there are still two days to go for that. Therefore, his dancing continues to be effective. He cites empirical grounds to support his wrong causal beliefs. Two years ago, he fell ill, and had to stop dancing after four days; and when the young men returned, they had not been brave. He concedes that there is something to our point of view, but he maintains that if the young men will have been brave, they will have been brave just because he will continue dancing for the next two days.

But we do not believe the argument from broken time when it is applied thus to the past. We believe that one and only one thing occurred, though we may not *know* which. We do not use the equations of physics to infer an ambiguity in the present, we do not appeal to chaotic evolution to amplify this ambiguity; we simply go on making a string of further observations. In short, we believe that there is no real ambiguity in the past. (Perhaps we do not believe this about the remoter past, but at least we believe this about the immediate mundane past.) We have here exactly the situation of something being *decided*, but not *known*. We may not *know* whether or not the young men have been brave, but we believe this is already *decided*. The situation is like a mystery novel which has been written, but the book has got torn. We have only part of the book, and no way to know where the butler was when the murder occurred. But we believe that a true intact copy of the book once existed, and maybe still does.

## *Schrödinger's Dance*

In contrast, the mundane belief about the future is different. The situation is not as simple as saying that the future may be decided, but it is not known. *We* decide the future, in a sense. We believe that the way the future turns out depends upon the decision we make now. We believe that what we decide now does make a difference to at least some mundane details about the future. These 'trivial' details may be terribly important to us. We believe that the decisions we make now will decide (mundane details about) the future, usually if not always. Furthermore, we believe that our decisions may be *usually* or often habitual, but are not *invariably* so.

To put matters in another way, it is not merely a question of unpredictability. Schrödinger invited us to think of cases such as the following.

> you are attending a formal dinner, with important persons, terribly boring. *Could* you, all at once, jump on the table…just for fun? Perhaps you could: maybe you feel like it: at any rate you *cannot*.[46]

To refute this, I did jump on a chair during a seminar on Schrödinger, and the participants found this behaviour quite unexpected and unpredictable, as Schrödinger correctly thought. But unpredictability is not the only issue here, for I may have planned my behaviour a month in advance! I could not have predicted the outcome with certainty—maybe I would have lost my nerve, maybe there would have been an earthquake—but I had a reasonable level of confidence that I could accomplish this; I had a betting advantage. *There is an asymmetry in your ability to predict what I would do,* *and my ability to predict what I would do.* This asymmetry is always present in a mundane situation: if you predict whether I will eat chocolates or ice-cream, and if you tell me your prediction, I can almost surely prove your prediction to be wrong. And I am almost sure that you could do the same. (Over large spaces and large times, my expectations may be as wrong as yours, but we will examine this later.)

To summarise, in mundane life we believe that the uncertainty of the future is ontic, but we have some control over it. The future is not all unpredictable at the mundane level: others may be unable to predict what one does, but one can predict what one will do; this may not be certain, but one has at least a betting advantage over others in predicting what one will do next. We also believe that uncertainty about the past is epistemic, and we have no control over it. The past corresponds to a mystery novel we are reading, of which we don't *know* the end. The future corresponds to a mystery novel, of which we don't know the end, just because we are still writing that novel.

But there is one problem with this business of mystery novels. It is assumed that one follows the rules and does not peek at the last page. We are assuming here that the only way to know the future is through rational calculation. And is there no way to change the past? What does relativity say?

∞

## *Summary*

- The distribution of social credits assumes mundane time: that human actions bring about the future.
- This idea of a future 'coming into existence' is abolished by relativity, which permits the world only to 'be'.
- In current physics, the 'now' decides both past and future.
- Broken time has been used to try to reconcile mundane time with a future decided by 'now' + physical laws.

- Time may be broken in two ways: epistemically or ontically.
- With epistemically broken time the ‘now’ still decides both past and future, but one cannot *know* the future (or past).
- Chance breaks time epistemically; chaos helps to reconcile this chance with mechanical laws. On this view, humans are complex automatons: unpredictable but devoid of creativity.
- Time in quantum mechanics is ontically broken: the ‘now’ does not decide the future after wavefunction collapse. But neither do humans.
- Broken time only destroys rationality, without ensuring ‘free will’; unpredictability excludes human creativity.
- *Q. Is it impossible to know the future by any means other than rational calculation? Is it impossible to dabble with the past?*

∞

# 7

# Time Travel

Is rational calculation the only way to know the future? Were time travel possible, rational calculation would be unnecessary: one could *manifestly* know the future by visiting it. One could turn directly to the last page of the mystery novel and read the ending; one would not need to *infer* who the murderer was. This sort of thing sounds like an idle fantasy, and time travel used to be science-fiction stuff; but in the last decade it has become a hot topic among serious physicists, particularly relativists. A common reason for the interest is the apparently insurmountable difficulty with *space* travel.

## Rapid Intergalactic Travel

Barely a hundred years ago, people laughed at the idle fantasies of those who dreamt of flying in the air. The moon was as far as imagination extended, and even flights of fancy did not travel to the stars; nor did anyone dream of exploring the vastness of deep space. Though no longer imponderable today, these distances still seem impenetrable. The speed of light presents an impassable barrier according to the theory of relativity, which is the bedrock of current physics, as we saw in Chapter 5. Today, the human life-span rarely extends beyond a hundred years, and most people, if they live that long, turn senile before that. Those undertaking a hazardous enterprise like space travel presumably must start as adults—at the age of 18, say. That seems to limit to a diameter of about 50 light years the circuit of ordinary mortals made of ordinary matter.

## *The Limits of Rocket Technology*

Current technology limits speeds to far below those of light.

This limit is an idealised limit: today we cannot hope to achieve even a tenth of it. In fact, it would be simply astounding if we could build rockets capable of a speed even a hundredth that of light. With such a rocket, one could travel to the moon and return in less than five minutes. Compare this with the snail's pace of a supersonic jet plane which takes hours just to travel between continents on earth, or the pedestrian dignity of an intercontinental ballistic missile. A bullet, say, would be far too slow in comparison: it would be as ineffective to fire a bullet at our hypothetical rocket as it would be to throw a stone after a supersonic fighter plane.

Even with a hundred-fold improvement in technology, the exploration of deep space is out of reach.

Suppose that in one or two hundred years from now, we manage to build a rocket ten times better than the rocket imagined in the above paragraph—a rocket which takes less than 15 *seconds* to go from the earth to the moon—this rocket would take us only to a distance of about 2.5 light years. The nearest star is about 4 light years away, so that even with such a fast rocket, one would probably not live to perform the journey to the nearest star and back—setting out as a young woman of 18 the astronaut would be a doddering 98 when she returns!

Only a long-lived species could explore intergalactic spaces. Is long life *technologically* possible *now*?

Is there any way to get around these limitations? To get around these limitations, it would seem, one must either break the light barrier, and develop some means to travel faster than the speed of light, or one must break the slight barrier connected with death, and become immortal or at least long-lived—one must extend one's life span to at least a few million years.

The second possibility, in a way, is the more natural one: immortality is a natural goal of biological evolution. The argument, examined in a later chapter, is that life would gravitate towards immortality, regardless of the planet on which it evolves, so that the first advanced extra-terrestrial beings to encounter the human species very likely would already have found the secret of immortality, in the sense of being very long-lived. On our own planet, we can imagine, for example, that genetic tinkering may serve to increase life-spans. Perhaps people could at will enter into a state of hibernation; in popular fantasy, this could be artificially achieved using cryogenics. Perhaps the rocket would be a space ark consisting of an entire self-contained community which may go through hundreds of generations during the journey. Such speculations apart, is there any way to increase individual life-spans *now*?

## Twins and Triplets

The simplest way to increase life-span is to slow down the clock! According to the theory of relativity, this can be done simply by moving about; a moving clock runs slower—travel keeps both mind and body young! Since motion is relative, this immediately suggests a paradox, usually formulated as the twin paradox. Deepa and Nanda are identical twins, very hard to tell apart, except by a slight difference in their personalities—Deepa is the stay-at-home type, while Nanda is the outgoing extrovert. While Deepa stays at home, Nanda travels out on a rocket, close to the speed of light. Because of the time dilation effect of relativity, it would seem to each twin that the other is aging more slowly. Eventually, Nanda stops and returns back to earth. Which twin is now older? Or are they both the same age? According to the standard understanding of relativity, Nanda will be younger, but this has been doubted.

Time dilation due to (a) velocity, and (b) acceleration.

The time dilation may be regarded as having two components: one due to velocity, and the other due to acceleration. First, consider only the effects due to velocity. One supposes that the rocket is quickly accelerated to a high velocity, and Nanda keeps travelling for a long time at this high velocity. She is then quickly decelerated, and performs the return journey the same way.

The twin paradox suggests that time dilation due to velocity ought to cancel by symmetry.

Suppose now that each twin is equipped with clocks of identical make. Each signals to the other using light signals, sent out at equal intervals of time—as they measure it by the clocks they carry. Each will observe that the other's clock is running slow. After a few years, it would seem to each that the other twin is substantially younger. But when the reunion takes place, the light signals from the other would catch up, and each would observe that the other ages catastrophically in a kind of 'Samris effect'. (In the comic strip 'Phantom', the beautiful Queen Samris was an Egyptian queen who magically stayed eternally young, provided only that she did not fall in love. She fell in love with Phantom and promptly underwent a terrible transformation. Within moments she aged into an old hag, and was then reduced to a pile of bones, which soon crumbled to fine 3000-year-old dust.)

This suggests that the time-dilation effect due to velocity should cancel out by symmetry, and at the end there should only be a small difference of age attributable to the accelerations that the travelling twin experienced. According to the standard understanding of relativity, however, the symmetry has been destroyed by the accelerations that the travelling twin experienced, so that the travelling twin will actually be much younger.

The triplet paradox strengthens the suggestion that the time dilation effect due to velocity ought to cancel by symmetry.

One can make the situation even more symmetrical by considering a triplet paradox. Suppose the twins are only two of a triplet, the third being Vibha. Suppose that Vibha's journey exactly mimics Nanda's (as seen by Deepa), except that she goes off to the left while Nanda goes off to the right. Vibha's velocity relative to Deepa is not the same as her velocity relative to Nanda. Therefore, at the family reunion, Vibha and Deepa might disagree about Nanda's age: they may quarrel about the presence of a grey streak in Nanda's hair. Similarly, Deepa and Nanda may disagree about the whiteness of Vibha's hair. Seemingly, an absurdity can be avoided only by supposing that all three are more or less the same age. According to the standard, understanding of relativity, however, triplets only make the situation more confusing, without altering it in any fundamental way: the astronauts will return younger.

Acceleration is absolute. So no confusion attaches to the slowing down of clocks due to acceleration.

The effect due to acceleration cannot cancel out, because while velocity is relative, acceleration is absolute: there would be no disagreement between either the twins or the triplets about the acceleration that the other experienced. No particular direction in space is currently known to be privileged: so the slowing down of an accelerating clock is quite indifferent to the spatial direction of the acceleration. It is quite possible for the rocket to accelerate for half the trip, rotate around, and decelerate for the other half. Except for the moment of rotation, people inside the rocket won't know the difference.

Time gain due to acceleration can be increased.

The small difference due to acceleration could be pushed up. A recent book on time travel[1] tabulates how much time could be saved, travelling at the constant comfortable acceleration of 1 gee (which generates on the rocket a pull equal to the gravitational pull on the earth's surface). Nahin calculates that one might save up to 50,000 years this way.

Waiving questions about the procedure, these figures are still not entirely convincing. Time dilation due to velocity will not desynchronise the biological clock from the proper clock required by relativity, for a uniform velocity, however high, is not locally discernible. But acceleration is locally discernible: it will affect the biological clock. However, it is not clear how this would affect the life-span: if one suddenly starts weighing twice as much as one normally does, this would make all muscles including the heart muscle seem a little inadequate! (It won't do to perform the journey at 1 gee because the stay-at-home twin presumably stays back on earth and is anyway experiencing 1 gee.) Will our own biological clock stay synchronised with the proper clock at 2 gees? Perhaps it will do so; perhaps it will counteract the strain on the muscles. But it is equally possible that the life-span may be adversely affected—- cosmonauts stationed on Jupiter may even die earlier, for they may find themselves grossly overweight.

In any case, the one-sided slowing down of the clock, due to either velocity or acceleration, does not help very much. As measured on earth, the round trip time to a star a million light years away cannot be less than a couple of million years, by the fastest possible rocket. Even if the astronaut lives to perform the journey, we, on earth, would be long dead by the time the astronaut returns. Why should NASA invest money now for possible returns a million years later? Clearly, a more practical method is required.

## *Tachyons*

Tachyons or information may travel faster than light on the current theory.

What about the other possibility? Can one travel faster than the speed of light? According to the current theory (of relativity), the answer is no. The current theory may prove to be, and hence in all likelihood is, wrong. This is universally the fate of all scientific theories, at any point of time! Nevertheless, it would be unscientific to speculate on the failure of the current theory without first constructing a better theory! So it is better to confine the arguments to the current (admittedly, possibly unsatisfactory) theory of relativity till one has a better one. The important thing is that the current theory does *not* rule out the possibility that *something* (tachyons, information) may travel faster than light. (From now on, all arguments will refer to the current theory without explicitly saying so.)

Particles which travel faster than light are called tachyons.

But we are running ahead of the argument. The point is that travelling faster than light means travelling in time. Particles which travel faster than light are called tachyons (from the Greek *tachys* meaning swift). Einstein stated that particles faster than light contradicted the theory of relativity, so that 'Velocities greater than that of light have…no possibility of existence'.[2] It was later pointed out that if tachyons exist that would contradict Einstein, but not the theory of relativity.[3]

Three species of non-interchangeable particles: tachyons, photons, bradyons.

To be sure the velocity of light remains an impassable barrier. Particles slower than light (bradyons, particles of which ordinary matter is composed) cannot be accelerated to a speed equal to or greater than that of light. But particles of light (photons) do travel at the speed of light—they are able to do this because they are 'created' at the speed of light. Photons can neither be speeded-up nor slowed down—they can only be destroyed or absorbed—and throughout their life they must travel at the speed of light. The same thing applies to tachyons. The velocity of light is an impenetrable barrier for tachyons in the sense that tachyons cannot *slow* down to a speed equal to or below the speed of light.[4]

Tachyons may travel backwards in time.

Travelling faster than light disturbs the time-sequence of events: it may be preserved, nullified, or reversed. For some observers, the tachyon would *simultaneously* seem to be everywhere it ever is, as if it had an infinite velocity. For other observers, the tachyon would seem to be travelling into the past! That is, if a tachyonic bullet is fired from a gun, one observer might see the bullet go off in the normal way, another might see the bullet hit the target instantly, while a third would see the bullet leap from the target into the gun! Tachyons have many such peculiar properties, though no tachyon has been observed so far.

The reinterpretation principle.

Why has no tachyon been observed? One believes that physical theories respect the principle of parsimony; they do not have redundant features. Hence, entities permitted to exist by the theory *must* exist, else the theory must be changed. Neither alternative being palatable, people searched for some physical principle which prevents the existence of tachyons. One such principle is that energy must be positive: if unboundedly negative energies were permitted, one could extract limitless energy from any source; and an infinity of energy, as we have already seen in Chapter 6, makes the whole concept of energy meaningless. Tachyons may carry negative energy, but there is a saving grace: *tachyons carry negative energy exactly when they travel back in time*. This means negative energy would disappear from the 'source' of a negative-energy tachyon at a *later* point of time, and reappear in the 'sink' which absorbs the tachyon at an *earlier* point of time. The 'source' of negative energy gains energy, while the 'sink' of negative energy loses energy. By interchanging the labels 'source' and 'sink' we see that this is just the ordinary process by which energy lost at an earlier time reappears at a later time. Hence the reinterpretation principle:[5] 'negative-energy particles travelling backwards in time' is only a convoluted mathematical description of a more ordinary process—positive energy particles travelling forward in time.

The tachyonic anti-telephone.

Following this logic, some experiments were performed to detect tachyons, but the results were negative. People again searched for principles that blocked the existence of tachyons. This time they appealed to the principle of 'causality'. It was pointed out that the experimental setup to detect tachyons was such that had these experiments succeeded one could build a tachyonic anti-telephone, which could be used to *signal to one's own past.* By speaking to one's future self over such an anti-telephone, one might, then, confidently predict the supernova that would be sighted in the sky tomorrow.

Shakespeare anti-telephones Francis Bacon, and dictates *Hamlet*. Does that make Bacon the author of *Hamlet*?

Rather early in the century, it was observed by the physicist Tolman[6] that the ability to signal to the past would result in causal paradoxes. Tolman rejected faster-than-light particles for this reason. The tachyonic anti-telephone is associated with a similar paradox. Suppose Shakespeare anti-telephones Francis Bacon, and dictates *Hamlet*. That would mean that Francis Bacon has physically written down *Hamlet* earlier than Shakespeare. On the strength of this priority, should Bacon be regarded as the real author of the play? Benford et al.[7] claimed that Shakespeare ought still to be regarded as the author because he was the one who was in control. Benford et al. conclude that experiments to detect tachyons can only yield negative results until a truly radical resolution of this paradox is found. We will resolve the paradox later in this chapter.

Of the two ways of space travel (immortality and instantaneous transfer of information) only the second is available *now*, and that necessarily involves time travel.

To sum up the preceding argument: within current knowledge there are just two ways to explore the depths of space. The first is to travel slower than light, but to acquire the secret of immortality, or at least to learn how to postpone death for a long time by suitably altering one's genes and behaviour, or subjecting oneself to huge accelerations. The second is to transfer information to the person instead of trasnporting the person to the information. Information *can* be transfered at a speed faster than light. One way to do this (not necessarily the best way) would be to use hypothetical tachyons which move faster than light—but any way of transfering information faster than the speed of light would necessarily involve time travel. The first method may take several human generations; the second method is the only one that can possibly be available *now*. That is, on the current theory, for anyone who plans to travel about today, *exploring deep space necessarily involves time travel*. Space agencies have little choice but to give grants to scientists to study time travel. (Presumably, the space agencies are alive to the possibility that time travel may make the atom bomb obsolete—for one could perhaps travel back into the past and kill off a single ancestor in the past to 'cleanly' destroy an entire race today. But we will return to this question a bit later.)

# Time Machines

## *Time Travel without Machines*

Light travelling back and forth in time permits instantaneous transfer of information across space.

The strange thing is that, unlike crossing the light barrier, the current theory does *not* prohibit travelling in time. This prohibition must be added on, *ad hoc*, to the theory. The moment one acknowledges the possibility of time travel, there is a third way to explore the depths of intergalactic space. In this kind of 'travel' the body is not moved to the source of information: as in a visiphone the information is brought to the body. Electromagnetic waves (photons) are routinely used to transmit information, as in the radio or TV. Time travel requires a pair of photons: one travelling forward in time, and the other backward in time. (Photons travelling backward in time are called advanced photons.) With such a pair, it is possible, in principle, for information to be transferred *instantaneously* over arbitrarily large distances. I regard this as the method of choice, for reasons that will presently become clear.

## *H. G. Wells' Time Machine*

But reality, today, is centred around machines. If it is real one should be able to build a machine around it! Amongst the better known machines, the earliest was the fictional one which was the theme of H. G. Wells' novel, *The Time Machine*. This is how Wells describes it:

> a glittering metallic framework, scarcely larger than a small clock, and very delicately made. There was ivory in it, and some transparent crystalline substance…'This little affair', said the Time Traveller, …'is only a model…you will notice that it looks singularly askew, and that there is an odd twinkling appearance about this bar, as though it was in some way unreal…Also, here is one little white lever, and here is another…This lever, being pressed over, sends the machine gliding into the future, and this other reverses the motion. This saddle represents the seat of the time traveller.'

Wells here sketches what Spengler[8] calls 'the figure of the modern sorcerer—a switchboard with levers and labels at which the workman calls mighty effects into play by the pressure of a finger without possessing the slightest notion of their essence'. Alas, this masterly sketchy description won't help us to build the machine, and the full-scale version got lost along with the Time Traveller.

But part of the explanation that Wells gave in 1895 for the possibility of time travel will still hold today. Wells was a science graduate who kept himself abreast of the latest scientific developments. He had no doubt heard about the speculations of the great mathematician and genius, Bernhard Riemann—about time as the fourth dimension. The chief difference between this notion and the relativistic notion of time as the fourth dimension is that in Riemann's idea time did not mix with space, because people wrongly thought that length could be measured without a clock (p. 159).

Wells used Riemann's idea of time as the fourth dimension.

Wells' account of time as the fourth dimension runs as follows. He starts by recalling school geometry, pointing out that a line of thickness *nil* has no real existence, and that a mathematical plane is similarly an abstraction. 'Nor, having only length, breadth and thickness, can a cube have any real existence.' The cube seems solid enough, but surprisingly it has no real existence because one is supposing here that it does not endure for even the smallest fraction of an instant: reality requires 'Length, Breadth, Thickness—and Duration'. A series of photographs of a single man, '[one] at eight years old, another at fifteen, another at seventeen, another at twenty three, and so on' are *sections:* three-dimensional representations[9] of a real four-dimensional being.

An SF story written a hundred years ago is not the best place for academic nitpicking. But some people have done exactly that. To travel to the day-after-tomorrow, doesn't one have to pass by tomorrow? In that case, how would the time machine work at all? It would not shimmer and disappear. It would stay where it was, today, tomorrow, and the day after.[10]

I thought that any SF fan knew the answer to this question. But such is not the case.[11] One has only to recall Wells' analogy between ourselves and Flatlanders: one can freely move forward and backward on the surface of the earth, but, before balloons, moving *up* was out of question, 'save for spasmodic jumping and inequalities of the surface'. On depressing the lever the Wellsian time machine moves *up and out*: into the fifth dimension of hyperspace, which we cannot see. Accordingly, the machine shimmers and vanishes, like a Flatlander plucked perpendicularly out of the surface he inhabits, into three (four) dimensional space. Chased by an angry mob,[12] one *could* use a time machine; this would *not* be the same as trying to escape danger by taking a nap. It would be more like an insect which escapes the common wall-lizard by jumping off the wall, and landing at a different place.

If the time traveller disappears into the fifth dimension, how does the procession of the ages at all register in his consciousness (as described by Wells)? Somewhat like an early model aircraft taking off, the machine keeps bouncing, making a few spasmodic contacts with the usual world of four dimensions. This is an imperfect analogy, because the time machine is *designed* to bounce. (How else would the time traveller steer?) Moreover, the time machine's contacts with the world are almost instantaneous, so that the machine has almost no real existence in the world at these instants—Wells' explanation is that it has a sub-critical existence, which he calls presentation 'below the threshold…diluted presentation'. Each bounce is not of *nil* duration, but of so small a duration as to be imperceptible. Just as the machine 'winks' in and out of existence in the world, the world seems to 'wink' in and out of existence for the time traveller. Nevertheless, these instantaneous

**Box 7: The pace of a time machine**

May one speak of something like the 'pace' of the time machine? This is an idea that philosophers have found endlessly amusing. Surely, the speed of any machine is *in* time? What, then, is meant by the speed of a time machine? Let us sum all the tiny little durations of those instants that the Wells' machine 'bounces' through the real world during its travel. (The sum might still be a small fraction of a second.) The 'pace' of the machine increases as the total duration of these 'bounces' in a day decreases. The total duration may decrease because (a) the number of bounces decreases or (b) the duration of each bounce decreases. One may imagine that the effect, on the time-traveller's consciousness, would be not unlike the speeding up of a video film when (a) the length of the tape is reduced by chopping off large sections of it, and (b) the playback speed is increased. This notion of speed may not coincide with the notion of speed in Newtonian mechanics, but that is a matter of nomenclature. A word may have more than one meaning in natural language, just as two different persons may have the same name.

presentations are recorded in the time traveller's brain as a series of sample snapshots: discrete frames to which the brain imparts a certain continuity.[13]

The moral of the story is that the time traveller *can* travel to the next century without passing through every instant in-between. The machine would *not* appear to be always located at the same place; it would appear to have disappeared, until it reappears in the future.

Some of these considerations are, in a way, twice removed from reality because they concern speculations about an admittedly speculative piece of fiction. Wells' explanation is about *why* the idea of time travel is reasonable; the explanation does not help us to understand how the machine is constructed. So let us turn to a more realistic idea of time travel.

## *Gödel's Cosmic Time Machine*

Does the directon of time remain the same throughout the cosmos? Gödel showed it might not.

In Chapter 6 we have already met the famous metamathematician Kurt Gödel, and his impossibility theorem which frustrated David Hilbert's programme to geometrise arithmetic. Gödel tried to do for physics (i.e., general relativity) what he had done in mathematics: show the falsity of some very basic and cherished assumptions. In this case, the basic assumption concerned time. Most relativists before Gödel tended to assume that the notion of time was global; that it was a cosmological notion. Gödel constructed a cosmos with a local notion of time, but no global notion.

The Gödel cosmos is not recurrent for it has no closed timelike geodesics, but it has closed timelike curves.

Using the Hilbert–Einstein equations he constructed a model in which locally there is a well-defined time-direction at any point, but globally it is impossible to define such a direction. One may not even speak of an 'instant of time' in Gödel's cosmology. Gödel's cosmos is *not* an 'eternally recurrent ' one: left to itself, no world line of matter ever returns to the same point of space and time. But this is somewhat like saying that left to itself, a stone always moves downhill. It is certainly possible for a person to climb hills. Similarly, in the Gödel cosmos, one may conceivably build a rocket which can take one round the cosmos and bring one back to the same *time* and place. This kind of time machine is different[14] from Wells' time machine: for the rocket stays in this world all the time. Gödel calculated that a round trip in this rocket would require a vast amount of energy,[15] so vast that he thought that it would be impossible to build an actual time machine in his cosmos.

Contrary to observations, the Gödel cosmos does not expand but rotates.

Gödel's model also seems empirically false. One reason is that it does not expand. Another is that the Gödel cosmos rotates, but there is no empirical evidence for cosmic rotation.[16] But this need not blind us to the point that he was making: namely that one could not infer anything about the global nature of time from the Hilbert–Einstein equations and the local observation of time asymmetry.

Indeed, later models (and earlier ones like those of de Sitter) can get around some of these 'difficulties' with, for example, the amount of energy required. These models have closed timelike *geodesics* so that no energy at all is required to go around the cosmos, and return to the same place and time.

## *The Wormhole Time Machine*

More recently, the wormhole time machine has been seriously proposed by Kip Thorne[17]—a well-known relativist from Caltech—and what has jokingly been called his Consortium. The equations of the general theory of relativity were formulated by trying to copy, as closely as possible, the 'local' aspect of Newtonian physics. We saw earlier that Newtonian physics is local and instantaneous, and cannot correctly be used to say anything about the global structure of time. Analogously, general relativity does not tell us how spacetime is globally connected. Like handles on a teacup, there may well be *wormholes* in spacetime.

Apples, worms and hyperspace.

What this means is that the old sci-fi idea of building rockets which jump through hyperspace is roughly right. Imagine that spacetime is the surface of an apple; then hyperspace (an aid to the imagination, it need not exist) is the inside of the apple. A worm which starts from the surface and comes out on the other side, say, has made a wormhole in the apple. Wormholes in spacetime are similar tunnels 'through hyperspace'.

A short wormhole may connect distant regions of spacetime.

It may happen that the two mouths of a short wormhole connect two points in spacetime that are ordinarily very far apart. Such wormholes may well already exist in spacetime, and may have existed since the big bang. In Carl Sagan's novel[18] *Contact*, travel to the star Vega is achieved through such a wormhole, which has been in existence since prehistoric times, and may have been made by an advanced extraterrestrial civilisation.

The characters in the story travel through some sort of 'tunnel' that takes them in less than an hour from Earth to an orbit around the star Vega. This sort of thing requires that the wormhole be traversable by ordinary human beings. Large stars may eventually collapse to form black holes, but the wormhole associated with a black hole is not traversable. A black hole has a horizon, a one-way membrane: normal matter can only fall through a black hole but can't come out of it. Going across this sort of wormhole may take an infinite amount of time. Someone falling into a black hole would be flattened by huge accelerations, and torn apart by huge tidal forces. (Tidal forces are accelerations that differ on different parts of the body.)

A ride through a traversable wormhole should be a comfortable two-way journey performed in, at most, one year.

What one requires of a traversable wormhole is a comfortable journey. First of all, it should be possible to perform the journey both ways: there should be no horizons or one-way membranes. Second, it should be possible to perform the journey in a reasonable period of time, say one year at the most.[19] Third, the accelerations and tidal forces that one experiences should not exceed the acceleration due to gravity that one is accustomed to. The Hilbert–Einstein equations admit many solutions satisfying these constraints.

Can a wormhole be made by an arbitrarily advanced civilisation?

Can one, then, make a wormhole? Yes, according to Thorne, if 'can' is taken in the sense of the limits imposed by current scientific theory rather than current technology. An arbitrarily advanced civilisation, for instance, would be able to overcome both the above limits of 5 and 50 light years. The members of this civilisation could very well travel large distances out to space because, while the theory of relativity restricts the speed to below that of light, nothing that we know theoretically restricts the life-span. Likewise, theory does not *prohibit* wormholes, though they may be difficult to build. What theoretical and practical difficulties would such an arbitrarily advanced civilisation face in building a wormhole?

Wormhole diptheria.

The main theoretical difficulty in making wormholes is that wormholes seem very susceptible to something worse than diptheria. The 'throat' of a wormhole quickly constricts, and pinches off the connection between the two mouths. The theory suggests that wormholes die almost as soon as they are born.

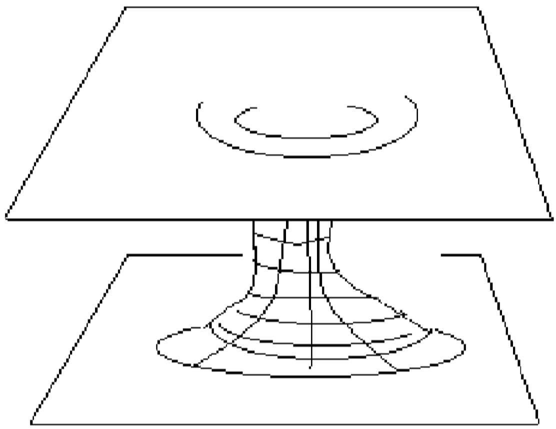

**Fig. 1: A Wormhole in Spacetime**
The wormhole may connect different parts of our universe or it might connect different universes. Which possibility occurs depends upon the way in which the spacetime manifold behaves elsewhere, i.e., whether or not the 'upper' manifold 'eventually' folds back to join the 'lower' one.

Forcing the throat of a wormhole to stay open needs exotic matter.

Can one make a wormhole traversable? Can one somehow prevent a wormhole throat from being pinched off? Can one somehow force the throat to remain open? One can, but this needs a tremendous amount of repulsive force. Such a force might be generated perhaps by an ultra-strong magnetic field. The magnitude of the repulsive force creates a difficulty because the force corresponds to energy with a negative sign. To keep the wormhole throat opened, and flaring outward, as shown in Fig. 1, the energy density of the magnetic tension used to keep the throat open must exceed the energy density of the throat material; the net force must be repulsive. But this means that the total energy density must seem negative in some reference frame (in the reference frame of an observer travelling close to the speed of light). The hypothetical species of matter needed to keep the wormhole throat open is called ‘exotic’. The odd thing about ‘exotic’ matter is that, in some reference frame, this matter will seem to have negative energy, and positively amusing properties.[20]

Exotic matter violates the weak energy-condition.

So what is wrong with negative energy? It is exactly like repulsive gravity. It can be used to set up a gravitational screen[21] (just the sort of thing that must be excluded to permit Hawking’s interpretation of singularities as a potential beginning or end of time). Though negative energy is counter-intuitive, the equations of physics do not prohibit the existence of negative energy, and such a prohibition must be imposed by hand, as in singularity theory. The particular energy condition violated in wormholes is known as the weak energy-condition.

Fluctuations of the quantum vacuum.

Quantum field theory shows how negative energies may occur. There is an actually observed effect called the Casimir effect, after the Dutch physicist Hendrik Casimir who predicted it in 1948. In quantum theory the conservation of energy holds only on the average, and is not absolute. Statistical fluctuations may occur, and the Heisenberg (energy-time) uncertainty relation allows larger violations of energy conservation for shorter durations. The quantum vacuum is thus not quite a vacuum: its energy density is zero only on the average, and the energy at any instant goes on fluctuating. One may make these energy fluctuations more concrete by thinking in terms of the constant creation and destruction of particle and anti-particle pairs, which appear and disappear in the vacuum.

The Casimir effect.

Casimir’s idea was that these noisy fluctuations of the quantum vacuum could be modified, if the vacuum were located inside a pair of parallel conducting plates. In quantum mechanics, each particle is associated with a wave; the presence of the parallel plates ensures that, in this vacuum layer, only those particles appear which have wavelengths that fit correctly (so that an integer times the wavelength equals the plate separation). If one ties down two ends of a string, as in a guitar, only certain notes will be heard, when the string is plucked. Photons with wavelengths larger than the plate separation do not appear, and this modifies the energy density of the vacuum so that the average energy-density turns negative.

Quantum foam—used to create negative energy to stabilise a wormhole.

That is, using the Casimir effect, one may produce negative energy virtually out of nothing (the quantum vacuum)! The theory of quantum gravity (it is not quite a theory as of now) suggests that these ideas may be applied to spacetime. On a large scale, empty spacetime would look like—nothing. On a very small scale, smaller than the size of atoms and even nuclei, smaller than anything we know—called the Planck scale (this also means a very small time)—larger energy fluctuations would arise. The placid nothing of empty spacetime would bubble up into a 'quantum foam'. The properties of this quantum foam may be modified by the curvature of spacetime: e.g., near a black hole. (Roughly speaking, a black hole is believed to evaporate for this reason.) It is also conceivable that an arbitrarily advanced civilisation could reach into this quantum foam, and modify it, *a la* Casimir, to create the negative energy densities required to stabilise a wormhole. Let us suppose, for the sake of argument, that this has been done. What would have been achieved?

The wormhole combined with the twin paradox yields backward time travel, though not to times before the wormhole was created.

A short wormhole connecting distant regions of spacetime allows rapid interstellar travel; in fact, faster than light travel. Is this a one-way trip into the future? Or does a wormhole permit also backward time travel? A wormhole could be used for backward time travel as follows. Suppose, to begin with, that the two mouths of the wormhole are synchronised like the clocks of the two twins. Let one mouth of the wormhole be taken on a 'twin-paradox' round trip. This might be accomplished, for instance, by dragging the mouth of the wormhole using an asteroid (something which an arbitrarily advanced civilisation could do). During this round trip, the wormhole itself does not stretch, and its length remains constant. How this seemingly paradoxical thing might be achieved is made clearer by Fig. 2. On returning, the two mouths of the wormhole are no longer synchronised. Travelling across the wormhole, then, one can travel into the past.

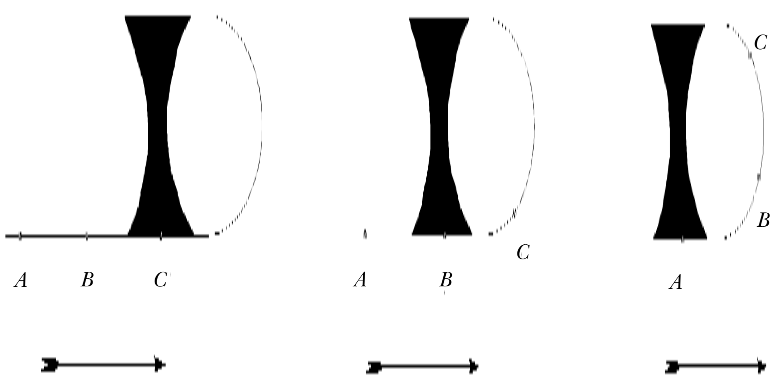


**Fig. 2: Moving the Mouth without Stretching the Throat**

The points A, B, C move across the wormhole mouth as seen from hyperspace. As seen from the real universe, it would seem as if the mouths of the wormhole are in relative motion, while the length of the wormhole remains fixed.

One cannot, however, use a wormhole time machine to travel back into the past before the wormhole came into existence. This means that one will be unable to use wormhole time machines to hunt *Tyrannosaurus rex*, unless these machines had already been created millions of years earlier by an arbitrarily advanced civilisation.

## *Chronology Protection*

Any time machine which enables travel back in time must be associated with (1) negative energy, and (2) closed loops in time.

The wormhole time machine is a concrete example of a time machine. But any time machine which travels back in time has two features. The first is the inevitable association with negative energy. Kip Thorne is a bundle of positive energy. If Thorne is put on a time machine and sent back in time, some energy disappears now and appears at an earlier time. The situation is equivalent to a negative-energy Kip Thorne travelling forward in time. The second feature of such time machines is that they can be used to execute a closed loop in time. This goes against Stephen Hawking's chronology condition which we encountered in Chapters 2 and 3.

Hawking's chronology protection conjecture

Hawking has responded by arguing that chronology will be protected. The construction of the wormhole time machine requires an appeal to quantum gravity to produce the material required to stabilise the wormhole. Accordingly, Hawking uses quantum gravity to make plausible his chronology protection conjecture, viz., that there are no closed loops in time. 'It seems there is a chronology protection agency, which prevents the appearance of closed timelike curves and so makes the universe safe for historians... *The laws of physics prevent the appearance of closed timelike*

> *curves*.'[22] Hawking admits that he does not have a proof (in fact there isn't even a proper quantum field-theory in curved spacetime on which to base the proof), but the idea of the conjectured proof has familiar ring to it. Something will circulate round the closed time loops and generate a contradiction. In this particular case, the something is not the argument itself but energy which will circulate, leading to a blow up.[23]

A hundred years ago, some people thought that man would never fly through the air. They regarded the following argument as a clincher: had God wanted man to fly through the air, He would have equipped man with wings. Since He didn't do that, it would be contrary to His desire for man to fly, and things contrary to His desire could obviously not take place.

So, today, if one can fly in the air, and travel to the moon, is there any reason why one can't travel through time? Clearly, talk of God will not do any more. But God can be substituted by the 'laws' through which he operates: the laws of physics or Hawking's 'Chronology Protection Agency'. Obviously one cannot do anything contrary to the laws of physics!

Nevertheless, these 'laws' must be interpreted for us by physicists, and Hawking's argument has some strange features. Hawking argues that chronology is protected, among other reasons, because the blow-up of energy might lead to a classical singularity. But what is a singularity? We have seen Hawking's belief that a singularity is a point where the laws of physics break down—where, in fact, the laws of physics ensure their own breakdown. Setting aside all the other difficulties we went through in Chapters 2 and 3, we have also seen that the 'laws of physics' do not do anything of the sort on their own: they are aided and abetted by conditions such as the chronology condition—that there are no closed timelike curves. That is, Hawking appeals to the existence of classical singularities, suitably interpreted, to make plausible his chronology protection conjecture, while he appealed to the chronology condition in his attempted proof of the existence of singularities. In this singular retreat from postulate to conjecture, we have a unique situation of a conjecture supported by (claimed) results obtained earlier by postulating it!

This sort of thinking may seem distinctly unsatisfactory, but we must examine it seriously for it comes from one who 'was born on the anniversary of Galileo's death, holds Newton's chair…and is widely regarded as the most brilliant theoretical physicist since Einstein'.[24]

There is a cultural malaise here in this desire to prohibit closed time loops in one way or another, a cultural malaise at the bottom of which lie the paradoxes of time travel—the same sort of paradoxes that confronted Augustine.

# The Paradoxes of Time Travel

## *The End of the Mystery Novel*

Let us recall Augustine's quibble about fatalism (Chapter 2, p. 49). God has foreknowledge of the future, but man does not; hence man's actions are 'free'. Reconciling God's foreknowledge of the future with human responsibility is very similar to reconciling the 'laws of physics' with the human freedom to experiment. Let us recall Popper's argument from chaos (Chapter 3): even Laplace's demon (the best possible supercomputer) cannot calculate the future, and a future which cannot be calculated is indistinguishable from a future which is open. Let us recall Penrose's similar argument (Chapter 3) from computability: the future is too complex for computers to calculate; and if all else fails, quantum mechanics will do the trick. Let us recall Hawking's argument (Chapter 3) from operationalism: 'the clearest operational test of an open future is this: can you predict it?' All these arguments are like the mystery novel: the book (of the future) has been written, but is as good as unwritten for one doesn't know what is at the end.

Time travel allows one to see the end of the mystery novel, and so is the end of all such mystery-novel arguments: ignorance of the future cannot be equated with the freedom to bring it about. Suppose you travel into the future, and learn that tomorrow you are going to die in a car accident; you could then avoid going out tomorrow, and prevent the accident. But then what you learnt about the future was false, so did you really travel into the future? Or else you really did travel into the future, and, despite your prior knowledge, you are somehow unable to prevent that car accident from taking place. In that case when were you free to bring about the future? And of what use is it to you to know the future? (The question of 'use-value' is best set aside for the time being, unless one has a particular urgency to convince a granting agency that time travel will help to unveil the Enemy's plans well enough in advance to abort them.)

## *The Grandfather Paradox*

The same frustration confronts the time traveller into the past. Tim, the time traveller, had a deprived childhood, being always short of money. The tragedy was that Tim's grandfather was rich, but he thought Tim's father to be a flippertygibbet. A day before Grandfather died an untimely death, he made a nasty will in a fit of anger. Tim wants to go back into the past and kill Grandfather a day before he actually died, to prevent him from making that will. This would hardly amount to murder, for Grandfather was anyway due to die the next day! Moreover, thinks Tim, this would not only restore to him a less-deprived childhood, he could live his future life more comfortably with all that ancestral wealth.

But if Tim can travel back in time to kill Grandfather a day before 'he was due to die', he can also travel further back in time and kill Grandfather several years before 'he was due to die'. That is exactly what happens. Before bumping off Grandfather, Tim confronts him and tells him that he can live for another day if only he will not sign that will. But Grandfather retorts nastily. Tim has inherited Grandfather's temper. In a fit of anger, Tim decides to go all the way back in time and kill Grandfather when Grandfather was an infant, and thus deprive Grandfather of *his* childhood. ('Serve the old codger right!') Angry as he is, Tim does not stop to consider the consequences. If Grandfather died before he had a chance to grow up, then Tim's father, and therefore Tim himself, could not have been born. So who killed Grandfather?

The other possibility is that try as he might, Tim is unable to change the past. He takes plenty of target practice, and becomes a champion sharpshooter; but, on that fateful day, he misses, for some trivial everyday reason, like the Jackal. Grandfather dies only on the day 'he was due to die'.

There are many variants of the grandfather paradox. There is autofanticide (killing oneself when one was an infant), and there is the matricide paradox (one kills one's mother, for motherhood is surer than fatherhood). These variations may be used to suit one's taste of whom to kill in order to destroy oneself—the basic point remains the same.

In short, time travel seems fatal to 'free will': if one travels to the future, the mystery of the future stands revealed, but that puts an end to one's freedom to do something to prevent the accident tomorrow (because according to Augustine, Popper, Penrose, Hawking,..., one's 'freedom' to prevent that accident tomorrow depends on our remaining ignorant of the future). On the other hand, if one travels to the past, one finds that one can do nothing there either, for the past cannot be changed.

## *Closed Causal Chains*

There are two other kinds of paradoxes. The first is that of a closed causal chain.[25] Suppose Tim has a flash of precognition, a dream perhaps: he sees himself winning a lottery ticket in the future. Motivated by this, Tim goes out and buys a lottery ticket, which wins. One could say that the future event of Tim winning 'caused' the flash of precognition, which induced Tim to go out and buy a ticket, which 'caused' Tim to win. The paradox is this: how did the chain get started?

It may seem that we cannot really call the future event of Tim's winning as a 'cause', since a 'cause' must be earlier than its effect. But this is merely a matter of nomenclature. Even though Shakespeare dictated *Hamlet* over the tachyonic anti-telephone to Bacon—thereby giving Bacon priority—we saw that it was thought quite reasonable to continue regarding Shakespeare as the author, for he was the cause in the sense that he controlled the process. The question is whether a theory of this kind is reasonable.

One very interesting property of this closed chain of causes is this: every event has a cause, but there is no first cause. Accepting the reality of a closed chain of causes would invalidate the first step in an old argument about the existence of God, which links creation to first cause. (This argument was considered in Chapter 3, p. 89). Every part of the closed chain has an explanation, but the whole chain has no explanation. Thus, even if we were able to assign a cause to everything in the cosmos, we could not, from that, infer that the cosmos as a whole has a cause.

This kind of closed chain of causes has been called *the bilking argument* (to 'bilk' means to cheat in the game of cribbage). We seem to be getting something out of nothing here. As another example, consider a book on time machines. The book travels to the past on the machine so that it can be read, the time machine built, and a book about it written. We know how the machine was built (because a 'how to do it' book was available). We know how the book was written (because one had the experience of building a machine). We know how the book travelled back in time (because the time machine was there to carry it back). How did the book get written in the first place? There is no first place, and no answer to that question.

As yet another example, reconsider the tachyonic anti-telephone. After jotting down *Hamlet,* Bacon mails it to Shakespeare so as to reach Shakespeare just before he wrote *Hamlet*. Finding the manuscript somewhat damaged in transit, Shakespeare promptly sits down and makes a copy; that is how Shakespeare came to write *Hamlet*! We know how Bacon wrote *Hamlet* (because Shakespeare dictated it over the anti-telephone), and we know how Shakespeare wrote *Hamlet* (because he got a copy of it from Bacon). But how did *Hamlet* get written in the first place?

## The Wheeler–Feynman Paradox Machine

The bilking argument may be modified to create a logical paradox. This is described in another one of Frederic Brown's Zen-SF stories, *Experiment*.[26] The inventor calls two friends to demonstrate his time machine. He sets the time machine to five minutes in the future, and drops a cube into it. The cube disappears and then reappears five minutes later. The inventor then demonstrates how the machine travels into the past. He sets the machine to travel five minutes into the past, and announces that he will drop the cube into the machine at 3 p.m.; till then he will hold the cube in his hand. Sure enough, the cube that he holds in his outstretched hand disappears at five minutes to three. The inventor tells his friends that the cube will reappear in his hand at 3 p.m. when he will drop it into the machine. The three contemplate this. 'But', asks a friend, 'what if you decide not to drop it at three?' When the cube reappears at 3 p.m. in the inventor's hand, the inventor hesitates. The Universe disappears.

This is only a slight variant of the grandfather paradox. If information of the future travels into the past, can one prevent that particular future from coming about? The original idea of the Wheeler–Feynman paradox was to eliminate human intervention, hence presumably all questions of free will. The logical paradox was to be achieved by mechanical means; and it applies also to time travel without machines. The (paradox) machine is designed as follows.[27]

Two charged particles, *a* and *b* are located at a distance of 5 light hours. A pellet moving towards *a* will strike an arm and accelerate *a* at 6 p.m. The effect of this acceleration will be communicated to *b* at 11 p.m. via retarded effects, and 1 p.m. via advanced effects. The advanced signal starting from *b* at 1 p.m. will arrive at *a* at 8 a.m., causing a slight premonitory movement of *a*. The machine is completed by supplying a shutter and a detector. If *a* moves in the morning at 8 a.m., the shutter blocks the action of the pellet, to prevent the acceleration of *a* at 6 p.m.; otherwise the shutter allows the pellet to strike and accelerate *a* at 6 p.m.

We are now left with a puzzle; if *a* moves at 8 a.m., why did it move? For the pellet did not strike *a* at 6 p.m., and so *b* was not accelerated at 1 p.m. so *a* should not have moved at 8 a.m. If, on the other hand, *a* does not move at 8 a.m., why did it not move? For the pellet did strike *a* at 6 p.m., and so *b* was accelerated at 1 p.m., so that *a* should have moved at 8 a.m.!

# Resolving the Paradoxes

## *Cosmic Disgust*

The simplest way out is by legislation. As with the chronology protection conjecture, one imposes a fiat to prevent the paradoxes from arising in the first place. The science-fiction analogue is cosmic disgust: the cosmos will defend whatever happens to be the theory of time in one's culture, otherwise the cosmos threatens to disappear, in sheer disgust. But this leaves one wondering whether there is any reason why there cannot also be a cosmic disgust against theories of cosmic disgust!

## *The Block Universe*

This is a natural resolution of the paradoxes of time travel within the general theory of relativity. In the theory of relativity, one may not continue to regard the world in the usual linguistic way as a procession of now-s. In the special theory of relativity, we saw how observers moving relative to each other will not agree on the events which constitute ‘now’; hence past and future might get mixed. To describe this sort of thing, relativity denies that the past has ceased to exist and the future is yet to come into existence.

In a famous letter, written a few months before his own death, Einstein consoled the family of his friend Besso, by suggesting that Besso continued to exist somewhere. Relativistically, past, present, and future, all coexist equally; that is, provided we can at all divide the world into past, present, and future. (In the Gödel universe, there cannot be *any* universal notion of now; hence the Gödel universe cannot even be divided into past, present, and future.)

In the famous and much-quoted words of Hermann Weyl ‘the objective world simply *is*, it does not happen.’ Relativity theory deals with *world-lines*: entire past and future histories of particles. The nature of these world-lines is decided by the evolutionary equations of the theory and the nature of the interaction between particles. There is nothing left to be decided by humans. Such a completely deterministic picture, like that of Laplace, is called the block universe: the entire universe exists as a single block with no parts, so no part of it either comes into existence or goes out of existence.

The paradoxes are resolved in the block universe as follows. There is no question of killing Grandfather. In fact, merely travelling back into the past would present a paradox, for it would seem to ‘change’ the past. Thus, one travels to the past only if one already was there. One may ‘affect’ the past in the sense that a time traveller may have been the ‘cause’ of the great London plague, though that must always have been the case.

There is no question of going round and round a loop in time: it is executed exactly once. One can, if one likes, think of going round the loop, more than once, provided each cycle is *identical* with the preceding one. Specifically, one is not allowed to increment a mental counter for each execution of the loop: there is no question of returning the eleventh time with a memory of the past ten visits.

## *Assumptions Underlying the Paradoxes*

Whatever its merits, the block-universe resolution of the paradoxes of time travel certainly makes time travel very unexciting. One can travel to the past—but only to do what one has already done. One can know about the future, but one is as powerless to change it as one is powerless to change the past—if Tim cannot kill Grandfather, neither can Grandfather kill Tim. There is only one past, one future, one lifetime, one world-line. The book of life has already been written. Even the thin pretense of the future as the unknown ending of an already-written mystery novel is in danger of being taken away: with the last page dangling open before one's eyes. Perhaps one cannot help reading the ending.

This way of resolving the paradoxes avoids a larger issue. Recall the arguments of Chapter 6 that the block universe may restrict the freedom to experiment—so that experimental test would no longer be a valid way to choose between different scientific theories. Is there any other way to resolve the paradoxes? Let us list and examine all the assumptions underlying the paradoxes. These are assumptions which one unthinkingly makes as the basis of everyday actions; it is the challenge to these assumptions which give the paradoxes their bite.

1. *Past linearity*. The past cannot be changed[28]—there is only one past. Nothing now can alter the past, not even a time machine built now.

2. *Future branching*. The future is malleable: what one does now partly decides the future.

3. *Law of contradictions.* A cat can't be both dead and alive at the same instant of time. God (or the cosmos) abhors contradiction, especially logical contradiction.

4. *Principle of causality*. Everything must have a cause, and nothing can exist without a cause. Likewise, every cause must have an effect, so that changing *one* cause has a domino effect into the future.

5. *Entropy law*. Something cannot come from nothing. Not even something as intangible as information.

In this chapter we will examine only the last two assumptions, leaving the first three for the next chapter.

## Spontaneity

Let us start with the fourth assumption. In the grandfather paradox, one starts by supposing that the past could be changed. But everything must have a cause. The cause of my existence is my father, and the cause of my father's existence is Grandfather. Nothing can exist without a cause. So without Grandfather, Father cannot exist, and without Father, I cannot exist. Hence, if Grandfather died before he could procreate, this will have a domino effect into the future so that I cannot exist.

But is it really true that nothing can exist without a cause? Consider the time traveller Tim, as he materialises at some time when Grandfather was a child, and Tim's father was not born. We may suppose (without loss of generality) that this was the earliest in the past that Tim travelled. We may refer to this earliest time at which Tim materialised as his 'birth', though this was clearly before Tim's own biological birth from his mother's womb. But what explanation can there be for Tim's 'birth'? We know that Tim pressed the button of his time machine and travelled into the past. This event may have been in Tim's subjective past, but objectively, this event was in the future (else there would be no question of time travel). What *causal* explanation can there be for Tim's birth? Clearly, there was nothing in the past which could be used to explain Tim's birth; nothing in the past which presaged Tim's appearance at this instant of time.

It could be objected that the above scenario uses a philosophical fairy story which assumes the naive picture of a Wellsian time machine, which allows people to materialise and disappear at the press of a button. But this objection has no substance. Consider Shakespeare's tachyonic anti-telephone to Bacon. If something in the past could explain why Bacon wrote down *Hamlet*, then Bacon would validly have to be regarded as the author of the play.

As yet another example, consider Popper's pond paradox (p. 305) in the case of time travel without machines. A stone is thrown into a pond, and we see the ripples spreading outwards. This is the normal retarded case. We film the whole sequence of events, and play the film backwards. This represents a physical possibility according to the equations of physics. Suppose one were to observe this in reality. The advanced ripple, travelling back in time, seems like a ripple which spontaneously starts converging. What *cause* can one assign to this? The 'cause' is that the molecules on the boundary of the pond started moving, and that they imparted this motion to the water molecules. This is not one 'cause' but a multiplicity of causes. This multiplicity must be synchronised; though causally unrelated, all the molecules must move at the right instant. Moreover, all these microphysical motions must be fine-tuned: they must be coherent, else they will not interfere correctly, and will not generate the right pattern to produce a converging ripple. Such a 'conspiracy of causes' seems impossible unless it is initiated and organised by one central cause. In short, the difficulty in producing a causal explanation of Tim's birth is not an artefact of Wellsian time travel, but is generic to time travel.

Let us now see what is wrong with the pond paradox. An explanation, to be one, must be simple. There is no simple explanation of the converging ripple just because one is looking for a 'causal' explanation. Consider. Time travel means that we allow some influence from the future to travel into the past. Let us say this influence interacts with the past at some time $t_0$. We now seek an explanation for events at and immediately after $t_0$, in terms of events at time $t$ earlier than $t_0$. If such an explanation existed, then the alleged influence from the future can simply be eliminated by appealing to simplicity: what need do we have for hypotheses about influences from the future at $t_0$ when *all* that happens at and immediately after $t_0$ can be explained by events at times $t$ earlier than $t_0$? That is, if the required causal explanation exists, then talk of time travel is merely that: it has no reality. The influence from the future can neither 'change' nor 'affect' the past (at time $t_0$), because whatever happens at $t_0$ is completely explicable and decided by events prior to $t_0$.

That is, any actual influence from the future *must* appear to be spontaneous and incapable of any causal explanation. In fact, one may regard the appearance of spontaneous events as the necessary empirical evidence for the existence of time travel or of influences travelling into the present from the future. A more quantitative account of this argument is given in Chapter 9.

## *Time Travel vs Time Machines*

The necessary involvement of spontaneity with time travel leads to a strange conclusion. Time travel involves spontaneity, and spontaneity cannot be mechanised, *hence there can be no time machines*: if at all time travel is possible, it can only take place without machines. This is not a mere play on words. In the absence of a causal explanation, one cannot give a prescription for making the time traveller appear. Can't this apparent spontaneity be controlled from the future? Can't the time traveller control things by setting his dials to appear at the appropriate instant? The answer seems to be: No.

Why this is so can be better understood in the context of a tilt in the arrow of time (Chapter 9), but may be summarily explained as follows. Teleological explanations are impossible for purely history-dependent phenomena; such phenomena admit only causal explanations (i.e., explanations of future from past). Symmetrically, causal explanations are impossible for purely anticipatory phenomena; such phenomena admit only teleological explanations (i.e., explanations of past from future). In the more realistic situation where one has mostly history dependence, and some anticipation, spontaneous events may appear rarely, but these cannot be controlled from either past or future, because both history-dependent and teleological explanations together may fail. Shakespeare can NOT control his anti-telephonic talk with Bacon any more than Bacon can give a causal account of it.

This spontaneity may be summarily distinguished from chance as follows. Recall the meaning of chance from Chapter 6. Also recall from Chapter 6 that the present-day formulation of the equations of physics is 'instantaneous': it provides an explanation of both future and past in terms of the present. *Hence*, the equations of physics are time-symmetric: they treat past and future on an equal footing. Hence, also, there is a great difficulty in establishing the entropy law, and one must appeal to chance to try and ensure the increase of entropy. Chance increases entropy.

But, like Maxwell's demon, spontaneity would create order (i.e., decrease entropy). Assumption 5 above would fail, for one would get something (information) apparently out of nothing—information would be created. The standard exorcism of Maxwell's demon by Brillouin and Szilard (p. 188) fails for the case of spontaneity, since that exorcism argument applies only to a *mechanical* version of the demon, and not to the creation of order through either chance fluctuations or spontaneity.

The difference between spontaneity and chance is then this: spontaneity creates order, while chance destroys order (i.e., creates entropy). This difference need not lead to any perceptible failure of the entropy law, a matter considered in greater detail in Chapter 9. Spontaneity cannot be mechanised, hence there is no failure of the entropy law.

## Time Travel and Life

If time travel cannot be mechanised, how will one ever know anything about it? *Where* should one look for the spontaneous events to gather evidence of time travel? Of what use would time travel be? (As before, we will postpone the question of use.)

Where would one expect to find spontaneous order creation? Living organisms are a good starting guess! The mathematical models of physics cannot, at least at present, deal with living organisms at the level of everyday life. But physics can deal with the building blocks of life, viz., biological macromolecules.

The idea here *is* a reductionist idea in a way. Spontaneity is not something possessed only by living organisms in the large. It may be more concentrated in living organisms, but it pervades the universe. It is present at the lowest level of the building blocks. It is at this level that one can test for spontaneity and the existence of a tilt in the arrow of time, by examining the structure of biological macromolecules. This study is at present going on, and may take another few years to complete.

## Dreaming the Future

To come to a layperson's question. Can this sort of time travel without machines be used to say something about the future? This is unfortunately a very speculative area which the above study is not going to resolve in any way. One thing we can say with confidence is this: nothing in physics, as we know it today (barring empty 'principles of causality') prevents one from obtaining information about the future. If that happens, no equation of physics would be upset, no physical 'law' would be 'violated'. We have already explained how that *could* happen: an advanced photon may carry information about the future into the present. The question is does it happen? Is it empirically observed to happen?

There are great difficulties in answering this question, especially from a layperson's perspective. Every now and then, when there is an air crash, newspapers carry stories of people who cancelled their tickets because they had a premonition of disaster. How would we ascertain the truth of a given story? Clearly, a long and expensive investigation may be required. Let us suppose, for the sake of argument, that the investigator is convinced. But why should I, a third party, share this conviction? Ideally, I would like to repeat the situation to convince myself. But spontaneous events need not be repeatable.

The second question is this: how should one separate the effects of spontaneity from those of chance? That is, it may happen, say 30 per cent of the time, that one has a premonition, and does travel, but the premonition fails to come true. The separation of spontaneity from chance becomes particularly difficult in individual cases, even granting the truth of such cases as the alleged premonition of the sinking of the *Titanic* that was supposedly published ahead of the event.[29]

There is, however, a famous claim that should be mentioned in this context. The claim was made by J. W. Dunne,[30] and later amplified by C. G. Jung,[31] and J. B. Priestley.[32] The claim concerns dreams which are certainly the epitome of spontaneity. Dunne's claim is simply that we dream of the past and future in equal proportions. Dunne is referring to specific images in dreams, such as seeing a man wearing a red shirt on a white horse with one eye, and to the correspondence of these images with events in everyday life. For Dunne, the details of the images in the dreams are important, and not the apparent narrative structure in which the dreams seem embedded. In fact, if one records the details, the narrative structure often disintegrates like an illusion.

A clear advantage of Dunne's claim is that it is in a way repeatable. To be sure one might not repeatedly dream of a white horse with one eye, but one does repeatedly dream in the course of a night's sleep.[33] Usually, one remembers only the last dream one had, and this too is forgotten so rapidly that some practice is needed to recall parts of it. Even then one tends to quickly forget the dream unless one jots it down. Dunne's experiment, then, is to keep a parallel record of the events of the day, and to compare the two.

The problems of repeatability and that of separating spontaneity from chance do not disappear, but here is an anecdote from my own experience. In 1976, I was a research scholar doing my Ph.D. at the Indian Statistical Institute in Delhi. India had just gone through the Emergency, which, however, left me more-or-less untouched, and largely unconcerned, barring a few loud-mouthed protests to which people only said, 'Hush, you will be arrested'. However, elections had just been announced. I woke up with the conviction that Indira Gandhi would not be back in power. The strength of the conviction puzzled me. Howsoever I looked at it, it did not make any sense to me: everyone (including me) was certain that Indira Gandhi would be re-elected with a thumping majority. I realised that I had been dreaming and decided to test Dunne's claim.

The statistical idea here is very simple. Some people wrongly estimate the accuracy of astrological forecasts because these forecasts are so vague that success is virtually assured under appropriate disambiguation. Then there is a subjective bias: focusing on the successful cases, and ignoring the failures. My dream looked like one of those yes–no cases which would prove false, and help to eliminate subjective bias.

Being unsystematic, I had no piece of paper on which to record this dream. Moreover, I would be sure to misplace the piece of paper. I was staying in the small hostel of the ISI, with only about a dozen people who met for breakfast, and I decided to remember the dream by taking a bet over the breakfast table. The two local political pundits (whom I will not name; one was from the faculty) were engrossed in discussing politics. I announced to them that Indira Gandhi would not come back to power. These two did not have a very high opinion of my political acumen, and they impatiently wondered what new craziness I was up to. They insisted that she would be re-elected, even if she had to rig the elections. I maintained that she would not be back in power. 'You mean she will be killed?' I stuck to my guns. There was no way to settle the dispute except through a bet. I offered to bet five rupees (then an awfully large amount to throw away), and I was given odds of 25 to 1! Of course, the gentlemen concerned being good at politics, the bet was never paid!

I know the incident is true; but in your place I would be sceptical, and would test Dunne's claims for myself. (P.S.: post the results to me.)

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## Summary

- A kind of cyclic time returns with the possibility of time travel in relativity.
- Time travel is of two kinds: with and without machines. Time machines may be of Wellsian, Gödelian, or the wormhole type.
- Travel to the past presents paradoxes like the grandfather paradox and Popper's pond.
- These paradoxes may be resolved by blocking choice (the block universe) or by blocking closed loops in time (Hawking's chronology protection conjecture). Such resolutions are unsatisfactory.
- A satisfactory resolution of the paradoxes requires a fresh approach to closed loops in time.
- Closed loops in time correspond also to a closed chain of causes.
- Internally, in a closed chain of causes every event has a cause, but there is no first cause.
- Externally, the earliest event on such a closed chain is a spontaneous event. Hence closed causal chains

imply spontaneity: not 'fatalism' or eternal recurrence, as has been generally imagined.

- Any interaction with the future necessarily involves a spontaneous event, that is in-principle causally inexplicable.
- Spontaneous events create order (decrease entropy), hence spontaneity cannot be mechanised. Hence time *machines* are impossible, and time travel can only be of the second kind.
- The speculation that such spontaneous events correspond to precognitive dreams is not ruled out by physical *theory*. But there are possible statistical biases in inferring from the experiments of J. W. Dunne and J. B. Priestley that some dreams are, in *fact*, precognitive.

∞

# PART 3

# DE-THEOLOGISING PHYSICS

The new resolution of the paradoxes of time travel also indicates the way to remove theology from physics, and delink science from the politics of religion. The key is to reject the Augustine–Hawking argument. The first step is to recall that the argument confused different pictures of time, by supposing that there is just one 'linear', 'Christian' picture of time opposed to one 'cyclic', 'pagan' picture of time. The confusion may be resolved by using one and one to make eleven—there are eleven pictures of time and not just two. The categories 'linear' and 'cyclic' are incoherent: the pictures within each category conflict with each other, while there need be no conflict between pictures across these categories.

Causality has been a key theological principle; it has also been regarded as a physical principle. Our second step is to reject the postulate of 'causality': that every event has a cause in the past, and that these causes can be traced indefinitely backwards to a moment of creation at the beginning of time. Within present-day physics, the most convenient way to reject 'causality' is to permit a tiny tilt in the arrow of time, so that some tiny influences may propagate also into the past. Physics can be mathematically reformulated using this idea of a tilt in the arrow of time. The quantitative consequences of this reformulation will not concern us here. A key qualitative consequence is that a tilt permits spontaneity (which differs from chance). Thus, physics may be reformulated so as to reject determinism and to resolve the problem of 'free will' vs determinism, or rather the problem of mundane time vs superlinear time.

Even though it may lead to a better physical theory, any new picture of time may initially seem paradoxical and counter-intuitive—because thinking involves language, which has an in-built picture of time. An alternative picture of time may even seem illogical and contradictory. But the time has come to displace logic from the metaphysical pedstal on which it was placed by rational theology. Logic is not a priori; there are many different logics to choose from, and changing the picture of time may change also the logic that applies to the world. The nature of logic must be decided by the picture of time that applies to the real world, not vice versa. It is time to end for ever the tyranny of metaphysics: the physical world—the empirically manifest—must be the ultimate arbiter also of the nature of logic.

# 8

# The Eleven Pictures of Time

Time travel allows closed loops in time—which resemble 'cyclic' time. The curse on cyclic time rejected 'cyclic' time as contrary to 'free will', and the same argument (grandfather paradox) was used to reject closed time loops, and, hence, to reject time travel. But we saw, in the previous chapter, how this argument should properly be stood upon its head: spontaneity is the empirical evidence for time travel!

This suggests that we also try to rid physics of the old curse on cyclic time which has infiltrated it since the time of Newton. Is time, then, 'linear' or 'cyclic'? Replacing 'linear' time by 'cyclic' time is hardly the right solution. The first step towards obtaining a solution is to recognise the question itself as meaningless. The curse on 'cyclic' time led to the belief in exactly two conflicting pictures of time: 'linear' and 'cyclic'. The belief in exactly two conflicting pictures of time may have been politically convenient in the Roman empire. But the categories 'linear' and 'cyclic' are defective, since each category incorporates many different pictures of time, and there need be *no* conflict between individual pictures *across* categories. Using 1 and 1 to make 11 instead of 2 also helps us to recognise the mutual incoherence of the distinct pictures of time within each of the 'linear' and 'cyclic' categories—there *are* conflicts between individual pictures *within* each category. The linear-cyclic dichotomy is, therefore, incoherent, and the crux of the matter is to resolve this incoherence.

Two further, deep-seated cultural prejudices, however, stand in the way. (1) Ideas of time are built into the language: an incompatible notion of time is hard to articulate, and seems counter-intuitive, and hard to believe. (2) In a subtle way, notions of time underlie logic, so that alternative notions of time may appear not only counter-intuitive but *illogical*. Unlike the counter-intuitive, which may eventually be accepted, it is hard to see how the illogical can *ever* be accepted.

## *Cosmic Disgust or Cultural Disgust?*

Recall the Zen-SF story (Chapter 7, p. 255) where the inventor of a time machine announces that he will send a cube five minutes into the past at 3 p.m. Sure enough, the cube disappears from his outstretched hand at five minutes to three. 'But', asks a puzzled friend, 'when the cube reappears in your hand at 3 p.m., what if you now decide *not* to drop the cube in to the time machine?' At 3 p.m., when the cube reappears in his hand, the inventor hesitates—the cosmos disappears! A contradiction has been created: for if the inventor did not drop the cube at 3 p.m., then the cube ought not to have vanished at five minutes to three. What is logically contradictory cannot exist physically—not even in SF! The cosmos abhors contradiction, and vanishes in sheer disgust, without looking too closely at the hypothesis. John Varley expressed this using an Einsteinian metaphor of a petulant God writing a note to the time traveller:[1]

> If you are going to play games like that I'll take my marbles and go home.
>
> Signed,
>
> God

The question before us is this: is this cosmic disgust or cultural disgust? A civilisation which is very insular and parochial tends to magnify every cultural eccentricity to cosmic proportions. Centuries of mind control seem to have made this process of magnification credible to many, though those who have escaped from this mind control may find it a matter of comic disgust.

We already saw in the preceding chapter that there is no real contradiction here; the paradoxes of time travel arise from an inconsistent superposition of mundane time beliefs on a novel picture of time. But the question we ask now is a different one: *what exactly is wrong with a contradiction?* The basic theory says that from contradictory premises any conclusion whatsoever may be drawn. The question is whether this basic theory applies to the real world:

whether the culturally assumed 2-valued logic is compatible with the nature of time that is empirically the case. It is a common thing to say that a man is both good and bad, and this statement could be so rendered that it presents a contradiction. But can one conclude anything one likes from the statement that a man is both good and bad? What precisely makes the cosmos, God, everything abhor contradictions?

## *The MICE which Half-Killed the Cat*

Consider another case where the contradiction is of a more real sort—the case of Schrödinger's cat, which arises in quantum mechanics. Recall quantum chance from Chapter 6 (p. 220). A particle 'really' splits into two—it goes through two slits simultaneously and interferes with itself. But when one looks, one never manages to catch the particle in the act of splitting into two—there always is only a whole particle, never two halves. The situation is captured by the paradox of Schrödinger's cat. Using the dangerous chemical MICE,[2] the fate of the cat is linked to the dynamics of the quantum particle (see Box 8). The quantum particle is both particle and wave, so also the cat is both alive and dead.

The question now is this: how can a cat be simultaneously both alive *and* dead? All cats one has come across are *either* alive *or* dead. But the cat is a large (macrophysical) object, while quantum effects are prominent for small (microphysical) objects. These microphysical quantum effects get destroyed or reduced, according to quantum mechanics, if they are mechanically linked to some macrophysical (measurement) apparatus. So real cats cannot be used to conclude anything about quantum particles; the cat must be regarded as a metaphorical substitute for a microphysical quantum particle.

## *Logic and the Picture of Time*

But isn't it logically impossible for even a quantum particle to exist in a contradictory state? So what would happen if a cat (a quantum particle) really is both alive and dead? Would the universe pack up in disgust? Would God take his marbles and go home? There is a simpler solution: *if the logically impossible is empirically observed, one should abandon the logic in use.*

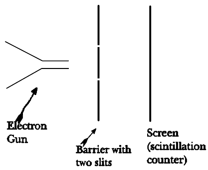


**Fig. 1**
Schematic experimental set-up.

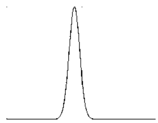

**Fig. 2**
Pattern seen with left slit open.

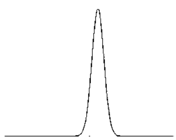

**Fig. 3**
Pattern seen with right slit open.

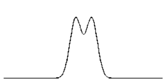

**Fig. 4**
Superposition of the two patterns.

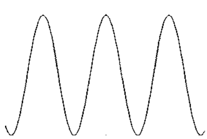

**Fig. 5**
Schematic interference pattern.

### Box 8: Schrödinger's cat and structured time

**1. Two-slit diffraction.** One of the mysteries of quantum mechanics is the following. The diagram (Fig. 1) schematically shows an actual experiment. In this experiment, an electron gun fires electrons towards a screen, *one at a time*. Between the electron gun and the screen there is a barrier that has two slits in it, each of which can be closed if required. When only the left slit is open, one gets a pattern like Fig. 2. This is called a bullet-shot pattern. (If a marksman shoots at a target, the bullets will be distributed around the 'bull's eye' in the same way.) When only the right slit is open, one gets a similar pattern (Fig. 3), except that the centre of this pattern (the 'bull's eye') is displaced, corresponding to bullets being fired from the position of the right slit. If both slits are open, what should one get? If two marksmen fire bullets from adjacent positions at the same target, one gets a superposition of two bullet-shot patterns as shown in Fig. 4. This is what one expects to find if electrons are bullets going through the slits. What one gets instead is an interference pattern (Fig. 5). The screen is a 'scintillation counter': it shows a bright spot at whatever point the electron strikes. If there were a large number of electrons one would see the interference pattern as a series of dark and white bands. What stops the electron from striking a certain part of the screen? One can explain this by saying that electrons are not particles, like bullets, but they are waves. These waves interfere with each other, redistributing the peaks and troughs. What

*(continued on p. 275)*

do these waves consist of? they are waves of probability (amplitude). But the classical notion of probability requires a large number of events, and the catch here is that the interference pattern is observed with a single wave, i.e., when the electron gun fires electrons one at a time. Does the single electron split into two parts with one part going through this slit, and the other part going through that? Seemingly, this is what it means to say that the electron is a wave. So let us watch one of the slits closely to catch half the electron as it comes out of the slit. But we can never catch half an electron. All electrons we see are whole electrons: never half or a quarter. What we can now say is that we know that each electron goes through exactly one slit, and we even know *which* slit each electron goes through. But lo and behold! something has changed with this additional knowledge. We no longer see the interference pattern (Fig. 5), what we get instead is the superposed bullet-shot pattern (Fig. 4) that we originally expected! This is the famous wave-particle duality. The electron behaves like a wave of some sort, provided we don't look—looking at the electron makes it behave like a particle.

**2. Schrödinger's cat.** Erwin Schrödinger was one of the founders of quantum theory. Exasperated by these allegations about the behaviour of the electron he constructed his own paradox. The paradox involved a photon fired at a half-silvered mirror. According to quantum mechanics, half the photon is reflected and half is transmitted; however, if we look we will find only a full photon which is either reflected or transmitted. Behind the mirror, there is a photon detector. If the photon is detected, the detector activates a plunger (Fig. 6), which breaks a glass bottle containing the dangerous chemical MICE (Methyl Iso-CyanatE).

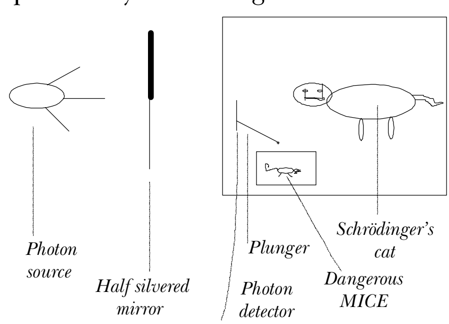


**Fig. 6: Schrödinger's Cat**

*(continued on p. 276)*

This dangerous MICE is locked inside a cage containing Schrödinger's cat, which it can kill in one minute. The question is this: what is the state of the cat after two minutes: is it alive or is it dead? According to quantum mechanics the cat is half-dead+half-alive! If we look we will only find a cat which is either fully alive or fully dead. If perchance we find a dead cat it is because curiosity (ours) killed the cat (Schrödinger's).

**3. Einstein–Podolsky–Rosen paradox.** Let us analyse the two-slit diffraction experiment a bit further. Any electron goes through only one slit. But its subsequent motion is decided by whether or not the other slit happens to be open. This seems unreasonable from the viewpoint of the philosophy of contact: how can the motion of the electron here (at this slit) be decided by something that happens elsewhere (at the position of the other slit)? As already pointed out, Einstein mistakenly thought that he could continue with the philosophy of contact even after abandoning the aether. Like Schrödinger, he too could not accept quantum mechanics. He therefore argued as follows. According to quantum mechanics, electrons spin like tops, except that the electron spin is always either up or down. Specifically, the spin of an electron is always either up or down regardless of the direction in space we choose to call 'up'. Suppose now that there are two electrons, one with spin up, and the other with spin down, so that the total spin of the system is zero. Next, let us allow these electrons to move apart, and let us measure the spin of electron number 1 here. According to quantum mechanics the total spin of the system must be conserved, so that if electron number 1 has spin up here, then electron number 2 must have spin down there. This is so regardless of the direction in space we choose to call up. Thus, as in a two-slit experiment, the spin of the electron there is decided by something that happens here; moreover, it is decided only when we look at the electron here, and therefore in less time than light would take to travel between the two electrons. Einstein thought that this exposed certain fundamental inadequacies of quantum theory. Actually, this experiment was repeatedly performed, and the results of quantum mechanics were re-confirmed in the 1980s by Alan Aspect and others. There must be, therefore, certain inadequacies in the philosophy of contact.

*(continued on p. 277)*

**4. Time travel and identity.** In addition to the problem of contact, there is a problem of identity in the two-slit experiment. The electron cannot 'know' what is happening at the other slit, except by being there: and how can it be in two places at once? A cat may be alive now, and dead a while later but how can a cat be both alive and dead at the same instant of time? Time machines allow us to visualise this situation. In the autofanticide paradox, our time traveller may be unable to kill himself when he was yet an infant, but nothing seems to prevent him from trying. In Kip Thorne's Carolee and Me story of time-travel, when Thorne peeks through his wormhole to see his own more youthful self, nothing prevents him from extending his hand through the wormhole and shaking hands with himself. He could even climb through the wormhole and meet his own youthful self face to face. In both cases we would have two Tim-s and two Kip Thorne-s at a single instant of time. We can extend this idea to Schrödinger's cat, which is now presumably dead. Let us put it on a time machine and send it back to the time when Schrödinger and his cat were both alive. In Thorne's wormhole scenario of time travel the cat stays dead, and so we have at one instant the same cat which is both dead and alive. It is another matter that Schrödinger may have thought of it as just another dead cat which resembled his, and may have disposed off the body.

**5. Structured time.** One way to explain how one thing can be in two places at the same time is through the idea that time has a non-trivial structure: for example, like that of fission-fusion time. (See text, p. 294) This requires a change of logic; a change to a logic better suited to quantum mechanics. I have argued separately the case for this structured-time interpretation of quantum mechanics, which differs from the many-worlds interpretation of quantum mechanics.

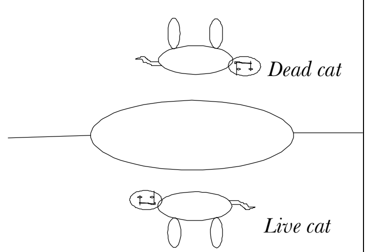


**Fig. 7: Structured Time**

Two logical cats corresponding to one physical cat at a single instant of time. The logical cats exist objectively.

What guarantees that (deductive) logic[3] is sacrosanct? that it must precede empirical reality instead of following from it? What guarantees the uniqueness of logic? What guarantees that precisely one logic can be used to describe physical reality? The only guarantees that one can find are cultural guarantees. The Greeks used a two-valued logic, and 'Euclid's' *Elements* were regarded in medieval Europe as the last word in certitude. Mathematics and the modern notion of a mathematical proof (Chapter 6, p. 211, and Appendix) are also based on a two-valued logic. Inspired by Plato, Aristotle, and the *Elements*, Rational Theology made logic its starting point. The philosopher Kant carried forward this belief that logic was *a priori*, that it was given independently of physical reality. Present-day mathematics, like Popper's philosophy of science, persists with this belief. Nevertheless, today, it is easy enough to see that culture decides which logic to use. Neither the logic nor the culture can be glibly assumed to be universal: we must move away from Western theology or go back to Buddha to see how a completely different logic could be culturally prevalent.

As we shall see (Chapter 11), from before the *Elements* and Aristotle, different types of logics were prevalent. In the heyday of colonialism Westerners believed that military victory was a sure sign of cultural superiority (rather than the other way around), so 'their' logic was right and universal. We saw in Chapter 3 that this was not an ignorant fallacy, but a myth deliberately propagated by a Church whose alliance with the state was based on an identification of truth with military victory. If history is fiction, the history of science must be science fiction: to guard their livelihood, theologians have assiduously cultivated the myth that science was a uniquely Western phenomenon, jealously hiding the enormous scientific and technological debt of the West to the non-West. (The debt extends back to before the time of Aristotle who probably got a great deal of information from the people—specially appointed by his pupil Alexander—who travelled along with Alexander, to gather knowledge and report it back to Aristotle.[4]) This has allowed them to put forward the argument that the West is militarily dominant because it is culturally superior. These are the only kinds of 'cultural superiority' arguments that can ultimately be offered in support of the *a priori* nature of logic. These arguments only reinforce the conclusion that culture decides which logic to use.

*The relationship of logic to culture is mediated by the picture of time used*. A (metaphorical) cat which is both alive and dead, at a single instant of time, presents a logical contradiction. The qualification 'at a single instant of time' is crucial to this contradiction, for it is of course quite possible to have an actual cat which is alive now, and dead a little while later. But what exactly is an 'instant of time'? Instead of speaking of the state of the world at an instant of time, one can invert this relationship to *define* an instant of time in terms of the state of the world at that instant of time. The present instant of time, thus, corresponds to all events 'now', and an instant of time consists of all events 'simultaneous' with a given event. The notion of an 'instant of time' is clearly very closely related to the notion of simultaneity, or to the notion of 'now'; and we have already seen that the latter cannot be regarded as having a self-evident meaning. In the Gödel cosmos there may be no 'now', hence no universal notion of an 'instant of time'.

Thus, it is not incidental that theories of cultural disgust are located exactly in the context of feared logical contradictions related to any possible cyclicity of time. (Even though there is no real contradiction in cyclicity, the point now is that the notion of contradiction itself may have to be re-examined if we change the picture of time.) We have already seen in Chapter 2, how the Church manufactured and instilled this cultural disgust of alternative pictures of time to suit its own political ambitions. *Logic relates to the picture of time also in the sense that changing the picture of time may change logic.* Relating a change of logic to a change in the picture of time also helps to clarify and resolve the temporal dichotomy of 'linear' vs 'cyclic' time, so deeply embedded in Western culture.

With this preliminary understanding of the intertwining of time with language and logic, let us proceed to sketch the various pictures of time.

## *Superlinear Time*

Time measurement is extremely important to physics. The difference between Newtonian physics and relativity relates, as we have seen in Chapter 6, to the issue of time measurement. But any sort of measurement of time presupposes a correspondence between time and number. We suppose that each instant of time may be associated with a number. What sort of number? The answer, today, is: real numbers. (We count integers and fractions as real number; we also count as real numbers those numbers which, like π, have a decimal expansion that neither terminates nor recurs.)

The association of time with real numbers is important also for another reason. From Newton's time, the 'laws' of physics have been formulated using the differential calculus. Like the zero which accompanied the import of the algorismus, the 'indivisibles' that accompanied the import of the calculus[5] created severe epistemological difficulties for mathematics in Europe—difficulties that were resolved only after Dedekind's formulation of real numbers. Therefore, the very formulation of the 'laws of physics'—whether of Newtonian physics, or of relativity, or of quantum mechanics— today assumes that instants of time correspond to real numbers.

In the West, numbers have traditionally been associated with a geometric line; and, today, one is taught at an elementary stage how to represent numbers pictorially by marking magnitudes along a line. Accordingly, time is like a line—the real line, i.e., the line of real numbers (Fig. 8).

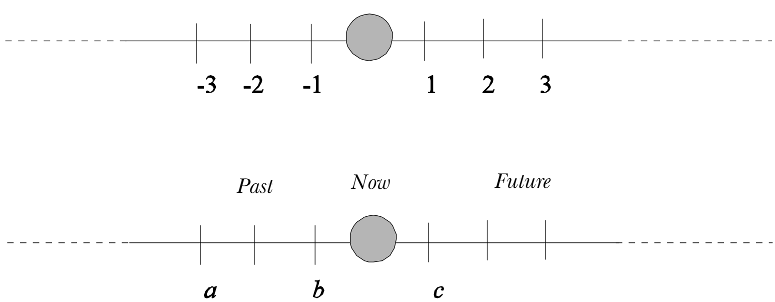


**Fig. 8: Superlinear Time**

The number line above, and its analogue, superlinear time, below. On the present understanding of mathematics, real numbers are needed to formulate physics.

This association of time with a line, relating as it does to the formulation of the 'laws of physics' as differential equations, hence also means that the physical world is described by the solutions of these equations. The solutions may be obtained, towards either past or future, given the present state of the world. Accordingly, in this picture of superlinear time, both future and past are decided by the present.

The association of time with real numbers was not so clear in Barrow's time: though he represented time by number, and number by a line, he allowed for the possibility that this line need not stretch out to infinity towards both past and future. As we understand things today, Barrow's understanding was essentially correct. The formulation of 'physical laws' as differential equation only requires time to be *locally* like the real line. Nothing prevents the distant future from 'wrapping around' to the remote past. Indeed, this is exactly what would happen if we represent time by numbers as they are represented on present-day digital computers—where the prevailing practice is to represent numbers in a way that 'wraps around' (Fig. 9).[6]

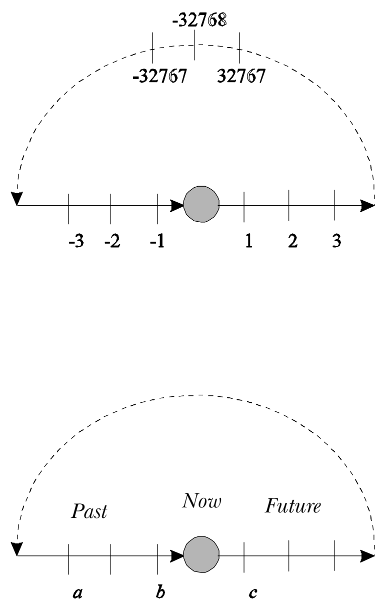


**Fig. 9: Supercyclic Time**

The actual number line on a personal computer folds around, as in the top figure. This resembles the 'folding around' of time in, say, a de Sitter-type cosmos.

## *Irreversible Time*

The representation of time by real numbers, and the formulation of 'physical laws' as differential equations (or the modeling of physical time evolution using differential equations), involves a more serious difficulty. It ensures the *time symmetry* of physics— that physics is unable to discriminate between future and past.

This is manifestly contrary to everyday experience which informs us that numerous processes in this world are asymmetric and irreversible, even though physics asserts that they are symmetric and reversible. The irreversibility of time may be pictorially represented, like direction, by an arrow (Fig. 10). (A. S. Eddington introduced this metaphor to the scientific community.)

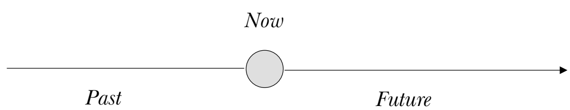


**Fig. 10: Irreversible Time**

Irreversibility of time is often expressed, like direction, by an arrow. In this case the arrow points to the future.

But adding this little decoration to the featureless real line has not proved to be easy. We have seen, in Chapter 6, how physicists since Boltzmann have been unsuccessfully trying to reconcile the time symmetry of physics with the observation of time asymmetry, and the entropy law. We have also seen that the observed time asymmetry cannot be explained, but must be 'explained away'.

In this process of 'explaining away', we seem to have lost sight of two key points. The first is that mundane experience is not necessarily reliable at the cosmological or microphysical level. On the earth, 'east' and 'west' are directions; but if one travels due west along the equator, one eventually arrives back to the east of the point one started from. How long this takes depends on one's speed and the size of the earth. Exactly the same thing happens in the case of a cosmos with closed timelike geodesic—the dashes turn around in a huge arc, so that future blends into the past.

Second, the problem is not merely that of reconciling super-linear time with irreversible time. At the mundane level, where it certainly does apply, everyday experience does not merely inform us that time is asymmetric—it tells us something more.

## *The Temporal Relation*

Mundane experience informs us that past and future not only differ, they differ in a special way. This difference is implicit in language and everyday speech. No use crying over spilt milk, says the old adage, which means that one cannot now change[7] the past. The event of spilling the milk is in the past, and the adage says that anything one does now cannot undo or cancel that past event. *What* is this past about which we say it cannot be changed? Implicitly, there are 'events', there is a 'now' and there is a 'past'. There is a before-after relation between events, which we may call the temporal relation. In everyday language time is represented by a *relation.*

It is easy to formalise this. The pastness, presentness or futurity of an event is decided by the temporal relation. 'This utterance' (if uttered now) is an event now. The spilling of the milk was an event in the past, i.e., the event of the spilling of milk was earlier than or simultaneous with the event of uttering 'This utterance'. All events 'now' are those which are simultaneous with 'This utterance'.

What have we gained by this convoluted, formal way of describing the spilling of milk? To begin with, we can reconcile the two descriptions of time—as magnitude and as relation. We can compare time-s exactly like magnitudes. The relation 'earlier than or simultaneous with' is believed (in ordinary language) to have properties very similar to the properties of the order relation $\leq$ (less than or equal to) among numbers. The relation 'earlier than' is believed to have properties very similar to the properties of the order relation $<$ (strictly less than) among numbers. The relation $<$ is

(1) **irreflexive**: whatever the number $a$, it is false that $a < a$;

(2) **transitive**: whatever the numbers $a, b, c$, if $a < b$ and $b < c$, then $a < c$.

Transitivity (property 2) makes sense for magnitudes: if $a$ is smaller than $b$ and $b$ is smaller than $c$ then it follows that $a$ is smaller than *c*. At the mundane level this makes sense also for events. If *a*, *b*, *c* are events (rather than numbers) then also it seems true that if *a* is earlier than *b*, and *b* is earlier than *c*, then *a* is earlier than *c*.

Second, the temporal relation enables us to handle notions such as 'the beginning of time'. This notion is potentially paradoxical, for a notion of time seems implicit in the very notion of beginning, so we might legitimately ask: in what kind of time does our time have a beginning? The similarity of the temporal relation with the order relation among numbers enables us to see that this statement is no more paradoxical than talking of the smallest number in a set.

Time may have a beginning, or an end, or both. These properties can be expressed using the temporal relation[8] $U$ as follows ($aUb$ means event $a$ is earlier than event $b$):

(1) **Beginning of time:** There exists an event $a$ such that $aUb$ for every event $b$, different from $a$.

(2) **End of time**: There exists an event $b$ such that $aUb$ for every event $a$, different from $b$.

In terms of the relation $<$ , these properties would have defined the smallest and the largest number in a given set of numbers. For example, we would have had

(1)' **Smallest number**: There exists a number $a$ such that $a < b$ for every number $b$, different from $a$.

## *Supercyclic Time*

The formal representation of time by a relation also helps us to identify and make explicit the assumptions underlying the picture of time. We have seen that the properties of the order relation between numbers depend upon which numbers we use—whether real numbers or numbers on a digital computer with a finite memory. A digital computer has available to it only a finite number of symbols. The number line of a computer, therefore, does not stretch to infinity on both sides, but folds around, as in Fig. 9. Thus, for numbers on a computer, the relation 'less than' is not irreflexive, but only 'locally irreflexive', i.e., it is irreflexive only if the gap between the two compared numbers is not too large. (Exactly how large is 'too large' depends upon the computer in use.)

Similarly, whether or not irreflexivity and transitivity are actually properties of the temporal relation depends upon the picture of time we use. For example, let us draw a picture depicting events in a circle, time increasing in the anti-clockwise direction. That is, event *a* is 'earlier than' *b* if one goes clockwise from *a* to *b*. With such a definition, however, if *a* is earlier than *b*, *b* also is earlier than *a*. Consequently, given that this relation is transitive, it is clear that *a* is earlier than *a*, so that the first condition of irreflexivity would fail to apply. (It is precisely to exclude this situation of Fig.11 that the condition of irreflexivity was put in in the first place.)

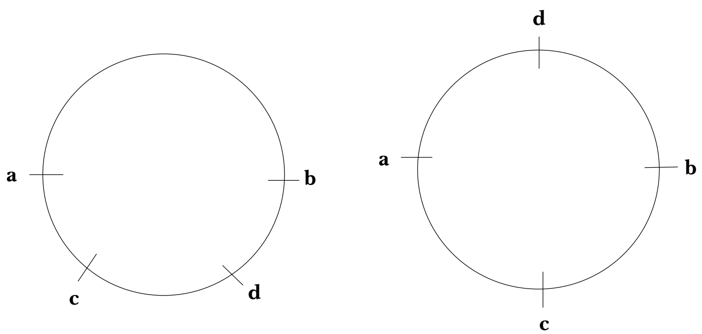


**Fig. 11: Inadequacy of a Binary Temporal Telation**

The figure shows two arrangements of events on a circle. In the first case, starting from *a* and going anti-clockwise, one encounters both the events *c* and *d* before *b*. In the second case, one encounters *d* after *b*. A 2-place earlier-later relation, as used in natural language, is incapable of distinguishing between these two distinguishable arrangements.

## *To Say 'a Earlier than b' Involves c and d*

If time happens to be as sketched in Fig. 11, one must change the properties used above for the temporal relation: one must allow the temporal relation to be *reflexive*. But a new problem now arises. Using the temporal relation *U*, introduced above, we see that *U* must be

(1) **reflexive**: *aUa*, for every event *a*;

(2) **symmetric**: if *aUb* then *bUa* for every event *a* and *b*; and

(3) **transitive**: if *aUb* and *bUc*, then *aUc* for every event a*, b, c*.

A relation which satisfies the three properties listed above is called an *equivalence relation*.

An equivalence relation is comparable to the equality between two numbers: $2/4 = 1/2$; though the numbers on the two sides of the equality relation are equal or equivalent, they are not *identical*. The new problem that now arises is this: one cannot discriminate between the two arrangements of events shown in Fig. 11. The problem is too technical to go into here.[9] Briefly, the difficulty is with the description of time in natural language. We tend to assume that the earlier-later relation is a *binary* relation, or a *two-place* relation. That is, we tend to suppose that given the events *a* and *b* it is possible to decide whether or not *a* is earlier than *b* without reference to any further events. This assumption, encouraged by natural language, presumably relates to mundane observation; and mundane observation, without adequate reflection, may misleadingly suggest, for example, that the earth is flat. A two-place, earlier-later relation cannot describe the difference between the two situations visualised in the above figure, for which one needs at least a *four-place* relation which may go something like this: *d* is on the same 'side' of *a* and *b* as *c*; or like this: starting from *a, b* separates *c* and *d*. The idea that *a* being earlier than *b* depends upon some third and fourth events *c* and *d* is something so contrary to the tense structure built into many natural languages, like English, that it simply cannot be expressed naturally! So something serious may after all be learnt by describing the spilling of milk in a convoluted way! The least that one learns is that asymmetry is not the only problem in the physics of time: it is the structure of time that is the key issue.

## Counterfactuals and Possible Worlds

To delve more deeply into the question of spilt milk, suppose some one does cry over it, and goes into recriminations as follows. 'If only you hadn't come in the way, I wouldn't have spilt the milk!' What does this statement mean? For the fact is that the milk was spilt, and the fact is that you did come in the way (though you may not be to blame). So the recriminatory statement refers to something contrary to the fact: 'If, contrary to the actual fact, you had not come in the way, I wouldn't have spilt the milk'. One could reframe this statement in the following way. At some time in the past you had a choice—you could have chosen to come in the way, or you could have chosen not to come in the way. If you had, at that time chosen not to come in the way, the world now would be a different world: it would be a world in which the milk would not have been spilt. This different world, though not the real world, is a possible world. The events in it, such as the non-spilling of milk, though contrary to fact, are possible events, or might-have-been events. The situation may be sketched as in Fig. 12.

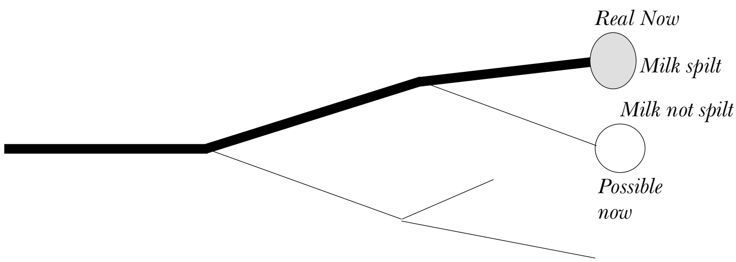


**Fig. 12: Possible-World Semantics**

Causes are sometimes ascertained by imagining what the world might have been if an event had not occurred, or a choice had been made otherwise. The branch points indicate choices: the thick line denotes the actual choices, and the thin lines the possible choices.

In sketching this picture, we have involved a new element: in addition to the idea of time as number and time as relation, we have now brought in the idea of an instant of time as a 'world'. As stated earlier, instead of speaking of the state of the world at an instant of time, we can invert this relationship to define an instant of time in terms of the state of the world at that instant of time. The present instant of time, thus, corresponds to all events 'now'. (In the mundane picture, we assume, of course, that the cosmos is such that it makes sense to speak of an instant of time.) Both real and possible worlds of events can be modelled by logical worlds of statements.[10] Formally, this logical 'world' is a collection of propositions, which models the real world, say, at an instant of time. The factual occurrence or non-occurrence of a given event in a given world is represented in the corresponding logical world by the truth or falsity of the statement asserting that the event in question occurs. For example, if it is raining now, this event is represented in the corresponding logical world by assigning the truth-value 'true' to the proposition 'It is raining now'.

The same thing can be done with future events. Aristotle was perplexed about future events such as the sea battle tomorrow: what truth value should one assign to a statement asserting the occurrence of a future event? Any assertion must be either true or false, and the future event must either occur or not; so Aristotle supposed we could declare the statement about the future event as true or false, *as of now*. The conclusion is that the sea battle tomorrow must take place (or not) regardless of what the naval commanders may do in the meanwhile. Aristotle's paradox of the sea battle suggests that one cannot assign a truth-value to statements about the future as of now. These statements may be regarded as only 'possible', or 'possibly true' and 'possibly false' rather than 'necessarily true', or 'necessarily false': the statement is true in a possible future world.

## *Mundane Time and Apocalyptic Time*

The difference between possible worlds in the future and possible worlds in the past is this: a possible future world may become real, whereas only one past world is real. The preceding statement does not sound especially meaningful, but our convoluted way of talking about spilt milk helps us to re-express this. For the (real) past the temporal relation $U$ is linear: it respects the law of trichotomy that applies to numbers. That is, in addition to irreflexivity and transitivity, the mundane temporal relation must satisfy the following.

(3) **Past linearity:** if $a$, $b$ are (real) past events then either $a$ is simultaneous with $b$ or $aUb$ or $bUa$.

The situation of a past-linear, future-branching mundane-time may be represented as follows (Fig. 3). This is the basis on which one lives everyday life. One does not cry over spilt milk, but one does have twinges of regret over the counterfactual might-have-been possibilities. One lives in apprehension of impending important events, especially as regards one's own role. The points at

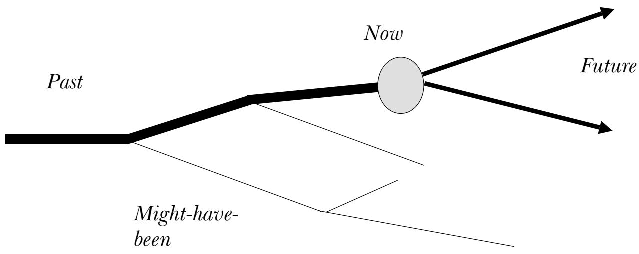


**Fig. 13: Mundane Time**

The thick line represents the unique real past (past linearity). The future branches, indicating that choices now will bring about the future. The thin lines are the counterfactual might-have been-s.

which there is a fork are points where choice can be exercised. The picture of apocalyptic time is to be similarly understood.

## *The Incoherent Pictures of 'Linear Time'*

We can now see the confusion in the category of 'linear' time. When people, especially theologians and philosophers, speak of 'linear time' they might be referring to (1) superlinear time, or to (2) irreversible time, or to (3) mundane time, or to (4) apocalyptic time. Generally speaking, to *do* physics people use the picture of superlinear time; to talk about time in physics they use the picture of irreversible time; in everyday life (or while designing experiments to test a physical theory) they use the picture of mundane time; and to discuss history or cosmology (especially in relation to religion) they use the picture of apocalyptic time, though nowadays they tend to use apocalyptic time only in an implicit way. So people use only one term to refer to four distinct pictures of time.

It is not even as if these pictures are more-or-less the same. Even attaching a little arrow to the picture of superlinear time presents a very serious difficulty. We have seen that in physics the symmetric picture of superlinear time directly conflicts with the asymmetric picture of irreversible time, and we must either accept time asymmetry as an illusion or fundamentally change physics. But this is only part of the story.

A fundamental incoherence exists between superlinear time and mundane time. The basic reason to believe in superlinear time is that the so-called 'laws' of physics use superlinear time. Our belief in these laws rests on experiment, and the possibility of experiment assumes mundane time. Thus, though physics assumes superlinear time, our belief in the validity of physics assumes mundane time.[11] Hence, one must either modify physics, or abandon the belief in its validity! That is, one must necessarily modify physics to resolve this paradox.

The four distinct pictures of time that go under the same name 'linear time' are incoherent. Thus, to speak of 'linear time' is like saying that 'that ship is to the north, south, east, and west of us', so that one may steer the argument in whatever direction one wants!

## *Epistemically and Ontically Broken Time*

We have already examined in great detail, in Chapter 6, the belief that this incoherence (between some of the different terms denoted by 'linear time') can somehow be resolved by 'breaking' time. In speaking of 'broken' time, we have brought in one more element—in addition to number, relation, and 'world'—to describe time. This new element is the connection between the world at one instant of time, and the world at another instant of time. We believe that (a) there *is* such a connection, and (b) that this connection is asymmetric or causal: we believe it is *past* events that decide the present, and the present decisions which will similarly decide the future. Breaking time breaks the causal connection between the future and the present (or between present and past). Time may be broken in two ways: epistemically or ontically. In the first case, a connection between two instants of time may well exist, but one does not *know* it. In the second case there *really* is no connection between the (worlds at the) two instants of time.

The 'breaking' of time may be depicted as follows. In mundane time we used the idea of branching to express the existence of a choice. Between choices, the world evolves deterministically, as expressed by the straight lines. But let us suppose that there is no way at all of telling what will happen next. Then these straight lines must be broken: there is no connecting link between one instant of time and the next.

Let us use the following pictures to remind ourselves of these two ways of breaking time. The first is the Lorenz butterfly, which

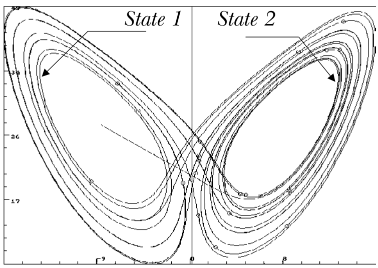


**Fig. 14: Epistemically Broken Time**

The figure shows two temporally adjacent states with the Lorentz model, which are far apart in phase. In this case a definite path exists from State 1 to State 2, but it is too complex to evaluate. Though State 2 is decided by State 1, we do not *know* how to calculate State 2 from a knowledge of State 1.

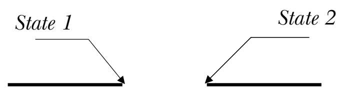


**Fig. 15: Broken Time**

The orderly time-evolution of the world is broken by a sudden transition from State 1 to State 2.

expresses the idea (Chapter 6) that we cannot predict rainfall because we cannot *know* everything like the flapping of a butterfly's wings in the Amazonian jungle which may cause a cyclone off the Andhra coast. The second is the idea of al Ghazālī's opponent that a man one meets in the market might *really* have formerly been a fruit.

The difference between epistemic and ontic may be illustrated by appealing to the mundane idea of past and future. Not everything about the mundane past is known. Nevertheless, we believe that nothing we do now can change the past. We feel that the difficulty is with our *knowledge* of the past: the past is already decided, it is not *really* open. On the other hand, we do not know the mundane future either. But we believe what we do now will decide the future. We believe that the difficulty is *not* only with our *knowledge* of the future: the future is *not* already decided, it is *really* open. With epistemically broken time, the present decides the future, but we do not know the future; with ontically broken time, the present does not decide the future, hence we do not know the future.

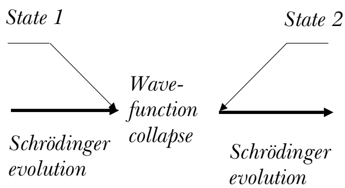


**Fig. 16: Ontically Broken Time in Quantum Mechanics**

The state of a quantum system evolves continuously, until we observe the system, when it jumps. State 2 is NOT decided by State 1.

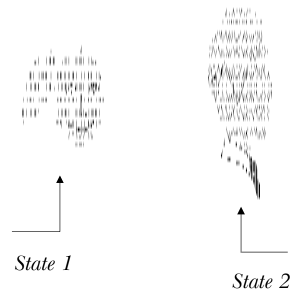


**Fig. 17: Ontically Broken Time as Imagined by al-Ghazālī**

People in the West have been so obsessed with the idea that God's foreknowledge does not restrict human culpability, that they thought breaking time was a good way to show that God's foreknowledge does not limit future possibilities. The best thing was to break time epistemically, so that one could have one's cake (of God's foreknowledge) and eat it too (retain 'free will'). We have seen, however that this idea does not work. To recapitulate, two simple reasons for this are the following. First, ignorance of the future does not imply that it is open. One is ignorant of much of the past, but one does not believe it is open. Second, mere indeterminism is inadequate: an occasionalistic world does not permit mundane choice, for mundane time requires *some* regularity; mundane choice requires some deterministic or statistical connections between present and future. So the mutual incoherence in the four pictures of time, all denoted by the same term 'linear time', cannot be resolved simply by breaking time.

## *The Incoherent Pictures of 'Cyclic' Time*

The category of 'cyclic time' is equally incoherent and meaningless. We have already seen the enormous confusion caused by lumping together two different types of 'cyclic' time, viz., (1) supercyclic time, and (2) quasi-cyclic time. We have already seen that even the case of supercyclic time is not as simple as, say, Augustine imagined it to be: even in the case of an exactly periodic cosmos, one may not talk about time in the usual way, for one needs a four-place earlier-later relation. We shall see, in the next chapter, that quasi-cyclic time is not just a matter of representing time by a spiral which can be unrolled into a line. Then there are (3) closed timelike curves. A cosmos with closed timelike curves may be non-recurrent like the Gödel cosmos, but may have other strange properties: there may be no universal notion of 'now', and no universal notion of past and future, though there may be a local distinction between past and future at any point. Or closed timelike curves may concern wormhole spacetimes, where time travel is possible. We have seen how the incoherence in the pictures of 'cyclic' time has led to a revival of Augustine's argument by Hawking: that closed-timelike curves should be rejected because they represent 'fatalism', as distinct from the determinism of science. We have also seen (in Chapter 7) that actually the exact opposite is true: closed loops in time necessarily imply spontaneity. There is yet another possibility of (4) microphysical time loops.

## *Structured Time and Microphysical Time Loops*

This fourth possibility concerns the idea of contradiction we started with, the idea that contradictory things may be true in the world at a given instant of time. With the mundane notion of time, contradictory statements may be really (ontically) true of future instants of time, and contradictory statements about past instants of time may be compatible with one's knowledge (epistemically true). The question is whether contradictory statements can be true at the present instant: can Schrödinger's cat be *now* both alive and dead? One way of looking at this is as follows: this question concerns the empirical world, and involves an additional hypothesis about the structure (or structurelessness) of the present instant of time. For, just as, with mundane time, future instants may have a non-trivial structure—more than one logical world may be needed to model the future—so also it is physically possible that the present instant too has a structure: more than one logical world may be needed to model the present. Given two distinct logical worlds, there must be at least one proposition which is true in one world, and false in the other. Since both these logical worlds correspond to the present instant, we have an example of a statement which is both true and false at the present instant.

According to the structured-time interpretation of quantum mechanics,[12] the situation prevailing in quantum mechanics may be related to microphysical time loops using what has been called fission-fusion time by Newton-Smith.[13] This may be represented a little more graphically as in Fig. 18.

There is a clear analogy to a Feynman diagram called the photon self-energy diagram (Fig. 19), which helps to provide a realistic example of this situation of microphysical loops and the structure of time. This analogy is not just a matter of the way the two pictures are drawn. It concerns a deeper question of the occurrence of a structure of time through microphysical loops in time in

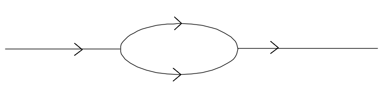

**Fig. 18: Fission-Fusion Time**

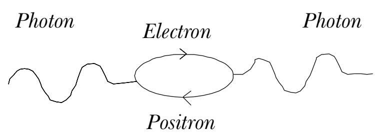


**Fig. 19: Photon Self-Energy Diagram**

With fission-fusion time (left), the stream of time objectively splits into two and then joins back: one physical cat is transformed into two logical cats one dead and one alive which are transformed back into one physical cat, either alive or dead. The self-energy diagram (right) shows a photon which spontaneously splits into an electron-positron pair, which recombine to regenerate the photon. Instead of creation and annihilation of a pair of particles, one may describe the process as a single electron executing a closed loop in time. Note the different senses in which the loop is traversed in the two figures.

the presence of a tilt in the arrow of time. (The diagram in Fig. 19 comes complete with an associated infinity!)

Thus, in the photon self-energy diagram, the wavy line denotes a photon. What we see is first the creation of an electron-positron pair: the photon, a pulse of energy, is changed into a pair of material particles. But we could describe this process differently.

The positron, the anti-particle of the electron, may be regarded as an electron travelling back in time. Like the time traveller Tim, the positron travels back in time to the point of time where its world line meets the wavy line. This corresponds to the point of time where Tim disembarks. At this stage the positron stops travelling back in time, and starts going forward in time, in the usual way. It now seems like an electron. To us observers, who have not participated in this time travel, the event appears as the creation of a pair of twin particles. The event is *spontaneous*, for quantum physics does not tell us exactly *when* such a pair will form.

Every particle has an anti-particle, and anti-matter is matter consisting of anti-particles. Anti-matter, or matter travelling back in time, is just like matter, except that when matter and anti-matter meet, they seem to us to annihilate each other and release energy. This is what happens at the other end of the diagram. The net result is again a photon. (In quantum physics, there are some infinities associated with this diagram, but we have seen earlier that these infinities are nothing to be frightened about.)

A photon comes in and a photon goes out. In between, the photon has disappeared. What happens in-between may be described as an electron travelling around a closed microphysical loop in time—for the creation and annihilation of an electron-positron pair can be regarded as just that. The first thing that strikes one is not the association of this closed loop with an infinitely repetitive process, but its beginning with a spontaneous event; for we have already seen that in a closed causal chain every event may have a cause, but the origin of the chain cannot be explained. The second striking feature is the transformation of identity. One may view the situation as one particle travelling around a closed loop in time, or one may view the situation as the spontaneous creation of a twin particle–anti-particle pair: a pair of distinct particles which are nevertheless sort-of mirror images of each other. One sees no contradiction in the possibility that the electron and positron pair may exist at different places at the same instant of time.

Thus, it seems that one has a choice between (a) retaining the customary notion of identity and changing customary logic or (b) changing the customary notion of identity and retaining customary logic. Instead of the electron splitting into two, the logical world may be split into two: one in which it is the case that the electron is here, and one in which it is the case that the electron is there (Fig. 7).

*Both* these logical worlds are part of the one and only physical world at one instant of time. This splitting of the real world is ontic rather than epistemic: i.e., it does not represent an incompleteness of our (general) subjective knowledge about the physical world, but is an objective condition which can produce perceptible interference patterns.

This splitting of logical worlds helps to reconstruct the formalism of quantum mechanics, as I have shown elsewhere.[14] A microphysical tilt in the arrow of time, as distinct from mechanical time-travel, helps to explain why this splitting is largely confined to microphysics.

Which description should one choose? Should one have two real particles in one world or one particle in two real worlds. Actually, this is not so much of a choice. Quantum chance differs from classical chance precisely in the sense that the logic underlying quantum chance is different.

The required logical difference may be explained by means of an (actual) experiment, known as the two-slit diffraction experiment (see Box 7). This experiment encapsulates the major puzzles of quantum theory. Suppose electrons are fired one at a time at a screen which has two slits. If exactly (any) one of the two slits is kept open, one obtains a bullet-shot pattern. But if both slits are kept open one obtains an interference pattern, consisting of bright and dark bands. On the wave theory of light, the explanation was that the light wave split into two: half of it went through one slit, and the other half went through the other slit. The two halves then interfered on the other side of the screen to produce the interference pattern. But the bullet-shot pattern suggests that the electron is a particle. Since electrons are being fired so slowly that there is only one electron going across at a time, each electron would have to divide into two. In fact, one never observes half an electron passing through each slit. What one sees is a full electron, passing through one slit or the other. But if one does look to see which slit the electron is going through, the interference pattern is destroyed, and one obtains instead a mixture of two bullet-shot patterns—exactly what one would expect if electrons were like bullets going through the two slits.

From the logical point of view one would say that the following two statements are **not** equivalent.[15]

(1) The electron reached the screen *and* passed through slit A *or* slit B.
(2) The electron reached the screen *and* passed through slit A *or* the electron reached the screen *and* passed through slit B.

The difference is an empirical matter. In one case one obtains an interference pattern, and in the other case one obtains a superposed pair of bullet-shot patterns.

The difference between the two statements above cannot be captured within Aristotelian logic. However, the quasi truth-functional logic corresponding to fission-fusion time does capture the difference.[16] This means one accepts that there is nothing contradictory in having a dead+alive cat at an instant of time. Since logic does not fit empirical reality, one resolved the paradox of Schrödinger's cat by rejecting logic. In general, permitting more than two possibilities at an instant of time, one obtains structured time. How can such a thing come about?

∞

## *Summary*

- Q. So, is time linear or cyclic?
- The question is meaningless because the categories 'linear' and 'cyclic' are meaningless. Some 'linear' pictures are incompatible among themselves, but are compatible with some 'cyclic' pictures.
- Different pictures of time correspond to different logics. Hence, logic must be adapted to empirical considerations.
- The usual logic cannot describe the quantum-mechanical phenomenon of Schrödinger's only cat which is literally half-dead+half-alive, at a single instant of time. A logic corresponding to microphysical closed loops in time can.
- *Q. What, then, is the correct picture of time?*

∞

# 9

# The Tilt in the Arrow of Time

## *Einstein's Mistake*

Relativity changed the notion of the instant; for an instant consists of all events that are simultaneous with it, and relativity changed the notion of simultaneity. But relativity also changed the notion of *instantaneity*; a possible change realised by Poincaré, but not by Einstein who made a mathematical mistake about it—a mistake that he did not correct till the end of his life.

What is instantaneity? Let us begin with the conventional idea that physics provides a 'causal' description of the world by relating causes to effects—physics describes how the state of the world *now* relates to its future states. The arrow continues to fly because of its state at the preceding instant, and physics enables us to calculate the future motion of the arrow, if the present state is known. We saw earlier (p. 178) that this 'causal' interpretation of physics is deceptive. The best argument against such an interpretation is Poincaré's philosophy that physics is defined by its mathematical equations, and not by the interpretations we assign to these equations. Instantaneity means that 'physical law is a differential equation', so that actually the state now decides *both* past and future states, so that all states are decided by the state at any one given instant. Thus, the formulation of physics using differential equations essentially means that the state of the world at any time is decided by its state at any one instant. One may say the arrow is flying now because it was flying a moment ago; with equal facility one may say the arrow is flying now because it will fall to the ground a moment later.

Why not simply say that the arrow is flying now because the archer released it from his bow two seconds earlier? There is a difficulty if one believes with Aristotle and Augustine that the past has ceased to exist; if so, locating causes in the past would make them non-existent! Therefore, the present motion of the arrow can be linked to the past action of the archer only through an intermediate chain of causes. This belief in the non-existence of the past is incompatible with relativity, as we have already seen—after relativity, the past does not cease to exist. Parts of the past may continue to exist in Buddhism, where the criterion of existence is causal efficacy, and there may be a possible delay between cause and effect. Therefore, Buddhists would say that a past event continues to exist if it has not yet produced its effects.

## The Philosophy of Contact

The belief that the past has ceased to exist is closely related to another belief in the desirability of explanation by contact: causes proximate in time are presumably also proximate in space. The philosophy of contact elevates this to a metaphysical principle: a physical explanation *must* locate causes not only in the immediate past, but in the immediate vicinity—the action of one body on another must be explained through physical contact between the two bodies. The archer cannot influence the motion of the arrow after it has left the bow, for he has lost contact with the arrow.

One observes, of course, the interaction between bodies that are evidently *not* in contact—like a pair of magnets. The aether, as an all-pervasive invisible substratum, was first introduced to help explain by contact such observed interactions between two spatially separated bodies. The aether was imbued with all manners of astounding properties to prevent this principle of action-by-contact from being falsified. In present-day physics (including relativity and quantum mechanics), the underlying philosophy of contact is preserved through the notion of the all-pervasive invisible substratum of the field, which has substituted the aether.[1]

The philosophical belief that only action by contact needed no explanation has an old history. Orthodox Indian philosophy (Nyāya-Vaiśeṣika) advocated the philosophy of *contact* (*saṁyoga*) and the related notion of *aether* (= sky= *ākāśa*).[2] Just at the time when numerous Indian texts were being translated and imported into renaissance Europe, this philosophy of contact and aether was adopted by Descartes. On the other hand, Francis Bacon was 'most ready to ascribe to action at a distance without any material medium…those [phenomena] which savour most of witchcraft, magic, astrology, and telepathy',[3] so that action at a distance often continues to be called 'spooky' in present-day discourses on physics. (This terminology has been particularly prominent in the debate over Bell 'locality': quantum mechanics is somehow 'spooky' because it enables interaction between particles that 'cannot' be in contact.)

Under such Cartesian and Baconian influence it came to be believed that a physical explanation, to be one, must relate a cause here and now to an effect here and now. The aether, it was thought, brought in clarity—also banishing spooks, like daylight. The natural mathematical corollary to this was instantaneity: that physical law must necessarily have the form of a differential equation.

Newtonian mechanics is characterised by this instantaneity. Though the force behind instantaneity was the idea of action by contact,[4] Newtonian physics only half-accepted the idea. Newtonian physics consists of two parts: Newton's laws of motion, and Newton's law of gravitation. Neither part can yield physics by itself, and the two must be combined to give physics.[5] Newton's laws of motion explained motion *here and now* using forces acting *here and now*, but Newton's law of gravitation explained the forces acting *here and now* using the positions of *distant* bodies *now*. After special relativity, the last 'now' in the previous sentence is not quite meaningful.

The sun, for example, is a distant body. Suppose it is switched off now. When will the earth first wobble in its orbit? After relativity, we believe that the information that the sun has been switched off will take some time to travel to us; we believe that this time cannot be shorter than the time taken by light to travel that distance—a little over eight minutes. So we will continue to see the sun, as it was before being switched off, for the next eight minutes, after which the earth will wobble. But according to Newtonian physics, the earth ought to wobble right away.

This thought experiment suggests a fundamental incompatibility between Newtonian gravitation and relativity, especially in interactions involving transients. Let us try to test this incompatibility. One cannot switch off the sun, so where should one look for gravitational interactions involving transients? The galaxy provides an example. (Though speculative, this is easier to explain than better examples.) While the planets of our solar system have gone around the sun many times since the solar system came into being, and have reached a steady state, our sun and other stars in the galaxy have gone around the centre of the galaxy barely a couple of times since the galaxy came into being.

## Dark Matter or the Failure of Instantaneity?

And, in fact, Newtonian gravitation does not correctly describe the observed motion of stars around the galactic centre. The stars seem to be moving far too fast. The amount of matter in the galaxy seems too small to hold together stars rotating at such high speed. The discrepancy is put down to something we do not observe, and something we cannot hope to see: dark matter in the galaxy—matter not in the form of stars, which hence cannot be seen.

Now, *a priori* one can accept that there may be non-luminous matter in the galaxy. One could even accept that matter in the galaxy is mostly dark, in the ratio of 10:1. But it is difficult to accept *the peculiar way in which this dark matter is required to be distributed*—with its density increasing *outwards* from the centre of the galaxy, and reaching a constant value where the density of luminous matter reaches zero. This peculiar *distribution* of dark matter seems an artificial hypothesis invented only to save Newtonian gravitation from being refuted.

Why not simply accept that Newton's laws fail to describe the situation correctly? Newton's laws are good for practical travelling to the moon, they are good to describe quickly the planetary orbits from which they were back-calculated, but they fail to describe the rotation of the galaxy.

## History Dependence

Let us try to understand this failure using the previous example of the sun being switched off. The question there was whether the gravitational force on a planet due to the sun relates to the sun as it is now or as it was last seen. This question appears with renewed force when we look at galactic rotation. Unlike a few planets going round a relatively very massive central body, in the case of the galaxy we have millions of stars going round a common centre. Each of these stars interacts gravitationally with all other stars. In calculating the gravitational force of star A on star B, at time *t*, should we use the position of star A at time *t*, or the position of star A as *last seen* from star B?

Relativistically, the second choice is preferable. (Though both these choices are technically incorrect, the following arguments apply perfectly well to the technically correct choice, where force depends upon both position and velocity.) Suppose we make the second choice. What difference does that make? To Einstein, it made no serious difference. Einstein only half-rejected the aether: he did not reject it in the sense of action by contact or instantaneity.[6] He thought, following Bacon, that action without contact was 'spooky', and stated as much while formulating the Einstein-Podolsky-Rosen paradox (Chapter 8). Poincaré, being a mathematician, understood that rejecting aether would change the equations of physics, making them what he called 'equations of finite differences'.

> Does our ether actually exist? We know the origin of our belief in ether. If light takes several years to reach us from a distant star, it is no longer on the star, nor is on the earth. It must be somewhere, and supported, so to speak, by some material agency…The same idea may be expressed in a more mathematical and more abstract form…in ordinary mechanics the state of the system under consideration depends only on its state at the moment immediately preceding; the system therefore satisfies certain differential equations. On the other hand, if we did not believe in the ether, the state of the material universe would depend not only on the state immediately preceding, but also on much older states; the system would satisfy *equations of finite differences*. The ether was invented to escape the breaking down of the laws of general mechanics.[7] [Emphasis mine.]

Today we would call these 'delay differential equations', or 'functional differential equations'. The names are unimportant, and what is important is this: if aether and action by contact are rejected, then, as a first step, instantaneity has to be replaced by *history dependence*.

Human memory is the simplest example of history dependence. The way in which we respond to a person depends upon whether or not we remember having met that person before. But can't memory be fitted to the paradigm of instantaneity? After all, memory is stored in the brain, so that the state of the brain at this instant incorporates all the memory in it, and it is this state which decides how the interaction proceeds. For any system with memory, one can hope to repeat this analysis because memory is stored somewhere. This account of history dependence, though plausible, tends to be erroneous or misleading— at least in physics[8]

Einstein's mathematical error—an error repeated also by other authors—published in the most reputed journal in mathematics, was exactly this: he believed that history dependence can always be reduced to instantaneity, in a simple-minded way.[9] Einstein took this erroneous mathematical belief to his grave. But this reduction cannot be done, in general, because *instantaneity is time-symmetric, while history-dependence is time asymmetric*. Instantaneity is time-symmetric: that is, the present state of a system, evolving under instantaneity, symmetrically decides both past and future: every state has a unique successor $t$ seconds into the future, and a unique precursor $t$ seconds into the past; distinct past states correspond in a one-to-one fashion with distinct future states. In particular, admitting chaos etc., one can retrodict the past typically to the extent that one can predict the future. This is no longer true with history dependence: past (history) decides the future, but the other way around is impossible, for systems with distinct histories may end up in the same future state (see Fig. 1). *Knowledge of the present state, therefore, does not enable a unique reconstruction of the past history of the system.*

## *Anticipation and Popper's Pond*

A relativistic theory of gravitation should not, therefore, mimic the Newtonian theory, but replace it. While on the subject of replacing the time-symmetric Newtonian theory, one can also reconsider the idea of cause. In passing from instantaneity to history dependence, we implicitly assumed a notion of 'causality': the *last* position is clearly a past position, and not a future one, so we assumed that past must decide the present, and that the future cannot have any

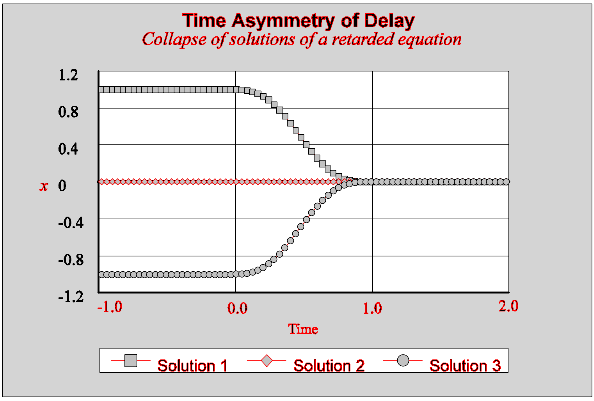


**Fig. 1: History dependence**

The figure shows three distinct past histories merging into the same future under history-dependent time evolution. In this situation, while past decides future, future cannot decide a unique past.

role in it. More generally, one may permit some anticipation or a tilt in the arrow of time.

On the face of it this seems outrageous. Just because it seems *outrageous* one must stop and think why. A tilt is not even a hypothesis, but simply a rejection of the hypothesis of causality. So, though culturally radical, the proposal for a tilt is physically conservative: it only involves exploring physics in the most general form available after special relativity. If we find that this form doesn't agree with observations, we can then reject it. But this general form has been rejected without attempting to understand it. Today, no one has a clear notion of what physics in this most general form would be like.

The great physicist P. A. M. Dirac[10] interestingly argued long ago that relativity provides an *a priori* reason for *not* rejecting anticipation offhand. His argument (p. 308) concerned electromagnetic waves—like sunlight, radio waves, or X-rays. Waves can be of two types: retarded or advanced. Retarded waves are like the ripples which spread out when a stone is dropped into a pond. Advanced waves are what one would see if one filmed these ripples, and played the film backwards, *viz.*, one would see ripples spontaneously commencing to converge from the boundary of the pond, and their convergence to the centre of the pond would generate enough energy to throw the stone out of the pond into one's outstretched hand.

One doesn't normally see this sort of thing, and the advanced waves are rejected as 'unphysical' for this reason. In fact, the problem is precisely that there is nothing unphysical about advanced waves: according to current physics they *may* occur, though they *do* not seem to. But suppose someone claims that this sort of thing does occur very rarely; that he has observed one such occurrence, and recorded it on film, and this is that film. Can a physicist refute such a claim? This is the paradox of Popper's pond.

Popper[11] claimed that a good physicist should be able to tell the end of the film from its beginning. Thus, a good physicist would ask: how can one *explain* this phenomenon which has allegedly been observed? How can one *arrange* for its repetition? Popper's answer was that there was no way to explain the phenomena without 'coordination from the centre', which means that one has a perfectly circular pond and the stone is dropped at its exact centre, so that a perfectly circular divergent ripple is reflected back as a convergent one. Apart from this, the only explanation was to appeal to a 'conspiracy of causes': to produce a convergent ripple by the constructive interference of spontaneously generated wavelets at the pond's boundary would require very 'fine tuning' (because of a technical condition known as coherence which is required for interference). Popper argued that such a conspiracy of causes would have virtually zero probability of occurrence, and hence would count as a miracle.

The first part of Popper's argument may be strengthened, for pure anticipation is the exact time-reverse of pure history-dependence. So, to understand the effects of pure anticipation one only needs to turn Fig. 1 around to obtain Fig. 2. With history dependence, even complete knowledge of the entire future does not decide a unique past; with anticipation even complete knowledge of the entire past does not decide a unique future. By its very nature, anticipation is incapable of causal explanation; anticipatory phenomena are causally inexplicable and would appear as spontaneous.

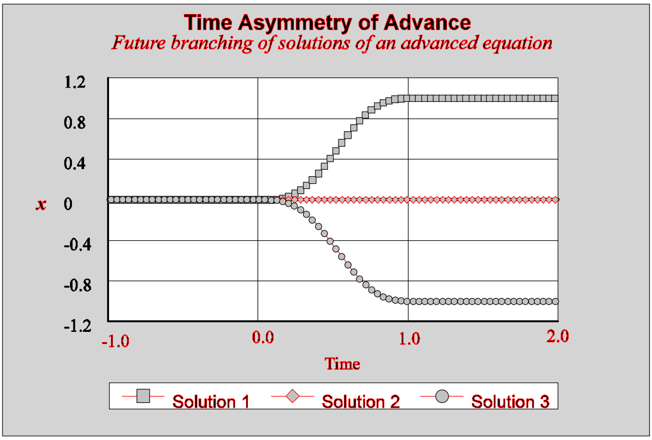


**Fig. 2: Anticipation**

The figure, viewed from right to left, shows three distinct future histories merging into the same past under anticipatory time evolution. In this situation, while future decides past, past cannot decide a unique future. Hence, as actually seen, from left to right, the 'branching' at $t = 0$, corresponding to the occurrence of any or all of the solutions after $t = 0$, would seem spontaneous, and causally inexplicable.

## *Tilt and Spontaneity*

Of course, a world in which *all* phenomena are anticipatory would not be any different from a world in which *all* phenomena are history-dependent. Time would run in the opposite direction, but this would be a matter of labels for there would be no way to tell the difference from inside such a world. What we need to do is to look at a world where only *some* phenomena are anticipatory. Some phenomena would now seem spontaneous, though there is a difference between pure anticipation and this case of a tilt. This difference is illustrated by Fig. 3.

Our study of time travel shows exactly how Popper's argument goes wrong. Recall our resolution of the grandfather paradox: the sudden appearance of the time-traveller Tim, or of any influence from the future, will appear to be spontaneous and incapable of causal explanation. We are now in a position to understand this better. If one forcibly attempts causal explanations of future influences, one is led to closed causal chains. I dream that I will win

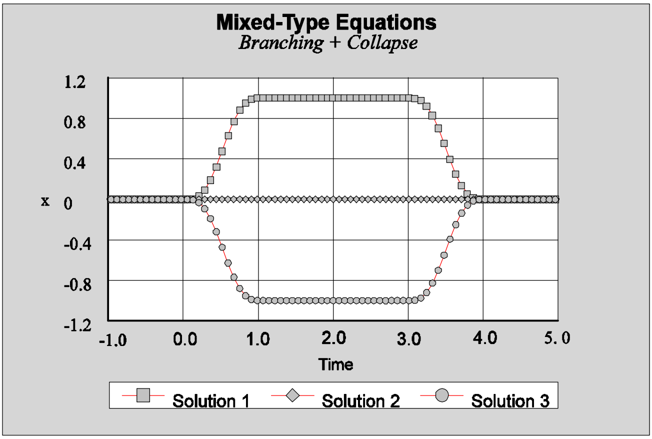


**Fig. 3: Tilt**

The figure shows three possible solutions of the equations with a tilt. All three solutions have the same past history and eventually the same future. Hence, both past and future may fail to decide a unique intermediate evolution. Hence, with a tilt, neither causal nor purposive explanations are necessarily adequate, though in a predominantly history dependent context even causal explanations alone may mostly suffice.

a lottery ticket. This causes me to go out and buy a lottery ticket. I win a prize just because I bought a ticket. And because I did win a prize, this caused the dream in the first place! But what caused the chain to begin? There can be no causal explanation for the entire chain. Hence also, the beginning of a closed causal chain has no explanation from the past.

Popper is partly right; in the absence of causal explanation for a spontaneous event, the event cannot be mechanically replicated; nor can one arrange beforehand for its occurrence. But why on earth should the world be such that every phenomenon in it can be mechanically replicated? Why should the world be such that every phenomenon in it is capable of *causal* explanation? Saying that every phenomenon *must* admit a causal explanation amounts to bending the world to fit one's metaphysical prejudices. Why should the world fit Popper's metaphysical prejudices and not someone else's? In fact, Popper[12] was the first to admit that this was a strong argument, so that he was possibly mistaken!

To summarise, 'causality' is a bad reason to reject anticipation; one is speaking here of rare anticipation rather than pure. Occasional anticipation, too, would manifest itself in the form of causally inexplicable spontaneous events, and one should reject (rare) anticipation only if one never observes any spontaneous events.

## *The Absorber Theory of Radiation*

Not only is causality a bad reason to reject anticipation, but Dirac[13] argued that in the case of electromagnetic waves, causality may be opposed to relativity; he chose in favour of relativity perhaps because he regarded 'causality' as an untested idea while relativity was already a tested physical theory. Electromagnetic waves are generated when a charged particle, like an electron, accelerates. These waves carry away energy, so conservation of energy requires that the electron should lose energy: power is needed to drive the antenna of a radio or television transmission station. How much energy does the electron lose? How much power is needed to drive a radio transmitter? To obtain a relativistically valid formula for this, Dirac found it necessary to introduce advanced electromagnetic waves.

So why are advanced electromagnetic interactions not observed? This question needs to be divided into two parts. (1) Why are electromagnetic interactions mostly retarded? (2) Are there any advanced interactions?

The answer to the first part of the question is provided by the absorber theory of radiation. Wheeler and Feynman's theory[14] is that even if all 'elementary' electromagnetic interactions between particles are time-symmetric, in the assembly of particles constituting this universe, the effective interactions will seem to be retarded, provided the universe behaves like the interior of a perfectly absorbing cavity. Thus, if locally one observes only retarded radiation then this gives a condition on the entire cosmos, viz., that it should be totally absorbing. An example of such a cosmos is the closed Friedmann model or the big bang model (Chapter 3).

It was later pointed out that the universe is almost transparent,[15] so that the average photon would travel practically to the ends of the cosmos before it interacted with anything. This would take a very long time during which the cosmos is not likely to remain the same. Advanced photons, travelling into the past, would therefore encounter substantially different conditions from retarded photons, travelling into the future. One should therefore distinguish between a past and a future absorber, and talk separately of their opacity or transparency.

Following this observation there are three theories. (i) The original one due to Wheeler and Feynman, as modified by Paul Davies;[16] this theory requires that both past and future absorbers should be opaque, so that the consistency of retarded radiation would put us into a closed Friedmann model (a big bang followed by a big crunch). (ii) The theory of Hoyle and Narlikar,[17] which requires that the past absorber is transparent and the future absorber is opaque; the consistency of retarded radiation would put us into a steady-state model (continuous creation). (iii) The author's theory,[18] which requires that the past absorber is opaque and the future absorber is transparent; the *approximate* consistency of retarded radiation would locate us either in the Einstein–de Sitter (big bang/ever-expanding) or the closed Friedmann model. Further, I have pointed out theoretical grounds for rejecting the other two theories: the theory of Wheeler–Feynman–Davies is internally inconsistent, while that of Hoyle–Narlikar is externally inconsistent (apart from being peppered with *ad hoc* and unjustified hypotheses). My theory concludes that perfect consistency of retarded radiation is not to be expected under any circumstances, so some advanced interactions must exist. In any case, regardless of the absorber theory, as stated earlier, the existence of some advanced interactions represents the most general situation; and unless one studies the consequences it is impossible to eliminate experimentally the possible existence of some advanced interactions.

## *Partridge's Experiment*

If some advanced interactions exist, how should one look for them? In 1973, Partridge[19] performed the following experiment, reasoning on the basis of the (incorrect) Wheeler–Feynman theory. He set up a horn antenna pointed to the sky which radiated into free space with a cover alternately on and off. Partridge measured the power consumed by the antenna in these two cases. If the absorber theory were right, and if some advanced interactions were present in the cosmos, then there ought to be a difference in the power consumed by the antenna in the two cases. Classical causality cannot accommodate such a power difference, for how much power an antenna consumes cannot depend on what subsequently happens to the radiation that leaves the antenna. Moreover, the expected power difference was positive for both the theories of Wheeler–Feynman and Hoyle–Narlikar, while it was negative for the author's theory. Partridge actually observed a very small negative difference of power consumption in the two cases; but it was so small (about 1 part in a billion) that the observed difference was within experimental error. Partridge concluded that advanced radiation did not exist to within the accuracy of his experiment.

To eliminate the doubt, one may want to repeat Partridge's experiment with greater accuracy. Such a proposal was made some time ago,[20] but was then abandoned due to technological difficulties. Perhaps it will be repeated some day soon, for the technological difficulties have now been essentially overcome.

## *Time Travel and Anti-Matter*

At this stage it is important to understand a key *difference* between electromagnetic waves and water waves in Popper's pond. A water wave in a pond is a macrophysical phenomenon (and the pond is not alive); so the occurrence of a spontaneously convergent ripple in an actual pond would indeed seem miraculous. When talking about very small amounts of advanced electromagnetic interactions, we are down to a microphysical level where electromagnetic interactions have a particle-like character, and are mediated by photons; 'small amounts of electromagnetic radiation' therefore refers to a small number of photons. But *a photon is its own anti-particle*. This makes the photon unlike many material particles like electrons and protons: for example, an electron travelling back in time will seem like a positron, for its charge would seem to have changed from negative to positive. But a photon itself does not carry any distinguishing features that enable one to tell by observation which way in time it is travelling; one cannot say that there are some advanced photons as easily as one can say that there is some anti-matter. More precisely, one can say this if one wants, but orthodoxy will hotly deny it! So we have to look for some indirect way to establish the existence of some advanced photons.

## *Chance and Spontaneity*

The key idea is this: advanced interactions are anticipatory; so, if some advanced interactions exist, they would show up through the occurrence of spontaneous events. This spontaneity due to anticipation differs from chance: *physics with a tilt is non-mechanistic without being statistical in character*. The difference is most easily stated mathematically. Physics with a tilt involves a type of time-evolution (Fig. 3) different from stochastic evolution (e.g., Markovian evolution, or Brownian motion; see Fig. 3 of Chapter 6).

One may try to bring out this difference non-mathematically as follows. We saw in Chapter 6 that chance is believed to increase entropy.[21] In contrast, the spontaneous appearance of a time traveller, or the spontaneous convergence of a ripple in Popper's pond, implies creation of order or a reduction of entropy. What we see is the molecules on the wall of the pond 'collectively conspiring' together to produce an ordered structure. The only difference is this: unlike Popper, we do not ascribe a zero or virtually zero probability of occurrence to spontaneous order-creation; a tilt means that there is a universal though rare tendency towards order creation. This tendency competes with the general history-dependent tendency towards entropy creation, and at the present epoch it is the history-dependent processes that dominate.

Occasional spontaneous order-creation does not offend the entropy law: in the absence of a causal explanation these order-decreasing processes cannot be mechanised, and so entropy cannot be systematically or mechanically decreased. Moreover, any decrease would occur against a background of history-dependent processes, which would increase entropy, so that overall one would only see an increase of entropy. There is, however, a difference of perception: the decrease of entropy here is not marked by a necessary increase of entropy elsewhere, it is only masked by an overall predominance of entropy-increasing processes.

## *The Tilt and Life*

Where should one look for spontaneous and non-mechanical processes which create order? Clearly, among living organisms. A tilt incorporates both memory and spontaneity better suited to model living organisms than Newton's laws adapted to the solar system. It should be clarified that one cannot hope, today, to numerically solve the equations with a tilt for an actual living organism. But one can hope to reduce the problem to manageable proportions, and solve the equations with a tilt for an interaction involving biological macromolecules.[22] One can then compare this with the usual (theoretically incorrect) way of studying this interaction using instantaneity, to see which model provides a better description. One can also compare this with the evolutionary models which use history dependence and/or chance. This is being done, and the results are not known at the present time. The point is that a do-able test of the tilt is available, and would be implemented within a few years.

At any rate it is clear that the old Newtonian physics won't do. Without awkward supplementary hypotheses, it fails if we go beyond the solar system to the galaxy. Even with all sorts of supplementary hypotheses it fails for atomic phenomena. It also fails to describe the special features that one associates with life. Newtonian physics, thus, fails at three scales: the very small, the middling, and the very large. All this is to be expected: Newtonian physics was back-calculated to fit the solar system and falling bodies. Some overly religious people took the universality attributed to Newton's (God's) 'laws' a little too seriously. As God receded from the thinking of post-Newtonian physicists many things became inexplicable. Living organisms were nothing special in the old physics. We saw in Chapter 6 how difficult it was even to talk of a separate class of living organisms within a mechanistic physics: for all physical purposes, living organisms were no different from an assembly of molecules constituting a rock or a planet.

One of the first physicists to make a serious attempt to talk of life within physics was Erwin Schrödinger.[23] He immediately identified order (= negative entropy = negentropy) as the characteristic feature of life: 'it feeds on negative entropy'. How was this order to be explained within physics? Naturally, Schrödinger invoked chance. As one of the founding fathers of quantum mechanics, Schrödinger emphasised that there was nothing quantum-mechanical about this chance, and that it was just the classical sort of chance we encountered in Chapter 6. This claim brings in its wake all the difficulties we saw of reconciling chance with a mechanistic physics.

The tilt being intrinsically non-mechanistic, there is no such fundamental problem of reconciling physics with the existence of living organisms. But a microphysical tilt permits only microphysical spontaneity and order creation, while the phrase 'living organisms' suggests human beings who are much larger. Thus, with a tilt one may classify living organisms as precisely those physical entities which can *amplify* this order creation.

## *Spontaneity and the Origin and Evolution of Life*

We see that we are once again confronted with the difference between spontaneity and (the classical vision of) chance. Let us try to understand this difference in the context of the theory of evolution. There are three questions here. (1) How did life originate? (2) Was there time enough for the present forms of life to evolve? (3) *Why does life want to survive?* The first two questions are common enough; but the third question is rarely asked, because the desire to survive seems the most natural thing in the world!

The common answer to the common questions is this. (1) By chance. (2) Yes, chance mutations and natural selection can lead to the growth of complexity. A little reflection shows that both these answers are quite meaningless. Chance is ordinarily meaningful when it relates to a large number of repetitions of a given event. We are here referring to a unique event—the origin of life—about which to say that it is due to chance is to say absolutely nothing. We may perhaps specify today that this chance is a propensity or a degree of subjective belief, or something like that, but for such a speculation to be meaningful, it must be refutable. Refutability, however, is a problem, for only a bad statistician will seek to draw inferences from a sample of size one. How often would life originate on other planets? We can only guess, not infer, for we must first guess how often the exact conditions on our own planet would be replicated. So we have no way to test the answer. Similar difficulties arise with the second answer. It is true that chance mutations and a selection process can lead to the growth of complexity. But the questions is, *how much* chance? and *how much* complexity? For, the time that is required to develop life in its present form through chance mutations and a selection process depends on the answers to these quantitative questions. Whatever the answers, we have no means to check them.

In contrast, with spontaneity, the origin of life appears as a natural process. With a tilt, we have two competing tendencies: a tendency for the growth of order, and a tendency for the growth of disorder. While entropy growth dominates, we can expect the growth of order in isolated pockets. *Life would originate universally, wherever it is able to survive*, regardless of whether this replicates the supposedly fortuitous circumstances on earth. The origin of life need not be a unique event even on our own planet. Ultimately, the difference between causally inexplicable spontaneity and such a hazy kind of chance is quantitative. A convergent electromagnetic wave could arise as a result of a chance fluctuation; but the probability of such an event happening by pure chance is a zillion times less than the probability of this event with a tilt. Similarly, with a 'systematic' tendency towards order creation, ordered organisms may evolve more quickly than by pure chance.

Prigogine has emphasised that: (1) in situations far from thermodynamic equilibrium, there may be a local tendency for order to increase; moreover, (2) living organisms are open systems, which can exchange energy with the environment (e.g., eat) to maintain a state of order. Both statements are perfectly valid; but they are far too weak. The first statement means that eventually these structures *must* dissipate: extinction of all life is the goal and destiny of evolution—death is the purpose of life!

The idea of purpose has been brought in here with a purpose, to remind us of the third question: why do living organisms want to survive? It is a bit facile to explain that living organisms can exchange energy with the surroundings for the *purpose* of maintaining life. We are so accustomed to the idea that living organisms seek to maintain life that it does not occur to us to ask why this is so. But, if we seek purely causal explanations, we must first provide a causal explanation for the evolution and constancy of this purpose. A facile answer would be to appeal to natural selection: those living organisms which did not seek to survive (which were they?) were selected out long ago!

A tilt links the present to both past and future. One views purpose neutrally as a future cause, as the time-symmetric counterpart of a past cause. (One should here try to avoid the mental trap of reverting to naive ideas of the non-existence of past and future: if one uses the non-existence of the future to eliminate future causes, and non-existence of the past to eliminate past causes, there is no escape from the mechanical paradigm of instantaneity!) In common parlance, the term 'purpose' is a term one attaches only to living organisms. This common-sense attitude involves two considerations. The first is an easy-going dismissal of the dogma of causality: an explanation in terms of purpose or motive is preferred, for it is often simpler and easier to comprehend than an explanation in terms of cause. (In fact, many people have difficulty in understanding mathematics just because the point of a complex mathematical argument is often seen only by hindsight.) The second is that the common-sense attitude reflects the observation that 'purposive' explanations fit only living organisms: a stone does not roll down a hill on purpose. (This restriction to living organisms is quite acceptable with a tilt.)

This type of purposive explanation should not be confused with the teleological explanations of medieval Christian theologians in Europe. Lightning does not strike church spires on purpose. The medieval beastiaries, building on the deification of nature, to prove the existence of God, only followed Augustine's invention of salamanders to prove to pagans, using only 'facts', how God could keep people alive 'in the flesh' despite burning them forever in the fires of hell. The only purpose here is that of the theologian to rule the world by fooling gullible people.

## *Multiplicity vs Collectivity of Causes*

Not only does a tilt permit purposive explanations, it changes the nature of causal explanations. In the first place, the picture with a tilt is rather like that of mundane time: history-dependent evolution punctuated by spontaneous interventions. This brings in its wake the difficulty with a multiplicity of causes that exists with mundane time.

With instantaneity we had deterministic superlinear time. Here every event had a multiplicity of causes, for any event could be the cause of any other. By convention one could agree to call only past events as causes, but for every cause that one identified there was a preceding cause, forcing one to consider the possibility of an initial cause. The point of this initial cause was that it involved a creative act inexplicable from the past; this privileged the hypothetical initial cause above all other possible causes.

One could allow such spontaneous events at other instants of time, and not only at the initial instant of time. If these events just take place in any arbitrary manner we would have 'breaks' in time, or providence. Mundane time suggests a different way to break out of this providence vs rationality debate: rational evolution is broken by the spontaneous creative acts of individuals. Hence, causes can be localised in individuals. This last conclusion, however, is fallacious: for one has not one single spontaneous act, but a sequence of such acts. Each element of this sequence can claim to be the cause. Within this *multiplicity of causes*, which one is most privileged? One way is to choose an immediately antecedent act as a cause. This choice seems appropriate in some instances. But if made a blanket rule, this would mean that in a soccer team all the credit invariably goes to the striker who shoots the goal. (That seems unfair.) If that were really so, one would have a match not between two teams but between 22 individuals.

A tilt acknowledges the existence of cooperative behaviour. In a truly cooperative situation like Popper's pond, there is a *collectivity of causes* rather than a mere multiplicity. The idea of a multiplicity of causes applies with mundane time, where there is a sequence of causes each preceding the other. In Popper's pond, there is no temporal sequence between this apparent multiplicity of causes: all the molecules at the boundary of the pond start moving simultaneously. Thus, there is not even a temporal sequence between these spontaneous events, and no possibility even of introducing a convention privileging the immediately antecedent event as the cause.

It should not be overlooked that even history dependence destroys this idea of privileging the immediately antecedent event as the cause, because it makes an event dependent upon a whole bunch of preceding causes. What if history dependence replaces a multiplicity of individual causes by a multiplicity of bunches of causes? This possible technical complication is resolved in present-day physics by making the future depend upon the *entire* past.

Thus, the idea that causes can always be located within individuals is not valid with a tilt. With instantaneity or pure history dependence, the time evolution of a physical system is still predictable from past data so that credits and blame cannot be localised within individuals. On the other hand, when we do have spontaneity, this is inextricably linked to a collectivity of causes, so that credits and blame once again cannot be localised within individuals.

We have already observed that the distribution of credits in society proceeds from the notion that causes *can* be localised within individuals. So how should credits be redistributed with this changed notion of cause? Before examining that, let us see how the distribution of credits has changed in the past with changes in the notion of cause.

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## *Summary*

- A tilt means partial anticipation.
- A tilt involves no hypothesis; it concerns an exploration of the most general form of physics after relativity.
- A tilt changes the *nature* of the equations currently used in physics.
- Physics with a tilt is non-mechanistic; it implies spontaneity.
- Physics with a tilt seems better suited to model life (and the cosmos beyond the solar system), since it permits both memory and spontaneity. But the suitability is still being tested.

- Spontaneity differs from chance in creating order instead of destroying it. Hence *a tilt implies a small universal tendency towards order creation.* But spontaneity cannot be mechanised, so this tendency does not contradict the entropy law. History dependence, in fact, helps explain entropy *increase*.
- A tilt means a non-trivial structure of time (hence quantum mechanics) in the small. A tilt also has other microphysical consequences that are too technical to be explained in more detail here, but have been considered elsewhere.
- A tilt permits purposive explanations in addition to causal ones. In fact, fully causal explanations are impossible with a tilt. This type of purposive explanation is quite different from medieval beastiaries.
- A tilt partly helps to reconcile time in physics with mundane time. But a tilt brings in a true collectivity of causes in addition to a multiplicity of causes. Hence, localising causes in individuals becomes problematic.

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# PART 4

# TIME AND VALUES

How does a changed picture of time affect everyday life?

It is not only through ideas of life after death that time perceptions have influenced the way of life. Time perceptions help shape also the present way of life in industrial society. The present way of life is based on the perception of time as money, so that one plans one's life in such a way as to make as much money as possible. The experience of early attempts to industrialise agricultural societies yields an important observation. *This change in values and time perceptions was essential for the success of industrial capitalism*—an observation needed also to understand the current attempts to globalise convenient values. Various *physical* assumptions about time are built into the perception of time as money: for example, rational planning presupposes an ability to *calculate* future rewards, and their discounted present-day value; it presupposes that the actual world is a rational world created by a rational God, together with a uniform rate of discount!

The Merchant's idea of conducting life, in anticipation of rationally calculated future profit in this life, has an obvious correspondence with the Priest's idea of conducting life, in anticipation of rationally calculated future rewards in a future life. Sociologists have opined that this congruence between Priest and Merchant arises because both believe in 'linear' time, and reject 'cyclic' time. This sociological opinion is based on (a) a neglect of the various pictures of 'linear' and 'cyclic' time, and (b) a profound neglect of the pictures of time in other traditions.

A thousand years before the Western Christian curse on 'cyclic' time, the 'people's philosophers' (Lokāyata) in India rejected 'cyclic' time, but they did so with exactly the opposite motivation of *wanting* equity. Since they advocated 'linear' mundane time rather than 'linear' apocalyptic time, they encouraged sexual indulgence, for example, which Western Christianity would regard as a sin. Since the Lokāyata advocated 'linear' mundane time rather than superlinear time, they denied that the benefits of deferred consumption could be rationally calculated, thus rejecting also the Merchant's way of life.

The Buddha did not directly reject 'cyclic time', but he denied its key consequence, for he denied that a soul or any other notion of personal identity continued even from one instant to the next. The Buddha's notion of conditioned coorigination (*paticca samuppāda*) differs from the usual (Augustinian) notion of cause. This notion of conditioned coorigination is also the key to the Buddha's way of life (*dhamma*) which rejects both the Merchant's glorification of accumulation, and the Priest's glorification of accumulation of virtue through suffering. The Buddha founded the *samgha*, his model of a society with equity, thus rejecting the Priest's and the Merchant's fundamental tenet that morality necessarily begins with accumulation and inequity.

In Islam there eventually prevailed the view of al Ghazālī who denied that the future could be rationally calculated from the past.

These different views of time lead to different recommendations of how to conduct one's life, all of which differ from the *time=money* of industrial capitalism. The harmony of industrial capitalism with Western culture arises because the Priest modified religion to suit the needs of the Merchant.

Changing the picture of time also changes logic, hence the very idea of rationality, which is thus not universal.

A tilt leads to the recommendation: *live so as to increase order in the cosmos*.

# 10

# Time as Money

Time and values are not related only by old beliefs in life after death. Let us look at our present lives. Many people today bemoan the collapse of older values. How has this come about? Does this change, too, relate to changed time beliefs? Much has been written about how time has become a commodity in industrial capitalist societies,[1] and a brief review of this literature,[2] with some corrections, will suffice for the purpose of showing that beliefs about time continue to provide the key to the values that govern our lives today. But let us first understand the genesis of this change.

## *The Church and the Mechanical Clock*

Today, in the West, it is customary to greet each other not by bowing, but, for example, by saying 'Good morning'. That is, one names the time of the day and prefixes it with 'good'! How might this strange ritual have originated? Why is it culturally so important to keep naming the time of the day?

Landes[3] argues that the Roman Church, unlike other religions, fixed the time of prayers without regard to natural phenomena, by dividing the day into equal parts, as was the custom in Roman times. In addition to morning and evening prayers, Tertullian prescribed prayers at the third, sixth, and ninth hours that were then publicly announced. In medieval times this was increased first to six, and then to seven daytime prayers, and one at night.[4] Afternoon, thus, meant after *none*, or the time after the *none* prayer. The ritual of naming the time of the day presumably relates to this ritual of prayer, which requires one to know the time of the day without regard to natural phenomena.

Landes, however, is completely wrong in locating the uniqueness of the church in its supposed unconcern for natural phenomena. Timekeeping was very important to the church, but the church never intended to disregard natural phenomena for timekeeping. The key point on the official agenda of the First Ecumenical Council (Nicene council) was to fix the date of Easter, and this date was fixed by a calendar which used the tropical year or the natural cycle of the vernal equinox. Reliance on the equinoctial cycle was the basis also of the Gregorian calendar reform of 1582, eventually adopted by Protestant Britain, and the US in 1752. This still continues to be the basis of the present Western civil calendar, and its peculiar system of unequal months and leap years.

As for the custom of dividing the day and night into eight 'equal' parts, this was hardly unique to the Roman church or to the Romans. This custom originated well before the Roman empire, and is found, for example, in the Indian *yāma* or *prahara* (still in use), which dates back to at least a thousand years before Plato, and in the related Arabic *zām* (later a navigational unit of distance, now almost obsolete). So what exactly was the unique element?

What Landes and other social historians have overlooked is this: it is not so *easy* to fix the exact time of the day from natural phenomena. Apart from a knowledge of the phenomena, one needs the ability to calculate. The unique feature of the Romans was their *inability* to calculate. The Romans calculated using calculi—stones. For more complex calulations, such as accounts of the state, they used the abacus—the same instrument that is today used as a toy in the kindergarten. If this sounds incredible, try to multiply XVIII by XIX. Worse still, try to divide MDCXVII by XVII. Even for the most learned people in the Roman empire, in Alexandria, in Africa, mathematics did *not* mean knowledge of calculation—it meant knowledge of previous lives (Chapter 1)! Because of this inability to calculate, the Roman calendar adopted an easy, but wrong, figure for the length of the (tropical) year as 365¼ days. The contemporary Indian calendar of the 5th century CE reflected a far more accurate knowledge of the length of the (sidereal) year.

But the Romans could easily have learnt from others, like the Arabs, Indians, and Chinese, who all learnt from each other. Why didn't the Romans learn better techniques of calculation from others? The other unique feature was the insularity of the Roman church; it objected to any learning from others. Theophilus and Cyril violently destroyed repositories of Neoplatonist or 'pagan' learning—like the Great Library of Alexandria. Augustine chided Porphyry for searching for knowledge among the 'mores and disciplines of Indi'. This religious resentment of learning certainly applied to mathematics, which the Neoplatonists especially valued, and which the church hence regarded as a 'pagan' 'religious' activity. Hence, mathematics was despised, and was no part of the curriculum of Christian priests: this state of affairs persisted until its disadvantages were painfully brought home a thousand years later when Rome renewed its direct contacts with India in the 16th century CE. On account of this insularity, Europe had to wait for centuries to learn how to add, subtract, multiply, and divide numbers easily, though some more enlightened medieval monks and some smart Florentine merchants kept bringing these techniques from India, via the Arabs, in the form of algorismus texts.[5]

In the 16th century CE, the European inability to calculate and tell the time became a major embarrassment to both church and state. Jesuit priests were forced to fall silent in debates involving technical aspects of mathematics and astronomy, as Clavius recorded:

> since talk about them [mathematical studies] comes up in conversations and gatherings of men of parts, at which it is taken for granted that Jesuits are learned in mathematics, it happens that Ours present are constrained to silence, to their own confusion. This same we have heard from those whose own experience this has been.[6]

The inability to calculate and the refusal to learn from others put the Roman church in a peculiar fix. The time for prayers had to be authoritatively fixed, but even the authorities did not quite know how to fix it, for it was very difficult for them to carry out the calculations to determine the time of the day from natural phenomena.

Therefore, when the mechanical clock became available,[7] it was natural for the church to adopt it. Early mechanical clocks were notoriously error prone, but they eventually became more accurate than the calculations made by an *untrained* person using a gnomon. Moreover, sundials were a technology better suited to the sunny climates of India, Arabia, and Egypt. The mechanical clock also suited the church in other ways, so that it soon became a religious symbol: a good clock, somewhat like a model human being, followed the rules set for it by the clockmaker! Though it was the mechanical clock which disregarded natural rhythms, it ironically became a model for nature. In the days when religion harmonised with science, a clockwork cosmos became a powerful metaphor for scientists, and classical physics is modelled on this metaphor. The clock taught other useful lessons in morals: when the first millennium had passed safely, and the second seemed far away, the ticking of the clock provided a good way to stress that time was running out. People could hardly be controlled unless they were impressed by the urgency to repent; the millennium card having been overplayed, continuous awareness of the passage of time, through the clock, helped to restore this sense of urgency.

The mechanical clock became a source of ritual discipline. Just as the day for ritual festivals like Easter was fixed by the calendar, the time of the day for important rituals like prayers was now disciplined by the clock, so that the clock itself assumed a ritual aspect. In personal terms, this monastic discipline imposed by the clock meant that one ate not when one felt hungry, but when the clock struck six. The best that one could do was to arrange to feel hungry when the clock struck six.

Early mechanical clocks, like early computers, were massive affairs, housed in separate buildings of ther own. This made them imposing enough to serve as icons. They were so expensive that the whole town had to come together to pay for them; but people accepted this, for a single clock served to announce the time to the entire town, partially replacing the church bells. In fact, the word 'clock' derives from the Latin *clocca,* the French *cloche,* and the Dutch *klok* meaning bell. Without the clock, rituals could not be correctly performed: soon clocks started appearing in every European town. This demand for clocks served to support a number of clockmakers. As Whitrow remarks, 'it seems inevitable that the development of the *mechanical* clock should have been primarily due to the Church'.[8]

## *Navigation and the Gregorian Calendar Reform*

The methods of timekeeping in Europe, whether through mechanical clocks or the calendar, remained remarkably inaccurate until the 16th century CE, when this became a major embarrassment to both church and state. Early 16th century Europe was very poor—the most prosperous regions were Spain and Portugal, just emerging from Arab rule. Trade with India and China represented the golden opportunity. Motivated by abject poverty and the hope of future riches, European sailors were ready to run huge risks: approximately a third of them used to die on each *successful* voyage to India. Ships sank frequently, and a sunken ship meant also loss of valuable cargo. Ultimately, successful trade needs secure trade routes, and secure travel from Europe to India or China and back needed, at the least, knowledge of navigation. Navigation was the strategic and economic key to the initial prosperity of Europe through trade and subsequent colonisation.

Contrary to the usual stories, Columbus and Vasco da Gama were hardly great navigators, though they certainly were great adventurers. Neither knew the celestial navigation techniques known to their Indian, Arab, and Chinese contemporaries. The European method of navigation by 'dead reckoning' necessarily relied upon maps and charts, so they did not know how to navigate on uncharted seas. To be sure they had heard of this technique of celestial navigation, used by Arab navigators, but they did not quite understand it.

> Now let us look at Columbus's ability at celestial sights…His first recorded attempt at using a quadrant to establish his latitude was on 2 November when he was off the northern shore of Cuba. This sadly erroneous sighting put him on the latitude of Cape Cod. Even so, Columbus failed to recognize this gross error and instead concluded that he was…on the mainland of Cathay…[This] illustrates Columbus's serious incompetence in celestial navigation. Columbus tried the quadrant again on 20 November and came up with the same deplorable result of 42 degrees north latitude, but this time he realized that something was wrong and blamed it on the quadrant which he said was broken and needed repair. How

> can a quadrant be broken when it has only one moving part and that part is a string with a weight on the end?[9]

Columbus, however, did not really need to know too much of navigation, since he was aimed at so massive a shoreline that he could hardly miss it!

Similarly, Vasco da Gama used the services of an Indian pilot, Kānhā, to 'discover' the sea route to India. To determine the latitude at sea, the pilot used an instrument, called *kamāl* or *rāpalagai*.[10] In its simplest form, the instrument consists of a small wooden board and a string graduated with knots. The local latitude is almost the same as the altitude of the pole star, or its angular elevation above the horizon. To determine the altitude of the pole star, the wooden board is held in front of the eye, at an appropriate distance, so that it blocks the portion between the horizon and the pole star, and the distance from the eye is measured. The distance is measured by holding the string between the teeth, and counting the number of knots. In the Arabic-Malayalam language, the pole star is hence called *kau*, which also means 'teeth'. Vasco da Gama, not understanding the principle of the instrument, thought the pilot was telling the distance with his teeth! He further recorded that he carried back a couple of copies of the instrument to get it graduated in inches! (The instrument involves a harmonic scale, whereas inches refer to a linear scale, so that graduating it in inches is intrinsically impossible.)

Though the Europeans did not know celestial navigation, their own technique of navigation by 'dead reckoning', using maps and charts, was very unreliable. Though a great deal of effort initially went into procuring and making accurate maps, it was eventually understood that, despite accurate maps, the European technique of navigation itself was inaccurate since it required measurement of the speed of the ship. The ship's speed was measured by a process called heaving the log: throwing overboard a log tied to a rope, and measuring out the amount of rope taken up in a given period of time. A sailing manual describes how inaccurate this process was, even in 1864:

> if the gale has not been the same during the whole hour, or time between heaving the log, or if there has been more sail set or handed, there must be an allowance made for it, according to the discretion of the officer. Sometimes, when the ship

> is before the wind and a great sea is setting after her, it will bring home the log; in such cases it is customary to allow one mile in ten, and less in proportion if the sea be not so great; a proper allowance ought also to be made if there be a head sea. In heaving the log, great care should be taken to veer out the line as fast as the log takes it; for if the log be left to turn the reel itself, it will come home, and give an erroneous distance.[11]

European ignorance of navigation was widely recognised as a major problem, because the immense economic and strategic importance of navigation for Europe was transparent to all. One sunken ship meant not only a fortune gone, but also more men gone than in a typical war of those times. Consequently, governments in Europe not only officially admitted the European ignorance of navigation, from the 16th to the 18th century they did everything possible to find a better technique of navigation. Pedro Nunes, a professor of mathematics at Lisbon and Coimbra, was appointed royal cosmographer in 1529. A huge prize was offered by Philip II of Spain, in 1567, for a reliable technique of navigation. This process of offering huge prizes for navigation was continued by many European governments over the next two centuries.

By the mid-16th century, the Europeans had learnt the basic technique of determining latitude by pole-star altitude, and had devised instruments like the cross staff for this purpose, though these simple instruments lacked the sophisticated interpolation techniques of the Indo-Arabic instrument—techniques which came into general use in Europe only after Vernier in the 17th century CE (after whom they are named).

Using the pole star for navigation had two drawbacks. For travelling from Europe to India, it is necessary to cross the equator. As one moves towards the equator in the northern hemisphere, the pole star ceases to be visible above the horizon; there is no similar star in the southern hemisphere. Moreover, the pole star is not at all visible in the daytime.

For navigation during the day, the Indo-Arabic technique of navigation involved measuring solar altitude at noon.[12] Solar altitude, like the altitude of the pole star, can be measured by any device used to measure angles, such as a cross-staff or a quadrant, or any one of the great variety of instruments that were devised for this purpose. But there was another problem because latitude cannot be calculated so easily from solar altitude. Unlike the pole star, the sun does not stay approximately fixed, but, as all of us know, the sun moves substantially to the north in summer (in the Northern hemisphere), and to the south in winter.

To calculate the latitude from the solar altitude, it was necessary to know the solar declination or its north–south deviation, at the time of measurement.[13] The solar declination varies from day to day. The declination is zero on the days of the equinoxes, and is a maximum on the days of the solstices. Knowing the maximum displacement, hence the average displacement per day, we can calculate the solar declination on any given day, if we know the number of days that have elapsed since the vernal equinox. For example, if we know that the altitude of the sun at noon is 90 degrees, *and* we know that today is 22 June (summer solstice), then we know that our latitude is the same as that of the Tropic of Cancer. If, however, today is 2 July, then we are far off from the Tropic of Cancer. The dates 22 June and 2 July are not meaningful in themselves, unless one has an accurate calendar, which correctly identifies the vernal equinox. So, to calculate latitude accurately from the measured solar altitude at noon it was necessary to have an accurate calendar.

The calendar used in Europe at that time was the Julian calendar, set up by Julius Caesar. Because the Romans found arithmetical calculations difficult, for simplicity in calculation, the Roman calendar had adopted the figure of 365¼ days for the length of the year—a figure which was wrong in the second decimal place, leading to an error of one day in a century. The resulting error had piled up over the centuries, so that in the 16th century the Roman calendar was inaccurate by 10 days. This introduced too large an inaccuracy in deducing latitude from measurement of solar altitude at noon. By way of contrast, the text of Bhāskara I, written a thousand years earlier, and widely used in India, speaks of corrections due to the change in solar declination from morning till evening! This latter change being about ⅛ of a degree, the error due to the inaccurate calendar amounted to some 3 degrees of the arc! (One must add also the error due to measurement and the error due to inaccurate sine values.) For a sailor this was easily the difference between life and death.

Since the inaccurate Roman calendar put European sailors in the 16th century to such an enormous disadvantage, and since navigation was economically so important to Europe, reform of the calendar became imperative. But correcting the calendar involved another problem. The equinoxes represent the zero point of solar declination, so correcting the calendar for navigation meant correcting the date of the equinoxes. But this meant also revising the date of Easter. This was a problem that involved the church: a powerful entity in 16th century Europe, in the heyday of the inquisition. Recall that the date of Easter was the key point on the agenda of the Nicene council, so the date of Easter practically defined the Nicene creed. Articulating a difference from the Nicene creed meant being branded a heretic—a dangerous proposition, even for a Newton in Protestant England, a hundred and fifty years later. So strong were the religious feelings in the matter, that the obvious corrections to the defective calendar were not accepted in England until 1752. Discontent with the Roman calendar had been earlier voiced in Europe for several centuries, but had been ignored until the 16th century, when an accurate calendar became a matter of the greatest practical importance to the state. Even after the Roman Catholic church had publicly accepted the need for a calendar reform, the actual process of reforming the calendar and revising the date of Easter took some 50 years. The calendar reform focused on the date of the equinox, and did not address the obvious absurdity of retaining a calendar with months, unrelated to the natural cycle of the moon, and varying in length from 28 to 31 days.[14] Thus, in the sixteenth century, fixing the date of Easter had again become the major scientific, technological and religious problem of Europe!

The Jesuit Christoph Clavius who eventually headed the calendar reform committee had studied at Coimbra under Pedro Nunes, the most famous European navigational theorist of the time. Clavius reformed the curriculum of Jesuit priests at Collegio Romano, to introduce (practical) mathematics into it, as noted earlier, and himself wrote a text on practical mathematics. From among the first batch of Jesuits, so trained in mathematics and navigation, the most capable, like Matteo Ricci, were sent to collect information about timekeeping from India, to help in Clavius' reform of the Gregorian calendar.

The insularity of the church now assumed a new form. Though it privately sought 'pagan' learning, it continued publicly to deny that there was any learning among the 'pagans'. It needed, therefore, to hide its dependence on pagan learning for so central a religious festival as Easter. Thus, though Matteo Ricci visited Cochin, a centre of Indian *jyotiṣa* (timekeeping through astronomy and mathematics), in 1581, and himself wrote that he was trying to learn about the methods of reckoning time from 'an intelligent Brahman or an honest Moor',[15] the *Encyclopaedia Britannica CD97* still records that 'Matteo Ricci was sent to Cochin for reasons of health'!

Indeed, Western historians, especially from the 18th to the 20th century, have spent much effort to show the irrelevance of 'pagan' learning. The claim is that the present stock of knowledge is entirely free of any corrupting 'pagan' influence. The classical trajectory of knowledge development, still widely prevalent today is:

Greece $\longrightarrow$Renaissance $\longrightarrow$Modern Science

According to this trajectory, no theologically incorrect part of the world has played any mentionable role in the development of knowledge. It is now beginning to be recognised that, for example, this trajectory needed to fabricate ancient Greece,[16] through appropriation of African learning. It bypassed Indian and Arabic learning: Copernicus' heliocentric model, for instance, was but a bad Latin translation of a Greek translation of an Arabic work on astronomy.[17] This very strange current-day belief that almost all serious knowledge in the world has been developed only by Christians, or their theologically correct predecessors in Greece, demonstrates the strength of the continuing cultural feeling against 'pagan' learning. There is nothing 'natural' or universal in hiding what one has learnt from others: the Arabs, for instance, did not mind learning from others, and they openly acknowledged it. This is another feature unique to the church: the idea that learning from others is something so shameful that, if it had to be done, the fact ought to be hidden as well as possible. Therefore, though the church sought knowledge about the calendar, specifically from India, and profusely imported astronomical texts (the Jesuits, of course, knew the languages of these texts, and had even started printing presses in some of these languages by then), this import of knowledge remained hidden. This imported knowledge played a key role in bringing the differential calculus to Europe, which story, however, would take us too far afield.[18]

## *Longitude*

After Pope Gregory's Bull of 1582, which reformed the Roman calendar by adding ten days to the calendar, on October 5, and introduced the system of bypassing leap years every century, the problem of determining the latitude at sea was solved. But the navigational problem persisted, because *longitude* could not be accurately determined!

The navigational knowledge of determining local latitude and longitude, that the Europeans sought, existed, for example, in widely distributed Indian calendrical manuals from the 7th century, such as the texts of Bhāskara.[19] This knowledge had been revised and updated over the centuries, by various people including Al-Bīrūnī in his famous treatise on mathematical geography,[20] and a prominent school of mathematics in Kerala. This revised and updated knowledge was recorded in calendrical and astronomical manuals widely distributed in the vicinity of Cochin, where Matteo Ricci and other Jesuits searched for them. Language was not a barrier, and after Clavius, knowledge of mathematics was also not a barrier. Ironically, however, this navigational knowledge in Indian and Arabic texts could not be used directly by the European navigators because of some other difficulties.

The first difficulty was still the same old inability to calculate. Though the experts in Europe were beginning to learn about the decimal representation, and knew by then how to use algorithms to add, subtract, multiply, and divide, they did not thoroughly understand the calculus and trigonometry. Trigonometry came to Europe, after Regiomontanus, at least a thousand years after it had developed in India. European errors in understanding trigonometry are embedded in the very names of the trigonometric functions! Thus, the Indian term for the sine was *jyā* or *jīvā*. This was taken into Arabic as *jībā*. However, Arabic writing often omits vowels, so the term *jībā*, written simply as *jb*, was misunderstood as *jāīb* or fold, and translated into the Latin *sinus*! Calculus was needed to derive precise values of the sine function—which were available in contemporary 16th century Indian texts like the *Tantrasangraha* and *Yuktibhāsā*. Key figures of the time in Europe, such as Pedro Nunes, Christoph Clavius, and Simon Stevin, all published texts containing tables of the sine function and other trigonometric functions useful in navigation, and tried to make their tables as accurate as the contemporary Indian tables. The sine function was involved in determining latitude. It was also involved in Bhāskara's method or Al Bīrūnī's method of determining longitude from a knowledge of the latitude difference together with some other information.

The calculation techniques in India had advanced substantially beyond the algorithms for multiplication and division, and decimal fractions that Europe was just beginning to get used to in the late 16th century CE. Though right from the time of Christoph Clavius, and the calendar reform of 1582, active efforts were being made to procure calendrical and mathematical knowledge from Indians, Arabs, and Chinese, Europeans had difficulty in understanding these texts. The results of this import of mathematical and astronomical knowledge is reflected in the work of the 17th century European mathematicians like Cavalieri, Fermat, Pascal, and Gregory, directly, and Leibniz, Wallis, and Newton, indirectly, though they did not mention their sources, and often did not reveal their methods. Fermat's famous challenge problem to European mathematicians, for instance, is found as a solved problem in several popular Indian astronomical and mathematical works, including those of Brahmagupta and Bhāskara II.[21] Nevertheless, leading European mathematicians had fundamental difficulties in understanding these imported techniques of calculation, involving infinite series, which Descartes declared to be beyond the capacity of the human mind. These difficulties were natural, for the traditional Indian understanding of mathematics as practical, computational, and empirical, contrasted sharply with the European understanding of mathematics as spiritual, proof-oriented, and formal.[22] In the*Yuktibhāṣā* derivation of the infinite series, in accordance with the Nyāya-Vaiśeṣika philosophy of atomism (p. 299, and Chapter 9, note 2), the process of subdividing a circle was presumed to stop when the subdivisions reached atomic proportions. But when the Jesuit Cavalieri[23] used the term 'indivisible', while similarly deriving the same infinite series, this led to a storm of protest. These difficulties with the infinitesimal calculus persisted in Europe until the late 19th century CE.

The size of the globe was another important piece of information that went into the Indo-Arabic methods of determining longitude.[24] Lacking an accurate knowledge of the size of the globe, Europeans could not use these methods in the 16th century and for much of the 17th century. Indians and Arabs had determined the size of the globe very accurately. The methods ranged from the inexpensive techniques documented by al Bīrūnī, to that of Caliph al Māmūn, who sent an expedition in the desert to physically measure out the distance of one degree of the arc. Though Europeans were presumably aware of the earlier Indo-Arabic estimates, the irony was that Columbus, perhaps to get finance for his voyage, had understated the size of the globe by 40 per cent. Columbus' 'success' seemed to confirm the estimate, so that few people cared to revise it! Instead, Portugal banned the use of the globe for navigation, despite Nunes' valiant attempts to defend it. Ultimately, when Newton did suggest a revision of the size of the earth, he was still 25 per cent below the mark.

By this time (mid–16th century CE), the navigational problem had assumed such acute proportions that the state started intervening more and more actively to encourage the development of a solution. The reward offered by Philip had been increased in 1598. The reward was now so large that the most prominent scientists of the time competed for it. Galileo, for example, tried to get the reward for nearly 16 years, starting in 1616. After that he shifted his attention to the prize offered by the Dutch government in 1636. In France, Colbert, following his predecessors Mazarin and Richelieu, offered vast sums of money for a solution to the navigational problem, and sent personal invitations to Huygens, Leibniz, Roemer, Newton, Picard...to tackle it. From the replies he received, he selected 15 people to form the French Royal Academy.

The British Royal Society was started similarly, around groups which met to discuss the 'longitude problem'. A 1661 poem describing the work going on at one of these groups at Gresham College went as follows:

> The Colledge will the whole world measure,
> Which most impossible conclude,
> And Navigators make a pleasure

By finding out the longitude.
Every Tarpalling shall then with ease
Sayle any ships to th'Antipodes.

(Tarpalling here means a tar or a sailor.) The group from Gresham College included John Wallis and Robert Hooke; it later merged with other groups to form the Royal Society of London. Christopher Wren, also a member of the Gresham College group, wrote the preamble to the Royal Society's charter. One of the stated aims of the newly founded Royal Society was: 'Finding the Longitude.'

As the first project of the French Royal Academy, Picard redetermined the size of the earth in 1671, using Caliph al Māmūn's technique of physically measuring one degree of the arc. For longitude, Picard's method used the same principle of timing eclipses that was used earlier by Bhāskara and al Bīrūnī. This principle provided an operational definition of simultaneity between physically separate locations, enabling one to measure the difference of local time between these locations. Picard's method, however, was adapted to the improved technology of the telescope, following a suggestion by Galileo, to use the eclipses of the moons of Jupiter. This enabled the first European determination of longitude on land.

## *The Chronometer and Navigation*

The Europeans, however, continued to have difficulties with determining longitude at sea—while at sea it was then (before the radio) not possible to compare notes with a distant observer. It was for this navigational problem that the mechanical clock was first put to *practical* use, instead of ritual use, so that its accuracy became significant from a practical point of view. The development of the mechanical clock not only provided a powerful metaphor for the development of a mechanical society, the mechanical clock is a serious contender with the steam engine as a symbol of the industrial revolution. Navigation using the mechanical clock revolutionised shipping even before railways could revolutionise overland transport.

Strictly speaking, a mechanical clock was not an essential prerequisite to the industrial society. After Picard's measurement of the size of the earth, and following the import of the calculus and precise sine values into Europe, it was possible for Europeans to have shifted to the Indo-Arabic techniques of celestial navigation. However, this would have required sailors to do advanced mathematical calculations in their head, and so would have required a transformation of the educational system—which remained the preserve of priests and the aristocracy. Considering that Britain had, by then, not yet accepted the reformed calendar, it was easier to develop the mechanical clock than to transform the society, by changing the educational system.

What has a clock got to do with longitude? Imagine that you are stranded in the Sahara desert. Let us say that, inspired by an amateur geological theory, you charter a flight to make an aerial survey of the seif dunes. The plane develops a fuel leak, and you are forced to land in the midst of a sand sea. You have just enough time to scramble out before the plane catches fire and explodes, killing the pilot. What should you do? The best thing is to sit near the debris of the plane and wait for a rescue party. An hour passes. The sun is very hot; you are thirsty. Another hour passes. You are weak with thirst. The rescue party had better come soon.

Suddenly you see a slight movement on the horizon. Is that a mirage? No. It is an approaching sandstorm. The air is clear; there is no dust; yet a vast quantity of sand is moving. You hide behind a rock, and wait for the sandstorm to pass. You survive, but the debris of the plane is completely buried under the sand. Nothing of the plane is now going to be visible from the air. No rescue party for you.

But you don't give up. You start thinking. You have thoroughly studied the area you proposed to survey. You have a map of it in your head. There are two oases nearby. But both are isolated. You must move in practically the exact direction towards an oasis. If you make a mistake, you will probably die of thirst before you find the oasis. Desperation sharpens your mental faculties. You can see very clearly the exact details of the map in your head. The best thing would be to travel during the night. (You are also an amateur astronomer, and have studied all about the ancient technique of navigating by the stars.) To make things a little easier for you, we will suppose that both oases lie exactly along an easy-to-identify stellar rhumb line.

But a new difficulty now arises. The two oases are far apart. If you can reach one, you can't reach the other. In which direction should you move? You must decide quickly; time is passing, and each passing moment makes you thirstier. Involuntarily you glance at your wrist watch. And you discover the mistake that saved your life. When you landed at the airport on the regular flight from Delhi, you forgot to correct your watch. It still shows Delhi time. You stick a pen vertically into the sand, and start marking the time against the tip of its shadow. When the shadow is shortest, the sun is as vertically overhead as it can get: so that locally it is noon. Comparing this with your watch tells you the time difference, hence the longitude relative to Delhi. (Each 4 minutes gain equals a degree of longitude, since 24 hours equals 360° of longitude.) Having made your calculation you settle down to wait for the evening. A quick glance at the setting sun, a few finger measurements with the rising stars, a short mental calculation, and you are confidently on your way.

Though the method of determining longitude from time difference was well known to Bhāskara I, your technique of navigating by the *mechanical* clock would have been unavailable to a 17th century traveller lost in the desert. Though the mechanical clock existed, it was neither portable nor accurate enough for this purpose. In fact, in the 17th century, Europe had still not learnt any reliable technique of navigation. Europeans still knew of no reliable way of determining longitude at sea, though ships used to travel great distances. Following some spectacular maritime disasters in 1707, Isaac Newton deposed before a Parliamentary committee formed to look into the matter:[25]

> That for determining the Longitude at Sea, there have been several Projects, true in theory, but difficult to execute. One is a Watch to keep Time exactly, but…such a Watch has not yet been made.

There were several difficulties in making such a Watch. For example, it had to be miniaturised, so that it could be easily carried aboard a ship. It had to be made immune to the constant motion of a ship, and immune even against the rolling of the ship during a storm—it had to be made 'shock proof'. It had to be made immune to variations in temperature, and humidity: 'waterproof' was the least the Watch had to be.

A bill was soon approved to provide a reward of £20,000, and a Board of Longitude was formed. Supported by the Board from 1735 onwards, John Harrison eventually produced the required mechanical watch, which easily passed the stipulated test on a voyage to Jamaica in 1757. (But he got only a part of the prize because the longitude of Jamaica was not known accurately enough to decide whether the watch had really passed the test!) By the mid-nineteenth century, the chronometer had become reliable enough to come into widespread use. The West had finally picked up a lead in technology over the East. The watch in this miniaturised and carefully standardised form, used as an instrument for navigation, came to be called the chronometer.

## *Social Standardisation of the Clock: Railways and GMT*

The physically standardised mechanical clock—the chronometer—played a key role in making sea routes more reliable, ensuring thereby a steady inflow of capital and technology. Physical standardisation made possible social standardisation: the socially standardised mechanical clock also played a key role in the greater synchronisation needed for production in an industrial society—the steam engine could not really function without the clock. Railways could not run even in a small place like the British Isles without time-standardisation, because there is a difference of 20 minutes between local London time and Bristol time. An 1841 timetable of the Great Western Railway now read:[26]

> London time is kept at all the Stations on the railway, which is about 4 minutes earlier than Reading time; 5 minutes before Circester time…

This necessitated the introduction of Greenwich Mean Time,[27] soon followed by all railways. Some confusion persisted because towns continued to follow their local time, so that there were watches manufactured with two dials showing GMT and local time. Eventually, all town and Church clocks got entrained into GMT by 1880, under a British Act of Parliament. In India, Bombay (now Mumbai) refused to deviate from local time until after independence.

## *The Value of Punctuality*

Pre-capitalist societies, even those like the Trobriands who did not directly use the sun and moon for timekeeping,[28] also needed to synchronise social and productive activities. Many pre-capitalist societies even admitted very fine divisions, of the order of a micro-second. But these divisions were for technical purposes, like music, or for complex calculations concerning astronomy or navigation. The Babylonian unit of *Gesh*, for example, equalled 4 minutes, while the Indian unit of *truti* used by Bhāskara II was 1⁄33750 second. Such fine time divisions, however, were not used either for social synchronisation or for economic production. In India, apart from the *yāma* or *prahara,* which was the fourth part of a day, or roughly three hours, a common unit was the *ghati*, which was 24 minutes, since the day was divided into 60 *ghati*-s of 24 minutes each, instead of 24 hours of 60 minutes each. While finer time-divisions such as *praāṇ* (= 4 seconds) were used in astronomy, there is no record of their use for social synchronisation or economic production. For social synchronisation, for events such as a marriage, what was typically prescribed was the *muhūrta* (= 48 minutes) or 2 *ghati*-s. Consequently, human life could follow its own rhythm—the internal clock was not driven by a mechanical mode of production. There was no sharp demarcation of work-time and 'own'–time. Very fine divisions of time made no economic or social sense. Consequently, no value was attached to punctuality.

Running a complex enterprise like the railways perhaps required a higher level of social coordination and punctuality. However, punctuality, today, is not confined to the matter of catching trains or airplanes; it has become a cultural value. Why is punctuality important today? Why is lack of punctuality frustrating? The answer is obviously that one could be doing something useful instead of wasting time waiting. One might elaborate this answer as follows.

With technological advance, smaller divisions of time acquired greater value (productive potential). If there is a power breakdown one day, or if there is a strike, newspapers immediately come out with large figures of lost production.

On the other hand, work-time is constrained, and as Marx observed in a detailed analysis in *Capital*, this drives technological advance. He quotes the report of a factory inspector on the consequence of the shortened work-day:

> The great improvement made in machines of every kind have raised their productive power very much. Without any doubt, the shortening of the hours of labour…gave the impetus to these improvements. The latter combined with the more intense strain on the workman have had the effect that at least as much is produced in the shortened working day…as was previously produced during the longer one.[29]

Marx went on to predict that the process would continue: improved technology would precipitate a 'crisis of overproduction'; to manage this crisis, working hours would be reduced, making the constraint reflexive:

> There cannot be the slightest doubt that the tendency that urges capital…must soon lead to a state…in which a reduction of the hours of labour will again be inevitable.

This continuous shortening of working hours has been observed over the last two centuries.[30] A hundred years ago, in England, children worked 14 hours, and adults worked 18 hours, seven days a week. They literally worked till they dropped dead. Since then, working hours have become systematically shorter, reaching the 40-hour working-week now regarded as a standard. In Germany, in the late 1980s a proposal was already afoot to reduce the working week to 36 hours.

Apart from shortening the working hours, technological advance affects work-time in another way, through mechanisation of the production process. With a mechanised production process, the creative element becomes unimportant: production is proportional to the number of hours of work, i.e., work-time becomes homogenised. In the capitalist production process, work-time is treated like any other factor of production. It becomes a commodity which admits a price of production (= cost of maintaining labour in a state of productivity). Much effort has gone into calculating this cost as precisely as possible.[31]

In contrast, the craftsman took pride in his work, though he was technologically less equipped. He did not mind taking a longer time to do the job well, for it involved an element of creativity. In the factory mode of production, this element is missing. The quality of the final product is standardised; only its *quantity* can vary. And the quantity of output from a machine, as we all know, is proportional to the number of hours the machine works. That is, in the factory mode of production, the ke factor in work became *the length of time one spent at the job*.

A craft requires some skill; it provides scope for some individuality. In contrast, most modern jobs are repetitive, requiring only a low level of skill, and like Charlie Chaplin in *Modern Times*, it is a bit hard to identify te particular screw one had turned in the final product. Pride in one's skill or the satisfaction of doing a job well became secondary considerations. The low level of skill required of workers meant that one worker could be easily substituted for another; work time could be exchanged. This meant that individual workers, unlike individual craftsmen, could not negotiate their own terms. In personal terms, this means that arriving in time at the workplace is more important than the mood in which one arrives; one is compelled to synchronise one's heartbeats with the pulse of production. The medieval clock and the navigational Watch have been transformed into that little modern timepiece, strapped around the wrist, which serves to shackle the worker to the time-discipline of the industrial workplace.

To summarise, work has come to mean the number of hours spent on a repetitive job; skills have become secondary, so that work-time can be exchanged. The social synchronisation of clocks has further standardised the valuation of time. With technological advance, not only have the hours of work reduced, but small amounts of work time have acquired greater value: one can calculate the value of not only one month spent on the job, but also the worth of a few minutes. All this has made work-time equatable with money.

A peculiar feature of industrial capitalist societies is that when people do not work, they do not play! This is true even of children. One can observe, among the Indian urban elite, how children are turning into armchair sportspersons who may avidly *watch* sports on television, and be familiar with the latest information, but who go out to play only infrequently.

Part of the reason is the lack of spaces in which to play. Agricultural societies primarily produced food; food was grown on farms; so people lived near their farms; they lived in small villages which were spread out, so that there were wide open spaces in which to play. But in industrial capitalist societies, factories produce wealth; and profit is greater if factories are kept close together, so that transport costs are kept down. Hence, the industrial capitalist mode of production requires people to stay as close together as possible, in huge urban conglomerations.

The other part of the story is that, as we saw, technological advance leads to a shortening of the working day. This means that a worker has more of his 'own' time. What is to be done with this idle work-force? If the worker has time to reflect on his condition, he may revolt. This becomes a major difficulty for industrial capitalism: how to keep the worker occupied, without putting him to work? A huge entertainment industry has grown up to solve this problem. This industry has found a huge marketing opportunity in the difficulty; for the worker is not just a producer, he is also a consumer, and increasing his consumption helps to solve also the classical crisis of overproduction.

But this means that entertainment through play, say, is no longer individually 'produced' it is 'consumed' *en masse*. Leisure time too has become a commodity: why laugh at the frantic tourist for trying to consume as much as possible of his leisure time?

The reduction to commodities of both work-time and 'own'-time completes the equation *time=money*. (The only time left to be human is when one is asleep and dreaming.)

Accordingly, being unpunctual is like stealing money from the other person—money which the other person has obtained in exchange for a part of his life.

## *The Utility Principle and the Way of Life*

The equation *time=money* has dimensions which extend far beyond the value of punctuality and the difference between work and play. With all human time having been equated with money, it becomes 'natural' to plan human life in exactly the same way that one plans a monetary investment. The moral law now takes the form, *'live so as to maximise the expected present value of future lifetime income'*.

One can observe this transformed moral law in the way of life of the Indian urban elite. It is 'good' for a child to study rather than play, because it is the study which contributes to the lifetime income.

Ask parents and they will rationalise through talk of heavy 'competition'. But why should everyone want to become a doctor or an engineer or an administrator? The choice of a career is dictated exactly by considerations of lifetime income, rather than aptitude or interest, or even happiness. (Are children happy to live like this? What of the children who commit suicide, for example, due to failure in examinations?)

The much lamented collapse of values in traditional societies like those in India and China is a consequence of this transformed moral law. Dowry, bride burning are 'natural' consequences of the imposition of this industrial culture of *time*=*money* on top of a traditional discrimination against women; for a number of people, marriage too is now oriented primarily towards monetary acquisition rather than reproduction. This is exactly the motivation for female foeticide: a female child today means a big monetary loss 20 years hence. People in different walks of life justify corruption differently; but all tacitly assume that wealth is better than honesty. Everyone wants to be honest, but only if this does not mean losing a financial opportunity. Hence, also, corruption is the 'natural' course to follow, provided only that the risk of paying a penalty is small (and the risk is bound to be small if enough people think the same way). Aged people should be discarded, unless rich, for their time is not worth anything. In short, the entire way of life from birth to death flows from the equation *time* = *money*.

Instead of economics based on a theory of human nature, as Kautiliya or Adam Smith attempted, one practically has here a theory of 'human nature' based on the economic system! This is not incidental; in order to control the production process more effectively, the capitalist has changed 'human nature'!

People behaved differently in pre-capitalist societies. They did not seek to maximise their earnings. In Europe, because of uncertain weather, the speed of harvesting decided between heavy profit and equally heavy loss. To speed up harvesting, a system of piece rates was widely prevalent. But, when the employer tried to further speed up the harvesting by increasing the piece-rate,

> the worker reacted to the increase not by increasing but by decreasing the amount of his work…He did not ask: how much can I earn in a day if I do as much work as possible? but: how much must I work in order to earn the wage…which I

> earned before...? A man does not 'by nature' wish to earn more and more money, but simply to live as he is accustomed to live and to earn as much as is necessary for that purpose.[32]

In England, workers stopped working when they had earned enough for the week.[33] The Kabyle reduced their work by one-third when their wages were increased by 30%.[34]

Differences between capitalist and pre-capitalist time-beliefs were a documented source of frustration tinged with racism during colonialism.[35] Africans and Indians were regarded as lazy ('due to the heat of the tropical sun'), for exhibiting similar behaviour. Forbes believed that Africans had nothing more than the rumbling of their stomach to tell them the time of the day. E. D. Young, who led an expedition to find Livingston, lamented that time meant nothing to the African. John Buchanan registered his typical traveller's complaint that Africans cared nothing about delays of days or even weeks, so long as they had food and drink. This was also the case in India. When railways were initially introduced, Gustave le Bon[36] reported that prospective passengers having learned that trains would not wait for them to drift in, adjusted not by showing up on time, but by arriving two to three hours early. 'In the language of the algebraist', he said, they 'simply changed the sign.' Edwin Arnold was right that 'thirty miles an hour is fatal to the slow deities of paganism' but for the reason that 'railways teach them that time is worth money...that speed attained is time, and therefore money saved or made'.[37] Curzon recounted as a 'Problem of the Far East' that most Indians operated to a time sense which was 'not only different from but doggedly contrary to that which the British *sought to establish* on the subcontinent'. [Emphasis mine.]

These differences clarify why the success of the capitalist enterprise depended upon changing the behaviour of people. To be able to maximise profit, the capitalist needed to control the production process. To control the production process, it was necessary for the capitalist to be able to vary the rate of production—to increase it when desired, and decrease it when needed. This was not possible if people were not ready to work hard *now* in return for a promise of future consumption. This was behaviour that had to be taught. In pre-capitalist societies it was not possible for the capitalist to double the production by doubling the wages. Therefore capitalism, to succeed, had to change human nature.

Unlike slaves, the capitalist enterprise did not control people using the whip or the sword. It controlled them using and propagating the equation *time=money.* The common wrist watch is hence a symbolic shackle to industrial capitalism.

Today's corporate enterprise recognises the key role of culture in successful management. Huntington's theory (Chapter 3) is a mere extension of this management technique to the strategy underlying the globalisation of information capitalism.

## *The Utility Principle and Inequity*

> It is a myth that industrial man was made by the machine; from its first origins industrialism is the application of calculative rationality to the productive order.
>
> **A. Giddens**[38]

To succeed, capitalism also needs inequity. So the racist argument—that contempt of humans in an industrial society for humans in non-industrial societies—has now been revived in a slightly different form, to justify inequity.

This argument becomes easier to understand using a technically simpler theological argument, once prevalent in India. At that time, India was a feudal (and prosperous) not an industrial (and poor) country, so that it had no systematic need to keep some people in a state of unemployment and starvation—something which even the rich industrial capitalist countries need today. Before casteism, a Brahmin literally meant one who searched for Brhman or the absolute truth about the world. Such a person could not be entangled in economically productive activities, and was supposed to live off the charity of others. Even a former prince like the Buddha preferred to adopt this path with his followers called *bhikhus* (literally beggars), who begged for a meal only once in a day. But later on the term Brahmin came to denote a caste, as if the desire to search for the absolute truth was genetically inherited! Side by side, charity became ritualised. On all important social occasions, it became the custom to invite people of the priestly class for a meal. It was argued that a meal given to a Brahmin fetched more *punya* (virtue, reward in the next life) than a meal given to a hundred others: the happiness of one Brahmin was superior to the happiness of a thousand others. This justification of the preference to feed Brahmins ensured food-security for them.

The revived racist form of this argument won the Nobel prize, which was an important ideological resource during the Cold War, in the 1960s, with British imperialism fading, and the US unable to establish control over the former British colonies, and facing an ideological challenge from Marxism. Food security, shelter, and health care for all was successfully ensured in the post-revolutionary societies in the Soviet Union and China. There was, however, a doubt whether they could ensure to *all* the standard of living enjoyed by *some* in the capitalist societies. So a very popular argument at that time was that capitalist countries sought the good of only a few privileged individuals, while socialist countries sought the good of all.

Kenneth Arrow's theory was addressed against this argument. Cultural prejudice required that a convincing argument must take the form of a theorem; so Arrow called his argument an impossibility theorem (like von Neumann's equally bogus impossibility theorem about quantum mechanics). Arrow started by arguing that people maximise utility and not money. The difference is that utility is an *ordinal* concept, while money is a *cardinal* concept. Utility enables one to *order* preferences, but does not enable one to say *how much* more one prefers one thing to another. In contrast, by comparing the prices of two commodities, one can say *how much* more expensive one commodity is.

Arrow's impossibility theorem is that to have a cardinal notion of utility one must be able to compare preferences *between* people. I might be able to say, for myself, that I like ice-cream *so much* more than chocolates, but can I say that my preference for ice-cream over chocolates is *greater than* your preference for chocolates over ice-cream? This sounds like an assault on your individual rights.

What does this have to do with social good? In order to make a *rational* (and utilitarian) social choice, one should be able to point to something like social good or social utility, which is increased by the choice. One should be able to say that here is something that is good for all people in the society. But that is precisely what is ruled out by Arrow's theorem. A social choice which increases my utility may decrease yours, and without comparing the two utilities, one cannot say that the society as a whole has become better off. Clearly, one cannot compare the two utilities without making a comparison between two persons, or without having a cardinal notion of utility, which amounts to the same thing. In technical jargon, Arrow's impossibility theorem says that a social choice function (i.e., a rational social choice) is impossible without admitting interpersonal comparisons of utility.

What is the alternative? The alternative is that the only situation that can be unambiguously called good for society as a whole is a situation where one person becomes better off without making another worse off. In jargon, this is called Pareto optimality, after the economist Pareto, who thought he had discovered something as profound as Newton's law of gravitation.

What does all this jargon about social choice and Pareto optimality actually *mean*? The meaning is very simple. To make the poor better off, one may have to make the rich worse off in some way. Even if one finds a virtually boundless source of energy, and one learns to synthesise food, and so on, so that the poor become better off, without having to *take* anything from the rich, the rich may be worse off in the sense that they may lose something of value: their power which derives from the poverty of others. In short, according to Arrow's impossibility theorem *it is impossible to say that fulfilling the needs of all is **better** than fulfilling the greed of a few*. Accordingly, one may merrily persist in the existing state of affairs. All that technicality was meant to make this sound like a very reasonable thing to say. This is naturally the kind of discovery which deserves to be rewarded with a Nobel prize.

However, the political situation has changed with the collapse of the Soviet Union. Some people now feel that it is politically possible to assert that fulfilling the greed of a few is actually *better* than fulfilling the needs of all. To justify this assertion, it is now expedient to have a cardinal definition of utility (which was there all along as a guide to decision-making in practice). That definition simply identifies utility with money. Accordingly, Lawrence Summers, then vice president of the World Bank, has argued in an internal report[39] that social choice is economic choice, and that utility maximisation is indistinguishable from profit maximisation. Summers' conclusion is that it is 'right' to move polluting industries, or at least the waste they produce, to the Third World, since the ill effects on 10 people earning $200 are economically preferable to the ill effects on one person earning $3000. In short, the argument is that it is right to dump radioactive waste in poorer countries, since the 'disutility' of the pollutants is less than the 'utility' that people of poorer countries derive from the compensation paid for dumping. Unfortunately, Summers' argument is so blatant that anyone can see through it—it has the flavour of state propaganda, rather than church theology!

## *Further Time Beliefs in the Utility Principle*

Given the importance of utilitarian thinking for the present way of life and for politics, it seems worth examining the utility principle in some detail. The exact statement of this principle is the following: *act so as to maximise the expected present-value of your lifetime utility*. We have seen that the reference to utility is primarily for the arcane theoretical purpose of winning a philosophical argument. In practice, we have the equation *time=money*, which changes the above principle to the rule: *act so as to maximise the expected present-value of your lifetime income*. In other words, plan your life like a monetary investment; try to maximise profit.

The belief in *time = money* is not the only assumption about time in the above form of the principle. Let us restate the principle, emphasising the key terms in it: ***act*** *so as to* ***maximise*** *the* ***expected present-value*** *of your* ***lifetime*** *income*. The first term, ***'act'***, presupposes that one is confronted with a choice, and the advice given by the principle assumes that (1) one is 'free' to choose. The next term is ***'maximise'***. It is clear that maximisation is not automatic; what one chooses will decide whether or not something is maximised. Thus, it is assumed that (2) the choice one makes will (to some extent) decide the future. (The term *lifetime* implicitly refers to 'future lifetime', so it is also assumed that one's choices will leave the past unaffected.) Thus, the injunction, to act so as to maximise future returns, incorporates within it the picture of mundane time.

The next highlighted term is ***'expected'***; this is a technical term from the theory of probability, which means exactly the same thing as 'average', except that 'expectation' refers to the future. One cannot make a rational choice, unless one can calculate this average; and the ability to calculate this average is assumed. It is, thus, further assumed that (3) the future, as decided by the ('free') choices made by a large number of individuals, is nevertheless statistically predictable, so that planning *is* possible.[40] The time assumption has here shifted from the picture of mundane time to a version of superlinear time. Human beings are no doubt free to choose, but their 'choices' are either mechanically predictable, or these human choices do not really make any serious difference to the future. Not only God or a Hari Seldon, but every human being can calculate the future, for without this ability to calculate the future precisely, the utilitarian injunction cannot be followed. The linear–cyclic dichotomy helps to mask the mid-sentence shift in time assumptions, from 'linear' mundane time to 'linear' superlinear time, which could easily be incoherent.

The next term is ***'present-value'***. This refers to the 'principle' (assumption) that the utility of deferred consumption can be related in a precise way to the utility of consumption now. (The validity of *any* intertemporal comparisons of utility is not at all obvious. In fact, on the Buddhist view, intertemporal comparisons of utility are *exactly* as problematic as interpersonal comparisons; this is examined in more detail in the next chapter.) It is further assumed that one can specify a unique discount rate, which is the same for all individuals. This supposedly unique discount rate is exactly analogous to the interest rate in a capitalist economy; it would be impossible to specify it if one believed in ontically broken time. In particular, it is assumed that (4) the present loss can be related to future gain in a precise way that can be rationally calculated. In short, one's entire lifestyle seems to flow from temporal assumptions one was unaware of!

Finally, there is a different sort of temporal assumption, connected with the term ***'lifetime'***, which I like to call the 'utilitarian fallacy'. This assumption pertains to the time-horizon of rational calculation of the future. The utilitarian principle assumes that the rational time-horizon must coincide with one's own lifespan: the expected present value is to be calculated only for one's own lifetime, and not for times that extend beyond that. The old man planting trees for future generations is being hopelessly irrational according to this principle. (The supposed difference between utility and money comes in handy to obfuscate such points.)

In actual practice, in poorer countries like India, there is a great deal of economic insecurity. This insecurity is demonstrated by the prevalence of high interest rates, e.g., much advertised schemes which will double your money in 3.5 years. A high interest rate is the same thing as a high discount rate for the future. This is an admission that there can be no rational calculation of the longer-term future (such as 15 years) under these circumstances. Thus, economic insecurity further collapses the time-horizon of rational calculation. Many people making short-term calculations with *time=money* corresponds precisely to the collapse of values.

## *Utilitarianism and Physics*

This change of values relates to a change in the physical world view, since some of the temporal assumptions underlying the utility principle are *physical* assumptions. But are they *valid* physical assumptions?

Thus, the *time=money* of industrial capitalism involves two key ideas, each consisting of a physical belief and an associated norm. The first physical belief is that this life is the only one that there is. The associated norm is that the period from birth to death is the only thing that one need think about—one *ought* not to think about the long term or about life or anything else after death. The second norm is that this life from birth to death ought to be so planned as to earn as much money as possible. The associated physical belief is that life *can* be so planned, since the future *can* be rationally calculated.

*These physical beliefs may be invalid*; and if the physical beliefs about time were to change, so would the associated norms. In the present world-view, the unexpected is only a complex situation where our expectation or calculation fails. However, time may be such that the future cannot be rationally calculated. In such a situation, planning would be impossible. This possibility—that the time beliefs of industrial capitalism need not be physically valid—has already been considered in some detail in Chapters 7, 8, and 9. Only one strand needs further exploration.

It may happen that rational calculation fails because *rationality* fails. Rationality need not be universal: rationality rests on logic, and logic may change with the picture of time. Hence, contrary to

Plato, the nature of logic may depend upon the nature of the empirical world. We saw this in the abstract in Chapter 8, and the next chapter provides concrete, though little-known, instances from tradition. The dependence of rationality on the empirical nature of time, and the cultural differences in the understanding of rationality, both, are particularly interesting in the context of present-day attempts to globalise culture by matching scientific time beliefs to cultural time beliefs.

## *The Cultural Revolt against Utilitarianism*

Even within Western culture, rationality is often perceived to be lacking in human warmth. The idea of 'cold calculation' of the future is anathema to cultural creativity which values the spontaneous expression of emotion. This has led to an *avant garde* cultural revolt against the mechanistic notion of time in an industrial society. Vladimir Nabokov, in *Speak, Memory* mourns *past* non-existence. Italo Calvino plays even more interesting tricks using multiple structures of time in 'narratives' like *If on a Winter's Night a Traveller*. Louis Borges had started this tradition in his *Labyrinths*. One finds this again in Umberto Eco's *The Name of the Rose*, or *Foucault's Pendulum*, or the *Island of the Day Before*. Other names which spring to mind are those of Henri Bergson, Aldous Huxley, Thomas Mann…. Eventually, this has been seen as a complete denial of temporality.[41] These ideas extend beyond literature in a particular language.[42]

The literature also gives one an idea of the effects of contracting and expanding time-horizons. If one extreme of conventionality is represented by Isaac Asimov's *Foundation*, which speeds up tempo by compressing tens of thousands of years, calculated using psychohistory, guided by the not-so-hidden hand of Hari Seldon's Plan (with Seldon Crises as the points to exercise 'free will'), the other extreme is represented by James Joyce who, in *Ulysses*, dilates a single day to epic proportions.

Could this be a possible source of social transformation? a source for regeneration of values? Not in itself—at least, this seems doubtful for various reasons. We have seen that leisure time or 'own'-time has also become a commodity in industrial capitalism. This has made traditional culture impotent to bring about a change because culture, like traditional values, has collapsed into economics: Vikram Seth's *A Suitable Boy* is most readily remembered for the amount of money it fetched in advance royalties. The arguments in Chapter 12 suggest that post-capitalism provides greater room for optimism.

The ineffectualness of culture to transform values throws light on a problem we encountered earlier. The collapse of values has brought out a basic contradiction of industrial capitalism. The early successes of capitalism actually rested on the pre-capitalist social ethic. The success of capitalism erodes the pre-capitalist ethos that made it possible. With unrestrained selfishness, private interest threatens to overwhelm the public good, so that the very existence of the society is threatened. Hence, the state seeks to revive traditional values, by reviving religion. But within an industrial society, the only credible way in which this can be done is through science. Hence the attempts to re-establish harmony between science and religion.

There is another reason why Western culture is unable to transform values in industrial capitalism. Neither Mircea Eliade, in his *Myth of the Eternal Return*, nor the latest fashionable attempt to deconstruct time[43] have been able to rise above the Augustinian temporal dichotomy. Rejection of linear time is seen as an invitation to *eternal* recurrence, whether by Ouspensky or by Nietzsche; it is seen as nostalgia for the reproductive rhythms of pre-capitalist society by Mircea Eliade:

> The work of two of the most significant writers of our day—T. S. Eliot and James Joyce—is saturated with the nostalgia for the myth of eternal repetition and, in the last analysis, for the abolition of time.[44]

This grand fight against temporality can, hence, lead to the most unexpected conclusions. The high-priest of high-modernity, T. S. Eliot, rejected the 'linear' notion of time to find his beginning in his end, but ended rather lamely by agreeing with Arnold Toynbee:

> Modern history can also be understood as a metaphysical tragedy…the attitudes and beliefs of Liberalism are destined to disappear, are already disappearing…our present day ruin is the external sign of a world religious crisis…The only hopeful course for a society which would thrive and continue its

> creative activity in the arts of civilization, is to become Christian.[45]

The key thing is not the change of heart which Eliot underwent, but the fact that the temporal dichotomy was respected in the whole process. Western culture is unable to regenerate values just because *Western culture harmonises with industrial capitalism*.

# 11

# The Transformation of Time in Tradition

Globalising culture suits industrial capitalism, which seeks to establish mechanical uniformity; but the culture that is globalised must suit it. The suitability depends upon the underlying time beliefs. Many recent writings on time have stressed that time beliefs in Western culture harmonise with time beliefs in industrial capitalism. What is the origin of this harmony? Why are time beliefs in industrial capitalism discordant with time beliefs in other traditions?

Two claims have been particularly prominent. (1) That the *time = money* of industrial capitalism is possible only because the 'rational', 'linear' time of industrial capitalism has replaced the 'cyclic' time of agricultural societies; and (2) that the origins of linear time can be traced ultimately to the Judaeo-Christian tradition.[1] These claims unfortunately rest on a profound ignorance of tradition, whether Judaeo-Christian or otherwise. To dispel this ignorance, let us begin with the story of Ajātasattu, through whose kingdom ran several streams of thought.

## *The King's Question: Rewarding Merit in this World*

King Ajātasattu could not sleep. Not that he was afraid that God would punish him—like most others in his time, he would have dismissed as a crude superstition the belief in a God who dispensed punishment. Nor did be believe in life after death—he thought this to be a doctrine of fools. Nevertheless, he was not entirely easy about the death of his father Bimbisāra. Like his father, and like so many of his neighbouring kings, Ajātasattu was a philosopher-king of just the kind Plato would extol a couple of centuries later. He encouraged and patronized philosophical debate. Having followed these debates closely, he was quite sure that he was not the *cause* of his father's death. After seizing the throne, he had only caused his father to be put in chains—the man had starved to death of his own accord! If Ajātasattu's act seems horrifying, we must allow that future generations may be similarly horrified by the insensitivity of the present-day elite who support, and materially benefit from, a system that constrains large numbers of poor people and allows them to starve to death, slowly and almost imperceptibly.

At that time there were six homeless wanderers, in Ajātasattu's kingdom, who taught and practiced profoundly ethical ways of life. Ajātasattu met each one of them and challenged them to justify their way of life. To each he posed the following question:

> There are, Sir, a number of ordinary crafts: mahouts, horsemen, charioteers, archers, standard bearers, camp marshalls, camp followers, high military officers of royal birth, military scouts…All these enjoy in this very world, the visible fruits of their craft…Can you, Sir, declare to me any such immediate fruit visible in this very world, of the life of a recluse.[2]

This question had two contexts: one personal, and the other social. We have seen the personal context. Ajātasattu had a special reason. Along with the belief in other worlds, he had also discarded the values that went with the belief. Though he could not sleep, he still thought he was justified in seizing the throne after deposing his father. In the personal context his question admitted a natural corollary: if the austere life of an ascetic fetched no reward in this world, why should the luxurious life of a parricide fetch any punishment? (One may parenthetically add that Ajātasattu's question was answered in his personal life in a way that many would regard as only poetically just: his son Udāyibhadda, finding his logic compelling, imitated his example, as did *his* son Anuruddhaka, and this series of parricides continued until the people revolted and deposed the ruler as born of a parricidal breed.)

The social context to Ajātasattu's question concerned the ethical beliefs that were then socially prevalent. To comprehend the full force of Ajātasattu's question, one needs to dig into the background of the ethical beliefs against which the question was posed. These ethical beliefs evolved around the nucleus of a belief in life beyond death in the *physical* context of quasi-cyclic time.

## *Quasi-Cyclic Time and Values*

Suppose that time is quasi-cyclic; or suppose that you are convinced that the world is really like that. What difference would it make to your everyday life? What are the consequences for ethics (or values) of the belief in life a long time after death?

Deliverance (*mokṣa*) is the 'natural' value associated with this picture of time. If this picture of time is taken seriously, the 'natural' inclination[3] is to avoid the pain of rebirth and re-death. This is the message of the symbols of rebirth from across the world (Chapter 1). This is the message that sweeps across the Upaniṣads: deliverance is possible by breaking all worldly relations through the union (*yoga*) of *ātman* with *Brhman*. Breaking all worldly relations broke also any causal relation between an action and its fruit: deliverance transcended mundane ideas of good and bad, it transcended morality.

For those not prepared for this 'highest of all achievements', the appropriate thing was to be 'good' in preparation for this ultimate objective. One reaped the reward for one's good deeds, and suffered for one's bad deeds, in the present world or in future worlds. This reward and suffering were not distributed by a God sitting in judgment; they were automatic consequences of causality.

'Causality' was the other time-belief on which the moral law rested. Here, 'causality' does *not* refer to the tautology that 'cause' precedes 'effect': both *post hoc ergo propter hoc* (after this hence because of this), and *propter hoc ergo post hoc* (because of this hence after this) land in a vicious circle! Rather, 'causality' refers to the belief in mundane time: that living organisms are (to some extent) able to create the future.

## *Karma and Compression of the Time-Scale*

*Karma* refers to an extended notion of causality: not only do one's actions decide the immediate future, but one's actions (*karma*) in the preceding life decide the dispositions (*saṁskāra*) in the present one. This is hardly a 'fatalistic' view as so many Western theologians have mischievously or ignorantly alleged.

In the Upaniṣads, the belief in cosmic 'causality' is quite modest. If you live life badly your punishment is this: you will have to live again. Living life badly (due to ignorance) *causes* you to be born again. Enlightenment frees you from this chain of cause and effect, and leads to deliverance from rebirth. There *is* a notion of good and bad here. But that is a *cosmic* notion, not to be confused with *social* notions of good and bad. The cosmos is not man made, *homo sapiens sapiens* cannot change it; if the cosmos happens to be such, the only thing a human being can do is to change his behaviour. But human society is man made, and people *can* change *that*.

The extension of mundane causality to cosmic *karma* created a difficulty because there is a discernible gap between action and consequence. Puraṇic cosmology gave a vast period of 8.64 billion years as the recurrence time for the cosmos. The intervention of a long period of (non-subjective) time between death and rebirth (the long night of the soul) tends to give an unreal quality to beliefs in life after death in the context of a quasi-cyclic cosmos. Compression of the time-scale has been a standard trick used to mitigate such feelings. Thus, in the Upaniṣads, for example, a protracted cycle of the cosmos is reduced[4] to an ephemeral (*aśaśrvat*) instant. This is a guiding principle for Upaniṣadic philosophy: the rewards for good action are but temporary, *hence* one must rise above good and evil.

## *Heaven and Hell*

Belief in a compressed time-scale may come naturally to a long-lived species. But human beings have short lives (in relation to the quasi-recurrence time of the cosmos). Many people remained unconvinced by this compression of the time-scale. They asked: During the long night of the soul, what did the soul *do*? *Where* was it, during this period? *How* was it rewarded?

One can find many exploratory answers to this question. The earliest Pali canons[5] record how the Buddha argued, 2500 years ago, against various wrong answers to this question: for instance, against people who maintained that consciousness survived after death. Amongst Greeks, Plato, for example, thought that the souls of good people became stars which guided others by their shining example in the dark night. (The three stars in 'Orion's belt' were named on this belief, after the hunter Orion in Greek mythology, who became a star after his death.)

*Where* was the soul between lives? Presumably, the notions of heaven and hell were first invented to answer this question. During the long night of the soul, the souls of the good went to heaven, where they were suitably rewarded, while the souls of the bad went to hell where they were punished.

## *Managing Shades of Grey*

Of course, the division between good and bad was not black and white like Augustine's heaven and hell. Most people do some good things and some bad things in life. So what would happen to such people? Would they be in heaven or would they be in hell? How would one weigh good and bad?

The *Mahābhārata* epic provides an example of a popular answer. Yudhiṣṭhira always spoke the truth, and always tried to do the right thing, so that he was known as the Prince of *dharma* (righteousness, justice). To be precise, in his entire life he told exactly one lie. During the great war, Yudhiṣṭhira's army was losing against the Kaurava-s led by Yudhiṣṭhira's guru, Droṇācārya. Yudhiṣṭhira was convinced that a Kaurava victory would be a total travesty of justice. So a plot was hatched. Droṇācārya had a son named Aśvatthāmā to whom he was very attached; but the Kaurava army also had an elephant named Aśvatthāmā. The elephant was killed, and a great cry went up: 'Aśvatthāmā is dead'. Droṇācārya refused to believe this, and asked Yudhiṣṭhira, for he knew that Yudhiṣṭhira always spoke the truth. Yudhiṣṭhira loudly confirmed that Aśvatthāmā was dead, adding too softly to be heard in the din of the battle that it was Aśvatthāmā the elephant.[6] The demotivated Droṇācārya laid down his arms, and was promptly killed, helping Yudhiṣṭhira to win the war. In a dramatic moment, after his own death, Yudhiṣṭhira finds himself in hell, where he is greatly distressed to learn his brothers have also landed. For telling a lie, Yudhiṣṭhira's punishment is that he must first do some time in hell.

When Yudhiṣṭhira completes this 'test', and goes over to heaven, he is very surprised to find Duryodhana there. Duryodhana was the arch villain of the epic, who tried to roast his cousins alive, wrongfully snatched the kingdom from Yudhiṣṭhira, giving him a barren part (Indraprastha, now supposedly Delhi), invited him to gamble with loaded dice, to cheat him even of this part which he had made fertile, and so on. Nevertheless, Duryodhana had his good points—he was brave in battle—so that he was entitled to some time in heaven. Yudhiṣṭhira would be rewarded with a longer time in heaven, so he first went to hell, whereas Duryodhana had a longer time in hell, so he first went to heaven.

In short, shades of grey were managed by supposing that a person went to both heaven and hell. One stayed in heaven for a time-period in proportion to one's good deeds, and in hell in proportion to one's bad deeds. Such a division was possible because one stayed in heaven and hell only for a *finite* time, unlike Augustine's heaven and hell where one had to stay for eternity. Such a division was possible also because individual actions rather than whole people were classified as good or bad.

## *The Orthodox Answer:* Status Quo *as Good*

*How* was the soul rewarded? This question permitted another sort of answer: that the person was rewarded not in some imagined heaven or hell, but right here on earth.

According to this key answer, the soul was rewarded in this very world, for its deeds in the previous life. These rewards were identified with tangible benefits in this life. The obvious danger with this answer was that it might confuse a subtler cosmic notion of good and bad with prevalent social norms about good and bad. And indeed, one's poor social position (e.g., birth in a low caste) was inferred to be the result of evil deeds in a previous life. By applying a compression of the time-scale, it was considered satisfactory that things could be changed *only* in the next life; similar to the formula 'work now, and enjoy later in life', austerities were believed to be rewarded in the next life: 'be austere now and enjoy in a later life'!

As a mischievous corollary, it was inferred that no change of social condition (such as birth in a low caste) was possible within this life. By this artifice, an unjust social condition was changed into a just moral condition which transcended both man and the cosmos! This fallacious belief that the organisation of human society was just, and could not be changed, obviously suited those who benefited (or thought they benefited) from that particular way of organising society.

Ajātasattu had seen through the hypocrisy of orthodoxy, and orthodoxy had no answer to his question: would austerities fetch any reward in *this* world?

## *The People's Answer: Lokāyata Rejection of Quasi-Cyclic Time*

The Lokāyata[7] ('people's philosophy') rejected the prevailing social condition. The Lokāyata philosophers (Cārvāka) rejected the belief about quasi-cyclic time used to justify the prevailing social condition as moral. They rejected not only the prevailing notion of quasi-cyclic time, but also logic or inference as a means of right knowledge. They refused to accept as valid anything that was not *manifest*. This refuted any causal analysis of the kind where actions (*karma*) in one cycle could result in dispositions (*saṁskāra*) in the next. Thus, we have seen the response of Ajit Keśakambali (p. 28), a contemporary of the Buddha, to Ajātasattu's question (as summarised by Ajātasattu). The ellipsis expand to reveal the social context:

> …but there his bones are bleached, and his offerings end in ashes. It is a doctrine of the fools, this talk of gifts. It is an empty lie, mere idle talk, when they say there is profit therein. Fools and wise alike, on the dissolution of the body, are cut off, annihilated, and after death they are not.[8]

'Offerings' and 'gifts' were the economic lifeline of the highest Brāhmin castes; priests have reaped economic benefits in this world from the belief in life after death. Rejecting this business of life after death stopped that economic benefit. Thus, Ajit Keśakambali explained to Ajātasattu how values (and social organisation) were transformed by transforming beliefs about time (and logic), even if his answer was only indirectly relevant to Ajātasattu's question.

Nevertheless, Ajit, by himself living an austere life, remained tied to a moral code that was incompatible with his belief.

Down the centuries, the opponents of Lokāyata (and there were many) have repeatedly and explicitly answered Ajātasattu's question on behalf of the Lokāyata. What was the reward for austerities in this life? None at all. Perhaps these opponents have only caricatured Lokāyata the way Greek tradition caricatured Epicureans; but we have no other, no direct accounts to go by. All opponents are agreed that Lokāyata denied all sources of valid knowledge apart from sense perception; that it denied soul (*ātman*), life after death, and God (*Īśvara*; there was a small sect which believed in God). But most representations of Lokāyata, like the one by the 14th century Mādhava,[9] in his *Sarva Darśan Samgraha* ('Compendium of All Philosophies'), charged that Lokāyata not only denied the existence of a soul, but engaged in *deha vāda* or body worship; that they denied all moral values, and cared only for bodily pleasures: i.e., they not only denied *karma* but advocated *kāma*, the *summum bonum* of human life was the enjoyment of gross sensual pleasure. A commentator, Guṇaratna, stated,

> [They] do not regard the existence of virtue and vice and do not trust anything else but what can be directly perceived. They drank wines and ate meat and were given to unrestricted sex-indulgence. Each year they gathered together on a particular day and had unrestricted intercourse with women.[10]

A contemporary philosopher, Chattopadhyaya, suggests a bias:[11] there would be no need to restrict this to just one day in the year, unless this was a Tāntric ritual, related to the agricultural means of production—the ritual may be viewed as *sympathetic magic* with the practical aim of increasing agricultural productivity. He cites a particularly pathetic example of this magic: during the 1935 famine and drought in the state of Uttar Pradesh, women resorted to running naked through the fields at night, in the hope that this might stimulate the creativity of the earth, and perhaps make it rain.

But despite possible misrepresentation and bias, the fact is that those closest to the Lokāyata today are the Tāntriks who traditionally have their five ma-s (*pancmakāra*: *madya* [intoxicants], *māmsa* [meat], *matsya* [fish], *mudra* [fried corn], *maithuna* [sexual intercourse]).[12] They think it is quite appropriate to heighten the pleasure through the use of substances like cannabis (*bhang*), even today traditionally consumed during Holi. Also, Tāntric priests often came from lower castes. At any rate, in these rituals

> The Brahmin and the Caṇḍāla, the king and the beggar took part with equal enthusiasm in the Madanotsava, in which Madan or Kāma was worshiped.[13]

Enthusiastic participation does create a tendency for caste distinctions to be submerged in related fertility festivals like Holi that one can currently observe.

Regardless of the exact stand that ought to be attributed to the Lokāyata, the moral of our story is quite clear: the Western Christian way of rejecting 'cyclic' time is not unique. The simplest way to reject 'cyclic' time is to reject also the associated notions of soul, heaven, and hell (not to mention God). Rejection of 'cyclic' time does not necessarily imply a morality based on inequity and a doctrine of sin; quite to the contrary it may imply an acceptance of equity and a rejection of sin. And this would then be incomprehensible without the understanding that the Lokāyata advocated 'linear' mundane time rather than Augustine's 'linear' apocalyptic time.

The Lokāyata was undoubtedly a materialist and this-worldly philosophy. Nevertheless, it would have rejected also the *time=money* of industrial capitalism. According to the opponents, for the Lokāyata only today mattered:[14] while life remains, let a man live happily; let him feed on *ghee* even though he runs in debt! This is an attitude incompatible with the doctrine of maximising discounted deferred consumption.

We see every day the iron discipline that the *time=money* of industrial capitalism enforces on children in newly industrialised societies; this discipline is justified on the doctrine of deferred consumption—studying now is good for children because it will help them to get into a good college. The children, when they grow up and go to college, must yet defer enjoyment and continue to work hard because it will help them to get a good job tomorrow. The young people who have managed to get a good job must continue to work hard because it will help them to get a promotion, and more money tomorrow. This process rarely ends until people retire, and suddenly discover that they are too old to enjoy themselves any more! So the net result of *time=money* is that people are made to work hard all their active lives, managing to snatch only a little bit of leisure here and there, while imagining all the time that this is good for them. The Lokāyata would have rejected this doctrine of deferred consumption too as a doctrine of fools: they would have regarded this doctrine, based on the hope of future rewards in this life, as a mere trick, similar to the doctrine based on the hope of rewards in a future life.

From our present point of view this last conclusion may seem a bit unreasonable. After all, isn't it true that the future, at least in this life, can be rationally calculated? However, the Lokāyata approach, though presentist, was not naively so: the Lokāyata would have denied that we could validly know the future by calculating it rationally; they would have asserted that there is no valid way to fix a uniform rate of discount for deferred consumption, so that a rational choice between consumption now and future consumption is impossible. In fact, they altogether denied the very basis of rationality: inference.

The orthodox tradition of Indian Logic, Nyāya, accepted four sources of valid knowledge: (1) the *empirically manifest* (*pratyakṣa* or directly perceived), (2) *inference (anumāna)*, (3) *reliable testimony* (of *śruti*, *smṛti*; what is heard or remembered or spoken as *śabda* = Credible Word = scriptural or apostolic testimony in the West), and (4) *analogy (upamāna)*. For our present purposes we may disregard analogy, or regard it as included in inference, leaving only three means of valid knowledge.

Of these three, the Buddhists rejected the third—testimony. This was articulated most succinctly by Dinnāga who stated that 'testimony was included in perception and inference': for 'if the person is Credible, this is an inference, if the event is Credible it must be manifest'. The Buddhist rejection of testimony was aimed against authority, and specifically against regarding the Veda or Upaniṣads as valid sources of knowledge.[15]

Lokāyata went a step further to reject even inference. This seems to be taking things a little too far. As Udayana of the orthodox Nyāya school argued, the Lokāyata insistence to rely only on the manifest would make practical life impossible.

> If this doctrine is consistently applied and people begin to disbelieve all that they do not perceive at any particular time, then all our practical life will be seriously disturbed and upset.[16]

For example, it was argued, each time the husband went out of the house, the wife must become a widow, for she could no longer directly perceive her husband.

In defence of the Lokāyata position it has been argued that this rejection of inference was aimed at certain key inferences; being a philosophy of the people the Lokāyata wanted to warn people against religious exploitation through such inferences. A medieval commentator, Maṇibhadra, states the reasons explicitly.[17] 'if even unperceived things are accepted as existing…a poor man, simply contemplating "I have heaps of gold", would, with the greatest ease, overcome all his miseries.' A servant could delude himself with the idea that he had become the master. The Lokāyata insistence on the manifest was meant to counter cunning deceivers in religious garb who fooled people into submission with illusory ideas of the next world, who convinced people that the *manifestly* bad was *ultimately* good. To establish these ideas, these deceivers relied upon inference and alleged testimony. The Lokāyata rejection of deceit naturally applies as much to capitalism as to religion: what is *manifestly* bad for children is held to be *ultimately* good.

But can one validly accept inference for some purposes but deny it elsewhere? Actually, Udayana is simply accusing the Lokāyata of adopting a tricky mode of disputation in accepting the inferences needed for practical life, but denying them elsewhere. A Buddhist commentator, Buddhaghosha, agrees, describing Lokāyata as a science of *vitaṇḍā* and *vāda*—cavil and disputation. (Opposition to Lokāyata was the one point on which Nayyāyika-s and Buddhists agreed.) But the Jaina commentator Vaḍideva Sūri, quoting a *sūtra* from Purandara—a 7th century commentator in the Lokāyata tradition—while agreeing that the purpose of exalting sense-perception was to limit inference to practical life, and deny it in the transcendental sphere, justifies it as follows:

> an inductive generalisation is made by observing a large number of cases of agreement in presence together with agreement in absence, and no case of agreement in presence can be observed in the transcendent sphere; for even if such spheres existed they could not be perceived by the senses.[18]

Limiting inference to perceived objects in this world was the Lokāyata method of defence against religious exploitation through talk of other worlds. Such a totally materialist doctrine is also a method of defence against capitalist exploitation through talk of future benefits.

Thus, the Lokāyata rejection of 'cyclic' time did not mean an acceptance of the 'linear' time of industrial capitalism. And this would then be incomprehensible if we did not distinguish between 'linear' mundane time and the 'linear' superlinear time of industrial capitalism.

To summarise, the Lokāyata transformation of time was connected with a three-fold transformation in (a) logic, valid reasoning, or methods of proof, (b) social organisation, and (c) values and the way of life. The Lokāyata rejection of quasi-cyclic time meant acceptance of mundane time, rather than the 'linear' apocalyptic time of Western Christianity, or the 'linear' superlinear time of industrial capitalism. The Lokāyata rejected the idea of inequity as the basis of morality; they rejected both the doctrine of sin and the doctrine of deferred consumption.

Despite its attractive features, like acceptance of equity, the Lokāyata ultimately disappeared. Perhaps this was only because it was opposed by the elite,[19] who obviously benefit from inequity, so that we may still see it being revived. Perhaps this was because Lokāyata proposed not only a radical change in values, but also a discontinuous change in beliefs about logic and facts—like quasi-cyclic time. Perhaps, also, by rejecting quasi-cyclic time as the basis of values, it destroyed the very basis of values. For this, ultimately, was Ajātasattu's real question: if a man benefits materially in this life by killing his father, why should he not do so?

## *Buddhist Momentariness and the Structured Instant as Cosmos*

The Buddha proceeded in a different way, without directly contesting beliefs about facts. He did not try to deny the physical belief that time was quasi-cyclic; he did not argue against the belief in other worlds. The affirmation may be found in the Jātaka stories or, for example, in the *Dhammapada* story of the inattentive laymen, in which the Buddha explains to his disciple Ananda why out of his audience of five only one is paying attention.

> Of these five men, he that sits there sound asleep, was reborn as a snake in five hundred states of existence, and in each of

> these…he laid his head in his coils and fell asleep; therefore at the present moment also he is sound asleep; not a sound I make enters his ear…The man who sits there scratching the earth with his finger was reborn…an earthworm…The man who sits there shaking a tree was reborn…a monkey, and from sheer force of habit…still continues to shake a tree…[He] who sits there gazing at the sky was…an astrologer…[20]

Quite possibly, this was intended only as a humorous allegory, for the Buddha simply denied the chief consequence of quasi-cyclic time—the existence of the soul. He granted that life may continue in other worlds, but denied that there was an immortal soul underlying one's life in various worlds. The Buddha granted the belief in quasi-cyclic time, but NOT the belief in the soul (*ātman*) as an unchanging essence, because the body (and its relations to other things) changed not only across cycles of the cosmos, but also across two instants.

Everyone agreed that from one cycle of the cosmos to another there was *some* change: though the inattentive listener continues to shake trees, there is a change—he was a monkey and is now a man. But to speak of a soul, there must be something, such as personal identity, some 'self' that remains constant across these changes. What, then, arose the question, was this 'self' that stayed constant and unaffected by time, across cosmic cycles? How could one know that anything at all stayed constant? How could one know that this 'self' existed? Surely one could not *perceive* that something remained constant in the changes across cosmic cycles. And since one could not perceive the changes either, how could one *infer* that something remained constant across a cosmic cycle? We recall that the Buddha admitted only the perceptibly manifest (*pratyakṣa*) and inference (*anumāna*) as the means of right knowledge. Tradition *did* authoritatively assert the existence of the soul, but the Buddha rejected mediated accounts of tradition. For how did our forefathers know anything except by relying on perception and inference?

To make it easier to understand change, instead of changes across cosmic cycles, consider the everyday change from one instant to the next. This notion of change between instants depends also upon what an 'instant' is: it depends upon the structure of time. To understand the Buddhist view of change, we first need to understand the Buddhist notion of instant. The Buddhist view of instant was not, of course, the same as the present view of an instant as a featureless point in a continuum. But we have seen in Chapter 8 that allowing the instant to have a structure changes logic, hence rationality (and we postpone Buddhist logic to the postscript to this chapter).

Atomic time.

The general belief in atomism was prevalent then, and the Buddha thought of an instant as a sort of time atom. More specifically, we know that the Buddha had sought out many teachers, two of whom were known[21] advocates of the Sāṁkhya-Yoga tradition. Both traditions believed in atomism. In the Yoga tradition, we know from the eloquent account of Vyāsa that time was definitely regarded as atomic:

> Just as the atom is the minimal limit of matter, so the instant [*kṣaṇa*] is the minimal limit of time. Or the time taken by a moving atom in order to leave one point and reach the next is an instant. The instants form a sequence called time. Two instants cannot be simultaneous, because it is impossible that there be a sequence between two things that occur simultaneously. Thus, in the present there is a single moment, and there are no combinations of earlier or later moments. Accordingly the whole world mutates in a single instant.[22]

Discrete time is distinct from occasionalism. The Sāṁkhya notion of cause assumed the latent presence of future and past in the present instant.

This sequence of mutations of the world which defined the sequence of time atoms was not the same as ontically broken time or occasionalism (*yadrcchāvād*; 'as-it-likes-ism'). The changes in the world from one instant to the next were not arbitrary, they were 'causally' linked, but there was a difficulty. The difficulty of linking cause to effect across a cycle of the cosmos was mirrored in the difficulty of linking cause to effect across the diastema (or timeless gap) intervening between two atomic instants. This difficulty was solved in Sāṁkhya-Yoga as follows. There was no creation *ex nihilo* at each instant here, nor was there destruction: the past and future were both latent in the present instant. The order of production of effects depended on a definite rule (*pariṇāmakramanīyama*), but potentially the effect exists before the causal operation to produce it is started—the statue potentially exists in the as-yet-uncut stone. Change is a rearrangement of atoms to form new collocations—the atoms themselves do not change. A yogi could, therefore, by appropriately enhancing his consciousness, see the entire past and future within the instant, like Laplace's demon, by working out in his mind's eye all the potentialities forward and backward in time. Thus, there was a continuity (of the atoms) between past and future, but there was a difference (of their collocations).

Inversion of the key analogy.

It is against this background that one can hope to understand the Buddha's theory of causation based on the notion of time as instant. Compression of the time-scale was the standard device used to bring the changes across a cosmic cycle of billions of years within the grasp of perception. *The Buddha inverted the cosmos-as-instant analogy into an instant-as-cosmos analogy*, ***equally*** applicable in a state of near timelessness. Accepting the contraction of billions of years into an ephemeral instant, he also expanded a time atom to fill all consciousness. Here was the ultimate vision of the macrocosm in the microcosm: *the entire cycle of the cosmos within a single time atom*. There was (simultaneously) growth, decay, and destruction *within* this time atom. The sequence of instants was analogous to the sequence of cosmic cycles. *This is the key to his metaphysics.*

> The instant…is the only thing which is a non-construction, a non-fiction…It is the fulcrum on which the whole edifice of reality was made to rest.[23]

'Causality' operated across instants in a way no less mysterious than the way in which it operated across cycles of the cosmos.

Equally, the chain of causes could be broken not only across cycles of the cosmos, but also at the very next instant: emancipation was available at the next instant—it was available within this life. This enabled the Buddha to answer Ajātasattu's question, which the other ascetics could not answer.[24] Quietude and freedom from suffering was available to the Buddhist monk at the very next instant. There was no need to wait for the next life. This was the fruit available to the homeless monk in this life: freedom from suffering—a fruit no one else could hope to get: neither the rich man, nor the warrior, nor the king.

## *Flux and the Fragmentation of Identity*

> Who are *You*? said the Caterpillar.
>
> …Alice replied…'I—I hardly know, Sir, just at present—at least I know who I was when I got up this morning, but I think I must have been changed several times since then.'
>
> 'What do you mean by that?' said the Caterpillar, sternly. 'Explain yourself!'
>
> 'I can't explain *myself*, I'm afraid, Sir,' said Alice, 'because I am not myself, you see.'
>
> 'I don't see.' said the Caterpillar.
>
> **Lewis Carroll**[25]

The Buddha's notion of time as instant fragments the usual notion of identity or self. This life itself became fragmented into a long series of lives lived within a series of instants-as-cosmos. These lives-within-an-instant are lived by a procession of individuals who are similar but not identical—there is no underlying reality of a soul which continues unchanged across these multiple existences. An individual changes from instant to instant, and there is no timeless substratum which remains constant across these changes, even for two instants. (Realisation of the fragmentation of identity naturally helped non-attachment; and attachment was regarded as one of the key causes of suffering.)

Imagine that each (atomic) instant is like a miniature cosmic cycle: a given individual dies each instant/cycle, and in the next instant/cycle another individual, very like the first, may be reborn. Unlike cosmic cycles, the changes across instants can now be manifestly perceived, for we remember the previous instant. But what enables one to infer that something stays constant? Such an inference would be valid at best when the changes are 'small': if a man were to change into a bird, would one say that there was still something that stayed constant? (Some people believed such 'large' changes of a man into a bird were to be expected across a cosmic cycle.) But what exactly is a 'small' change or a 'large' change? Isn't 'smallness' or 'largeness' a matter of what one is accustomed to? If one stayed in Wonderland, like Alice, one might pretty soon get accustomed to strange changes of size—just as readers of the story soon start expecting changes of size, and no longer find them strange.

Continuation of merely memory does NOT establish a continuation of identity, even between two instants. (This view must seem practically incomprehensible in Western traditions, where the debate for and against life after death, since Leibniz has assumed the identity of identity with memory.) Alice might remember her cat Dinah, but with the change in her height, her relation to Dinah had changed; for Dinah chancing upon a six-inch tall Alice might well pounce upon her and kill her. So her memories are the same, but is she the same Alice? Though more dramatic in Wonderland, the same problem of identity may arise in the most mundane circumstances: as the British philosopher McTaggart eloquently argued, the fall of a sandcastle on the English coast changes the nature of the Great Pyramid.

Thus, unlike Augustine who denied quasi-cyclic time but accepted its chief consequence—the existence of the soul—the Buddha did not deny quasi-cyclic time, as such, but rejected its chief consequence—the existence of the soul. For, while change is manifest, the existence of an underlying changeless entity—the soul—is neither manifest, nor can it be readily inferred.

The Buddhist denial of the soul shatters the basis of values in Augustine's doctrine of sin. Augustine wanted to classify people as good or bad, through his notion of heaven and hell. The Buddha classified not people but only *actions* as good or bad. Now, it does not make sense to say an action is good without specifying, implicitly or explicitly, *what* it is good *for*. By Augustine's definition, an action is good if it pleases God. The Buddha dismissed the idea of God (*Īśvara*) since God can neither be perceived nor can his existence validly be inferred. (In the Buddha's time there wasn't even any need to reject an authoritative tradition of belief in God, for only a few outlandish people then believed in such ideas like God.) The Buddha's concern was with human beings, and with human suffering. An action was good if it led to cessation of suffering. In Nietzsche's language, Buddhism

> no longer speaks of 'the struggle against *sin*' but…'the struggle against *suffering*'…it already has…the self-deception of moral concepts behind it…it is *beyond* good and evil…Buddha…demands ideas which produce repose or cheerfulness… *Prayer* is excluded, as is *asceticism*; no categorical imperative, no *compulsion* at all…[26]

Buddhist values certainly differ also from values in industrial capitalism. In an industrial-capitalist society, an action is regarded as good if it helps one to increase the present value of lifetime earnings or consumption. The Buddha rejected this idea of material acquisition at the very beginning of his search for knowledge, having abandoned a princely life, which would have better enabled him to pursue the Lokāyata recommendation of material comfort, or the industrial-capitalist norm of maximising acquisition and consumption. The Buddha did not accept that increasing consumption would increase one's happiness; he thought the right aim was freedom from suffering, and the right way to this was through compassion.[27]

## *Arrow's Theorem Extended: The Impossibility of Rational Choice*

Apart from this obvious difference, there is also a subtler difference: fragmentation of identity shatters the idea of rationally-deferred consumption—an idea fundamental to the *time=money* of industrial capitalism—for instead of one individual from life to death one must deal with a whole procession of individuals, one for each instant. Referring back to Arrow's impossibility theorem (Chapter 10), we observe that the fragmentation of identity shatters also the individual's utility function, so that instead of one utility function over all time, one has numerous different utility functions at different times. As a person changes with time so will her preferences: Alice lost her fondness for puppies when her size reduced to just six inches. Can all these numerous utility functions somehow be incorporated into a single utility function? In this situation, Arrow's impossibility theorem tells us that this is impossible without permitting inter-temporal comparisons in utility. One would have to be able to say that this child's preference for playing now is less than his preference for possessing a car as an adult. Isn't this an assault on the child's rights? Thus, fragmentation of identity makes intertemporal comparisons of utility (or preference ordering) for one person at different points of time *exactly* as difficult (or unacceptable)[28] as interpersonal comparisons of utility: rational choice is, therefore, *exactly* as impossible as social choice! It is impossible to decide rationally between consumption now and deferred consumption!

## *Conditioned Coorigination and Cause*

The Buddhist idea of time as instant also changes the notion of cause. We have seen that the industrial-capitalist idea of rational calculation of the future depends upon a certain superlinear picture of time. The Buddhist notion of cause differs from the super-linear-time idea of the present as the inevitable consequence of the past and the cause of the inevitable future.

Suffering and cause.

What was the great insight of the Buddha which made him adopt the title of the Enlightened One—the Buddha?

> I have penetrated this doctrine which is profound, difficult to perceive and to understand, which brings quietude of heart, which is exalted, which is unattainable by reasoning, abstruse, intelligible (only) to the wise. This people, on the other hand, is given to desire, intent upon desire, delighting in desire. To this people, therefore, who are given to desire, intent upon desire, delighting in desire, the law of causality and the chain of causation will be a matter difficult to understand.[29]

The Buddha had understood the *cause* of suffering, hence how to end it. The Buddhist idea of causality, however, corresponds NOT to the 'law of causality' in Max-Mueller's translation, but to 'conditioned co-origination' (*paticca samuppāda*) or 'dependent origination'.[30] It is the centre of the Buddhist doctrine, and as the Buddha said, 'one who understands conditioned coorigination understands the Dhamma'. It may be expressed in a simple formula: this being that happens, this ceasing, that ceases (but this is not the *cause* of that, that cooriginates, conditioned by this). Let us see how conditioned cooriginatation differs from the usual notion of cause.

Thus, a seed is not the cause of the plant. For common events in everyday life, *there always is at least a multiplicity of causes*. The traditional explanation went as follows. It is not the seed alone which produces the plant, but the seed together with earth and water. The seed in the granary was incapable of producing a plant, it could only go on producing [a near replica of] itself every instant. The seed in the ground was capable of producing a plant (for it was a *different* seed, being bloated up etc.). In common parlance one overlooks the difference between the two seeds, and calls them the same seed—but this is a practical matter of economising on names. Also, it is purely a convention, a mere clinging to orthodoxy, that the seed is the 'main' cause, and the earth and water are 'subsidiary' or 'supporting' causes. To understand why this is merely a convention, let us look at contemporary patriarchal society, where the father (who provides the seed) is traditionally regarded as the main cause, while the mother (who receives the seed) is regarded as the subsidiary cause, so that people conventionally take their last name from their fathers and not mothers. The relevance of this changed notion of cause to equity is considered in more detail below.

The relevance of this changed notion of cause to suffering is the following. It is not actions alone (*kamma*, *karma*) which produces suffering, but the actions when combined with attachment and craving. Hence, detached actions (not non-action or suicide[31]) will produce no future fruit. This cessation from suffering is available here and now. Hence, quasi-cyclicity of time, though granted, becomes irrelevant: it merely increases the length of the string of instants-as-cosmos, which is of little significance—for the enlightened man can obtain deliverance from suffering at the next instant.

## *Conditioned Cooriginatation and Equity*

We have so far ignored the question of the material basis of values: the belief that values can only relate to the production relations.

Kosambi (the mathematician and Marxist historian son, quoting the Buddhist scholar and Harvard-professor father) offers the valuable insight that the economic base of Buddhism was different. Orientalist thinkers of the last century presumed that the Buddhists, like the Lokāyata, fought a philosophical battle against the caste system and other-worldliness. But India was clearly in a state of great intellectual ferment at that time, 2500 years ago; no orientalist thought of relating this intellectual ferment to changes in the organisation of economic production.

The economic base.

This was Kosambi's insight:[32] classless and undifferentiated tribal societies coexisted with kingdoms as they coexist even today with the Indian state, though the tribes were relatively more numerous then. In fact, the kingdoms had formed but recently then, around the sites of former tribal headquarters; the formation of the kingdoms coincided with the shift from a pastoral to a predominantly agricultural economy able to generate enough surplus to support a large population of economically unproductive warriors, priests, and merchants. The kingdoms were expanding, trying to bring more agricultural land under their control, and ruthlessly exterminating tribal societies. The Buddha who came from one such tribe (the Śākya-s) tried to restore tribal values, as is suggested by the modelling of the classless, undifferentiated, explicitly democratic, Buddhist *samgha*-s on the tribal pattern. The *samgha*-s were respected by both kingdoms and tribes: as such they provided the middle ground where traders could seek a safe haven for the night. The monasteries, therefore, lay along trade routes. It was this that enabled the monks to exist in large numbers without actively participating in economic production.[33]

While accepting this insight, it seems incorrect to argue, as Chattopadhyaya[34] does, that this is all that matters in Buddhism, that the rest of Buddhism was a grand illusion, in straitjacket agreement with the orthodox Marxist thought about religion. Marx opined about the religions he was familiar with; to extend these remarks uncritically to other 'religions' is as risky as believing that 'scientific proofs' of God's existence through the anthropic principle, say, help establish the unity of science and religion! The mindless labelling of teachings, arguments and philosophical systems as 'religious' leads with the natural competitive illogic of the theologian to the Reader's Digest map[35] of world religions in which Marxism is clubbed as a religion!

The temporal base.

Two basic principles of Buddhist thought—reliance only on the empirically manifest (*pratyakṣa*) and inference (*anumāna*)—are the same as those of science—reliance only on observation, and inference; but the notions of time and cause are radically different. Therefore, at the very least, if it is to be *vāda* (disputation) and not *vitaṇḍā* (cavil) it is necessary to recognise the following: the belief that the production relations are the base or *cause* of values assumes a certain notion of *cause*. So, the only fair way to do a Marxist analysis of Buddhism would be to start with a *pūrva-pakṣa* (ante-thesis) which criticises Marx's *causal assumptions* and his method of causal analysis from a Buddhist perspective. This would be beneficial also from entirely within the Marxist perspective. In Marxist terminology, if the cultural superstructure is not allowed to interact back on the economic base, this would make it impossible to *initiate* a revolutionary change: such a change would take place only when it (causally) became inevitable. Accepting the last position would be, to my mind, a gross misreading of Marx.

The difference between conditioned coorigination and causality becomes more apparent if we apply it to everyday life (together with the rejection of traditional authority as a valid source of knowledge). In practical terms this meant the rejection of the traditional organisation of the society. Thus, the Buddha did not merely propound an abstract and subtle doctrine of causality as the fruit of his extended meditations; he applied it to start a new social organisation in the *samgha*, which departed from tradition. One key feature of the *samgha* was its explicitly democratic character which, unlike the 'democracy' of Athens, admitted both 'slaves' and women as equals. (The Buddha's first counter-question to Ajātasattu asks him how he would treat a slave who had left his service to join the *samgha*—Ajātasattu answers, 'with respect'. A woman married to an old hunchbacked husband left him to join the *samgha* and sing, 'O free I am, thrice free.') Though the *samgha* has been regarded as organised along tribal lines,[36] the fact is that admission to a tribe is hereditary, whereas admission to the *samgha* was on the principle of majority vote (with the assent of those who kept quiet after three chances being presumed).

The theory of conditioned coordination explicitly denied that individuals were the sole causes. Therefore, it also denied that they were the appropriate recipients of credit and blame. It therefore denied that the social hierarchy reflected a distribution of merit. For, in Buddhism, the cessation from suffering is available now. It is available at the very next instant. Buddhism emphasised the capability of creative action (*puruṣkāra*), more than hereditary dispositions (*saṁskāra*). Nirvaṇa was available to a poor person from the lowest caste, and he or she could join the *samgha*. It was not necessary for a person to wait to be reborn into a higher caste before seeking deliverance; deliverance was available now if the person were so motivated. The traditional order was not necessarily a moral order. Indeed, changing the social order could reduce suffering (and compassion therefore required one to change the social order).

Since even perceptive scholars like the two Kosambi-s seem to have overlooked the key role of the idea of 'cause' in the organization of society, I would like to present a closer example. One can better understand the relation of 'cause' to society by applying conditioned coorigination in place of 'cause' to our present situation of industrial capitalism. The purpose of life in industrial capitalism is not to obtain deliverance, but to maximise happiness or money on the equation *time=money*. A capitalist society is necessarily hierarchically organised so that only a few people have capital.

Those who don't have money (most people) must first spend their lives trying to earn money to be happy. So many unhappy people cannot be contained through force alone, their actions must be inhibited by making the system *seem* legitimate. The legitimation is through the notion of cause: almost every rich man argues that he has wealth *because* of meritorious action.

Capitalist society needs a particular notion of cause for its legitimation, just as much as it needs the time perceptions underlying *time=money* to control the behaviour of people. By changing these time perceptions, and the accompanying notion of cause, conditioned coorigination becomes a vehicle for transforming society. With conditioned coorigination it can no longer be maintained that the existing distribution of wealth reflects a distribution of 'merit'. With conditioned coorigination, wealth ('accumulated merit') cannot be legitimately inherited. It cannot be maintained that poor means bad as in 'poor argument'. This ceasing, that ceases—much suffering would cease if society were reorganised to remove these disparities. The formation of the *samgha* as a separate entity represents, therefore, a moderate rather than a revolutionary presentation of this proposal for social reorganisation, through a changed understanding of time and cause.

## *Contact and the Existence of the Past*

In connection with the question of the globalisation of culture and the related question of science and religion, we have already, in passing, observed (Chapter 3) the following. The Buddhist rejection of authority and acceptance of only the manifest and inference as the means of right knowledge, both, are manifestly closer to science in principle, though the Western Christian acceptance of authority is closer to science in practice. In this context, it is interesting also to ask how the changed notion of time relates to scientific theory. The key question is: does the past exist? That is, can 'causes' of an event reside in the past? or is contiguity essential to the notion of 'cause'?

Cause and contact.

The central point of the orthodox view of causality in Indian tradition was the notion of *karma*. An obvious difficulty with the cosmic extension of the idea of *karma* was this: how does an action *now* cause an effect 8.64 billion years later? The key difficulty is the lack of immediacy: an act does not immediately produce all its effect; some effects take a long time. Is this possible? This difficulty arises from the belief that the past has ceased to exist; while there may be some doubt about the non-existence of the immediate past, the belief goes, the remote past, at any rate, does not exist. Therefore, locating causes in the remote past amounts to saying that the cause does not exist!

We saw earlier (Chapter 9) that in physics this belief in the non-existence of the past, and the consequent need to seek causes in the immediate present, is reflected in the Cartesian doctrine of action by contact which underlies Newtonian mechanics: effects cannot be transmitted except through contact, here and now. Contiguity must hold both in space and time, so that a cause must produce its effect at the very next instant, in an immediately adjacent spatial location.

We also saw that this Cartesian viewpoint was represented in Indian tradition by the orthodoxy of Nyāya-Vaiśeṣika (from which it was perhaps derived). The furthest that tradition could stretch was defined by Kaṇāda ('atom eater') in the authoritative Vaiśeṣika sūtra: neither contact (*saṁyoga*) nor disjunction (*viyoga*) between cause and effect.[37] Effect could neither coexist with cause, nor could there be a discontinuity between cause and effect. This theorising about contiguity was at variance with observations like that of a lodestone and a needle, or the moon and tides, involving an interaction between physically separate objects. So, to preserve the theory, it was imagined that space was filled with an unperceived fluid called *ākāśa* or aether through which the distant entities interacted. So, what provided contact between *karma* and *saṁskāra*? This was not provided by the underlying aether (*ākāśa*) but was 'unseen' (*adṛṣṭa*) like the contact between a jewel and the thief it attracted, or the attraction between a lodestone and a needle.[38] Thus, to preserve this requirement of action by contact, one is compelled to introduce various entities, like the aether, which cannot be directly perceived.

Buddhists objected to this process of filling up space with unperceived fluids. They argued that the alleged all-pervasiveness of the aether was at variance with the posited indivisibility of atoms.[39] The Nayyāyika responded that aether is all-pervasive by contact.[40] This was countered by the argument that the very notion of contact was meaningless, for if atoms were capable of contact, they must have parts.[41] The related debates in Europe[42]—e.g., between Leibniz and Kant—echo the difficulties enumerated in the *Nyāya Sūtra*: 'atoms must have parts for they are capable of contact'. Indeed, Kant would not have needed an antinomy to resolve this had he been better informed about other traditions, particularly the Buddhist debate with orthodoxy on this point. Though no Buddhists were left to respond to Udyotkara's linguistic resolution of the paradox,[43] that clearly is not the end of the story: for one can no longer say when two bodies are *not* in contact, so the very notion of contact becomes physically meaningless.

Fields and action by contact vs retarded action-at-a-distance. Action without contact and the existence of the past.

Even today, as we have seen (Chapter 9), physics has not quite abandoned the belief in aether in the sense of action by contact—the underlying entity providing contact is nowadays called a field. We have also seen that a much clearer physics is possible if we abandon such non-manifest entities like aether and field, and simply permit action across distance and time, as manifestly observed. Dispensing with non-manifest intermediaries, and locating causes in the past, requires us to accept that parts of the past continue to exist in some sense. The Buddha accepted that some part of the past exists. Accepting the existence of some things past has some interesting consequences.

Death has no longer the significance one attaches to it in everyday life; but not because it is only intermediate non-existence. If one's acts now will produce fruit in (what one could continue to call) a later life, then 'one' (the act) continues to exist in the sense of causal efficacy. (We have already noted, in Chapter 1, the similarity of this belief with the African belief in life after death.[44])

We have also seen in Chapter 9 that, in present-day physics, history dependence *cannot*, in general, be reduced to instantaneity. That is, a history-dependent future *cannot* be represented as a consequence of the present alone by, e.g., including in the present a memory of the past. That is, the Buddhist view of the past is fundamentally incompatible with Augustine's idea of 'a present of things past: memory'. This incompatibility is a physical rather than purely a metaphysical matter: as we have seen, instantaneity, being time symmetric, is physically different from history dependence, which is time asymmetric.

## *Summary*

To summarise, the Buddha's transformation of time corresponded to a changed way of life (cessation of suffering, and the Middle Way for householders), a changed social organisation (the *samgha*) which was not hierarchical, and a rejection of traditional authority as a valid means of knowledge. This transformation of time was also connected to a change of logic considered later on (in the postscript to this chapter).

The Buddhist teaching was challenged on the one side by orthodoxy and, on the other side, by those of his contemporaries like Mahavira who rejected orthodoxy. Subsequently there were internal differences within Buddhism. Eventually, the continuity and difference from Sāṁkhya-Yoga crystallised into various schools of thought, which adopted all possible positions. Thus, one can find the Tibetan belief in almost immediate rebirth, and the complete denial of any continuation of personal identity in *Therāvāda*. The *Sarvastivādin*-s ('all-exists-ites', *Abhidharma*), adopted a position similar to *Sāṁkhya*. The *Sautrāntika*-s denied the existence of anything apart from the instant, and the *Mādhyamika*-s (Nagarjuna) took an intermediate stand, though some have (wrongly) understood this (*śūnyavāda*) as complete nihilism. It is not of interest here to map all these divisions of opinion: the above exposition of Buddhism seems to me the best way to understand the Buddha's thinking today, and it is especially helpful in identifying the key time perceptions underlying Buddhism that remain relevant to contemporary and future science and society.

Since creationism has figured so prominently in debates on science and religion in the West, it is worth observing also that most forms of Buddhism remained explicitly atheistic, and denied the creation of the world by God or a similar entity. Using his famous *prasang* (*reductio ad absurdum*), Nagarjuna showed that the idea of an omniscient, omnipotent, and good God is incompatible with the existence of suffering in the world. The denial of God as creator, by the learned Śāntarakṣita, for example (p. 57), continued more than a thousand years after the Buddha. Incidentally, that denial was followed by a refutation of 'Sauri (Viṣṇu), Ātmaja (Brahma) and the like' as possible creators. Kamalaśīla explains that 'and the like' refers to Time, which is conceived by some opponents to possess wisdom as is explained by their claim:

> Time ripens the beings.
> Time annihilates the creatures.
> Time awakes when [people] are deep asleep.
> Time is indeed invincible.[45]

## *Extreme Non-Violence and Indirect Causation*

Mahavira, founder of Jainism, was another one of the ascetics in Ajātasattu's kingdom: according to Jain records his answer satisfied Ajātasattu; according to Buddhist records it did not. We can only speculate about that answer: what we do know is that, unlike the Buddha who wanted to end suffering and rejected harsh ascetic practices, Jains value suffering and ascetic practice as an end in itself. The ideal ascetic practice, according to Jains, is to starve oneself to death. (Did this thought provide some solace to Ajātasattu?) One still finds some Jain *muni*-s attempting this. Gandhi, who for obvious reasons was deeply influenced by Jain beliefs, especially in non-violence, regarded his fasts not merely as political instruments, but also as experiments on a grand scale to test the efficacy of this belief in the ethical value of self-sacrifice.

Mahavira and the Buddha both accepted time as discrete, though Mahavira more explicitly rejected quasi-cyclic time or the belief in life after death. But a key controversy between Buddhists and Jains concerned the question of intention. This does relate to time perceptions, for intention typically concerns the future, and the question is whether the future, real or desired, has any bearing on creative acts in the present. From the point of view of science, we have seen that if intent (or the real or desired future) were to be wholly decided by the past, then the present act could not be creative. Both Buddha and Mahavira, however, strongly believed in *puruṣkāra*, or the human ability to create.

The Buddha thought that intention was important; Mahavira, who advocated extreme non-violence, thought that talk of intention was only an excuse: one did not 'unintentionally' step on an ant, one stepped on the ant because one could not have cared less for the ant. If one really did not intend to step on the ant, one should carry a broom to sweep ants out of one's path; one should cover one's mouth to avoid 'unintentionally' inhaling insects. (Orthodox Jains can still be seen doing both.)

The Jains ferociously argued against the Buddhist view of the value of intention as follows. Suppose a man were to go to a hen coop, and suppose that unknown to him instead of a hen there were a human child inside the hen-coop. Suppose the man were to take his spear and plunge it into the coop, and suppose that he were to carry the speared child at the end of his spear, and roast it over a fire, all along not knowing that it was not a hen but a human child—well, that would be a meal fit for a Buddha!

But the Jain teaching of extreme non-violence made it difficult for people even to live. The Jain sages could not easily eat cooked food (see Box 9, p. 398). Many Jains still avoid eating tubers for these are the roots of plants. But one must eat to live—at least till such time as one is prepared for the ultimate ascetic goal of starving oneself to death. Therefore, to reconcile their beliefs, Jains used a theory of direct causation: the sage was not responsible for any violence that he had not *directly* caused. The Jaina *muni* can eat a cooked meal, provided the meal was not specially cooked for him; in that case, he cannot be held responsible for the insects, etc., that might have died in the process of cooking the meal. One might interpret this theory of direct causation as intended to discriminate between real and professed intention, just as, in contemporary society, one would judge a politician not by his professed intentions, but by the direct consequences of his actions.

Today, people taunt the followers of Mahavira with having interpreted his teaching of non-violence very narrowly, as merely an injunction against killing insects. Following this injunction, the Jains could only become traders and moneylenders, many of whom are now very rich, and think it is entirely in accordance with the teachings of Mahavira to rely on 'indirect' state violence to control exploited people dying of hunger. Gandhi, of course, recognised state violence as a collective form of violence, for which the individual shared responsibility: capitalism needs inequity, and inequity can be maintained only through violence.

Mahavira, of course, also taught and practised *aparigraha* or renunciation, as part of his belief in the value of austerity, but this part of his teaching, too, has been reinterpreted in a way that reconciles it with both feudal and capitalist values attached to accumulation. Renunciation has been seen as an injunction against consumption, not acquisition. Thus, some Jains still maintain a lifestyle that is personally austere, and the choice of profession, combined with personal austerity, has helped them to accumulate. (This 'Jain ethic' is compared below with the 'Protestant ethic'.) The reinterpreted doctrines enabled the Jains to blend so well with the surrounding social ethos that they remain a flourishing community, while Buddhists, who openly challenged the social order, were eventually driven out of the country.

## *Islam and Ontically Broken Time*

Some simplified history may help to understand the currents of thought about time and cause in Islam. Pre-Islamic Arabia was a land of blood feuds and hedonism, as it emerges from early Arabic literature.[46] As the Arab tribes were amalgamated into Islamic kingdoms, there arose the need for jurisprudence. Justice was dispensed through authority, and the highest authority was the Ku'rān. This focused attention on certain obscure passages of the Ku'rān. What did they mean?

The Mu'tazilah school of rationalists advocated *aql-i-kalām*: the word of God (*kalām*) intelligently understood, by exercising also one's mental faculties and reason (*aql*) to understand the passages. The two basic premises from which the Islamic rationalists proceeded were (1) divine unity, and (2) divine justice. They believed that the rest of their doctrine could be deduced from these premises using Aristotelian logic. They held Euclid's *Elements* in high regard, because they saw in it a demonstration of their beliefs that even manifest truths could be deduced from the premise of unity or equality.[47] This school flourished for some time, and some Sultans even persecuted those who refused to subscribe to these beliefs.

Clearly, interpretations proliferated to the detriment of standardisation and authority. One did not know what to expect. Two opposed contenders for justice could maintain opposed interpretations of the same passage, so that the authority of the Ku'rān could not be used to decide the matter. Al-Ash'arī, a former member of the school of rationalists, opposed them. He maintained that the passages of the Ku'rān had to be accepted 'without asking how'; they could not be interpreted, even if they seemed opposed to reason. The advocates of a certain interpretation had to produce in their support not reason but a chain of authorities (*isnād*): '*z* was told by *y* who was told by *x* who heard this from the Prophet'. This led to an interest in recorded history, for people wanted to check, for example, that *z* was born before *y* died.

Against this background, we see three traditions about time in Islam. The first is that of the Philosophers, the second is that of orthodoxy, and the third is that of Sufi-s. The Philosophers propagated quasi-cyclic time, orthodoxy propagated ontically broken time, and the Sufi-s tried to combine both. The Philosophers were also aligned with the rationalists. In addition to Aristotelian logic, they propagated the 'theology of Aristotle'. Today scholars believe[48] that this actually consisted of the *Enneads* of Plotinus who was, as we have seen, a very distinguished Neoplatonist and student of Origen. Prominent amongst the Philosophers was Ibn Sīnā, whose interpretation of divine unity was particularly fascinating: inanimate matter also has a measure of creativity 'akin to that of the First Cause, for it is an emanation of that cause'.[49] This creativity gets more concentrated and effective as one moves from mineral to vegetable to animal to human. This is what the poem by the great Sufi poet Rūmī (p. 29) expresses.

The rationalists were opposed by al-Ash'arī, and the Philosophers by al-Ghazālī. The Ash'arites held that every time-atom, Allah creates an entirely new set of accidental properties, though these could be the same accidents as before. In al-Ghazālī's example, the Hand does not cause the Pen to move. Instead, Allah creates the necessary power, the motion of the Hand, and the motion of the Pen. None of these items is the cause of any other; they merely coexist in time, and Allah is the only cause. In Maimonides' example the dye cannot similarly be regarded as causing the cloth to turn black.[50]

Islamic theology brought about a transformation in values through the notion of ontically broken time (occasionalism). Al-Ghazālī emphasised the multiplicity in a sequence of causes. Given an ink-spot on the paper, the Paper blamed the Ink, the Ink blamed the Pen, the Pen complained about the Hand…. Al-Ghazālī's intention was to emphasise the absurdity of attributing agency to inanimate objects: in a rigid chain of cause-effect-cause, how can one fix upon any one element as *the* cause. To speak properly of cause, a creative element was required, and the Mu'tazilite belief in rationality (*aql-i-kalām*) seemed to limit the creative powers of Allah by fixing this sequence of cause-effect-cause: Allah had no option but to create smoke with fire. For Ash'arīya-s the danger of this belief was that man would become arrogant for it was no longer entirely clear why there should be any Allah at all. There was little room for Allah in this world between creation and resurrection. Hence they insisted on continuous creation: that Allah created the world afresh each instant, but in a habitual sequence not in a causally fixed sequence. Anyone who seriously believes this view of time cannot but surrender to the will of Allah: this sort of thing is only too clear in popular narrative.

Al-Ghazālī's destruction of Islamic rational theology was meant to revive religious and ethical practice. These practices, combined with the doctrine of Grace, became widespread among orthodox Muslims. They were also widely prevalent in medieval India, along with the *Sufi* and *Bhakti* tradition. With ontically broken time, there was no definite connection between one instant and the next; anything could happen at the next instant, so the world could not be rationally understood. Hence, knowledge was devalued, and ethical practice was venerated, as in the poem of the weaver Kabir that reading any number of books did not make one learned, for there was more learning in two-and-a-half alphabets of love.

Strictly speaking the Sūfī-s, including al-Ghazālī, did not reject reason, they merely wished to displace it from a pedestal of primacy, and supplement it with the faculty of intuitive insight. Thus, Ibn al-'Arabī, the Shaykh of Sūfī-s wrote:

> The meaning of philosopher is lover of wisdom, since *sophia* in Greek is 'wisdom', and *phil* is 'love', so the word means 'the love of wisdom' and every man of intelligence loves wisdom. However, the mistakes of the people of reflection in the divine matters (*ilāhiyāt*) are greater than their hitting the mark…they are criticized for the mistakes they made in the knowledge of God…If, while loving wisdom, they had sought it from God, not through reflection, they would have hit the mark in everything…for instance, they hold that if they were to apply to God the literal meanings of some of the words of the law-giver (*shāri'*), which the proofs of reason (*'aql*) hold to be impossible, they would fall into unbelief (*kufr*). Hence they interpret these words. They do not know that God has a faculty in some of His servants that gives a judgement different to the one given by the rational faculty in certain affairs, while it agrees with reason in others. This is a station outside the domain of reason, so reason cannot perceive it on its own, neither can reason [man] have faith in it, unless the person possesses that faculty within him. Then he knows that reason is limited and that [the existence of such a faculty] is true.[51]

Ibn 'Arabī presumably intended to emphasise that intuitive insight is an important element of the creative process, something with which few will disagree. However, the sad practical fact is that intuition can be professed even more easily than intention. Also, intuition may genuinely go wrong, for it may merely reflect prejudices, or hopes and fears. Moreover, intuition needs training, for the intuition of an expert often is more valuable than that of a novice. Thus, the worth of an intuition depends upon the worth of the person, and there is often no way to assess the worth of a person except by relying on social authority. Hence, the net practical effect of downplaying the critical role of reason often has been to elevate reliance on social authority.

To summarise, the Sūfī-s believed in a globally quasi-cyclic time that was locally ontically broken. Since all would eventually unite back with the creator, the Sūfī-s, like the Islamic rationalists and the Philosophers, continued to believe in divine unity. Thus, the threefold transformation that they brought about in social organisation, way of life, and logic may be described as follows. Because of divine unity there could be no fundamental hierarchy. (Some Sūfī-s did believe in a temporal hierarchy of the novice-adept-master kind; others, like al-Ghazālī, thought that the absence of any fundamental hierarchy ought not to be revealed to those not prepared for it.) The Sūfī-s won the respect of the common folk because of the exemplary ethical standards that many of them maintained, as a way of life. As for logic, we have seen that they denied logic in the sense that they rated the intuitive apperception of God—the direct experience of God-ness—as higher than reason, as something that reason could not grasp, any more than we can experience the colours of the infra-red (as some extraterrestrial species might).

Since ontically broken time required surrender to God, and since the rejection of logic required also the suspension of one's critical faculties, those more closely linked to the state[52] used this to privilege hierarchy and reinforce authority. They did not repudiate divine unity, they reinterpreted it: they claimed that the 'unity of existence' (*tauhīd-i-wudjūdī*) had been confused with 'unity of experience' (*tauhīd-i-shuhūdī*).[53] Though originating in pre-colonial times, this development flowered during colonialism.

## *Why Rationality Won and Providence Lost*

The Islamic debate on providence, put together with the curse on 'cyclic' time, helps to understand the development of modern rationality. The curse on 'cyclic' time, proceeding from state-inspired motivations, reinforced authority by separating man from God. The separation is quite explicitly articulated in the curse: the souls of men would not be like drops of water merging back into the one and the same, they would remain forever in their 'present form'. Medieval European theologians of rationality, like Thomas Aquinas, proceeded from this established context of apocalyptic time. The people for whom they were concerned did not doubt that they would be hauled up to give an account before God. Ontically broken time conferred *too much authority* on a God who was already regarded as both transcendent and vindictive, after the curse. Therefore, Aquinas rejected (complete) providence. For al-Ghazālī man was part of God, and could hence continue to create. For Aquinas, man was separate from God, so that ontically broken time deprived man of all causal and creative power which were reserved for God. Hence, Aquinas' solution was to make God more mechanical.

The Islamic rational theologians, the Mu'tazilah and the *falāsifa*, were opposed by al-Ghazālī who argued that while God was bound by the laws of logic, he was not bound by any causal necessity. Al-Ghazālī did not at reject reason in the sense of logic—he accepted that God was bound by the laws of Aristotelian logic—what he rejected was reason in the sense of *mechanism*: that God was bound by a mechanical chain of causes. Hence, the past could not be used to predict the future with certainty. Ibn 'Arabī amplified this to the explicit belief that the world could not be understood by reason alone, but required 'faith'. Opposing al-Ghazālī, Ibn Rushd (Averröes) supposedly argued that there may be two truths, ultimately irreconcilable (like two cultures): one of faith and one of reason. Thomas Aquinas opposed both, arguing that God proceeded not from habit, as al-Ghazālī had maintained, but had imposed definite laws on nature (*physis*), and that these (causal) laws could be understood according to *logos* (i.e., 'rationally'). Hence, he argued against Ibn Rushd that reason was not incompatible with faith.

Hence, rationality won and providence lost in European theology: apocalyptic time changed to superlinear time. The change took time. We have seen that Newton retained room for providential intervention; after Newton, rational theology changed to calculative rationality. The shift to superlinear time was completed with Laplace's demon which still rules (and we have examined in some detail the attempts to exorcise this demon through broken time). Industrial capitalism was the application of mechanical rationality to the productive and distributive order, and the application of mechanical rationality to one's life leads directly to the values associated with *time=money*.

## *Summary*

The beliefs in quasi-cyclic time and causality were transformed in different ways by Lokāyata, Buddhist, Jain, and Islamic traditions. The transformed time-beliefs and associated notions of human identity were taken to be factual matters. In each case this transformation of time-beliefs was related to a three-fold transformation: in logic (or acceptable rules of evidence), in social organisation, and in values and the way of life.

## *Comparison with Time = Money*

All that has now changed; but there is no longer any need to bemoan the collapse of values, because we now begin to understand it. The *time = money* of industrial capitalism has displaced the earlier time beliefs and values.

The earlier time-beliefs, and related values, are incompatible with the *time = money* of industrial capitalism. Contrast, for instance, the value of accumulation in industrial capitalism with the case of Abu Yazīd, who was disturbed one evening. He asked his disciples to see if there was anything 'valuable' in his house. Because of the extreme simplicity of his lifestyle, nothing was found except half-a-bunch of grapes. Abu Yazīd immediately asked his disciples to give them away, saying: 'My house is not a fruiterer's shop'.[54] Only after that did he recover his composure. These traditional values are simply not possible values in an industrial-capitalist society. Any attempt to restore those values must first reorganise society.

Western Christianity also transformed the notion of time. Didn't industrial capitalism displace also these time beliefs and the associated values?

This question is important because almost every recent sociological study of time asserts that the rational, or 'linear', view of time can be traced ultimately to the Judaeo-Christian tradition. We now see that this conclusion is true only in a substantially qualified way. In Chapter 2 we saw one qualification: tradition must be distinguished from scripture—the notion of 'linear' time originated not so much in scriptural tradition as in medieval Christian politics. We have now seen another qualification: Western Christianity was not the first. Other traditions had rejected quasi-cyclic time, long before Western Christianity even adopted it. The Lokāyata fiercely rejected quasi-cyclic time and life after death. But they did so because they wanted a more equitable social system. The Western curse on 'cyclic' time, however, proceeded with exactly the opposite motivation. Origen was the one who wanted equity, while Augustine and Justinian believed in authority and hierarchy. The roots of industrial capitalism can be traced to Western Christianity in exactly this sense: both support an iniquitous and hierarchically organised society.

## *The Protestant Ethic*

Around 1905, the sociologist Max Weber[55] put forward the thesis that capitalism developed in the West because of Protestantism. Weber's initial empirical observation was that in one European city the Protestants were better off than the Catholics. Their prosperity, he felt, was caused by the value they attached to hard work and thrift. Protestants, especially Calvinists, regard worldly success as a sign that God has elected that person for eternal salvation. In Ronald Reagan's language, they believed that 'the rich are good because they have the money'. Later on, Weber expanded his thesis to contrast the this-worldly view of Protestantism with the other-worldly orientation that he attributed to a number of other religions including Buddhism.

We have seen that industrial capitalism harmonises with Western Christianity, but is discordant with other religions. But Weber errs in his causal analysis and in supposing that this harmony can be restricted to Protestantism. In the case of the Jains there is a clearer connection linking religious beliefs to the prosperity of the community: given their belief in non-violence, they felt obliged to earn their livelihood through trading, or money-lending—and money-lenders of any kind are notoriously prosperous, especially if they feel obliged, on religious grounds, to lead a personally austere life. Weber is unable to put forward a similarly clear connection. Like the slaves of yesterday, there are millions of hard-working and thrifty people, today, who are born poor and die poor, so it is difficult to believe that hard work and thrift, by themselves, ensure prosperity. Moreover, prosperity is not the key issue, for wealthy people have surely existed in all traditions. While both are wealthy, the capitalist differs from the merchant in *controlling* the means of production. Weber simply ignores this key issue.[56]

Granting an empirical correlation between Protestants and prosperity, the causal analysis could run either way. The base-superstructure theory would maintain that religion (a part of the superstructure) was modified to suit changes in the economic base—the Priest modified his theology to suit the Merchant/ Capitalist. Theological decentralisation made this easier and quicker for Protestants, but, today, prominent Catholics too can be found maintaining that 'poverty is the gift of God'.[57] Therefore, the harmony of industrial capitalism with Western Christianity cannot be further specialised to Protestantism, as Weber does.

The caste system in India similarly sanctified a social advantage as due to 'merit'. Weber's own thesis illustrates this process of appropriation, for he conceptualises class as a slightly leaky,[58] religiously sanctioned version of caste. No one denies the religious sanction, but Weber was wrong in supposing that classes originated *because* of such sanction—the classes were there, the sanction followed. Not even the caste system in India depends upon prior religious sanction; for, as Weber correctly observed, the caste system in India is not confined to any particular religion, but extends also to Christianity and Islam.

## *The Multiplicity of Causes*

To summarise, Weber is right to the extent that there is harmony between capitalism and Western Christianity. But his causal analysis is unsustainable. Does prosperity arise from hard work and thrift, or does it arise from loot, cruelty, and dishonesty? The North American Indian would maintain that American prosperity derives, first and foremost, from the loot of an entire continent. Black slaves, in North America, worked very hard, and they lived on very little, but strangely enough they were not prosperous. But the prosperity of their masters obviously derived from the hard work that they so cruelly extracted from the slaves. Thus, the causal analysis in Weber's thesis itself illustrates how the socially privileged appropriate morality using Augustine's notion of cause by matching merit to privilege. Such a causal analysis helps to maintain the converse of Reagan's proposition: 'the rich have money *because* they are good'.

Two things about this Augustinian notion of causality need to be clarified. First, this causality is NOT the same as human agency. It is possible to conceive of human agency without wanting to distribute rewards and punishments. The classic example is the famous Samkhyā doctrine in the *Bhagvad Gītā*: 'your right extends to action, definitely not to its fruit'. The second feature is that the causality in question refers to social causality rather than physical causality. The difference is this, human agency typically operates in a social context where there is more than one human agent, hence more than one cause. In the social context, the reference to human agency is largely rhetorical: what is paramount is a methodology of distributing rewards and punishment, credits and blame.

Consider the following situation. A husband and wife start from their house exactly five minutes later than planned, because the wife could not finish her packing as scheduled. They have nine minutes to spare, but while driving to the station, the husband scrapes another vehicle. There is no serious damage, but they are delayed by exactly another five minutes, and miss their train. Who is to blame? The two have a quarrel, each blaming the other, and counterfactuals fly through the air. 'If only you had finished your packing in time, we could still have caught that train.' 'Well, if you hadn't driven so rashly, we could still have caught the train.' How should this quarrel be settled?

This is a common enough quarrel, so one should first ask: how *would* this quarrel be settled? The answer should be clear to any observer of human affairs. There is no absolute way to decide, so the decision can only be made on the strength of authority. The dominant one in the pair will carry the day.

As an actual example, a monkey on a balcony toppled a flower pot which fell on the head of a person standing below, killing him. Who was responsible? The monkey foraging for food in a high-rise apartment or the person who had so negligently kept the flower pot on the edge of the ledge? The media held the monkey responsible, and there was an outcry about the monkey menace!

In a social context there are always more than two actors, and always at least a multiplicity of causes. One can understand this as follows. Referring back to the picture of mundane time, we now need to focus on the straight lines between the branch points. These straight lines signify that the world evolves deterministically between the choices represented by branching. But when other agents are involved, this deterministic evolution is not guaranteed. I may reach for a glass, and in mundane circumstances, I should be able to pick it up. But suppose, as in a 'Western', somebody shoots the glass before my hand touches it. Would one maintain that the glass shattered just *because* I reached for it?

Consider, now, the reverse sort of example. A student tops an examination. Conventionally, one maintains that the student is deserving and meritorious. But there were so many factors that the student took for granted. There were the parents; there were the teachers; there was the school, its building, its environs, its equipments; there were the books, the people who wrote the books, the ones who produced them, the ones who distributed and sold them, the ones who made the paper on which the book was written, the ones who built the factory building in which the paper was made, and so on. These are not trivial factors: it may well be that there are thousands of students in the mofussil who may be 'intrinsically more meritorious' in the sense that they would have done better, given exactly the same teachers, the same building, the same environment, the same affluence at home to enable buying books and supplementary reading material and computers, and so on. Any analysis of cause and effect in terms of the simple picture of mundane time is quite hopeless for so complex an enterprise, involving such a large number of people and things. Why then do we declare the student who has topped to be meritorious?

We do this because that is the social convention. This society is not interested in an elaborate causal analysis. It is interested in a practical means of distributing rewards and punishments (= negative rewards). Convention is one of the ways of resolving disputes over causes or the distribution of credits.

In general, linking credits to causes ensures that a dispute over causes/credits can be settled *only* politically. In practice, this means that those who are already politically powerful 'legitimately' appropriate all credit. The classic example is what every schoolboy knows: the Taj Mahal was built by Shah Jehan, who neither designed it, nor laboured to build it, nor created the needed wealth. As emperor of the Mughal empire he was, however, the politically most prominent person, who, therefore, 'naturally' gets the credit. The capitalist takes the 'lion's share' of the surplus, just because the capitalist is politically more powerful than the labourer. The purported causal analysis about capital investment being a more important causal agent than the labour is so much bunkum, because there is no way such a causal dispute can be settled using mundane time beliefs.

Distribution of rewards in proportion to political strength means exactly that *status quo* is maintained. That is, the theology of causation provides a justification for the distribution of credits in proportion to existing political strength, hence for maintenance of a *status quo* in which theologians have shared power and wealth with aristocrats or industrialists. The entire judicial system, founded on this naive premise about causality, therefore, also serves to maintain *status quo*. As a judge, Augustine surely understood this.

This, then, is the real significance of the rejection of quasi-cyclic time today. This rejection did not lead to a collapse of values only at the time of Ajātasattu—the entire collapse of values today observed among the Indian elite flows from this rejection, as we saw in the preceding chapter. (This phenomenon is not confined to India, but also afflicts industrial capitalism elsewhere.) 'Causality', 'agency', 'creativity' remain only as metaphysical skeletons of dead arguments which prop a practical system of distributing resources according to existing political strength.

This also explains the privileged position that Western Christianity expects as the universal church of the future universal state. This is the only religion that has already harmonised with the *time=money* of the industrial capitalism. At the foundational level of time beliefs, there is complete harmony between Western Christianity and industrial capitalism. Altering that time belief by, e.g., accepting quasi-cyclic time would rock the entire industrial capitalist lifestyle and the religious metaphysic suited to it—Keynesian economics does not go well with the belief that in the long run one returns to life. No wonder scientific authority is needed to reinforce the manufactured cultural disgust that so many people in the West exhibit towards quasi-cyclic time.

## Postscript: Culture, Logic, and Rationality

We saw in Chapter 9 that different pictures of time correspond to different logics. In view of the manufactured cultural disgust against quasi-cyclic time, it is important to show that even *logic* is not universal; that the tacit assumption of a two-valued logic involves a cultural bias. This is the antithesis of the Platonic view that mathematical 'truths' are somehow out there, independent of culture. This thesis is developed further in the appendix to this book, in the context of geometry, 'proof', and the philosophy of science.[59] The importance of a difference of logic cannot be overstated: it throws into doubt the Western (Greek) notion of 'proof' and the entire edifice of formal mathematics built on it, hence also inferences about physical 'facts' drawn from this mathematics.

Western thought has long regarded deduction as infallible and certain, and induction as fallible and uncertain. However, deduction rests on logic, so if different cultures used different logics, as this postscript shows, then deduction would refer to a cultural truth rather than a certain or universal truth. In that case, induction, based on the empirically manifest, may be more certain and more universal, so that the Western valuation of deduction over induction may also need to be revalued.

Rationality may or may not be universal, but ideas of *what* constitutes rationality are not God-given. The current belief in the universality of a particular method of reasoning is not based on any profound study, but on the opposite: mere parochialism and lack of information about other cultures. (As Paulos Mar Gregorios remarked, in the West, a person who has not read something of Plato would be regarded as improperly educated; shouldn't one similarly regard a person who has not even heard of Akṣapad Gautam or Nagarjuna?) The object of this postscript is only to provide concrete examples of alternative logics. This section necessarily involves some technicalities, and may be skipped by those without the necessary background.

## *Syādavāda and the Logic of Structured Time*

To make contact with earlier discussions of changed logic in more recent times, let us first examine alternative logic in the context of the Jaina system of *syādavāda*. The distinguished commentators who have sought to make this logic a new basis for statistics,[60] referred to its significance for experimental physiology,[61] or to

Bohr's complementarity principle,[62] have assumed[63] that non–2-valued logic is exclusively a Jaina phenomenon.

Actually, an earlier available reference to such a logic relates to Sañjaya Belaṭṭhaputta, one of the five wanderers to whom King Ajātasattu addressed his question. His reply, as summarised by Ajātasattu, ran as follows.

> If you ask me whether there is another world—well, if I thought there were, I would say so. But I don't say so. And I don't think it is thus…And I don't think it is otherwise. And I don't deny it. And I don't say there neither is nor is not, another world. And if you ask me about the beings produced by chance; or whether there is any fruit, any result, of good or bad actions; or whether a man who has won the truth continues, or not, after death—to each or any of these questions do I give the same reply.[64]

Sañjaya's formula for a five-fold negation is summarised in the Pali śloka: *evam pi me no, tathā ti pi me no, annathā ti pi me no, iti ti pi me no, no ti ti pi me no*.

Ajātasattu himself thought that Sañjaya Belaṭṭhaputta had simply evaded his question.

> Thus, Lord, Sañjaya Belaṭṭhaputta, on being asked about the fruits of the homeless life, replied by evasion. Just as if on being asked about a mango he were to describe a breadfruit tree…And I thought: 'Of all these ascetics and Brahmins, Sañjaya Belaṭṭhaputta is the most stupid and confused.' So I neither applauded nor rejected his words, but go[t] up and left.[65]

The Jaina logic[66] of *syādavāda* involves seven categories instead of Sañjaya's five. The system is attributed to the commentator Bhadrabāhu. Jaina records and literature mention two Bhadrabāhu-s who lived about a thousand years apart. Between the two sects of the Jains there is no agreement as to the date of the later Bhadrabāhu, who may have lived as early as the 4th or as late as the 5th–6th century,[67] as his elaborate ten-limbed syllogism (see Box 9) suggests.

The word *syat* means 'may be', and the quickest way to see this is that the word *shāyad* in current Hindustani means 'perhaps'. Hence, *syādavāda* means 'perhaps-ism' or 'may-be-ism' or 'discourse on the may be'. In this view certainty is not possible, and uncertainty requires the making of judgments (*naya*). The seven-fold judgments (*saptabhanginaya*) are: (1) *syadasti* (may be it is), (2) *syatnasti* (may be it is not), (3) *syadasti nasti ca* (may be it is and is not), (4) *syadavaktavyah* (may be it is inexpressible [=indeterminate]), (5) *syadasti ca avaktavyasca* (may be it is and is indeterminate), (6) *syatnasti ca avaktavyasca* (may be it is not and is indeterminate), (7) *syadasti nasti ca avaktavyasca* (may be it is, is not, and is indeterminate). [According to some there is an eighth category, *syat vaktavasya avaktavasyaca* (may be it is both expressible and inexpressible).]

**Box 9: Bhadrabāhu's ten-limbed syllogism**

According to the traditional Nyāya system of logic a syllogism (*avayava*) had five parts: a proposition (*pratijñā*), a reason (*hetu*), an example (*udāharaṇa, drṣṭānta*), an application of the example (*upanaya*), and a conclusion (*nigamana*). An example of a syllogism is as follows. The hill is fiery [proposition] because it is smoky [reason]. Whatever is smoky is fiery, as is a kitchen [example]. So is this hill smoky [application]. Therefore, the hill is fiery [conclusion].

Bhadrabāhu expanded this to a syllogism of ten parts (*daśavayava vākya*). He was interested not in analysing the means of valid knowledge (*pramāṇa*), but in illustrating the principles of Jaina religion. The following is an example.

(1) The proposition (*pratijñā*): To refrain from taking life is the greatest of virtues.

(2) The limitation of the proposition (*pratijñā vibhakti*): To refrain from taking life is the greatest of virtues, according to the Jaina Tirthankara-s (sages).

(3) The reason (*hetu*): To refrain from taking life is the greatest of virtues because those who so refrain are loved by the gods, and to do them honour is an act of merit to men.

(4) The limitation of the reason (*hetu vibhakti*): None but those who refrain from taking life are most virtuous.

*(continued on p. 399)*

(5) The counter proposition (*vipakṣa*): Men who take life in sacrifices are said to be most virtuous. A man may salute his father-in-law as an act of virtue, even though the latter despises Jaina Tirthankaras, and habitually takes life.

(6) The opposition to the counter-proposition (*vipakṣa-pratishedha*): Those who take life do not deserve honour. It is as likely that fire will be cold as that they will be loved by the gods.

(7) An instance (*dṛṣṭānta*): The sadhu-s do not even cook food lest in so doing they should take life. They depend on the householders for their meals.

(8) The doubt (*āśankā*): The food which the householders cook is as much for the sadhu-s as for themselves. If therefore any insects are destroyed in the process the sadhus must share the blame.

(9) Piercing the doubt (*āśankā pratishedha*): The sadhu-s go to the householders without prior notice and not at fixed hours. How then can it be said that the householders cooked the food for the sadhu-s? Thus, the blame cannot be shared by the sadhu-s.

(10) Conclusion (*nigamana*). To refrain from taking life is therefore the best of virtues. Those who so refrain are loved by the gods, and to do them honour is an act of virtue for men.

Haldane relates this to human perception, and I think he was right in supposing that this was not far from what Bhadrabāhu had in mind.

> In the study of the physiology of the sense organs it is important to determine a threshold. For example a light cannot be seen below a certain intensity, or a solution of a substance which is tasted as bitter when concentrated cannot be distinguished from water when it is diluted. Some experimenters order their subjects to answer 'yes' or 'no' to the question 'Is this illuminated?', or 'Is this bitter?'. If the experimenter is interested in the psychology of perception he will permit the subject also to answer 'It is uncertain'.[68]

Suppose now that a subject is given a randomised series of stimuli, and we record his responses. The experiment is repeated a few times. Especially for stimuli very close to the threshold, it is now possible that the subject may say 'no' to a stimulus to which he had earlier said 'yes'; or 'uncertain' (='may be') to a stimulus to which he had earlier said 'no'. After at least three repetitions of the experiment, the responses to a given stimulus may be naturally classified in a seven-fold way: (1) Y, (2) N, (3) Y and N, (4) U, (5) Y and U, (6) N and U, (7) Y and U and N, though the last possibility seems a bit unlikely. These predications correspond exactly to the *saptabhanginaya*. On this interpretation, what we have here is something like a 3-valued logic, so the proposed relation to Bohr complementarity is exactly like the (unsuccessful) one of Reichenbach.[69]

## *The Wheel of Reason*

Haldane's interpretation of Bhadrabāhu resolves the apparent contradiction in asserting that something both is and is not, by making these statements true at different moments of time. Such an exposition, however, may be impossible in the case of both quantum mechanics and Buddhism.

An important consequence of the Buddhist idea of time as instant, a consequence only dimly noticed by earlier commentators, is this: *the dilation of the instant* into an analogue of a cycle of the cosmos *also gives* a structure to the instant, i.e., *a structure to time*, in the sense of temporal logic, *if* we were to replace the atomic instant by a *point* of time. Within the microcosm of an atomic instant there could be both growth and cessation, in complete analogy with both birth and death within a cycle of the cosmos. But if we insist upon thinking of the atomic instant as a *point* of time (realists like Udyotkara did just that) then *one must alter the logic* of discourse: for Udyotkara's act can then be simultaneously both begun and complete, like Schrödinger's cat which can be simultaneously alive and dead. This altered notion of simultaneity alters the very logic of debate, making it very difficult for opponents to refute the Buddha's view. Udyotkara, who came some 15 centuries after the Buddha, still gives completely tangential arguments in an attempted refutation of the Buddhist logic of the instant, following the above plan of deducing a contradiction.

Let us therefore revert to the earlier idea where Haldane's different moments of time are not perceptually different, but are packed within the same atomic instant of time.[70] For the sake of consistency, one might want to treat this atomic instant as really indivisible, as a single point of time. In that case, one way to make sense out of this logic is to attach multiple logical worlds to the same instant of time. This corresponds to the idea of a quasi truth-functional logic. (The quasi truth-functional logic, as we have seen,[71] corresponds to a quantum logic, and gives genuine complementarity.) Alternatively, one may use a many-valued logic, though the two are NOT equivalent (since the structured-time interpretation of quantum mechanics is not the same as Reichenbach's interpretation).

Prior to the Buddha, there must have been prevalent a logic different from that subsequently adopted by Aristotle, as B. M. Barua[72] pointed out. Maurice Walshe refers to this as 'the four "alternatives" of Indian logic: a thing (a) is, (b) is not, (c) both is and is not, and (d) neither is nor is not'.[73] This theory of Four Alternatives, which certainly did not apply to all Indian logic, but was frequently used by Nagarjuna in his famous tetralemma, may be illustrated by an example from the *Brahmajāla Sutta* of the *Dīgha Nikāya*. This Sutta records the Buddha's discourse against various wrong views. The Buddha described four wrong views concerning the nature of the world—whether it is Finite or Infinite—whose adherents claim as follows.

> '…I know that the world is finite and bounded by a circle.' This is the first case…'…I know that this world is infinite and unbounded.' This is the second case. And what is the third way?…'…I …perceiv[e] the world as finite up-and-down, and infinite across. Therefore I know that the world is both finite and infinite.' This is the third case. And what is the fourth case? Here a certain ascetic or Brahmin is a logician, a reasoner. Hammering it out by reason, he argues: 'This world is neither finite nor infinite. Those who say it is finite are wrong, and so are those who say it is infinite, and those who say it is finite and infinite. This world is neither finite nor infinite.' This is the fourth case. These are the four ways in which these ascetics and Brahmins are Finitists and Infinitists…There is no other way.[74]

As an example of the fourth case, consider a piece of burning wood. The fire is not the same thing as the piece of wood. Nor can one maintain that the fire is entirely separate from the wood. Nor even can one say that the fire both is and is not wood. Therefore, one might choose the option (d)—fire is neither wood nor is it entirely separate from wood. Nagarjuna (the founder of *śūnyavāda*, an offshoot of which is Zen Buddhism) declares: 'Everything is such, not such, both such and not such, and neither such and not such.'[75]

In 2-valued logic, accepting a statement and its negation implies every other statement. But this acceptance of 4-alternative logic did not mean that anything at all was both true and false. A little later in the same *Brahmajāla Sutta* of the *Dīgha Nikāya*, we find the discourse of the Buddha rejecting another of the wrong views labelled as the Wriggling of the Eel.

> Because of his dullness and stupidity, when he is questioned he resorts to evasive statements and wriggles like an eel. 'If you ask me whether there is another world—if I thought so, I would say there is another world. But I don't say so. And I don't say otherwise. And I don't say it is not, and I don't not say it is not.' 'Is there no other world?...' 'Is there both another world and no other world?...' 'Is there neither another world nor no other world?...'[76]

Unlike Ajātasattu's account of Sañjaya Belaṭṭhaputta, we have here clearly a list of seven negations: (1) I don't say so, (2) I don't say *otherwise*, (3) I don't say it is not, (4) I don't not say it is not, (5) I don't affirm that there is no other world, (6) I don't say there both is and is not another world, (7) I don't say there is neither another world nor no other world. If we add to this the affirmative proposition of which these are negations, then we obtain the eight possibilities. (It is clearly rather hard to describe so many negations using natural language.[77])

Despite the Buddha's own rejection of such numerous truth values as leading to confusion, a distinguished biologist, G. N. Ramachandran has suggested[78] another interpretation which applies the many-valued-logic point of view to Buddhist logic as expounded by Nagarjuna: namely that this could be seen as an 8-valued logic[79] with a cyclic negation. The peculiarity of the Buddhist notion of negation is found at the very beginning of Nagarjuna's treatise on the Middle Way:

> I salute the Buddha
> The foremost of all teachers,

He has taught
The doctrine of dependent co-arising,
The cessation of all conceptual games.
No origination, no extinction;
No permanence, no impermanence;
No identity; no difference;
No arrival, no departure.[80]

The diversity of interpretation shows that, as of the moment, Buddhist logic is not fully understood. Also, given the evolution of opinion and the various divisions of opinion within Buddhism, it is not necessary that there is a uniform notion of logic across Buddhism.

However, the suggestion to use many-valued logic is not necessarily orthogonal to the suggestion to use quasi truth-functional logic: one can well conceive of a quasi truth-functional logic, in which the multiple logical worlds attached to a single instant of time are themselves many-valued. This would happen, for instance, with Haldane's interpretation of Jaina logic, if the different moments of time that he uses were treated as perceptually indistinguishable.

That the base logic of sentences is itself not two-valued is also clear from the work of Dignāga, a celebrated Buddhist logician, who developed something like a predicate calculus. We do not know his exact date, but he taught with distinction at the University of Nālandā, from where some of his works were obtained by the Chinese traveller Huen Tsang, and first translated into Chinese in 557–569. Dignāga must have been alive in 480 when his teacher Vāsubandhu lived. He wrote in Sanskrit, rather than Pali, and his treatise on logic was composed in the *anusṭhub* metre, as we can infer from the fragments of it quoted by his opponents. Tibetan prose translations are, however, extant.

An enigmatic and very terse (two printed pages) treatise on the 'logic of nine reason' by Dignāga is the *Hetu-cakra-hamaru* (*hetu* = reason, *cakra* = wheel; in Tibetan this is called the Wheel of Reason put in order). Because of its classical terseness (46 lines of verse = about 20 lines of prose + 1 diagram), this treatise admits diverse interpretations. The adoption of such a classically terse style suggests that the author was recognised as an all-time great authority, as indeed he was. The first three and last three stanzas read as follows.[81]

…
Homage to the Omniscient One, who is
The destroyer of the snare of ignorance.
I am expounding the determination of
The *probans* with three-fold characteristics.

Among the three possible cases of 'presence, 'absence' and 'both'
Of the *probans* in the *probandum*,
Only the case of its 'presence' is valid,
While its 'absence' is not.

The case of 'both presence and absence' is inconclusive.
It is therefore not valid either.
The 'presence, 'absence' and 'both'
Of the *probans* in similar instances,
Combined with those in dissimilar instances,
There are three combinations in each of three.

…

Since there are nine classes of *probans*
Accordingly we have nine sets of examples:

Space-pot, pot-space,
Pot-lightning-space,
Space-pot, (space-pot), space-pot-lightning,
Lightning-space-pot,
Pot-lightning-space,
Space-atom-action-pot.

The above concerns the determined *probans* only;
As regards the 'doubtful' ones,
There are also nine combinations of
'Presence', 'absence' and 'both'.

The Treatise on the Wheel of Reasons by Ācārya Diganāga.

S. C. Vidyābhuṣaṇ, an adherent of Nyāya, has suggested one interpretation.[82] This has been strongly disputed by R. S. Y. Chi,[83] who asserts that Vidyābhuṣaṇ 'had confused the notions of "like" and "unlike" altogether…As a result his translation is almost incomprehensible.'

There is a definite difficulty in understanding the three possible cases of 'presence', 'absence', and 'both' mentioned in the *Hetucakra*, the last term being particularly obscure in Tibetan. In the *Nyāyavarttika* of Udyotkara, the Sanskrit formulae used are 'for all' (*vyāpaka*), 'for none' (*avrtti*), and 'for some' (*ekādesavrtti*), corresponding to the quantifiers of modern predicate logic. While I agree that Dignāga was the first logician to have introduced logical quantification, as generally believed, (1) I do not see why it should be assumed that Dignāga's predicate calculus was based on a two-valued logic.[84] (2) Also, I do not see why Dignāga, a Buddhist who taught at Nālandā, should have automatically ignored the question of identity across time,[85] in the manner of undergraduate courses[86] in logic taught at Oxford and Cambridge today. [87] (The absence of any meaning of identity across time is the focus of the Buddhist philosophy of momentariness, and the question of logical identity between possibly different entities at different times is only crudely addressed ['in the flesh'] by Augustine, roughly contemporaneous with Dignāga.)

Dignāga maps a $3 \times 3$ table onto the Wheel of Reason, which has eight spokes like the eight spokes of the Wheel of Time, with the ninth place being the centre. The second turn of the Wheel, given by the last stanza, suggests that Dignāga's system of predication is based on (at least) a 3-valued logic of sentences.

To summarise, logic varies with culture: the 2-valued logic, assumed *a priori* in the West, is *not* universal. Nor need it empirically be the case. This suggests that we should revalue the relative worth of deduction (which is unrelated to the empirical) and induction (which relates to the empirical).

# 12

# Revaluation of All Values

## *Changing Pictures of Time and the Collapse of Values*

We now have a better understanding of time as the interface between science, religion, and society. Changing the picture of time changes the equations of physics. It changes the notions of life after death. It also changes the perception of *cause*, used to distribute credits within society. One's lifestyle changes with changes in what one regards as valuable.

We now have before us several examples which illustrate how values have changed together with the picture of time. The classical trajectory of changes in the picture of time was from 'primitive' quasi-cyclicity to rational 'linearity' (Fig. 1). The classical trajectory was part oversimplification, and part fabrication. The revised trajectory of changes in Fig. 2, though still simplified, better illustrates the changes in time beliefs and values in tradition.

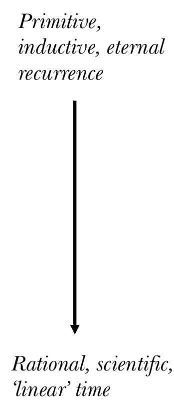



**Fig. 1**

Customary hypothetical trajectory of changes in the picture of time.

To recapitulate a key case, the Western Christian attempt moved beliefs from quasi-cyclic time to 'linear' apocalyptic time, corresponding to a changed

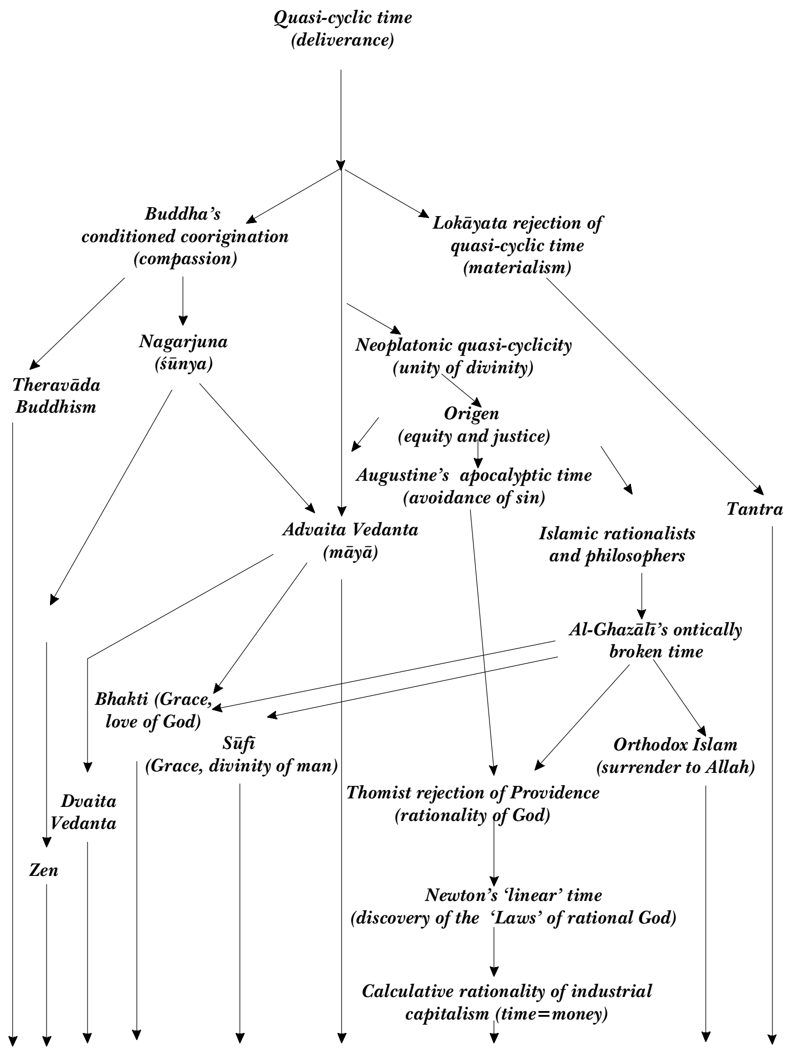
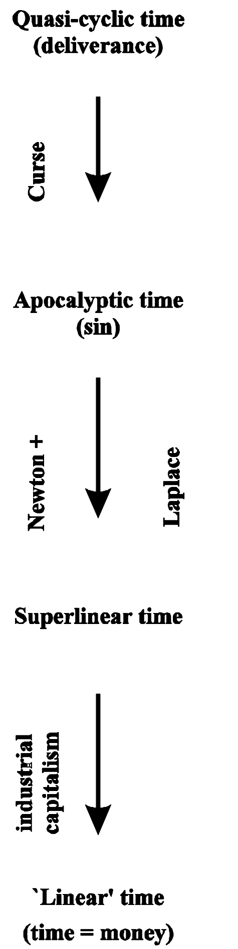



**Fig. 2: The Transformation of Time in Tradition**

belief in life after death: instead of a sequence of lives after death, there was only one life after death. This required a changed notion of cause, localised in individuals, to enable God to distribute eternal rewards and punishment. The changed picture of time was accompanied by a changed value system. With quasi-cyclic time, the objective was to achieve deliverance from the sequence of lives. The objective was to lose one's individuality, and rewards and punishments were anyway temporary, and hence not of lasting value. With apocalyptic time the objective shifted to avoidance of sin: the ideal was to live a *blameless* life. Alongside, there was a shift from the idea of detached action to the idea of action for the sake of reward in the hereafter. In search of this future reward, people abandoned freedom to embrace bondage to obscure rules which one must not at any cost overstep. These obscure rules could be interpreted only by priests who hence became indispensable. Ordinary people were reduced to the status of illiterates in a bureaucracy.

God, like the state, punished those who overstepped the rules. The existence of these rules was important. If the world were capricious, how could man be blamed? And being able to blame man was the fundamental theological requirement, else the priests




**<u>Fig. 3: Collapse of Values</u>**

The changes in the picture of time associated with the current 'collapse of values'.

would go out of business. So the world had to be rule-bound, just as much as man had to be culpable. Modern clerkdom embodies this clerical vision with one difference: in clerkdom there is a rule book somewhere, but no one had seen God's rule book. It was these rules of God that Newton himself, and scientists for the next two centuries, thought he had discovered. Though Newton did not intend this, Laplace accelerated the shift from apocalyptic time to superlinear time, by pushing chance *nee* Providence completely out of the picture.

The industrial revolution and the capitalist production process moved beliefs a step further. In the initial stages, utilitarians shifted the focus from eternal boredom in the hereafter to happiness now. The good life meant happiness now, in this life. The world remained rule-bound, so that happiness now could be obtained, and spread across one's life, in a rationally calculable way. Later on, individuals could no longer really decide what made them happy; they were bound by the equation *time=money*: the good life now means the one in which there is plenty of money. Those who don't have money must postpone happiness, and work to earn money. There is no place for deviants who are happy with less: the capitalist production process ensures the non-survival of deviants; it compels compliance by threatening to push the deviants into its reserve army of unemployed labour, starving or on the verge of starvation, so that most people live under a constant threat to their survival. Since about half the people in the world don't have money enough even to feed themselves, most people must postpone happiness, so that a few rich people can be 'happy'. This leads to our present situation organised around the premise that it is more important to fulfil the greed of a few than to satisfy the basic needs of all. The trajectory of changes in the picture of time corresponding to this 'collapse of values' is summarised in Fig. 3.

This is not a very stable situation. The technology of mass murder and mass opiates, devised to overwhelm the opposition, may blow up one day in the face of the greedy—increasing technological sophistication makes disaffection increasingly dangerous. Even if *people* are unable to change things there is the inescapable logic of environmental degradation. The logic of control and profit requires the proliferation of machines, machines produce primarily waste, and this waste piles up. At first there are only some ugly patches and some nostalgia for the lost greenery of the valley. After some time there is acute discomfort at the basic level of food, water and air. Eventually, it would be impossible to live amidst the waste. What can one do about it?

## *Time in Social and Physical Reality*

An alternative needs an appropriate picture of time. What ought to decide the appropriateness of an alternative picture of time: society or physics?

Just because social organisation and values change with beliefs about time, it is clear that perceptions of time in social reality cannot be separated from notions of time in physical reality. The equation *time=money* or 'calculative rationality', for example, cannot be sustained together with a firm belief that time in physical reality is ontically broken or quasi-cyclic, or even superlinear. (With ontically broken time, say, the future is not predictable, so that the expected present value cannot be rationally calculated.) Indeed, this incompatibility is an important reason why alternative time-beliefs are socially so disreputable: few societies will readily accept beliefs that fundamentally undermine the basis on which the society is organised.

Scientists, who are also human beings, have been unable to resist the social pressure to conform. This has resulted in complete incoherence about time beliefs in physics. Given the relation between values and time, this amounts to saying that *even a hard science like physics cannot claim to have been even structurally value-neutral*. Time is a fundamental concept of physics, but conceptions of time in physics have evolved under the pressure of social value transformations. Science need *not* necessarily conform, at the level of structure, to social values, but value-neutrality has not been the case.

On the other hand, history shows that social approval is a poor guide to physical reality. An appropriate picture of time can come only from an acceptable scientific theory of time—a theory whose acceptability does not flow merely from facile social premises. But what is an acceptable scientific theory? We have already seen the problems that arise in deciding what an 'acceptable scientific theory' ideally is. Existing physical theory assumes the picture of superlinear time. For the theory to be physical, however, one must be able to test it. To test the physical theory one assumes mundane time. The two pictures of time cannot be reconciled, through chance or chaos or collapse, though the hypothesis of a tilt may provide a solution.

Given that the interaction between social and physical reality works both ways, via time, a new picture of time cannot be without social consequences. It cannot likewise be without religious consequences. We will have to re-evaluate and revalue all values. What values are appropriate to this new notion of time? An exploration of this question seems worthwhile, for the current crisis of values is manifest; and, regarding the current situation, I agree with Marx that the point is to change it. To this end, let us start by re-examining the relationship between science and values, to free our thinking from some old platitudes that Western philosophers are unduly fond of.

# The Naturalist 'Fallacy'

## *'Is' and 'Ought': The Truce between Science and Religion*

*Can* a new scientific theory change values? Traditionally, in Western philosophy, science and values have been divorced by the 'naturalist fallacy': facts have no bearing on values. Facts concern the way things *are*, while values concern the way things *ought* to be. It may be a fact that a man *is* a murderer, but one could still maintain that he *ought* not to have committed murder. There are two distinct categories of statements, one involving 'ought' and the other involving 'is': 'ought'-type statements cannot be deduced from 'is'-type statements.[1] From the time of Hume, the two types of statements are believed to be fundamentally different, and one now even has two different logics—a deontic logic for 'ought'-type statements, which differs from the usual propositional logic applicable to 'is'-type statements.

'Is'-type statements are the concern of science while 'ought'-type statements are the concern of religion. The belief is that the core of religious teaching concerns values—'[Thou ought to] Love thy neighbour', say—and this core is forever immune from any development in science. Many scientists would agree with this thesis, since value-neutrality seems the essence of objectivity.

Science and religion can, thus, happily continue forever in their separate compartments. Thus, the disconnection of 'is' from 'ought' also demarcates a truce between science and 'religion'. This prevents science from overrunning religion by saving the domain of values for religion; the truce serves also to restrain 'religion' from the 'is'-type statements which it had earlier profligately derived from 'ought'-type statements. We have seen that various institutional interests are served by harmony or at least truce between science and 'religion'; but *can* there be a truce between two systems, both of which claim to be universal?

## Natural Inclinations as the Link

Indeed, the disconnection of 'is' from 'ought'[2] runs counter to even the most superficial mundane observation. Traditional values often derived from naive religious beliefs. The belief was that good actions would lead to an accumulation of virtue (*puṇya*), that bad actions would lead to sin (*pāp*), and that the balance between the two would decide the nature of one's life in this world or the next. With a moral law, good actions would be rewarded and bad actions punished. Under these circumstances, the 'natural inclination' was to be 'good'.

As Bertrand Russell remarked about Socrates' dramatic death:[3] 'His courage in the face of death would have been more remarkable if he had not believed that he was going to enjoy eternal bliss in the company of the gods.' Given Socrates' belief in life after death, it was 'natural' or 'unremarkable' for him to accept hemlock. Socrates himself thought that virtue was closely connected to knowledge: he maintained that 'no man sins wittingly, and therefore only knowledge is needed to make all men perfectly virtuous'.[4] The 'ought' of traditional values followed from 'natural human inclinations' plus certain 'is'-beliefs, like the religious belief in a moral law operating universally. Hence science can change values by changing 'is'-beliefs.

## The Unnatural Fallacy

One may question this idea that '*ought* follows from *is* + *natural inclinations*'. (1) What are these 'natural inclinations'? (2) In what sense does 'ought' *follow* from 'is'? The 'natural inclinations' are embedded in an evolutionary theory of human behaviour, in the next section (p. 415).[5] The answer to the second question is: in an everyday sense. If a gun (whether loaded or metaphysical) is pointed at one's head, the 'natural inclination' is to part with one's wallet. The parting with one's wallet is not compelled by *modus ponens*, nor by Aristotelian necessity, nor even by the theory of evolution. When 'the Godfather made him an offer he could not refuse', he could, indeed, have refused. What one understands from the statement is that the likelihood of his refusal as (subjectively) estimated from empirical observations of human behaviour was small. This statistical-empirical sense is implicit in the semantics of everyday speech. (In everyday speech a 'rule' refers to something that applies to *most* cases that one *observes*; such a rule is not falsified by one or two or even more exceptions: for example, 'people are right-handed as a rule'.) For understanding past changes in values, or for the humanistic objective of further changing values, this sense of 'follows' is adequate.

Is this sense of 'follows' adequate from an absolute moral standpoint? This question invites the counter-question: is there such a standpoint? The Greeks had a dream of constructing compelling arguments that would not only force assent, but would be true regardless of the nature of the contingent world. Plato imagined that non-empirical logical inference is superior to any other form of inference. As a corollary to this Greek dream, rational theology sought to construct values with the force of *a priori* compulsion. Not to speak of values, mathematics too must be rejected—like Euclidean geometry—if it does not conform to empirical reality. Even two-valued logic does not exist in an empirical void and may be rejected, as in quantum mechanics, or with a changed picture of time. We have already seen several concrete instances in tradition in which this logic itself is rejected, so that the main force behind deduction is force! We must, therefore, revalue our methods of inference, without being deterred by the subsequent copious footnotes to Plato.

Suppose one had some *a priori* values that would necessarily hold regardless of the nature of the empirical world. These *a priori* values must, then, apply with equal force of logical necessity to every entity ranging from robots to the widow spider. Any other sense of the *a priori* (such as God-given), divorced from the empirical, tends to boil down, in practice, to an appeal to cultural predilections, and these could be based perhaps on an incorrect understanding of causality and choice.

Therefore, no honest system of values can divorce its 'oughts' from what humans are, and what the world is. There is no 'naturalist fallacy'[6] but only the unnatural fallacy of trying to construct values without reference to what humans are. Talk of an absolute moral standpoint, or the viewpoint that God would supposedly need on the Day of Judgment to classify sinners, is just a priest's trick used to 'fool and rule'.

A classical logical analysis would no doubt reveal that in appealing to 'natural inclinations' one is appealing to an already existing valuation (life preferable to wallet) or to an already existing principle ('act so as to maximise the likelihood of "your" survival'). There is no difficulty in pleading guilty to this charge, since the relevant 'natural inclinations' are demonstrably constant across cultures, geographically and temporally: in moving from 'is' to 'ought', Augustine appeals to the same 'natural inclinations' as does the advertiser selling Forhans in market-oriented India today ('Forhans *is* a toothpaste created by a dentist [expert], hence you *ought* to buy Forhans'). Between the self-sacrificing freedom-fighter and the commercially-oriented grandson (or even between the samurai and the modern-day commercial warrior), there isn't time enough for human nature to have changed: the 'ought' has changed because beliefs about the world have changed. 'Natural inclinations', therefore, are not the key either to understanding the *change* in values or to the enterprise of further transforming them.

To summarise this position on an old philosophical debate, it is neither necessary nor desirable to cast 'oughts' in the formalistic mould of Euclidean geometry. Divorcing 'oughts' from empirical human behaviour invites irrelevance through generalisation, or masks cultural proselytisation. Only statistical-empirical inferences about 'oughts' are credible. Values concern practice; they concern decisions about 'oughts' in the present tense, and, in practice, 'ought' is linked to 'is' through natural inclinations that, being of evolutionary origin, are geographically constant on the historical time-scale. The key to value changes in the past and the present are, therefore, credible changes in 'is'-type beliefs. Furthermore, the historical perspective developed above suggests that the key 'is'-type belief is the perception of time.

## A Generalised Naturalistic Ethic

Let us, therefore, set aside these doubts about the role of science in reconstructing values, and return to the original question: how does the 'tilt' affect values? We first set up a theoretical base of 'natural inclinations' from which differences can be pointed out.

The universality (or universalisability) of values must rest on observed universality in human behaviour. The principle of simplicity suggests that one must seek universal explanations for universal phenomena. Therefore, as a first approximation, one may accept evolutionary theories of behaviour, without totally committing oneself to any particular view (such as Darwin's) of the process of biological evolution.

### *The Lorenz Theory*

One evolutionary theory of behaviour is that of Konrad Lorenz. Briefly, the theory concerns behaviour related to status, territory (or more abstract derivatives like money), stratification, reproduction, rearing, group warfare, etc. The theory is that the corresponding patterns of behaviour have evolved on account of their survival value for the species.

The value of reproduction and rearing for the survival of the species is obvious. The survival value of territory is described by Lorenz:[7] the danger of too dense a population settling on one part of the biotope and thereby exhausting all its resources can be avoided by a mutual repulsion between individuals, tending to disperse them uniformly like charge on a conducting surface. The survival value of status and stratification pertains to intra-specific conflicts that are bound to arise during the long process of evolution, because different members of a species are likely to have similar preferences. The notion of status ensures that not every such conflict has a gory ending. Every change in the established pecking order or division of territory is likely to generate conflicts, and stratification ensures that such conflicts are inhibited.

These rather simple categories of status, territory, etc., do in fact serve to describe a great deal of human behaviour. Most people spend most of their lives in the acquisition of status and territory, the consolidation of these acquisitions, and in reproduction and rearing. Even children, today, are aware of the explicit link between education and status acquisition. Where this link does not exist, or is perceived as non-existent, the process of education is abruptly terminated.

## *Standing Spencer on His Head*

Some interesting conclusions may be drawn from the Lorenz theory. The 'fittest' cannot emerge unless one guarantees a rough equality of opportunity. Declaring those who have survived as the 'fittest' does not serve the *purpose* of the survival of the species. For example, in a 100 metre race, a participant with a start of 99 metres may be declared the winner, and adorned with a medal; but this way of declaring winners is of no use if the object is to select the fastest runner.

Another interesting conclusion is that even the kind of behaviour usually regarded as 'most private' involves larger social and specific concerns. For example, on this theory one cannot maintain that an individual participates in sexual activity (or its simulation) because of the pleasure ('utility') that he derives from it. Rather one must maintain that the pleasure that the individual derives from sexual activity or its simulation arises because of the function that reproductive activity serves for the purpose of the survival of the species.

These conclusions show how one might accept the broad framework of the theory of evolution without accepting the racist conclusions of a Spencer or a Darwin.

## *Ambiguities in Evolutionary Values*

Survival of the species thus seems to appear as a universal value, though forms of territory and status symbols may vary from culture to culture. Nevertheless, this universal value is inadequate. Using this value as a guide to action may result in ambiguous and conflicting recommendations in practice. The theory, by itself, is unable to resolve these ambiguities and conflicts.

Consider, for example, the mundane case of the head of a middle-class family getting a better-paid job in a remote locality which lacks a good school for the children. On the one hand, survival of the species demands survival of the individual, which suggests maximisation of the status of the individual, hence acceptance of the job. On the other hand, survival of the species requires the same for the children, hence demands rejection of the job. This conflict appears in sharper form in the case of a soldier who dies for her country or a social activist who sacrifices his career to bring about social change. Voluntary soldiers and disinterested social activists may be rare, but they exist just as much as the bee which stings and dies in order to save its hive. (The reality of altruistic behaviour is discussed in more detail later on.)

Another situation where this conflict may be seen is the following. The whole idea behind the Mutually Assured Destruction nuclear strategy of the USA was to threaten the survival not only of the species but of all life on the planet, in order that one small group may continue to maintain an abnormally preferential level of consumption. Thus, it is an empirical fact that a group, apparently in pursuit of its own 'survival', may engage in behaviour that endangers the survival of the species and, in fact, of all life on the planet.

These ambiguities in evolutionary values may also take on a more subtle form. On the one hand, as argued earlier, the fittest can emerge only in a system which is just. On the other hand, any attempt to bring about a change upsets the existing stratification, leading to conflicts, and some people find this adequate ground to condemn the whole philosophy which proposes the change.

## Removing the Ambiguities

To analyse these conflicts and to remove some of the underlying ambiguities, it helps to begin by thinking of *identity, time-horizon,* and *purpose*, embedded in an ethical principle of the following sort: *act so as to maximise the current expected likelihood of 'your' survival.*

This principle of evolutionary ethics has been formulated in a way that resembles the utilitarian ethical principle (p. 349); the resemblance is both deliberate and superficial. The meaningless notion of 'utility' has been replaced by the more straightforward concept of survival. (This eliminates the retrograde uses of the utility principle by means of Arrow's impossibility theorem, explained in Chapter 10, p. 347.) The resemblance is that the phrase 'current expected likelihood' is intended to draw attention to some (implicit) process of evaluation over an (implicitly defined) expected future lifetime.

To carry out this evaluation, one must prescribe a future time-horizon. If the future time-horizon is provided by the death of the individual, 'identity' collapses to mean an individual between birth and death. With this notion of identity, and with this time horizon, one obtains, roughly speaking, the mundane ethic or the collapse of values that is apparent in industrial capitalism. An individual who seeks to maximise the likelihood of his survival (without reference to others except in so far as they affect him directly, and in the short term) would naturally seek to maximise status and territory, *at any cost* (and in industrial capitalist societies, both are measured in terms of money).

However, it would be empirically invalid to assume, as is done automatically in utility theory, that this is the only time-horizon and the only notion of identity that is possible. An individual may, and usually does, identify with a larger grouping. In such a situation, the interests of the group may sometimes assume greater importance than the survival of the individual. For many people, concern for their children extends even beyond their own death. Utility theory excludes such concerns along with the value of the family, or the value of nationalism, or the value of humanitarianism.

The ambiguities in evolutionary ethics may be regarded as arising from differences in identity and the related differences in time-horizons.

There are two points of interest here. One is that the diffusion of identity to larger groupings (such as family or clan or genetic group or species) leads also to an expansion of time horizons, since the expected lifetime of the larger groupings is typically longer. The time-horizon taken into consideration can radically affect decision-making. This difference between tactical and strategic thinking is easily formalised: a perfectly formal and pretty demonstration is provided by computer chess played at different levels. The levels correspond to the depth of the search or the level of the look-ahead tree (Fig. 4) that is used. The decisions at level 1, based on short-term considerations, differ radically from the decisions at level 8 based on longer-term considerations.

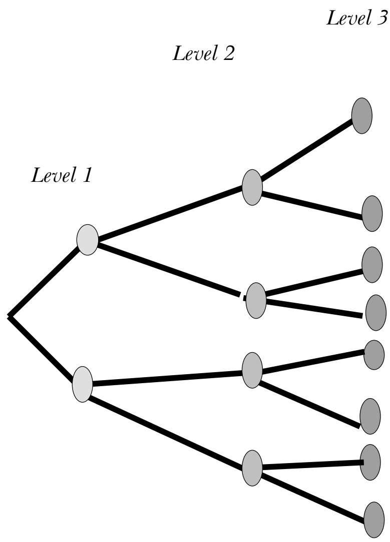



**Fig. 4: A Binary Decision Tree**

The figure illustrates the different levels in a decision tree in which there are only two choices at any stage. A computer playing a game like chess, for example, calculates some preassigned payoff along such a decision tree to arrive at the optimal playing strategy. The more the levels to which the computer is able to compute, the greater its ability to look ahead in the game. Increasing the look-ahead changes the character of the play from tactical to strategic.

The second point of interest is that the species is not necessarily the upper limit on possible groupings. Inter-specific interactions may form an 'insignificant' part of human behaviour, and concern for the environment is, today, more of a fad. But it is a fact that one does not go around killing every dog one sees in the street; this may be seen to be true even of very poor people in a metropolis, or on a railway platform like Rourkela, who directly compete with dogs for the food thrown on to the platform.

### *Acceptable Values*

The central thesis may now be formulated: the more acceptable values are those which involve larger groupings and longer time-horizons. This agrees with intuition (howsoever obtained).

This formulation helps to resolve some of the ambiguities in the naturalistic ethic. But, instead of classifying acts as good and bad, as black and white, this gives a gradation more in the nature of a range of greys. This generalised naturalistic ethic makes the moral dichotomy between good and bad irrelevant: for no one need go to hell. But one can still say that it is an unacceptable thing to threaten the existence of life on the planet to safeguard an abnormally preferential level of consumption. Moreover, this statement would *not* be a purely subjective matter.

To summarise, evolutionary values account for a good deal of human behaviour. Some ambiguities in the naturalistic ethic may be analysed and resolved using the notions of identity and time-horizon. The more acceptable values are those which involve the diffusion of identity to larger groupings together with a deepening of the time-horizon.

## The Tilt and Values

We are now in a position to examine the question: how does a tilt affect values?

### *The Tilt and Mundane Time*

An answer to this question requires us to understand the similarities and differences between a tilt and mundane time. The tilt provides a better basis for the conflicting requirements of both choice and determinism in mundane time. It also removes the need to gloss over 'purpose' or 'intent' or the tiny 'teleological' element built into the naturalistic or the utilitarian principle. The purpose (of survival) or intent (of maximisation), needed in the value principle, cannot obviously be always determined from the past—without obliterating choice.

Four differences are immediate in the values resulting from 'natural inclinations' + tilt.

(1) **Causal analysis**: Mundane time permits at most a multiplicity of causes, while a tilt allows for a true collectivity of causes; in neither case can causes be located entirely in individuals.
(2) **Time-horizon**: With mundane time, long-term purposive activity is a meaningless sort of thing, with a tilt it is not.
(3) **Identity**: With mundane time, life and death are asymmetric, so it is taken for granted that an individual is that which exists between birth and death; with a tilt, different identifications are possible, depending upon whether or not a tilt increases with time, i.e., depending upon the long-term future of the cosmos.
(4) **Purpose**: With mundane time, the purpose must be extrinsically given—for example, the purpose of survival was given extrinsically by the theory of evolution (within which it has no explanation); a tilt links long-term purposive activity to spontaneous order creation.

The last difference also takes us properly beyond the Darwinian theory: though order-creation usually includes survival, or order-preservation, the ultimate value is now the creation of order rather than survival—creativity rather than domination. These differences are brought out in more detail below.

## *Causal Analysis in a Social Setting*

The first difference pertains to the nature of causal analysis. According to current conventions, the individual is regarded as the sole recipient of credit or blame. For example, Einstein gets the credit for the theory of relativity. This is a bit hard to understand, even on the hypothesis of mundane time, for, in the social context, there is inevitably a multiplicity or a sequence of causes. With, for example, a chain of causes, selecting a 'main' cause is not easy. In a football team, should all credit go to the striker who ultimately shot the goal? Should some credit go to the winger who gave that brilliant pass? And what about the back who so accurately supplied the winger?

The problem becomes more acute in a model of a true cooperative situation like a convergent ripple in Popper's pond, where there is a collectivity of causes. In the frame of causal analysis, there are some $10^{23}$ candidates for the cause of the ripple. Allocating credit (for originating the convergent ripple) to any one of them, or to any group, would merely reflect one's personal liking for one part of the pond's periphery. The solution, as we have seen, is that the frame of causal analysis is inappropriate and inapplicable to cooperative phenomena. The requirement of causality is a must only for Augustinian morality, which seeks to pin down blame or distribute credits to individuals in every situation. Causality is not an essential physical or moral principle.

The consequences of changed causal analysis may be illustrated in the context of some common current claims.

## Market and Efficiency

Consider the claim that the market leads to efficiency.

Colloquially, the probability of success in the market is decided by one's capital base. In the formalistic tradition of game theory, monopolies emerge in an *n*-person zero-sum game. The distribution of control is decided with high probability by the initial distribution of capital. The system is not water-tight—there is room for personal abilities—but the porosity is of the kind that one expects in a hereditary system of kingship rather than in a (true) democracy.

What about the *validity* of the claim that the market leads to efficiency? Efficiency is not to be confused with profitability, and improvements in management have only a limited impact. The dramatic increases in efficiency come from technological innovation. Suppose we carry out a traditional input–output analysis to identify the inputs responsible for technological innovation. The analysis might proceed as follows. Technological innovation requires engineers with more skills, their greater skills require better training, and better training requires better colleges—a necessary input to which may be better buildings built by ill-paid contract labour.[8] Technological innovation cannot be de-linked from any part of the economy. Under these circumstances, the classical causal analysis is naive, unless it is meant solely to achieve the political objective of misleading people into thinking that there is some independent justification for an unjustifiable state of affairs. Allocating credit to the market achieves the political objective of distributing opportunity by wealth.

## Intellectual Property Rights

The justification for the notion of intellectual property, and ownership rights in it, also presupposes that Augustinian morality may be applied to the real world. Specifically, it supposes that the individual, as the legitimate recipient of credit or blame, may be identified as the sole causative agent. The notion that innovations flow from individuals is very important to retain control of wealth. As the world-economy becomes increasingly information-oriented, information held in secret has come to acquire a high commercial value. So, localising social credit (for generation, hence ownership, of information) becomes an important means of localising wealth and accumulating capital.

We have seen that no individual or group of individuals can ever be unambiguously identified as the *cause* of an innovation, and the removal of this ambiguity, in practice, involves social and judicial arbitration, where political dominance becomes the deciding factor. Therefore, the GATT comes along with a peculiar[9] mediation mechanism to sort out the causal disputes in a manner consistent with the political *status quo*.

There is another assumption underlying the idea of intellectual property rights, namely that creativity is tied to the availability of *monetary* incentives. Imagine a football team in which a large cash reward is offered exclusively to the striker who shoots the goal. Would the team play better? Or would it disintegrate into eleven individual players, each trying to grab the reward? Would the winger pass the ball? or would he prefer to dribble it to the goal? Would the back supply the winger? or would he be tempted to take on the role of a forward? Wouldn't the goalkeeper, too, want to join the mêlée to carry the ball individually into the other goal?

The question is serious; incentives may destroy cooperation. In the post-revolutionary societies,[10] management by incentives not only did not achieve the desired objective, it set up a fundamental contradiction between a state tied to social objectives, but comprising of individuals governed by selfish objectives. The entire decentralisation/recentralisation debate, hinging on this proposal of monetary incentives,[11] unhinged the concerned economies (which were open to change through debate).

The question is equally serious for capitalist societies. Technological and scientific innovation assumes widespread cooperative sharing of information. Cash incentives for innovation discourage information sharing, as in the case of computer software. Hence, localising credit in this way is bound to slow down and eventually halt the present process of technological innovation.

## Causal Analysis in Other Contexts

There are other contexts, such as that of history, in which the frame of causal analysis, with causes terminating on specific individuals, has already been recognised as dubious. For instance, consider the famous problem of changing Cleopatra's nose just a little bit. Mark Antony might not, then, have married her. Not only would the course of her story and history have changed, even the course of Shakespeare's plays would have changed!

The kind of reasoning used here is called counterfactual reasoning (Chapter 8, p. 286). It is commonly used in statements of the kind, 'India would have remained backward, but for the British Empire.' Starting from the real world, one imagines a possible world in which one single fact, like Cleopatra's nose has changed. One then tries to imagine how the world would have evolved. If there are many possible scenarios, one tries to use the one that is 'closest' in some unspecified sense. One then says that if Cleopatra's nose had been just a little shorter, not all of Shakespeare's plays would have been written. This reasoning can be quite dubious, especially if one has no way of knowing which of the possible worlds is 'closest' to the truth. Actually, to change Cleopatra's nose realistically, one would need to change her genes, hence parents, with the result that there might be no Cleopatra at all! The dubiousness of locating credits using counterfactual implication, when the closest accessible world is decided with facility, is here superimposed on the dubiousness of causal analysis with a multiplicity of causes. The brittle nature of causal analysis in complex situations, like sensitive dependence on initial conditions in a chaotic context, may fail to apply with a 'tilt': changing one condition may not necessarily change the long-term future evolution of a system.

Long-term history might remain unaffected by the absence of Cleopatra entailed by changing her nose.

## *The Time-Horizon and Selfishness: The Utilitarian Fallacy*

The second and third differences, between mundane time and a tilt, relate to the time-horizon and identity, both of which are crucial for values.

We earlier identified more acceptable values as those which involve the diffusion of identity to larger groupings and a deepening of the time-horizon. A natural question arises: are these acceptable values achievable? Confronted with very large groupings and long time-scales an individual is often filled with a sense of futility. One may ask: is purposive activity meaningful on such long time-scales?

Consider, first, the mundane view. Let us say, one chooses action $A$ because one intends consequence $B$. Because choices made by others may intervene between $A$ and $B$, if others choose indeterministically, there would, in general, be *no* connection between $A$ and $B$. One can intend $B$ only to the extent that others cannot (or are unlikely to) intervene between $A$ and $B$. But, to the extent that there are rigid (or probabilistic) connections between $A$ and $B$, the choices made by others are constrained; hence also one's own choices are constrained, to the extent that others' choices are free. Therefore, on the mundane view, there is a competition between choice and intention. This competition turns into a contradiction in the 'long term'. So, on the mundane view of time, long-term purposive activity is rather meaningless. This does not happen with a tilt in the arrow of time.

There is a common belief in contiguity or action by contact; or at least there is a belief in some generalised kind of locality—that 'effects' somehow die out in proportion to their distance in space and time from the 'cause', somewhat in the manner of a divergent ripple: the ripple is weaker the further it is from the source. Thermodynamically, this belief is complemented by the belief that large-scale purposive activity requires, in the words of Popper, either 'organisation from the centre' or a 'conspiracy of causes'. We have seen that both these beliefs are false with the model of a tilt in the arrow of time. With a tilt, the world is largely local, but not entirely so. Moreover, Popper's arguments against spontaneous generation of order fail. Therefore, long-term purposive activity is possible, at least in principle, for living organisms.

Long-term purposive activity, apart from being physically meaningful also has a human meaning. We have seen earlier that differences in the time-horizon relate to differences in identity: shorter time horizons correspond to selfishness, i.e., narrower notions of identity. A consequence of the ethic of *time=money* is the need to justify selfishness as 'natural'; Lorenz's group selection hypothesis has perhaps hence been opposed in the attempts[12] by Wilson or Dawkins to explain all phenotypically altruistic behaviour as being genetically selfish. This debate is not very relevant here; humans could presumably refashion genes to be altruistic, if only the notion of an altruistic gene were explained clearly enough. (That is, the notion of the selfish gene is not refutable.) At any rate, selfishness at the human level in the utilitarian sense does not stand scrutiny: the utilitarian principle takes a rather narrow view of the 'self' as that which exists between birth and death. The future look-ahead is axiomatically taken to be the individual's lifetime: the individual axiomatically *ought* not to be concerned with events after his death. We have seen that this axiomatic selfishness contradicts even the most superficial observation of human reproductive and parental behaviour.

Though identity and time-horizon are closely linked, distinguishing between them helps us to identify a second factor promoting selfishness in the utilitarian principle. Even if the individual were to take a broader view of the self, and identify with a larger grouping, the utilitarian principle provides another reason to limit the time-horizon, or the future look-ahead. Even with an increased future look-ahead, the discount rate (in the utilitarian principle) ensures that the long-term future is infinitely discounted: 'in the long run we are all dead', in the famous words of Keynes. This principle of discounting future utility is clearly suspect. An amount $x$ of money now may be more valuable than the same amount $x$ of money twenty years hence. But why should this apply to utility? A parent may prefer an offspring to be married rather than not, but does it follow that the parent vastly prefers the offspring to be married now (at age 1) rather than twenty years later? For a capitalist economy in equilibrium there may be a homogeneous discount rate, but why should this discount rate be the same (across age groups, say) for individual preferences? Discounting the longer-term future in effect shortens the future look-ahead, with devastating consequences on values.

As already pointed out, the effect of shortening the time-horizon is not such a subjective matter. Formally, a chess program with a look-ahead of 1 level plays chess in a way that any chess player would recognise as involving gross tactical play and over-valuation of material. The same program with a look ahead of 24 levels 'understands' all the subtleties of strategy and tempo, and may be willing to exchange gross material for less tangible gains in time and space. (The program with the larger look-ahead invariably wins.) Thus, the shortening of the time-horizon, either by restricting the self, or by discounting the future, reinforces gross materialism.

If more distant effects are taken into account, it becomes much more difficult to classify an act as good or bad, for something that seems bad now may seem good in the long run, and vice versa. Fifty years ago a factory chimney was a symbol of progress; today it is a symbol of pollution. Taking the longer term into account makes it impossible to continue moralising in the classical mode associated with Western theology.

With a 'tilt', long-term (future) correlations are physically significant. To paraphrase Tetrode, 'the stars would not radiate without other bodies [millions of light years away] to absorb the light'.[13] Consequently, the long-term future cannot be infinitely discounted, and the time-horizon deepens. Within a naturalist value principle, the deepening of the time-horizon corresponds (both ways) to an expansion of identity from the utilitarian self to family, clan, species, planetary life…. It is not difficult to see that this leads back to some traditional values.

Current concerns with ecology, bio-ethics, or sustainability also concern long-term planning: machines produce waste, and the accumulation of waste becomes catastrophic only in the long run. The current concerns are part of a definite social trend of expansion of the time-horizon from paleolithic to neolithic to industrial society. With further technological advance, longer time-scales must perforce be taken into consideration. For instance, if one relies on nuclear energy, one must plan the disposal of nuclear waste, a process which might easily take tens of thousands of years. Similarly, a search for extra-terrestrial intelligence, or deep-space travel, involves expenditure now which may yield returns only several thousands or millions of years in the future. Over such long time-scales a thermodynamic analysis,[14] hence the nature of time, becomes relevant to the question of planning.

As the future look-ahead expands further, and the time-horizon is pushed to the very limits of the cosmos, the nature of time becomes even more critical, for the tilt then raises even more fundamental questions such as those about 'identity' in the presence of quasi-cyclicity.

## *The Quasi-Recurrent Cosmos*

Long-term purposive activity is meaningful, in principle, in a world with a tilt in the arrow of time. That is, acceptable values may also be achievable. But are they preferable? In particular, why would a rich brat, say, prefer them to individual survival? (The second question is intended purely as a test of the strength of the arguments.) It is possible, of course, to argue that some of our feelings are 'hard-wired' or 'burnt into the ROM' by the evolutionary process so that the satisfaction that one gets from activity oriented towards more acceptable values is deeper than the satisfaction derived from short-term orientations.

But there is another sort of answer. Speaking of the survival of all of planetary life or of all life in the cosmos involves a time-scale which approaches cosmological time-scales. Over such long periods of time, what happens to the tilt in the arrow of time? A natural hypothesis in this context is to suppose that the tilt in the arrow of time *increases* with time. This suggests a picture of the cosmos where the arrow of time eventually starts pointing towards what is currently the past, so that the remote future blends into the remote past.

Quasi-recurrence is logically stronger than the hypothesis of a tilt in the arrow of time: quasi-recurrence implies a tilt without being implied by it. Quasi-recurrence is a 'natural hypothesis' only in the context of the more usual cosmological models which permit a tilt in the arrow of time. The relevant thing is that in a quasi-recurrent cosmos, the notion of identity is completely transformed.

While the change in the notion of time is 'slight' in the sense that the expected effects at the current epoch are rather hard to measure, the change in the notion of identity is radical.

## *Survival vs Order-Creation*

A final question. The world looks radically different when seen over such large groupings and over such long time-scales. So, does the survival of the species, or of all planetary life, or of all life in the cosmos, continue to represent the ultimate value?

Stated more naively, the question is: what is the purpose of life? Does the 'purpose' expand along with the expansion in identity and time-horizon? This way of restating the question is philosophically objectionable precisely because of the use of the term 'purpose', which is the fourth difference between mundane time and tilt. With mundane time the purpose must be extrinsically given; in our context, the purpose is survival if the extrinsic given is the theory of evolution. The situation is different with tilt. Recall that, with a tilt in the arrow of time, only purposive activity corresponds to choice. Recall also the relationship between purposive activity (more precisely, anticipatory phenomena) and order creation (entropy reduction, cooperative phenomena).

This leads to a fundamental revision of views regarding the very nature of life and the evolutionary process. The evolutionary process classically involves two things: creation of new mutants, and their selection. The Darwinian theory emphasises the selection process. It vaguely equates the creative process with chance. The present theory has explored the process of order-creation: chance cannot create order, but a tilt can. With a tilt, life and evolution correspond to spontaneous order creation, not chance.

Hence, survival cannot be the ultimate value. The pursuit of individual survival, for example, is meaningful only so long as one sees the world as a jungle where chance, uncertainty, death, and extinction lurk behind every tree. Individual survival is important, but pursuing it as the *ultimate* value seems especially pointless in a quasi-recurrent cosmos where survival is more than amply assured. So what happens to our acceptable values?

With a tilt, the focus shifts from survival to order-creation: *life and evolution concern not so much survival as order creation and order* *increase*. (We speak of increase and not maximisation, for an increase of order cannot be achieved mechanically.) In many common situations, the principle of 'order increase' includes the formula of 'survival', for survival is simply order preservation: or the maintenance of created order. But in some conceivable situations like a quasi-recurrent cosmos, there is a divergence between cooperative order creation and survival, for order creation may lead to 'deliverance' rather than indefinitely continued existence. This suggests the formulation of the value principle in a way that does not depend upon any uncertainty in our knowledge about the cosmos.

## *Final Formulation of the Value Principle*

The final formulation of the value principle is: *act so as to increase order in the cosmos*.

## *Increasing Order in the Cosmos*

What does this value principle imply for the organisation of society and the way of life?

First, let us see how the principle of order-creation revalues and re-interprets the principle of survival. Survival continues to be a value, for survival is preservation of order. However, survival is no longer the ultimate value. Consider the tradition of Christ on the cross. If survival were the ultimate value, Jesus ought to have recanted before the Roman court. When the Western Christian inquisition persecuted people for their religious beliefs, the priest Giordono Bruno should have recanted like the scientist Galileo. We believe that the two who died did so for a larger cause, because they valued something more than individual survival. There are many such cases of 'altruism', so that survival cannot at any rate mean individual survival. (The idea of the 'selfish gene'—that there are smaller rather than larger interests involved here—is one that it is hardly necessary to refute in detail in this context, for it seems clear that human beings can deliberately modify genes to suit larger purposes, if they so wish.)

What are these 'larger interests'? Undoubtedly, 'larger interests' refers to survival of the group or the species; but that is not the only thing it refers to. Consider, for instance, the practical possibility (within the next five or fifty or five hundred years) that someone manages to design an 'improved variety of human being' using genetic engineering. Here 'improved variety' simply means one better equipped to survive, somewhat like humans are better equipped to survive than monkeys. For the sake of argument let us suppose that this superiority is (perceived to be) assured. The concerned species or sub-species would soon start dominating human beings, and might even decimate us; if we were lucky we might live on as their pets or bonded labour. Therefore, if survival of the group or the species were the ultimate value, then the right thing to do would be to destroy all possible samples of the genes under consideration. If order-creation is the value, that ought not to be done. Thus, survival can no longer even mean survival of the group or species, but must start referring to all of planetary life. An individual or a group may pursue survival only so long as this pursuit does not interfere with the larger interest of the survival of the species. Likewise, survival of the species must give way to the larger interest of the survival of all of planetary life.

But perhaps a gene created by us is like an intellectual child, and people can be proud when their children excel them. At any rate there is a genetic continuity. Let us, therefore, consider the case of an alien species. There may be less genetic continuity here than between humans and molluscs. So what should we do? Should we try to eat them? They may be made of minerals we don't need! Should we try to dominate them? That may not be possible, for they may be a lot more advanced than us. Will they try to dominate us? They may be disinterested.

Nothing in our experience tells us how the interaction with an alien species would proceed. The closest thing to it is the case of the first European travellers who arrived by the sea route in India and China. In fact, it was as impossible then for these travellers to dominate these countries as it was for them to dominate the Arabs (to avoid whom they searched for the roundabout sea routes in the first place); but neither Indians nor Chinese had the slightest interest in pursuing the Europeans back to their homeland and capturing it.

Of course, an advanced extra-terrestrial intelligence (AETI) may not be so trusting as the Indians and the Chinese: they would presumably be aware that contact leads to a flow of information, and that information accumulated through an asymmetric flow can eventually be used to dominate. So they may avoid contact altogether until they are convinced that the human species is mature enough and socially well-enough organised to avoid attempting mindless domination. In fact, it is not inconceivable that we already have been found by an AETI, but have been kept in a state of quarantine until our system of values develops to match our knowledge!

The question remains: what would we *do* when confronted with an advanced extra-terrestrial species which we have no hope of dominating? If survival of the species or even planetary life were the ultimate purpose of life, there is nothing that we ought to do except to lie in wait for the day when we could hope to dominate. This was roughly what the European colonists did in India and China in the 16th and 17th centuries. If we initiate an information exchange, like the Europeans, it could never be with any purpose other than that of eventual domination. Therefore, from the viewpoint of survival of the species, we ought to give out as little information as possible, while trying to extract as much information from them. It seems to me unlikely that any species or group can stably pursue knowledge while retaining such attitudes. Such attitudes cannot coexist with advancing knowledge for very long.

On the other hand, if increasing order in the cosmos is the goal, then one could contemplate the possibility of a frank exchange of information even if it does not particularly help us, for it might help them. One can understand this better by asking the question: what ought an advanced extra-terrestrial species to do with *us* when it finds us? We may already have been found; and they may have been studying us for millennia, and may already have learnt all there is to learn about us; and there may be nothing much more that we have to tell them. Should that species *now* try to help us? should it share its knowledge with us? or should it drown all or most of us out of fear that any cooperation with us might one day make us dominant? (If the European interaction with the indigenous populations in the Americas and Australia is the only possible guide, it is clear what the answer should be.) Order-creation, then, means that the survival of all life in the cosmos is a larger interest than survival of planetary life, and one must act accordingly.

As observed earlier, even preservation of cosmic life need not be the ultimate value. In a quasi-recurrent cosmos, for example, survival is assured. But one can still act so as to increase order in the cosmos.

Order-creation, then, is a truly universal value, which subsumes not only concerns relating to individual survival, or the survival of the group, or species, or all of planetary life, or even the survival of all life in the cosmos, but applies also to even longer-term concerns that may extend across possible cycles of the cosmos.

## *Ecolomics*

With this big picture in the background, let us return to earth to examine some immediate problems, which illustrate the application of the order principle in more mundane situations. The curse on cyclic time, and the resulting doctrine of sin led to the theological requirement of a rule-based world. Industrial capitalism has created a rule-based society with the ideal rule-based entity: the machine. As machines proliferate, many people today are worried about the ecological consequences of industrialisation. We know that a machine can never be perfectly efficient; it cannot create order—it can only redistribute disorder in the manner of a refrigerator. In the process, the machine creates a net amount of disorder. The more machines we produce, the faster we run them, and the more things we produce using machines, the more the disorder that is created. The greater the industrial production, the greater the waste. This waste accumulates, and shows up as environmental degradation. Making more efficient machines cannot solve the problem of waste production; it can at best postpone it; usually the effort only changes the nature of the waste produced. Thus, making more efficient machines is a solution only from the short–time-horizon viewpoint of survival. If the objective is to increase order, one must reject mindless industrialisation. To give a slogan formulation: the order principle means less machines, and more spontaneity.

It is well to recognise that this solution is not feasible in a capitalist society driven inexorably by the motives of profit and accumulation, control and domination. Building more machines to produce more goods faster to produce more profit comes as naturally to such a society as the production of waste flows naturally from the running of these machines. More profit through more waste is the unspoken slogan of industrial capitalism. Building more efficient machines suits industrial capitalism and its philosophy of obsolescence. So, such a society will always peddle the hope of the miracle round the corner. Theologians have pitched in in support with their talk of the 'optimism of progress'.

Thus, ecological concerns, or the concern with growing disorder, cannot be met without a fundamental transformation of society. The direction that this transformation takes depends upon the picture of time. We have already examined the way of life that flows from the *time = money* of the industrial-capitalist society. But this way of life is embedded in a social organisation which has two characteristics. (1) The slightest natural requirement, such as clean air, drinking water, or healthy food cannot be fulfilled without money. (2) At any time, only a few people have most of the money.

The first point is clear to everyone; the second is not. Thus, most people must spend most of their lives trying to earn money, or hoping to earn more. This naturally allows the people who control the money to control the rest. But this is not the way in which individuals perceive things. Someone who remains unemployed (or fails to earn enough money) puts it down to his incompetence; at least most others put it down to this cause. On the reverse side, someone who has money is seen as meritorious. This confusion between the social order and the moral order is common. Thus, it is necessary to emphasise that the capitalist society is unjust exactly because the social order in it does not coincide with the intuitively perceived moral order.

But this confusion between the social order and the moral order is actively maintained through the notion of cause. To maintain the necessary inequality in a capitalist society, whenever something is produced, the capitalist gets a relatively larger share. If everyone were to see this unequal share as unfairly large, the social organisation would have to be changed. Therefore, to legitimise this unequal distribution, the capitalist is made a *symbolic cause* of production. He is declared to be the owner of the means of production. The means of production are the inanimate machinery, land, etc., that are incidentally involved in the production process. Since these are not efficient causes, their causal efficiency is symbolically vested in the socially recognised owner, who usually contributes nothing to the production process. One now uses some woolly doctrine of major and minor causes to regard the owner of the means of production as the major cause, hence entitled to the major share. (On a consistent application of this doctrine, those few people who have the most money should also take the most blame for ruining the environment.)

It is at this stage that theology steps in. The hierarchy in society reflected the divine order implicit in Providence: if some people were poor and suffering, this was because God had so planned it, so that it was just and proper. (Some people did oppose this sort of thing, but so nominally that they only strengthened that which they supposedly opposed.)

There was another way in which theology supported the social hierarchy. This was through the idea that God would distribute rewards and punishment to individual human beings. This allowed theologians to exploit the sequence or multiplicity of causes that is always present in a social context. In the absence of any logical way to resolve the actual multiplicity of causes, the resolution could only be political. Thus theology was able to explain how rich men in society can get most of the benefits of economic production while simultaneously avoiding the blame for the waste that is inevitably produced alongside and degrades the environment.

This theological legitimisation of an unjust society and the waste and disorder that it produces cannot be sustained with a different view of time. The social reorganisation suggested by a tilt is summarised below.

## *Social Reorganisation with a Tilt*

The social reorganisation flowing from a tilt is not drastically different from the reorganisation suggested by the Buddhist idea of conditioned coorigination. We have already seen that income and wealth inequalities help to produce waste or disorder, not order. Therefore, these inequalities must be eliminated—like the Buddhist *samgha*, society should be properly equitable, democratic, and decentralised. (This model of democracy is not that of classical Athens which excluded women and slaves, hence most people, from the ambit of 'democracy'.) The processes which generate these inequalities should also be eliminated. 'Ownership of means of production' is another phrase for 'socially recognised right to an unequal share'. Such a right ought neither to exist, nor ought it be hereditarily (genetically) bequeathed. In its place there should be a right to exist. As in the case of the Jain Bhadrabāhu (p. 398), a principle of 'direct causation'—you are entitled to consume only what you produce—is too narrow. People must, of course, share with others what they produce—whether food or ideas. This sharing may well take the form of exchange, so long as it is not the systemically unequal exchange of the modern market. The in-principle test of a social institution is whether or not it helps the creation of order. A simple test of this is to see whether or not the institution encourages cooperation.

With a tilt, life is physically characterised as non-mechanical, so that one must reject the mechanisation of social organisation to suit machines or the purpose of domination ('survival'). A few simple and indicative rules are all right, so long as there is no rigid adherence to these rules, and the rules are supplemented by judgment. How does one ensure right judgment? One way is by making sure that there are no judges appointed and invested by authority, but anyone may be a judge. When there are so many judges, the possibility of perverting judgments to meet narrow, selfish ends is reduced. That would not eliminate genuine errors of judgment, for it may happen that the majority is wrong; in fact, this is always true whenever someone gets a new idea. In the absence of authority and vested interests, society need not remain closed to new ideas. Till such a society materialises there should be sanctuaries where new and different ideas can grow. To summarise, the order principle means that society must be reorganised to make it less hierarchical and more equitable, to eliminate injustice and promote cooperative harmony.

## *A New Way of Life*

We can and must reorganise society, if only because advancing knowledge cannot coexist for very long with a barbaric form of social organisation. But, with the order principle, social reorganisation alone is inadequate. The former socialist nations reorganised society, and their collapse has led to the minute study of socialist societies, from which emerges the following lesson. If we refashion society so that everyone's material needs are met, and if we do not recognise any dimensions to human existence beyond material and aesthetic needs, then alienation follows. One cannot make a benevolent state out of a collection of selfish individuals; the selfishness of individuals must also be abandoned. The individual way of life must be transformed together with society.

How should the individual way of life be transformed? We have before us a variety of value principles. In the Buddhist Way, non-attachment leads to cessation of suffering. In Western Christianity one seeks eternal reward in heaven by avoiding sin. In utilitarianism one pursues individual happiness. In industrial capitalism one accumulates as much money as possible, for money is the currency of happiness. With the new value principle, one creates order.

How can one pursue spontaneous order-creation in a social world which is mechanical and geared to the creation of disorder? So the society must first be refashioned. There is a difficulty, but no insoluble paradox here. The process of transition from one form of social organisation to another is bound to throw up tensions, for one must live in one society while trying to create another. These tensions are particularly acute in industrial capitalism, for there is no physical space outside it that it has not invaded. But these tensions need not detain us for they are implicit in any process of creation and social transformation, for refashioning society is an endeavour that can be pursued along with the immediate pursuit of larger interests in deeper time-horizons within this society.

The order principle provides a new model for an individual. This is not the conventional religious model of a person devoutly bound to rituals and scriptures. This is not the utilitarian model of the selfish individual. Nor is it the model of the scientist: knowledgeable but an ethically irresponsible puppet in the hands of the state or the church. Nor even is it the standard social model of the wealthy individual. This model is of an individual who has abandoned selfishness, for he finds his self distributed everywhere; and, finding his self distributed everywhere, he becomes someone who can rise above narrow individuality, above loyalty to family, to nation, to religion, and who can rise above even humanity to identify with all life. This model is of a person who is far-sighted enough to pursue knowledge without abandoning ethics, and to try to live ethically without abandoning knowledge. This model is of a person who lives to create order, to perfect the world, to complete the unfinished task of creation.

# Epilogue

> 'Bring a fruit of that Nyagrodha tree.'
> 'Here it is, sir.'
> 'Break it.'
> 'It is broken, sir.'
> 'What do you see?'
> 'Some seeds, extremely small, sir.'
> 'Break one of them.'
> 'It is broken, sir.'
> 'What do you see?'
> 'Nothing, sir.'
> 'The subtle essence you do not see, and in that is the whole of the vast Nyagrodha tree…that which is the subtle essence—in that have all things there existence. That is the truth. That is the Self. And that, Svetaketu, THAT ART THOU.'
>
> **Chandogya Upaniṣad**[1]
> **6.12.1–3.**

The Fisherman walked along disconsolate. He did not know where he was going. Nor did he know where he wanted to go. At long last he stumbled upon a wise old man. The Fisherman eagerly asked him, 'Tell me sir, what should I do? Whom should I believe? the Priest, the Merchant, or the Scientist? What should I do to find my mermaid once again? Was she perhaps not a mermaid, after all, but only that woman from a neighbouring village, pretending to be a mermaid? What is the truth?'

The wise man laughed loud and long. But seeing the Fisherman's distress, he took pity and said, 'You catch fish everyday, and yet you don't understand! Well, if the fish understood your tricks, would you be able to catch them? The Priest, the

1. Modified from Swami Prabhavananda and Frederick Manchester, trans., *The Upanishads*, Mentor, New York, p. 70.

Merchant, and the Scientist have trapped you like a fish, O Fisherman!'

'What should I do then? How can I escape? Where will I find my mermaid?'

The wise man beckoned to the Fisherman to come closer, and whispered something in his ear. The Fisherman sprang back startled, 'What are you saying! I am only a poor fisherman, how can I be the Creator? the very Lord Almighty!'

'Yes', said the wise man, 'Origen taught equity because he thought all are one with the Creator. Abu Yazīd went to meet God, and finding the throne empty he sat down on it—to discover that he was God. He was not arrogant—he was the same Abu Yazīd who stepped aside to give right of way to a dog. The Buddha and Mahavira denied God or a Creator for the world—but neither denied *your* ability to create.

'The Priest', continued the wise man, 'painted the picture of an all-powerful God to frighten you into submission, and to enslave you. He took away your real soul, and gave you back only a husk in return. It is this husk of a soul he asked you never to part with, for if you throw it away, the Priest will lose his power over you, he will no longer be able to control you, through talk of reward or punishment given by his all powerful God.'

'Is that why the Scientist said I have no soul?'

'No', said the wise man, 'in the Priest's world, to obtain your reward, you had to know what God wanted. If God were capricious, it would be hard for you to know what he wanted. So, to make things easier for you, the Priest said the world is rule-bound. The Scientist seriously developed this picture of the cosmos as the clockwork of a distant God—he now thinks you are no more than a piece of this clockwork, bound to it by rigid laws. Where the Priest used a fishing line, the Scientist uses a net. Perhaps you can show him that you have a soul after all by making a hole in his net? Perhaps you can show the Scientist that the laws of the clockwork cosmos can be bent a little!'

'What of the Merchant, then? why did he say he has no use for my soul?'

'The Merchant lives off the work of many people—he wants them all to obey him. So, the Merchant designed a clockwork society. The Scientist only *thought* of you as a piece of clockwork; the Merchant *changed* you into one. He taught you to decide mechanically by calculating future profit. The clockwork society can be easily controlled by a few Merchant-clockmakers at the top, and it functions for their benefit. Your love for your mermaid has no place in this society—it is unprofitable for the Merchant like your thoughts about your soul.'

'But', said the Fisherman, 'who am I to change things? How can I be the Creator? I am not all-powerful, I have only a little power. I am not all-knowing, I have only a little knowledge. I am not eternal, my life is short. I cannot be everywhere, but only live in a small hut on the shore of this vast ocean, in which my mermaid has disappeared. Can I do anything at all?'

'Yes', said the wise man, 'what you say is quite true. You, as Creator, have created an imperfect world, to perfect which you must continue with your act of creation.'

Will the Fisherman ever find his mermaid? Will he ever discover the truth? Will he manage to escape? Will the Fisherman someday surprise the Priest, the Scientist, and the Merchant? God certainly does not know!

# APPENDIX

# Patterns of Irrationality

## *Nine 'Proofs' of the Existence of God*

*Theorem.* God exists.

*Proof 1 (by intimidation).* If you don't believe in God, you will go to Hell and boil/bake/freeze/fry/roast/rot for the rest of eternity. Hence God exists.

*Proof 2 (by rewards).* If you believe in God, and observe the rules, you will certainly go to Heaven and enjoy yourself for the rest of eternity. Hence God exists.

*Proof 3 (by stratification).* People have believed in God from time immemorial. If God did not exist, the notion would have been discarded long ago. Hence God exists.

*Proof 4 (by numbers).* So many people believe in God. They can't all be wrong, can they? Hence God exists.

*Proof 5 (by expertise).* I, too, have had doubts regarding the existence of God. But they have now been clarified. See, for example [obscure reference]. Hence God exists.

*Proof 6 (by experts).* Many great people have believed in God. Hence God exists.

*Proof 7 (by territory limitation).* Science is all very well in the material domain, but it doesn't apply to subtler spiritual matters. Hence God exists.

*Proof 8 (by hope).* If God did not exist, how could I ever hope to get all the things that I want. Hence God exists.

*Proof 9 (by example).* The sea receded before Moses. Hence God exists.

The days of hellfire-and-brimstone arguments are not over. To see this, one has only to scan a newspaper or magazine, or switch on the radio or TV. 'If you don't use Colgate you will develop bad breath' (intimidation). 'If you do, you will have sparkling white teeth (see photo)' (rewards). '...backed by a hundred years of experience' (stratification). 'Casio, the world's largest selling calculator' (numbers). 'Actual tests prove that Surf washes whitest' (expertise). 'Forhans, the toothpaste created by a dentist' (experts). 'Buy Cadbury and win a free trip to Timbuctoo' (hope). 'Sheila is a careful housewife, her choice is Rin' (example). These advertisers certainly understand their business better than us!

More seriously, the fact remains that proofs of the above kind are not out of date. They continue to be used, and there is an undeniable parallel between medieval theology and current-day advertising. The words may have changed, the product being sold may have changed, but the form of the 'proofs' remains the same. Let us compare these proofs with current ideas of a logical proof.

## *What is a Logical Proof ?*

We start with statements A, B, C,... that assert something. For example, 'all philosophers are impractical fools' is an assertive statement, as is the statement 'a true scientists is a cold-blooded creature'. But the question: 'are all philosophers impractical fools?' does not assert anything, and so is not one of A, B, C,.... Assertive statements may be true or false, but they cannot be both, or neither.

We accept some of these statements as true. These are called *premises*. Next, we build bridges between the premises using the following rule of reasoning.

1. If A is true then B must be true.
2. A is true.
3. Hence, B is true.

To hide the simplicity of this rule of reasoning, let us give it a Latin name: *modus ponens*. Here is an example of *modus ponens*.

1. If Socrates was a philosopher, then Socrates was an impractical fool.
2. Socrates was a philosopher.

Therefore,

3. Socrates was an impractical fool.

Another rule of reasoning is called *instantiation*: a universally true assertion must be true in this instance. Here is an example of instantiation.

1. All philosophers are impractical fools.
2. Socrates was a philosopher.

Therefore,

3. Socrates was an impractical fool.

A logical proof is a repetition of these simple patterns. It uses only premises, *modus ponens*, instantiation, or similar 'self-evident rules of reasoning'. The idea is that a moron or a machine, with limited intelligence but unlimited patience, should be able to *check* the correctness of a logical proof. In this sense every logical proof is addressed to a machine, though, in practice, it may be abbreviated to avoid tedium. Formally, a logical proof is a sequence of statements, each of which is either a premise, or is derived from some preceding statements by using a rule of reasoning such as *modus ponens* or instantiation. The last statement in this sequence is the assertion proved.

The conclusion of a logical proof is only as true as its premises. In actual fact, Socrates need not have been an impractical fool. This would only mean that the first premise is false, so that there are some philosophers who are not impractical or not fools.

On the other hand, the following is *not* a logical proof.

1. Philosophers have the habit of questioning everything.

Therefore,

2. The sun rises from the east.

We may have independent reasons to believe that the sun rises from the east, but there is no logical connection between the rising of the sun and philosophers or their habit of questioning everything. Such a non-proof is called a *non-sequitur* ('it does not follow').

## Comparison with the Nine Proofs

From a logical point of view, each one of the nine 'proofs' of the existence of God is a complete *non-sequitur*. There are no clearly stated premises, no *modus ponens*, hence no proof. The tragedy is that the nine 'proofs' are not even fallacious. A fallacious proof might run as follows.

1. All philosophers are impractical fools.
Therefore,
2. All impractical fools are philosophers.
Or,
1. All scientists are rational.
Therefore,
2. There are many rational people in this world.

Fallacious proofs are yet *impersonal* (if one is not a philosopher!). Any logical proof, even a fallacious one, is addressed to a machine. In contrast, each one of the nine 'proofs' is addressed, implicitly or explicitly, to a *person*. It would be wrong to classify the nine 'proofs' as fallacious, because there has been no attempt at a proof. To distinguish such 'proofs' from the run-of-the-mill Aristotelian fallacies, we shall refer to them as *irrational*, although *arational* would, perhaps, be a better word.

One cannot lightly dismiss irrational arguments because people do get convinced by them. Indeed, irrational arguments often carry more conviction than logical arguments. It is for this reason that advertisements use irrational arguments.

Even a proof by intimidation may be subtle enough to carry conviction. For example, consider the following argument advanced by my uncle. 'You should not disregard the teachings of our ancestors and question everything. You cannot know everything directly. For example, you cannot know who your father was, because that happened before you were born. But I can tell you because I attended the marriage of your parents. You are prepared to take my word for that. Likewise there are many things that I learnt from my elders. If I tell you about these things, you say 'How do I know they are correct?' How do you know who your father is?' I had considerable difficulty in countering this argument: facing up to loss of face can be difficult.

## Non-Verbal Communication

The essential message underlying an irrational proof is so simple that most animals manage to convey it without using words. One has only to sharpen one's observation a little to see this kind of communication among dogs, cats, cattle, hens, sparrows, crows, goldfish, and butterflies too.

For example, a timid dog may tuck its tail between its legs and flee from a ferocious one. But, 'the courage of the fugitive returns as he nears his own headquarters, while that of the pursuer sinks in proportion to the distance covered in enemy territory'. Once the timid fellow is close enough home, he will turn snarling on his tormentor. In effect, the timid one is saying, 'I accept your superiority, but this is my territory, and if you try to drive me out of here, there will be a bloody fight. I might lose, but you are sure to get hurt'. The message, corresponding to a proof by territory limitation, predictably gets across.

Other examples are only a little harder to find. If a butterfly sitting in a sunlit spot, in a forest, goes away for a while and returns to find another butterfly sitting there, it will inform the other butterfly of its prior claim by performing an intricate spiralling flight (proof by stratification). Sheep will follow their leader even over a cliff (proof by experts). Crows collect together to protect an injured crow (proof by numbers). Proof by expertise is, of course a little harder to come by: monkeys reportedly consult older monkeys on advice about crossing a tiger trail, or a busy road for that matter.

To abstract still further, irrational arguments are based on the notions of *status*, *territory*, and *stratification*.

Some form of status or pecking order is explicit in the behaviour of all gregarious species. The term 'pecking order' is used because the first reported studies in this direction were among hens. If grain is scattered among hens in a coop, the chief-hen pecks first, the vice-chief hen next, and so on down the line. Similar behaviour may be observed among human beings at, say, a formal dinner. It is impolite to begin eating before the chief guest. The clothes we wear, the perfume (e.g., soap) we use, the jewellery (e.g., watches) we flaunt, the car we drive, are all indicators of our standing in the social pecking order.

We are occasionally amused by the fascination that lamp-posts exert on dogs. The sense of smell is very important for dogs, and a dog uses lamp-posts to mark out his territory. Vision is very important for human beings, and when we leave a table in a library, intending to come back, we usually leave behind some personal possessions—handwritten notes, a pen, or even a handkerchief—in a visually prominent place.

It is an unwritten rule that in a crowded train, say, a seat 'belongs' to the person who occupies it first. This is stratification at work. Another kind of stratification is in the pecking order: promotion by seniority means that a pecking order, once established, is not to be disturbed, and all new entrants enter at the bottom of the order.

A conflict is implicit in all the above situations. In an assembly of individuals, who should eat first and who should risk going without food? To whom does a certain piece of property or territory belong? Status, territory, and stratification correspond to the general rules for settling such conflicts.

In a conflict between two individuals (of a given species) *A* is 'right' and *B* is 'wrong' if

1. *A* has a higher status than *B*, or
2. the conflict occurs in *A*'s territory, or
3. *A* has a prior claim to the territory now occupied by *B*.

When *A* offers a proof by intimidation, he is trying to convince *B* that *A*, or the party on whose behalf he is pleading (perhaps God), has a higher status than *B*. Therefore, *B* should accept as correct whatever *A* says—the boss is always right. Other irrational proofs have similar interpretations.

To sum up: *irrational arguments are just a reflection of non-verbal behaviour in verbal behaviour.* Proof by authority is convincing and widely used because of its survival value.

Irrational arguments are deeply convincing because, being of evolutionary origin, they represent a gut response. But what is the survival value of a proof by hope? This seems obvious enough: for someone who gives up hope too soon may perish even when there is a chance of surviving. So the following example might help to clarify the question. As a child, I once watched a small grass snake trying to catch a frog. Whenever the frog hopped, the snake pursued vigorously. Whenever the frog paused, the snake froze into immobility. This continued for some time, with the snake gaining only a little. It was very difficult to understand why the snake didn't catch up while the frog was resting; it was equally difficult to understand why the frog sat still, for it could hop away when the snake had stopped. (The common wall lizard stalking an insect behaves similarly.)

A plausible explanation is as follows. Like many animals, reptiles especially have poor vision! They can see an object only when there is relative movement between the object and the eye. So when the frog and snake were both stationary, they must have been as good as invisible to each other. Since, in this case, the speeds of the frog and snake were about equal, each was afraid that the slightest movement would reveal its whereabouts, and give the other a fractional advantage. So it is that the reaction of an animal to the first sign of danger is to stand stock still.

With hindsight, the frog's line of thinking seems almost obvious: 'If I can't see danger, danger cannot see me.' For some obscure reason, it is the ostrich which reportedly makes the most use of a proof by hope. When tired of running from hunters, it simply buries its head in the sand, so that it can no longer see its pursuers.

The ostrich seems comic, but are we humans much better in hoping that the evolutionary gut-responses that have helped us to survive till now will continue to ensure our survival regardless of the accumulation of knowledge? Are irrational gut-responses compatible with scientific theory? Is it not struthious to imagine that irrational attitudes can indefinitely exist side by side with the possession of nuclear weaponry or biotechnology? Is it not the same as handing a sword to a monkey who lacks the discrimination to use it?

## *The Criteria for a Scientific Theory*

One possibility is to exercise discrimination in the manner of the law. One decides a valid argument by appealing, like the Nayyāyikas, to (a) the manifest (empirical data), (b) inference (logic, reason), and (c) testimony (authority, precedent). Another possibility is to reject authority, as the Buddhists or the materialist Lokāyata do: to rely blindly on authority is to be as indiscriminate as the ostrich (for the same reasons). On the other hand, as the Buddhists pointed out, any claim to discrimination in relying on authority cannot be justified except in terms of (a) and (b).

1. **Internal consistency:** Not every statement is allowed to be true. There should be some statements that are labelled as false.

2. **Brevity:** The theory should make as few assumptions as possible. This is also sometimes called Occam's razor. A razor is used to remove hair which we regard as superfluous; likewise Occam's razor is used to dispose off unnecessary assumptions.

3. **Refutability:** The theory should be testable; it should lead to some conclusions that are *conceivably* false. For example, the statement 'all swans are white' is refutable, if we are ready to call as

'swan' a bird which is like a swan in all respects except that it is not white. The idea is that if we do come across such a bird, we should not start hedging, and hang on to our theory by claiming that it is essential for swans to be white, so that the bird in question is not a swan at all. If we do that, there is no way the statement 'all swans are white' can be tested, for it is a defining characteristic of a swan that it should be white. Similarly, the statement 'God exists' is refutable only if we are ready to conceive of some material circumstance which would conclusively establish the statement to be *false*. The statement that 'all humans are selfish' becomes refutable only if we are able to conceive of some possible actions to which we would be ready to apply the label 'altruistic'.

4. **External consistency:** The theory should not already have been refuted. A theory is refuted if an experiment shows it to be false. For example, the theory that 'all swans are white' is refuted if we find (or build) a black swan, in fact. The theory that 'all human actions are selfish' is refuted if we find an altruistic action in fact.

5. **Likelihood:** This is the trickiest part. Every experiment involves some possibility of error, and there is some doubt about its outcome. This forces us to choose between two or more possibilities. For example, we may accept the results of the experiment, or we may doubt the results and may want to repeat the experiment. The principle of maximum likelihood simply says that we should choose that possibility which is most likely.

How does one decide what is most likely? This is the difficult part. One way is to repeat the experiment. If two experiments come out in favour of the theory, and ten experiments are against it, we reject the theory. In this sense this principle replaces the older principle of induction, because each repetition of the experiment updates our estimate of the likelihood of the external consistency of the theory.[1]

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1. There is a confusing technical point here, about induction. Repeated experiments do not change the probability that the theory is externally consistent: Popper rightly pointed out that probabilities are not ampliative. But he wrongly imagined that that settles the problem of induction, for the repeated experiments do change our *estimate* of these probabilities. We never actually know the probabilities, and can only estimate them. See, K. R. Popper, *The Open Universe: An Argument for Indeterminism*, Hutchinson, London, 1982.

But when we dismiss some new speculation—say Eric Lerner's ideas—as 'interesting but very improbable', we are naively applying this principle. This is tricky because one is tempted by territorial familiarity to dismiss all new ideas in this way. To try to assess new ideas as 'likely' or 'unlikely' on the basis of our expertise and acumen is to misuse this principle. The principle is to be applied only to decide whether external consistency holds. To apply the principle directly to hypotheses is as good or as bad as trying to guess the results of an experiment we have never performed.

A valid scientific theory is not, however, the truth. A scientific theory is always tentative. It does not provide any certainty. Neither is there any guarantee that a series of scientific theories will take us ever closer to the truth. We have scientific theories only because we do not know the truth, so we can hardly say that a scientific theory is so close or so far from the truth. Nor even can we bring in the truth indirectly, without naming it. For example, we cannot say that successive scientific theories will come closer to each other, for a new scientific theory need not leave unchanged the core concepts of the older scientific theory it replaced—aether and phlogiston are examples.

## *The Temporal Hypothesis Underlying the Criteria for a Scientific Theory*

Using the above criteria to decide between competing theories is certainly preferable to deciding truth by authority. But there are difficulties with these criteria, especially when the theories concern the nature of time. Thus the above criteria involve what might be called a layered approach. At the topmost layer there is the scientific theory about the world. Beneath that is a layer of mathematics or the process of inference which connects the hypothesis of the scientific theory to its conclusions. Beneath the mathematics is the metamathematical layer of logic. The philosophical criteria for deciding between scientific theories lies beneath all that. Each layer depends upon the one directly beneath it, so that the philosophical criteria provide the foundation for everything. But what does this foundation rest upon? Only theologians of a certain persuasion can contend that the foundation concerns principles that are universal because they are laid down by God. For, unfortunately, the chain is not such a linear one derived from God's authority: it relates back to the empirical world above the topmost layer of scientific theory!

Specifically, the above criteria involve hypotheses about the empirical nature of time. The hypothesis typically is that of mundane time: that the structure of time is of the sort that one takes for granted in everyday life. For the present purpose this hypothesis cannot be taken for granted: the need for scientific theories arises just because unanalysed mundane experience is not the best guide to the truth. How does one go about deciding the validity of temporal hypotheses underlying the criteria of a scientific theory? However, our immediate concern is not with the validity of these hypotheses, but only with pointing out that there are such hypotheses about the nature of time underlying the above criteria. Not only does the nature of science depend strongly upon time assumptions, but the nature of what we *call* science also depends strongly upon time assumptions. It is, therefore, a difficult situation when the two pictures of time are different.

Thus, consider the criterion of external consistency. When the report of an experiment is published, what one actually has are the reports of the experiment. One believes that the reports of the experiment still faithfully reflect the results of the experiment that was performed several months ago. So one has assumed, as with mundane time, that the past is linear and unchanging. This seems like a very reasonable belief, but if any interaction could propagate backward in time, the belief would not be strictly valid. Is the disagreement with mundane time sufficient ground to reject the belief that interactions can propagate backward in time? No, for the assumption of mundane time already contradicts the assumption of superlinear time used in formulating current scientific theory.

Thus, consider the criterion of refutability. Refutability may be regarded as being of two kinds: logical refutability and empirical refutability. A statement is logically refutable if it is not a tautology. A statement is empirically refutable if one can actually carry out an empirical test. But what decides whether or not one can actually carry out such a test—our everyday experience of what one is free to do and what one is not able to do. If the past were to decide the future, this criterion might or might not filter out bad theories—for things may have been so decided that one persists with a false theory just because one can never ever carry out the critical test that could falsify the theory. In short, the criterion of refutability accepts the mundane belief that the future is open and is shaped, at least in a small way, by human actions. This is another perfectly mundane belief, but it contradicts the superlinear time of physics. One could consider modifying physics to overcome this problem,[2] but what if the physical theory necessary for an open future also makes the past a little bit open?

## *The Uncertainty of Deduction*

Finally, consider the criterion of internal consistency. This criterion usually assumes that the world is such that logic must necessarly be 2-valued. But the world may not be like that if time has the structure of fission-fusion time as in Chapter 9. Schrödinger's cat may then actually be both alive and dead. Changing the nature of logic would naturally change also the nature of inference, and this would change the conclusions that could be drawn from a given hypothesis. (This was forcefully demonstrated during the controversy over intuitionism in mathematics.) Thus, induction is not the only reason why a scientific theory lacks certainty. There can be no certainty even to deduction or mathematics. The certainty that has been attributed to deduction is merely cultural certainty.

The uncertainty of deduction pertains to time perceptions. To reiterate the ground covered in Chapters 6, 10, and 11, the current definition of a mathematical proof dates back to Hilbert. The idea was that a moron or a machine should *mechanically* be able to check the correctness of the proof. This idea suits an industrial culture. But *which logic* ought one to use for this proof? Hilbert assumed the universality of 2-valued logic; and universality, or standardisation, also suits an industrial culture. Other cultures did not understand rationality or inference in this mechanical and standardised way. The Arab rationalists understood by rationality the exercise of the faculty of intelligence (*aql*) in the widest sense, which very much

2. The difficulty of assuming conflicting pictures of time, and the possible remedy of modifying physics, using a tilt in the arrow of time, is discussed in detail in C. K. Raju, *Time: Towards a Consistent Theory*, Kluwer Academic, Dordrecht, 1994.

included the faculty of judgment. Buddhists would not necessarily accept such a mathematical proof as a valid argument, for they would reject both 2-valued logic, and the mathematical *authority* behind it: they might maintain that the assertive statement, 'This man is good', is *both* true and false. Neither would the Lokāyata—the people's philosophers of Indian tradition—have accepted Hilbert's idea of a mathematical proof; they would have been quick to point out who benefited from treating such inferences as universally valid! Thus, internal consistency and deduction both depend upon the underlying logic, and 2-valued logic is not necessarily universal, but depends upon cultural and empirical beliefs about the nature of time—beliefs that may or may not be valid.

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## *Summary*

- A valid scientific theory is decidedly preferable to authority, but the truth of a valid scientific theory is intrinsically uncertain.
- The validity of a scientific theory is decided using criteria such as internal consistency, refutability, and external consistency.
- However, these criteria involve hypotheses about the nature of time.
- Hence, *the validity of the present-day criteria of a valid scientific theory depends upon the validity of the underlying picture of time.*
- Hence, also, the validity of a picture of time cannot be decided simply by checking it against the picture of time in current scientific theory: hypotheses about the nature of time in scientific theory must be compatible with hypotheses about the nature of time used to decide the scientific nature of the theory.
- A tilt in the arrow of time provides approximate compatibility.

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# The Argument

## Part 1: Time and Eschatology

**1. Life after death.** Belief in the soul relates to belief in life after death. In its original form the belief in life after death involved a belief in quasi-cyclic time: it was thought that the entire cosmos went through cycles. Like days on earth, each cycle of the cosmos was believed to be much like the preceding one, though *not* exactly like it. It was thought that all events approximately repeated; so did individual human beings, reborn in successive cycles of the cosmos, though bodies might change a bit across cycles, somewhat the way a person grows imperceptibly older each day. People thought that death interrupted epochs of life in cosmic cycles like sleep interrupts our daily periods of wakefulness. One finds this belief across the ancient world. Some, like Socrates, even thought that with due effort one could recall the previous experiences of one's soul.

Quite possibly our ancestors were mistaken—one can certainly imagine a world in which time is *not* quasi-cyclic. But that already gives us an important clue. Our ability to imagine a time that is *not* quasi-cyclic tells us that quasi-cyclic time, like the accompanying notion of the soul, is a *physical* notion—since it is refutable. But is this a *valid* physical notion? How does quasi-cyclic time compare with the notions of time in present-day science? Can one look forward to a life beyond the present one?

Current physical theory does *not* fundamentally rule out the possibility of quasi-cyclic time. On the contrary, it is known that there are many circumstances in which quasi-cyclicity is inevitable. But present-day observation does not allow us to decide whether, in fact, these circumstances prevail.

*Conclusion:* There is life after death *if* time is quasi-cyclic.

*Q. Is time linear or cyclic?*

**2. The curse on 'cyclic' time.** A similar belief in life after death, in the context of quasi-cyclic time, existed also in early Christianity and among the 'pagans' in the Roman empire. This kind of life after death was *not* considered desirable, deliverance from it was. It was thought that deliverance from life after death was available to *all*. This belief in universal deliverance was used by early church fathers like Origen to support equity; a soul which repeatedly ascended to heaven and descended to earth, like a raindrop, represented complete equity—for raindrops join in streams that ultimately pour back into the ocean. After Constantine, the church found equity increasingly inconvenient; and after consummating its marriage to the Roman state, by about the middle of the 6th century, the church decisively rejected equity. If everyone would anyway be saved, why have an institution like the church? The church wanted to be needed like the state. The state is needed to mediate reward and punishment here; the church sought the role of mediating reward and punishment in the hereafter. To this end, it needed to construct an appropriate hereafter.

Hence, the state-church cursed 'cyclic' time; it accepted Augustine's arguments that, for the world to be morally intelligible, the hereafter must be such that it clearly and *eternally* separated sinners from the virtuous. This changed idea of heaven and hell changed also the belief in life after death: instead of a sequence of lives in successive cycles of the cosmos, the church decreed that people should believe in life after death just once. Instead of universal deliverance, some now went to heaven and others to hell, both of which would last eternally. The changed picture of the hereafter changed the way of life here. The earlier ideal was dispassionate action leading to deliverance. This was replaced by a prescription better suited to purposes of state: motivation through hope of eternal reward and fear of eternal punishment in the hereafter. The Priest could guide action by explaining what act led where.

*Q. Why should this medieval curse concern us today? Can't science decide whether there is life after death? Can't science decide whether time is 'linear' or 'cyclic'?*

It can, but the decison is not so easy. The notion of time is fundamental to both science and religion, and beliefs about time in one sphere have influenced beliefs about time in the other—the curse on 'cyclic' time decides ideas about time in science today. For example, to try to establish that time had a beginning, at a moment of creation, Stephen Hawking reintroduced the old curse on 'cyclic' time as a *postulate* (called the 'chronology condition') into current physics. His arguments in support of this postulate are fundamentally the same as those used by Augustine to condemn 'cyclic' time.

What were those arguments? The four key ideas are summarised in Box 10.

**Box 10: Augustine and Hawking on time**

**Step 1. Confusing distinct pictures of time: 'linear' vs 'cyclic' time.** Augustine confused quasi-cyclic time with supercyclic time or eternal return—a picture of time where each cycle of the cosmos was supposedly *exactly* like the 'preceding' one. This notion of eternal return naively supposed that one returned to *exactly* the same time, but with the *difference* that one had a memory of the 'preceding' same times! An unexpected fallout of this confusion is the belief that there are just two competing types of time: Christian 'linear' vs pagan 'cyclic'. (Where Augustine confuses different pictures of 'cyclic' time, Hawking confounds different pictures of 'linear' time.)

**Step 2. 'Cyclic' time contrary to 'free will'.** Augustine rejected this confused notion of 'cyclic' time as contrary to 'free will'. Hawking concurs.

**Step 3. Rewarding and punishing the individual.** Why is 'free will' important? Without 'free will' neither society nor God could justly distribute reward and punishment to *individuals*. Punishment could be just only if blame were first fixed on an individual as the *cause* of something bad. But is the nature of time such that causes can always be localised within individuals? It may not be, but this belief is essential to *justify* the unequal distribution of resources in society. (Hawking argues that 'free will' is essential for the philosophy of science, which justifies science.)

**Step 4. Not surprising God.** The last step was to defend 'linear' apocalyptic time: the idea that the world progressively unfolded

*(continued on p. 458)*

until the day of the apocalypse, according to God's plan. This idea is incompatible with the everyday idea ('mundane time') that the future is decided by the choices we make now. Augustine tried to reconcile the two through the quibble that 'determinism' was different from 'fatalism'. Thus, 'free will' was needed *only* to distribute rewards and punishment; 'free will' did not lead to any genuine novelty—man could not surprise God. (Hawking's idea of 'free will' also has no room for genuine novelty in a world evolving according to the equations of general relativity—man cannot do anything contrary to these equations that modify the 'Laws of physics' through which Newton thought the divine plan operated.)

All four of these ideas—(1) the confusion between distinct pictures of 'cyclic' and 'linear' time, (2) the idea that any kind of 'cyclicity' is contrary to 'free will', (3) the idea that credits for innovations can always be located in individuals, and (4) the idea that 'free will' can somehow be reconciled with the deterministic 'laws' of physics without changing them—are ideas with considerable currency in current science.

*Conclusion:* Science cannot straightaway answer questions about time in a way independent of theology. Contrary to the popular image of their opposing postures in the Fisherman's story, the Priest and the Scientist have reached an understanding offstage!

Is this conclusion hasty? While theological ideas may naturally percolate into scientific thought, through the scientist's mind, could it not be that in the case of time the Priest and the Scientist have independently arrived at the same answer? Perhaps science and religion harmonise because they express different aspects of the same truth?

**3. Creation, Immortality, and the New Physics.** But with *which* religion does science harmonise? For religions differ, so that the harmony of science with one religion may involve its discord with other religions. If science were somehow to establish the existence of God, that would be discordant with Buddhism, which denies both God and creation. 'Religion' in the talk of the harmony of 'science and religion' clearly also does not refer to Islam, for it is the *conflict* between science and religion that is seen to prevail in this case. That is, the new harmony between science and 'religion' concerns also the discord between 'religion' and religion. The timing of this harmony and discord is politically very significant.

After the Cold War, further expansion in the power of the West requires investment in 'soft power', not nuclear weapons. Power is the capability to control the behaviour of others, and further investment in nuclear weapons will neither alter the behaviour of any more people, nor will it help to 'fine tune' behaviour. Thus, this agenda for a unipolar world requires globalisation of culture and values. Values have traditionally related to religion. But the perceived conflict between science and 'religion' has led to a loss of credibility for 'religion'. So the credibility of 'religion' is sought to be restored by harmonising religion with science, which today represents a global and *public* set of beliefs.

Both 'religion' (= Western Christianity) and science have traditionally had close links with the state. 'Religion' has been re-interpreted to suit the concerns of state and capital. Similar concerns have made science authoritarian, with increasing specialisation and widespread scientific illiteracy. Scientific illiterates (or over-specialised scientists) have no option but to trust *some* scientific authority—employed by the state or private capital. Hence, it is practically possible to adjust both science and 'religion' to achieve the requisite harmony—at least for the time period that is critical to the agenda of establishing a unipolar world. To achieve the harmony, it is necessary only to adjust the *time beliefs* that are at the interface of science and religion. The pope has explicitly outlined the minimum agenda for the new harmony of science and 'religion': belief in *creation*, and belief in *immortality.* These beliefs legitimise the authority of the church and the associated values.

One expects that priests will actively pursue this agenda. And, it is evident that this harmony agenda derives support from the *popular* works of a number of scientists and scientific authorities (whatever their personal beliefs). These include Stephen Hawking, Roger Penrose, Ilya Prigogine, Paul Davies, F. J. Tipler, etc. Since these popular works are implicitly believed by millions of scientific illiterates, they are clearly a political matter. Much new political physics is growing around attempts to harmonise science and 'religion'! Scientists are changing science to suit the agenda.

The new harmony is reflected in the way the Brave New Physics treats time, especially *creation* (the beginning of time) and *apocalypse* (end of time). The big bang and Hawking–Penrose singularities have been taken as conclusive proof of creation. Tipler has written a book claiming that theology is a branch of physics, and that present-day physics can be used to calculate that there will be life after death, 'in the flesh', precisely once, exactly as Augustine imagined, but in the virtual reality that an apocalyptic supercomputer would create at the end of time. It is difficult to distinguish such 'theologically correct' claims from the 'ideologically correct' claims of the Russian scientist Lysenko who claimed that wheat planted in a field of corn would sprout corn.

## PART 2: TIME IN CURRENT PHYSICS

*Q. Did the original marriage of science and religion similarly influence physics?*

All social scientists believe they know the answer to this question. All become either speechless or polemical if asked, 'Show me the cultural influences in Schrödinger's equation. Tell me how physical theory would change under different cultural circumstances.' The answer: time is the interface between science and religion. Cultural influences have travelled from religion to science through the notion of time; they have shaped the picture of time, and the picture of time decides the equations of physics. (We postpone to Part 3 the question of how physics would change with the picture of time.)

**4. Newton's secret.** If one turns the pages of history, one finds that theology has helped shape science since the days of Newton. As one who was at once both a deep scientific and religious thinker, Newton symbolises the then-believed harmony of science and religion. However, the religious side of Newton is largely unknown. Newton spent 50 years of his life secretly writing an 8-volume history of the church, and diligently collecting every scrap of evidence to show how the Bible had been distorted to suit the interests of the clergy; his work on physics was, for him, almost in the nature of a distraction. Historians of science, who wrote authoritative biographies of Newton, deliberately lied about his life—they did not want people to know about this terrible religious quarrel between the Priest and so reputed a scientist. For two centuries these lies circulated widely. The secret first leaked out to people at large in the 1950s, and more material became available in the 1970s, but the final version of Newton's history of the church is still kept a secret, underlining its relevance to the current political agenda of the church.

This secrecy has made it very difficult to examine dispassionately how prevalent theological beliefs affected Newtonian physics. Newton too was a victim of the curse on 'cyclic' time. The curse led to the confused dichotomy of 'linear' vs 'cyclic' time—which dichotomy was taught by his teacher, Isaac Barrow, as the non-quack view. Newton the historian chose 'linear' time, for no clear physical reason that Newton the physicist could supply, and perhaps because it was only the religious hope of apocalypse that brought meaning to his secret life by situating it in a wider cosmic context.

**5. In Einstein's shadow.** It is not widely known that Newton's physics failed *exactly* due to difficulties with his notion of time. This is not widely known because physics texts misrepresent the creative process by which the Newtonian theory was replaced by relativity. Most physics texts describe special relativity as Einstein's 1905 theory following from the Michelson–Morley experiment, which found that the speed of light remained the same whether the source of light was moving or stationary. Such a view is quite indefensible. To measure speed, one needs to measure time—but what are equal intervals of time? One cannot put two intervals of time side by side to compare them—one must use a clock. But which clock should one use? The difficulty with time in Newtonian physics was this: how to measure 'equal intervals of time' with a democracy of clocks? So the speed of light could not have been properly measured at all.

History corroborates what physics makes evident. Barrow had defined: *equal causes take equal times to produce equal effects*. Poincaré modified this slightly by changing 'equal' to *'almost equal'* in the preceding definition. He argued that it best suited physics to use light signals to determine equal intervals of time. Hence the velocity of light was constant by *postulate*. (Poincaré also derived, reported, and published *all* of special relativity ahead of Einstein.) Einstein, who had avidly read Poincaré, agreed that the breakthrough came at the moment it was clear that time was the problem.

The *Times* headlines, the atomic bomb, and the changed political map of Arabia made Einstein a superhero. At just about that time, in 1952, one of the first histories of the subject, written by Sir Edmund Whittaker, had a chapter entitled 'The Relativity Theory of Lorentz and Poincaré'. This suggested that Einstein had used, without acknowledgment, Poincaré's theory published earlier, even borrowing the very terms in it, such as 'Principle of Relativity'. Einstein was probably aware that this did not legally amount to plagiarism. (To process patent applications, as a patent clerk, Einstein had to learn the legality that *ideas* cannot be patented.) On the other hand, Whittaker, who wrote Einstein's biography for the Royal Society, was probably aware that this was neither the first nor the last case where Einstein claimed to have independently rediscovered results reported a short while earlier by the most prominent scientists of those times. In favour of Einstein, some subsequent historians of science have repeatedly asserted, without the least factual basis, that Einstein took one step more than Poincaré. As we shall see later, Einstein, not knowing enough mathematics, actually took one step less—unlike Poincaré, he failed lifelong to appreciate a key mathematical consequence of relativity.

This dispute also brings us face to face with another relation between time and politics: heroes and villains are decided, and reward and punishment is socially distributed by appealing to a *causal* analysis which serves to fix credits and blame. Any causal analysis proceeds on a picture of time. To distribute credits, scientists use the mundane picture of time, and not the picture of time in relativity. Credit is distributed among individual scientists by appealing to the same causal principles (see Step 3 in Box 10, p. 457) that are used to distribute wealth and income in a capitalist society. A special feature of this principle of locating causes in individuals is this: such a causal analysis can *never* be conclusive. Hence, a dispute over credits can be settled *only* by appeal to authority (even though the authority, like that of Einstein, may not be reliable). This enables the politically powerful to appropriate most credits, by locating causes 'judiciously'. The patent clerk symbolises the patent law, which is a step in this process of appropriating credits—

just as much as the current attempts to universalise the patent law are a step towards hegemony.

A priority dispute only replaces one causal analysis with another, while accepting the principle of priority—that credit should go to the one who first made a discovery. But there is another difficulty with the principle of priority.

*Q. Is the principle of priority compatible with the principle of relativity?*

Is it possible to fix credit and blame using the notion of time in relativity? Is mundane time compatible with time in physics? Science itself stands in the way: can the Scientist go along with the Priest and the Merchant without sacrificing science?

**6. Broken time: chance, chaos, computability.** Theories of chance, chaos, and computability, have been widely used to try to settle this difficulty (as in Step 4, Box 10, p. 457). The theories try to show that the 'free will' needed to validate physics is compatible with the validity of the deterministic laws of physics. The arguments involve the idea of 'broken' time: in some complex situations, the laws of physics cannot be used to predict the future, so that the future, though decided by the laws, will remain unknowable. Some have argued that quantum mechanics ensures that the future is intrinsically undecided. The future will continue to surprise man. But that is not at all the point. A chocolate–ice cream machine may stuff either chocolates or ice cream into your mouth in a way that you are quite unable to predict; you may be surprised by what you eat, but that is not the same as your choosing between ice cream and chocolates. Chance, chaos, and uncomputability are, thus, beside the point—the question is not whether the future can surprise man, the question is whether man can surprise God.

Whether or not physics decides the future, it provides no room for man to do so. Moreover, no one believes these arguments from broken time if they are applied to 'bring about' the past instead of the future. A similar argument from broken time was used by al-Ghazālī to support providence in the debate between rationality and providence, in Islamic theology. These arguments were subsequently attacked in medieval Christian theology, which favoured rationality: God functioned through rational laws, for repeated acts of direct divine intervention (miracles) would make the world quite unpredictable. Such a world did not suit a God who needed to punish humans, for in a completely unpredictable world it is impossible to plan, so that one cannot rationally choose between different courses of action, by comparing their consequences.

*Conclusion:* Broken time destroys rationality without enabling 'free will'. It does not help to reconcile the relativistic notion of time with the principle of locating causes in individuals. Most amusingly, the sacrifice of rationality does *not* ensure even that the future is surprising to man.

*Q. Is rational calculation the only way to know the future?*

**7. Time travel.** Time travel has recently moved from SF to physics. If one can travel to the future in a time machine, the future must already be 'out there'. One can, then, *perceive* the future without having to calculate it; one can report this perception on returning to the present. The possibility of time travel has brought to the forefront of physics the question of 'free will' vs the deterministic laws of physics: can man bring about a future not already decided by God or physics? If the future is already 'out there' it would seem that one can no more bring about the future than one can change the past. Changing the future becomes exactly as paradoxical as a time traveller changing the past. Suppose one uses a time machine to travel to the past to kill one's grandfather before he could procreate. Then one couldn't have been born in the first place, so who killed Grandfather? The alternative seems to be that try as one might, one is unable to kill Grandfather—he survives just because time travel is fatal to 'free will'! Not willing to trust this, and the better to defend Grandfather, Hawking has introduced a *chronology protection conjecture*. To travel to the past and return to the present one must execute a closed loop in time. The chronology protection conjecture abolishes by fiat such shades of 'cyclic' time. *Hence* it prohibits time travel.

We reconsider the Augustine–Hawking argument about closed loops in time: Tim time-travels to meet Grandfather, and returns to the present. There is no question of repeatedly going round such a closed loop, mentally incrementing a counter for each circuit. Rather, the earliest event on this loop will be spontaneous in the sense of being in-principle causally inexplicable from any past set of events. One can explain Tim's arrival by saying that he pressed the button of his time machine—but that locates the cause in the future; it is an explanation from a future event (though this future event seems to be in Tim's past). On a closed time loop, every event has a ‘cause’, but there is no first cause. There is, in principle, no explanation from past causes for the entire loop or for the earliest event on it.

The unheralded appearance of the time traveller corresponds to an event that spontaneously creates order (reduces entropy). A machine can neither be spontaneous, nor can it create order. To create order mechanically would be to build a perpetual motion machine. In fact, it is impossible to control spontaneous order-creation mechanically either from past or from future. Hence, there can be no time *machines*. But the prohibition applies only to mechanical devices; time travel in the sense of information transfer between future and present is not prohibited. Living organisms may, for example, directly obtain sporadic information about the distant future, without having to calculate it, but it is not possible to repeat this feat mechanically. There is no theoretical prohibition, for example, on dreaming the future. Whether or not one actually does dream of the future is, however, a matter best decided empirically.

## PART 3: DE-THEOLOGISING PHYSICS

Probing the ideas of time in physics has brought us back to the question with which we started.

*Q. Is time ‘linear’ or ‘cyclic’?*

**8. The eleven pictures of time.** The conclusion is that to find answers to any questions about time, one must first de-theologise physics—one must separate the Scientist from the overpowering influence of the Priest. This involves a refutation of each of the four steps (Box 10, p. 457) involved in the curse on ‘cyclic’ time. *To arrive at clarity about time, those four archetypal arguments in Western thought must all be stood on their head. This book does exactly that.* Our first step is to resolve the confused categories of ‘linear’ vs ‘cyclic’ time into distinct pictures of time. This brings into the open the conflict between different ‘linear’ pictures of time. The incompatibility of ‘linear’ mundane time with the superlinear time of physics cannot be settled by the psychological trick of appealing to some imagined antagonism between all ‘linear’ and ‘cyclic’ varieties of time. One must either change physics or abandon the mundane view of time.

As regards Step 2 (Box 10, p. 457), from Augustine to time travel it has become a fixture of Western thought that 'cyclic' time is anathema to 'free will'. We have seen that the exact opposite is true. But does this understanding correspond to a picture of time that is at all physically realistic? Would it ever be possible to incorporate a non-'linear' picture of time into a realistic physical theory?

**9. The tilt in the arrow of time.** This has already been done: an alternative physics with a tilt in the arrow of time has already been formulated. A tilt means partial anticipation. This involves no new physical hypothesis, but concerns an exploration of the most general form of physics after relativity.

Einstein has been credited with relativity on the grounds that Poincaré 'waffled' on the question of aether. The term 'aether' has two meanings: Poincaré unambiguously rejected aether in the sense of absolute velocity, but Einstein hung on to aether in the original sense of action by contact used by Descartes (and the early Indian *Nyāya-Vaisesika* tradition). Einstein regarded action without contact as something 'spooky'; he erred lifelong in supposing that after rejecting absolute velocity, one could hang on to aether in the sense of action by contact. (This led him to assert a mathematical absurdity in the authoritative *Annals of Mathematics*.) After relativity, it is necessary to reject aether in both senses; hence also it is necessary to reject the paradigm of 'instantaneity' used in physics till now. (Poincaré understood this correctly.) Most physicists today continue with this error, eliminated by either history-dependence or a tilt.

But a tilt goes a step further than history-dependence. A universe with a tilt is no longer a grand piece of clockwork. Physics with a tilt is non-mechanistic: it implies spontaneity which differs from chance. Spontaneous order creation is a cooperative process, so that Step 3 of Augustine's argument is exactly denied—it is, in principle, impossible to locate the credit for creative acts within any one individual. (What one has here is not a sequential multiplicity of causes, but a simultaneous collectivity of causes, so that priority disputes cannot even be resolved through convention.)

This picture of spontaneity is quite compatible with physics. It is not, however, compatible with the theological excess baggage of 'causality': it forces us to consider the equations of relativity in their most general form, corresponding to a tilt in the arrow of time.

While this is a minimal change in physics, it does lead to many qualitative and quantitative differences.

## PART 4: TIME AND VALUES

*Q. So what difference does that make to me?*

Along with various religions, industrial capitalism too has modified time perceptions to shape values, the present way of life, and the way resources are distributed in society. A new picture of time means new values, a new way of life, and a new society.

**10. Time as money.** How does a changed picture of time affect our social and personal life? The quickest answer to this question is provided by examining our current value-system and way of life, which flows from the equation *time=money:* act so as to maximise the expected present-value of lifetime income. Howsoever dull and repetitive the work, it still is most 'natural' to 'spend' one's lifetime working harder to earn more money. People are surprised by someone who abandons a job for another which has half the salary but twice the leisure. In newly industrialised countries, these beliefs have generated the competitive pressures that make children abandon play and focus on study in the hope of getting better paid jobs later on. Time has become a commodity in modern industrial capitalist societies: one barters lifetime now for money later on.

Early attempts to export industrial capitalism show that these transformed values, and the accompanying changes in human behaviour and society, were essential pre-requisites for the success of industrial capitalism—a lesson to be remembered in the context of the current strategic agenda to globalise convenient values.

Industrial capitalism has been characterised by a shift from a traditional 'cyclic' pattern of time in agricultural societies to the modern 'rational', 'linear' picture of time in industrial societies. Significant changes in the calendar and the clock were required for the success of shipping and railways—key inputs to the industrial revolution. Equally significant changes in the human sense of time, hence human behaviour, were essential for successful control of the production process.

We isolate the key assumptions about time that go into the making of the way of life in industrial society. For example, the profit motive, in requiring the rational calculation of future profit, assumes that the future *can* (only) be rationally calculated. Two distinct pictures of 'linear' time—mundane time and superlinear time—underlie this idea of rational choice, and the linear-cyclic dichotomy helps to mask the incoherence between these conflicting pictures of time.

Further, there is the facile assumption that intertemporal comparisions of utility are unproblematic, and, in fact, uniform across individuals (like the rate of interest in a capitalist economy), while interpersonal comparisons of utility are anathema. Arrow's impossibility theorem is extended in Chapter 11 to show that rational choice is surely impossible if social choice is. Finally, to the extent that the assumptions about time underlying the industrial life are physical assumptions, they may be invalid.

**11. The transformation of time in tradition.** Industrial values exhibit a harmony between the Priest and the Merchant, and many writers have claimed that this harmony was possible because 'linear' time is uniquely a part of Judaeo-Christian tradition. This is qualifiedly true. First, 'linear' time relates to the curse on 'cyclic' time, which concerns a tradition commencing with 4th to 6th century religious politics: it concerns Augustine's Christianity rather than that of Jesus. And it concerns an incoherent and constant 'reversal of perspective' between 'linear' mundane time and 'linear' apocalyptic time.

Second, the claim involves a profound ignorance of the pictures of time in other traditions—the rejection of 'cyclic' time may mean neither 'linear' apocalyptic time, nor superlinear time, but 'linear' mundane time. This was the case, for example, with the Lokāyata ('people's philosophy'), which rejected quasi-cyclic time, a thousand years before the curse. One difference was this: while the Lokāyata rejection of 'cyclic' time was intended to benefit the *people*, by rejecting social inequity, the Western Christian curse on 'cyclic' time was intended to benefit the *state*, by rejecting equity and reinforcing hierarchy. The values related to 'linear' mundane time differed from those related to apocalyptic time: the Lokāyata accepted as desirable many things, like intoxicants and sexual indulgence, that Western Christianity regarded as sinful. The values related to 'linear' mundane time differed also from the values related to superlinear time: unlike the case of *time=money*, Lokāyata rejected the need to defer present consumption in the hope of future rewards, or fear of future punishment, on grounds similar to those they used to reject quasi-cyclic time.

The bald denial of quasi-cyclic time (whether or not it led to 'free will') undeniably led to a sense of moral liberty, as in the story of the philosopher-King Ajātasattu, and his question addressed to the Buddha. The Buddha, without directly contesting the belief in quasi-cyclic time, denied its chief consequence—the belief in a soul. (This was the exact opposite of Augustine's decision to deny quasi-cyclic time, but accept the existence of the soul.) As is to be expected, this denial of the soul shatters the basis of morality in Western Christianity. In fact, the Buddha denied belief in the continuation of identity even from one instant to next: this realisation of change with time shatters also the basis of *time=money*, since it makes impossible rational choice with deferred consumption. The Buddhist notion of time endows the instant with a structure, and a non-trivial structure of time corresponding to a rejection of the very basis of classical rationality: 2-valued truth-functional logic. Finally, the Buddha's perception of time as instant replaced 'cause' by conditioned coorigination, and this destroys the usual justification for inequity. He established the *samgha* as his model for a society with equity.

Drawing inspiration from the Neoplatonists (whom the church called pagans and pantheists), the rational theologians of Islam, like Ibn Sīnā, believed in quasi-cyclicity, as did the Sūfī-s, like Rūmī and Ibn 'Arabī. But all today acknowledge the authority of al-Ghazālī who attacked the rationalists using ontically broken time: he contended that the rational predictability of the future depended upon God's habit, which might change unexpectedly. In that debate between rationality and providence, providence won in Islam. For al-Ghazālī the location of all creative processes in God was not a problem, for, like the Sūfī's, he subscribed to the belief in the unity of existence—that God was within man.

But the curse on 'cyclic' time created a problem for providence in Christianity, for the curse had eternally separated man from God. Providence vested too much power in a God who was transcendent *and* vindictive. If all creative power were reserved for God, why should man be punished eternally? Hence rational theology, with its image of a rule-bound God and its vision of a rule-bound society, won in medieval Christianity: Aquinas' arguments against al-Ghazālī came to be accepted, and the advocates of providence came to be known as Dunces. Newton's 'laws' were called laws exactly because of his belief in rational laws with which God governed the world, relying occasionally on providence. Eventually, Laplace's demon (p. 174) occupied even the small space reserved for providence in Newtonian physics, for the demon could rationally calculate the entire future.

Industrial capitalism applied calculative rationality not only to production, but also to the distribution of resources. To distribute credits by cause, one must be able to identify causes. But, with the assumption of mundane time, in any realistic social context, there always is a multiplicity of causes. Hence, a dispute over credits cannot be settled except by appeal to political authority: hence credits (and resources) are inevitably distributed in proportion to political authority—an arrangement which suited industrial capitalism very well.

The values based on the earlier varied time-beliefs of the Buddhists, the Jains, early Christians, the Advait-Vedantin-s, the Sūfī-s, the Sunni-s, etc., are all hence intrinsically incompatible with the values corresponding to the *time=money* of industrial capitalism. It is in this sense that industrial capitalism harmonises with Western Christianity while being discordant with other religions: both industrial capitalism and Western Christianity believe that morality begins with inequity! This harmony cannot be further restricted to a harmony with the Protestant ethic alone: the root 'cause' of the harmony is the very notion of cause, related to the curse on 'cyclic' time, for the accompanying Augustinian ethic was needed to help justify the concentration of resources with the politically powerful.

(With calculative rationality, the unexpected refers to a situation where the calculation fails: it may, however, happen that classical rationality itself fails, for rationality rests on logic, and logic changes with the picture of time. Hence, logic may be a cultural artefact: deduction may refer to an insecure cultural truth rather than an *a priori* and secure universal certainty. To provide an example of this, a postscript examines in some detail the Buddhist and Jain perceptions of time and logic, pointing out the Buddha's use of a logic of four alternatives: in which, for example, Schrödinger's cat may be simultaneously both dead and alive without contradiction.)

**12. Revaluation of all values.** A tilt in the arrow of time, too, is intrinsically incompatible with *time=money*, for the temporal assumptions underlying calculative rationality fail with a tilt. A tilt too changes perception of how one ought to live, and how society ought to be organised. There is no 'naturalist fallacy' here, because natural inclinations link 'is' to 'ought', so a change in 'is'-type beliefs also changes 'ought'-type beliefs. These 'natural inclinations' derive from the process of biological evolution. However, a tilt modifies the Darwinian view of evolution by focusing on the neglected (cooperative) creative process (not 'chance') which generates mutations, rather than the (competitive) selection process which eliminates them. Hence, modifying the usual naturalistic ethic ('survival'), a tilt suggests the principle: 'live to increase order in the cosmos'.

Order-creation includes the legitimate concerns of 'survival' and of environmental ethics, or, more generally, harmony (order preservation). But order cannot be created mechanically—machines help to dominate and to make profit, but machines necessarily create disorder, degrading the environment and making all life difficult. Only living organisms, capable of spontaneity, can possibly create order. With a tilt, order-creation *is* possible, and order-creation, as the very purpose of life, is valued over mindless domination in the name of 'survival'. Order-creation is a cooperative process: credit for creating order cannot be localised in individuals, and so, with a tilt, there is no longer any justification for the iniquitous distribution of resources. Thus, contrary to *time=money* which makes our present life so mechanical and enforces social inequity through technology—which generates life-threatening disorder—a tilt suggests a way of life and a social organisation based upon harmony, spontaneity, and equity.

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# Persons

*A one dimensional view of persons as they relate to the theme of this book.* (Abbreviations: b. = born, d. = died, ca. = *circa* = about.)

**Abu Yazīd** al-Bistāmī (d. 874). Famous Sūfī, also known as Bayazīd, from Bistām, a small town in northern Iran.

**Ajātasattu** [Ajātashatru] (d. –459). Son of King Bimbisāra (b. ca. –543, a friend of the Buddha), who seized the throne by patricide (in –491) through the 'indirect' cause of keeping his father in chains and allowing him to starve to death. His rule lasted about thirty years, during which his Magadha empire expanded to dominate the Gangetic plains. He founded the city of Pataliputra (now Patna). He questioned various wanderers like the Buddha and Mahavira about the benefits in this world of an ascetic life. Distinct from a character of the same name in the Upanishads.

**Aquinas.** See Thomas Aquinas.

**Archimedes** (b. –287, d. –212). The allusion is to his work on levers, which was used to build efficient catapults, that helped sink ships attacking Greece. His well-known remark, 'Give me a place to stand on, and I will move the earth' is from Pappus of Alexandria.

**Aristotle** (b. –384, d. –322). His father was personal physician to the grandfather of his famous pupil, Alexander the Great (d. –323). Aristotle accumulated knowledge from far-off places in two ways. (1) In deference to his teacher, Alexander appointed two persons whose only job was to collect knowledge and information from all the lands through which Alexander travelled, and report it back to Aristotle. (2) Over a thousand years after his death, Europe came to know of Aristotle through Islamic theologians, who indiscriminately attributed to Aristotle various works such as the *Enneads* of Plotinus.

**Arius** (ca. 256–336). Pastor of the Church, rejected by the First Ecumenical Council (Nicene Council, 325), restored to favour by Constantine and his successor. His teachings were rejected again as the Arian heresy.

**Arrow,** Kenneth (b. 1921). Won the Nobel prize in economics. Proved Arrow's impossibility theorem that it is impossible to talk about the good of the society as a whole, except in a dictatorship.

**al-Ash'arī,** Abu'l-Hasan (d. 935). A medieval Islamic theologian. Traditionalist and founder of the Asharite school of atoms and accidents, in opposition to the Mu'tazilite philosophy of rationality in theology. He renounced reason, and announced his key idea that the contentious passages of the Ku'rān must be accepted 'without asking how'. This precipitated the debate between rationality and providence in Islam, which later moved into Western theology.

**Athanasius** (ca. 293–373). Victor at the Council of Nicaea. Was declared a heretic by Constantine II, but was then restored to favour.

**Augustine** (ca. 354–430). An early medieval Christian theologian, and a judge of imperial Rome in Africa, who 'forcefully' argued for the idea that heaven and hell last for eternity. He thought time was subjective, and further adjusted ideas of time to enable God to make black-and-white judgments. He fought against both the majority Donatist Christians and a variety of pagans, and founded Western Christian theology. He advocated the use of force to convert people, and died when invading Vandals did to his church what he and his friends had earlier done to pagan temples. This marked the fulfilment of an earlier pagan prophecy that Christianity would disappear from Africa.

**Avicenna.** See Ibn Sīnā.

**Bacon,** Roger (ca. 1219–1291). Recommended the use of science in the Christian Crusades against Islam, to save Christian lives.

**Bacon,** Francis (1561–1626). Prophet of modern science, and Lord Chancellor of England; allowed that 'spooky' things like witchcraft may be explained through action at a distance. Later on Einstein, and others working on the foundations of quantum mechanics, reversed the association, and thought that anything explained using action at a distance must be 'spooky'.

**Barrow,** Isaac (1630–77). Newton's teacher and the first Lucasian Professor. He sold his books and ran away from Cambridge to return after fighting pirates on the high seas, by which time the official doctrine had changed. Was the Dean of Trinity College when Newton, the next Lucasian Professor, was denouncing the Trinity in his secret writings. He thought scientists without a clear idea of time were quacks, and he started his lectures by clarifying the concept of time. He argued for the even tenor hypothesis, usually credited to Newton.

**Bergson,** Henri (1859–1941). Winner of the Nobel prize for literature. Regarded time as durée.

**Bohr,** Niels Henrik David (1885–1962). One of the founders of quantum theory, and winner of the Nobel prize. His earliest model of the atom resembled the solar system, with electrons (like planets) going round a nucleus (like the sun), except that some 'quantization conditions' were introduced by hand to prevent the electron from falling in.

**Boltzmann,** Ludwig (1844–1906). Valiantly fought to prove the entropy law from mechanics. Committed suicide, perhaps in despair over the constant opposition he faced. His work came to be widely accepted soon after his death.

**Bruno,** Giordono (1548–1600). Generally considered an early scientific martyr to Western Christianity. Burned alive by the Inquisition.

**Buddha** (b. –563, d. –483). Properly known as Siddhartha Gotama. Born a prince, he abandoned his kingdom and wife and child, at age 29, to find a solution to the problem of universal suffering. On finding the solution after many years of asceticism and meditation, he assumed the title of The Buddha ('The Enlightened One'). He taught a new notion of 'causality' (conditioned coorigination, *praticca samuppada*), through understanding which one understood also the Right Way (Law, Dharma). He founded a new social order called the *Sangha*, where, unlike Athens, both 'slaves' and women were accepted as equals. For householders, he taught compassion, and the Middle Way, the probable source of Aristotle's Doctrine of the Golden Mean. The Buddha primarily rejected the authority of Tradition ('Scripture'), and rejected *en passant* those who engaged in God-discourse (*Ishwaravadins*), and talk of Creation. Seven hundred years later, Nagarjuna rejected this more forcefully. More than a thousand years later, when the doctrine of God as the Creator started being propagated in India by Advaita Vedantins, probably under Syrian Christian influence, the Buddhists thoroughly refuted it in all its forms, including the idea of God as Intelligent Time. Buddhism spread to S. E. Asia (where it still survives in its traditional form of Theravada), to China and Japan on one side (where it survives in its more adaptive forms like Zen), and to Syria on the other side of India, and probably deeply influenced early Christianity. The Buddha was accepted as a Christian saint (St. Jesophat) by Eastern Christian sects, and also in an embarrassing Papal error by Western Christianity. The Buddha, in one of his rare predictions, had predicted the decline of Dhamma in five hundred years, and Buddhism was driven out of Syria, Iraq, and Persia by Zoroastrianism, and out of South India by the rise of Advaita Vedanta, and the rise of God-worship and the construction of a religious hierarchy after Śankara (ca. 9th century). About eight hundred years ago, ca. 1192, Nalanda one of the two major Buddhist universities in North India, which attracted students from as far off as China for hundreds of years, was destroyed by invading Muslims, and the few surviving Buddhists fled to Tibet. In modern India, Buddhism was revived by Ambedkar, a member of the Constituent Assembly and a backward caste leader, who converted to Buddhism and urged other members of backward castes to do likewise.

**Cantor,** Georg (1845–1918). Mathematician best known for his work on the theory of sets, and on how to count the elements in an infinite set.

**Chuang-tzu** ( b. –369, d. –286). Major exponent of Taoism, and opponent of Confucianism, whose work that bears his name is considered more definitive than that of Lao-tze, the founder of Taoism. The butterfly story comes from that book.

**Curie**, Marie (1867–1934). Famous for the discovery of radium, the ethical refusal to patent it, and for winning two Nobel prizes. Nominated Poincaré for the Nobel prize.

**Cārvāka.** A generic term for the 'people's philosopher', who articulated bitter truths, rejecting both the authority of tradition and the belief in another world. They were frowned upon by all other schools of thought in India, and the Buddha himself, possibly because of the fertility rites that they encouraged. We know of them only through their opponents. The first mention of Cārvāka is in the *Mahabharata* epic, where he is depicted as a man who stands up and condemns Yudhisthira, during his coronation, for having killed his teacher and brothers to obtain the crown; this Cārvāka was declared a demon and an enemy agent, and killed on the spot. The traditional date for this is ca. –1000.

**Constantine** (d. 337). Pagan Roman emperor, reportedly converted to Christianity, and baptised just before his death. He was superstitiously convinced by a priest that the sign of the cross on his flag was the real 'cause' of his martial victories; hence he extended state support to Christianity. (This is part of the 'fraud' to which Gibbon alludes.) He convened the first council of Nicaea to ensure religious peace in his empire, and resolve the religious disputes through collective authority.

**Darwin,** Charles Robert (1809–82). Famous for the theory of evolution. Karl Marx wanted Darwin to write a foreword to *Capital,* unaware that Darwin had modelled his theory on Malthus, a priest whose sellout to rich merchants is also condemned for 'school-boyish plagiarism' in *Capital*. It is, therefore, not surprising that social Darwinism is as racist, ill-founded, and empirically false as Malthus' ideas about the relative rates of growth of population and food.

**Davies,** Paul C. W. (b. 1946). Did his Ph.D. in the absorber theory of radiation. Using the background material on time, he started off with an excellent expository book on *The Physics of Time Asymmetry*, which he followed with a number of other expository books, winning the Templeton award in 1995.

**Dirac**, Paul Adrian Maurice (1902–84). An original theoretical physicist, founder of quantum theory (the Dirac equation), winner of the 1934 Nobel prize in physics, and author of a classic text on quantum mechanics which is still used. He fearlessly used the delta function to handle infinities, possibly because of his background in electrical engineering, but opined that quantum field theory was a mere coincidence like the Bohr atom, until a better way to handle infinities (arising from, e.g., squaring that function) was found. He believed that the truth was beautiful, hence he thought the beauty of a theory was more important than its agreement with facts. While formulating his own (Fermi-Dirac) statistics, he rescued S. N. Bose from the oblivion imposed by the terminology of 'Einstein statistics'. (Einstein translated the paper by Bose into German, without pointing out some minor corrections, which he later independently published.) He used the large-number coincidences to construct a cosmological model in which the gravitational constant varied with time. In his seventies, he wrote an elegant introduction to the theory of relativity. Dirac's kind comments were decisive when I was in deep trouble for challenging my supervisor (for 'plagiarism') during my Ph.D.

**Drude,** Paul Karl Ludwig (1863–1906). Editor of *Annalen der Physik,* object of Einstein's fury in 1903.

**Einstein,** Albert (1879–1955). Einstein has the image of having been a super-genius and one of the greatest scientists of the century. This image is under great strain today because of the remarkably large number of frontline theories which he seemingly independently reinvented, sometimes even 'independently' reinventing the very terms (like relativity) used a short while earlier by celebrated authors in papers he claimed not to have read. Unlike Poincaré, but like many historians of science, Einstein did not, until his death, quite understand the full consequences of rejecting the aether (see Chapter 9, pp. 298–303).

**Eliot,** T. S. (1888–1965). Eliot is a celebrated English poet. He exemplifies how the cultural revolt against linear time may eventually return to the politics of the Western church.

**Faraday,** Michael (1791–1867). Untutored genius, who performed many key experiments in electromagnetic theory, and developed the intuitive idea of lines of force.

**FitzGerald,** George Francis (1851–1901). Known for the contraction effect about which he first published in *Science* (1889). This was of so little importance to him that when Lorentz wrote to him, he could not say whether his paper had been published by *Science*.

**Feynman,** Richard P. (1918–88). Was best liked for his *Lectures in Physics*, and the book *Surely you are joking Mr Feynman*. Expressed moral doubts about working on the atom bomb. Along with J. A. Wheeler, he proposed the absorber theory of radiation, a modified version of which was first used to formulate a tilt in the arrow of time. He also advocated Stueckelberg's proposal that positrons are electrons travelling back in time.

**Friedmann,** Alexander Alexandrovich (1888–1925). Wrote a key paper on cosmology in 1922, introducing the assumptions of homogeneity and isotropy, which we still cannot quite dispense with. All three Friedmann models correspond to the big-bang theory which they inspired.

**Galileo** Galilei (1564–1642). Forced by the Pope to recant from his position that the earth moved round the sun. Graciously pardoned recently.

**al-Ghazālī** (1058–1111). Celebrated Islamic traditionalist *and* Sufi. Used reason to destroy the arguments of the rationalists (Mu'tāzilāh) and also the philosophers (mainly Ibn Sīnā [Avicenna]), in a book called *The Destruction of the Philosophers*. Some of his sceptical arguments were later repeated by David Hume, who recognised them as unanswerable, but Ghazālī used them to establish the role of God as Creator. He valued ethical practice above reason, and his word is practically treated as law by the orthodox (Sunni) Muslims today.

**Gibbs,** Josiah Willard (1839–1903). One of the founders of statistical mechanics, along with Boltzmann. He reportedly applied these principles to the stock market to net a tidy fortune. He was one of the people whose work Einstein reinvented. His *Elementary Principles in Statistical Mechanics* was published in 1902.

**Gödel,** Kurt (1906–78). Gödel was a metamathematician: one who theorises *about* mathematics, rather than does mathematics. His paper which shattered Hilbert's dream was published in 1931. He wrote very few papers, but with each paper he sought to bring about a fundamental change in the existing thinking. This was true also of his cosmological model, challenging the extension of naive ideas of time to relativity on the 40th anniversary of relativity. He went mad in his last years, and died of self-inflicted starvation.

**Grossman,** Marcel (1878–1936). Einstein's friend; helped to get Einstein his job in the patent office. It was to him that Einstein turned for learning the absolute differential geometry they both used to restate the laws of gravitation. Was a popular teacher of mathematics at Berne, and wrote a very popular text.

**Hadamard**, Jacques-Salamon (1865–1963). French mathematician—famous for his proof of the prime number theorem—who gave the first example of chaotic motion at the turn of the century.

**Haldane,** J. B. S. (1892–1964). British geneticist, and Marxist. Moved to India and worked at the Indian Statistical Institute founded by P. C. Mahalanobis.

**Hawking,** Stephen (b. 1942). Hawking is famous for singularities, and *A Brief History of Time*. He is the Lucasian Professor at Cambridge. He is a member of various academies including the Papal Academy of Sciences.

**Heaviside,** Oliver (1850–1925). An electrical engineer who symbolically handled infinity in a way that was successful but not appreciated by most of his contemporaries. The Dirac delta function is obtained by applying his technique of differentiation to what is now called the Heaviside function. The fundamental change that this brought to the calculus is yet to be appreciated by most physicists who are still stuck with the old calculus.

**Hilbert,** David (1862–1943). He worked on the foundations of geometry during 1899–1903, and on theoretical physics from 1912–15. From 1918 onwards he remained involved with the foundations of mathematics, until Gödel proved in 1931 that Hilbert's approach was not feasible.

**Hooke,** Robert (1635–1702). Worked for the Royal Society. Came up with many intuitive ideas which he did not always develop systematically. He was rather unfortunately treated by his contemporaries, and subsequent historians of science for two centuries, but has again become important as a tool against Newton.

**Ibn Sīnā** (980–1037). He argued for a helically quasi-cyclic time in which creativity is all-pervading, and the soul creatively evolves from minerals to the rational soul that only humans possess.

**Ibn Fārid** (1181–1235). Sufi and Arab poet who abandoned a career in law to live a solitary life near Cairo, in the Muquattam hills. His best known collection of verse is the *Nazm as-suluk*.

**Joyce,** James (1882–1941). Well-known Irish author; treated language and time in many diverse ways in his books, particularly *Ulysses* and *Finnegan's Wake*.

**Kant,** Immanuel (1724–1804). Well known German philosopher and theologian who taught a truce between science and religion.

**Keynes,** John Maynard (1883–1946). Neo-classical economist elected to the Royal Society. He bought Newton's papers at the Sotheby auction, and a long-term consequence of this was that some of Newton's papers finally came into the Cambridge library as part of Keynes' papers, after his death.

**Laplace,** Pierre Simon, Marquis de (1749–1827). This famous French mathematician was Napoleon's teacher, and lived very well through several revolutionary changes of government. To explain the concept of probability he invented the 'Intelligence' now known as Laplace's demon, possibly because of his response to Napoleon, described in Chapter 6, Box 3, p. 174 ff.

**Larmor**, Joseph (1857–1942). Became well-known for his Adams Prize essay on *Aether and Matter*, later published as a book. Did work on the theory of electrons, roughly comparable to that of Lorentz.

**Leibniz,** Gottfried Wilhelm (1646–1716). Mathematician and philosopher, involved in a priority dispute with Newton over the origin of the calculus. This three-century-old dispute has now ended with the discovery that the calculus was already invented by the time of the 14th–15th century Kerala mathematician, Madhava of Sangamagrama, whose use of 'Taylor's' series to compute precise sine and cosine values was widely disseminated in the 1501 manuscript the *Tantrasangraha* of Neelakantha, and the ca. 1530 manuscript, the *Ganitayuktibhāsā* of Jyesthadeva, probably brought to Europe by some Jesuits.

**Lenard**, Philipp (1862–1947). A physicist whose work fascinated Einstein when his girlfriend Mileva had to face both her exams and the birth of an illegitimate child.

**Lorentz,** Hendrik Antoon (1853–1928). Introduced, independently of Fitzgerald, the contraction hypothesis to explain the null result of the Michelson–Morley experiment. Shared the 1902 Nobel prize in physics with Pieter Zeeman. Was urged by Poincaré in 1900 not to make *ad hoc* explanations, but to adopt a single unified explanation. Introduced the idea of 'local time' but admittedly did not realise its conceptual significance.

**Mahavira** (b. –599?, d. –527). A contemporary of the Buddha, and teacher of the Jains. He taught asceticism and extreme non-violence, so that his followers had to invent a theory of indirect causation to justify the incidental violence that may be needed to survive or to eat cooked food. A slight extension of this enabled them to integrate well with the society, and some of the richest people in India are Jains. They engaged in bitter debates with Buddhists, especially over the role of intention in judging an act.

**Marx,** Karl (1818–83). Visionary author of *Capital* and joint author of *The Communist Manifesto*. He explained how the surplus produced by labourers was appropriated by capitalists, and argued that such a state of affairs, requiring the ignorance of the labourer, could not long continue. Inspired by his vision, people all over the world revolted against capitalism, so that capitalists have invested huge amounts in propagating all kinds of falsehoods and half-truths directed against him and his followers.

**Maxwell,** James Clerk (1831–79). Unified the theories of electricity and magnetism and calculated the speed of light. It was his suggestion, published posthumously, which led to the Michelson–Morley experiment.

**Michelson,** Albert Abraham (1852–1931). Believed that very precise experiments were necessary because future developments in physics would affect only the seventh decimal place. Awarded the Nobel prize. Nominated Poincaré for the Nobel prize.

**Michelson–Morley.** Two people joined together by a common experiment first performed during five days in July 1887. Michelson's aim was to discriminate between the competing aether theories of Fresnel and Stokes by conducting very precise experiments. Most physics textbooks misrepresent this as an experiment to measure the speed of light. The experimenters concluded in favour of Stokes' theory, a conclusion which Lorentz could not swallow because of the now-obvious mathematical absurdity of Stokes' theory.

**Miller,** Dayton Clarence (1866–1941). Miller repeated the Michelson–Morley experiment, to arrive at the opposite conclusion in 1925. For this he received a prize of a $1,000 from the American Association for the Advancement of Science. But his experimental claim was so widely disbelieved that no one even bothered to refute it for many years. His data were subjected to statistical tests only in 1950.

**Morley,** Edward Williams (1838–1923). Dedicated experimenter and Michelson's partner in the famous experiment.

**Minkowski,** Hermann (1864–1909). Einstein's teacher. Invented and polemically introduced the term spacetime in 1909 for what Poincaré had called 4-dimensional space in his paper of 1905.

**Newton,** Isaac (1642–1727). His father died on 6 October 1642. Author of the *Principia*. Widely regarded as one of the founders of physics. Jesuit priests used his theory of the solar system to dazzle the Chinese with their accurate computation of planetary movements, at a time when Europe was poor and lagged in most spheres of technology behind China, India, and the Arabs. Newton's theories held sway for two and a half centuries, and he was elevated to nearly the status of God. However, ever since the publication of parts of his heretical theological manuscripts, an easily noticeable amount of effort has been made to rake up as much 300-year-old muck about him as is possible. The last page of Stephen Hawking's *A Brief History of Time* provides an example.

**Nietzsche,** Friedrich (1844–1900). Nietzsche argued for the German aristocracy, and against socialist ideas of equality—which latter he regarded as Christian. He fell into Augustine's trap, and mistook quasi-recurrence for eternal recurrence. Eternal recurrence was the 'very centre' of his thinking as elaborated by Heidegger. This idea was used in the form of the (wrong) swastika symbol by the Nazis.

**Origen** (ca. 185–254). A great teacher of the early (ante-Nicene) church. See text, p. 38.

**Penrose,** Roger (b. 1931). Oxford mathematician, and an examiner for Stephen Hawking's Ph.D. thesis. Originally introduced singularities to prove that even non-spherical stars collapse into black holes, if they are massive enough. (It was this idea that was later extended by Hawking.) Author of *Emperor's New Mind*, and *Shadows of the Mind*, asserting that mathematical truths are universal and 'out there', indicating the reality and universality of his Platonic world of ideas.

**Planck,** Max Karl Ernst Ludwig (1859–1947). Influential editor of the *Annals of Physics*, and one of the founders of quantum theory. Identified Lorentz and Einstein as the inventors of the theory of relativity.

**Poincaré,** Jules Henri (1854–1912). French mathematical genius, and a popular expositor of science, also stated the complete theory of relativity ahead of Einstein. Poincaré's recommendation was sought to get Einstein his first academic job at the ETH Zurich. Poincaré also proved the recurrence theorem, and observed that chaos reconciled determinism with chance. His criticism of Hilbert's foundational programme for mathematics was amongst the factors that motivated Hilbert to identify consistency as a key requirement. He explicitly used the idea of refutability later championed by Popper. A childhood attack of diphtheria left him with physical disabilities which he turned to his advantage—unable to see the blackboard, he did all calculations in his head. He was excessively modest and, instead of claiming, generously gave credit to others for his own work—e.g., the automorphic functions he named after Fuchs or the group of transformations he named after Lorentz.

**Popper,** Karl (1902–94). Philosopher of science, most well-known for his criterion of *falsifiability*: a thousand experiments cannot prove a theory right, but one decisive experiment may prove it to be wrong. He used this criterion to separate science from non-science.

**Prigogine,** Ilya (b. 1917). Won the 1977 Nobel prize in chemistry. Has done extensive work on thermodynamics of open systems and dissipative structures. Joint author of *Order out of Chaos*. He believes that physics need not be changed to establish entropy increase, and that searching ever-new mathematical techniques will eventually do the trick.

**al Rāzī,** Abu Bakr Muhammad Ibn Zakariaya' (865–932). Persian philosopher, considered to have been the greatest physician of the Islamic world. His significant medical books like *Kitab al-Mansuri* were translated into Latin from the 12th century, and used as standard medical texts for some four centuries in medieval Western universities. In another book, *Kitab al hawi,* he surveyed many early systems of medicine.

**Rumi,** Jalal ud Din (1207–1273). Persian mystical poet whose famous collections of poems include the *Masnawi*, the *Diwan-i-Shams-i-Tabriz*, the *Diya-al-Haqq*.

**Shah Jehan** (1592–1666). Moghul Emperor 1628–58 who ordered the building of the Taj Mahal, as a tomb for his beloved Mumtaz Mahal.

**Schwarzschild,** Karl (1873–1916). Obtained the first rigorous solutions (black-hole solutions) of the gravitational field equations.

**de Sitter,** William (1872–1934). Proposed several cosmological models, one with closed time-like curves, and one known as the Einstein–de Sitter model. Ahead of Hubble, he related cosmic expansion to stellar redshift.

**Spengler,** Oswald (1880–1936). A high-school teacher who abandoned his position, to live a penurious life writing *The Decline of the West*, to communicate this grand idea that he had. His communication was an instant success, and his forecasts still continue to trouble sensitive Americans like Gerald Holton. Toynbee, in his monumental work, laboriously reworked the same basic idea, in a more parochial way that Spengler had rejected.

**Tipler,** F. J. (b. 1947) A mathematical physicist at Tulane University in the USA, who has actively participated in many controversies, such as one claiming that intelligent extra-terrestrial life cannot possibly exist in the galaxy.

**Toynbee,** Arnold Joseph (1889–1975). Historian and author of the twelve-volume *A Study of History*. The abridgement into 2 volumes captures the key ideas in Toynbee's own words. Some of the original ideas are like this: the disintegration of civilisations has a rhythm of 3½ notes on the musical scale: rout-rally-rout-rally-rout-rally-rout.

**Thorne,** Kip (b. 1940). Relativist at Caltech, and a student of Wheeler, worked in many areas including shock waves. Wrote an influential text on relativity along with Wheeler. More recently he became prominent for his work on time travel.

**Turing,** Alan. (1912–54). British mathematician and logician, initially conceived his machine as a computing device that would infallibly recognise undecidable propositions. Concluded that it would need an infinity of time, i.e., that his machine would not halt on an undecidable proposition.

**Wells,** H. G. (1886–1946). The father of modern science fiction, studied under T. H. Huxley. *The Time Machine*, whose author crash-lands in 802701 was his first major novel.

**Wheeler,** John Archibald (b. 1911). Worked with the team that designed the first hydrogen (fusion) bomb in the USA. Teacher to a generation of influential physicists including Feynman and Kip Thorne. Proposed, along with Feynman, the absorber theory of radiation. Proposed the idea of quantum foam used by Thorne to make time travel plausible.

**Whitehead,** Alfred North (1861–1947). Joint author with Bertrand Russell of the *Principia Mathematica*. Believed in a 'process view' of time, along with Henri Bergson.

**Whittaker,** Sir Edmund Taylor (1873–1956). Elected a Fellow of the Royal Society in 1905 for his work on the Laplace equation and for having originated the confluent hypergeometric function, still widely used in mathematical physics. By that time he had already written a text on mathematical analysis, and a treatise on classical dynamics. The second volume of his *History of Aether and Electricity* published in 1953, 43 years after the first volume, was intended to cover the new developments in the first quarter of the 20th century.

**Wigner,** Eugene Paul (b. 1902). Dirac's brother-in-law and winner of the Nobel prize for Physics in 1963. He pioneered the use of symmetry groups in physics. His basic observation of 1935, which he proved in 1971, established that quantum probabilities are fundamentally different from classical probabilities. In 1967 he published two papers asserting (incorrectly) that one could continue with instantaneity in the presence of advanced interactions.

**Zeeman,** Pieter (1865–1943). Dutch physicist who observed in 1896 that if sodium is burnt between strong magnetic poles, the sharp yellow lines (D-lines) in its spectrum are broadened (through splitting into multiple lines). Awarded the Nobel prize in 1902, jointly with Lorentz.

# Dates

*A 'non-linear' chronology of human beliefs about time covered in this book.*

< –600, throughout the world. Belief in life after death in the physical context of quasi-cyclic time.

ca. –600 to ca.– 450, India. Rejection of quasi-cyclic time. Lokāyata: immediate present as the only reality. Rise of materialism, and collapse of values: e.g., Ajātashatru seizes kingdom by chaining his father Bimbisāra, and allowing him to starve to death. Seeks a convincing answer to the rewards of asceticism in this world.

ca. –500, India. The Buddha expounds a new idea of 'causation': *paticca samuppāda* (conditioned coorigination) and its relation to the 'Law' (*Dhamma*), and to a truly democratic social order (*samgha*) and the compassionate Way of Life (Middle Way), beginning with five listeners at Gaya. Mahavira teaches extreme non-violence.

ca. –450, India. Pāyāsi, the sceptical king, explains his 40 experiments with life after death, but converts to Buddhism after a long debate with Kumara Kassapa, the boy-Wanderer, and disciple of the Buddha.

ca. –399, Athens. Plato's character, Socrates, peacefully consumes hemlock, firmly believing in life after death, and chides his well-wishers for their sorrow.

ca. 200, India. Nagārjuna argues the absurdity of the belief in God and Creation. Regards the world as flux. Reassertion of conditioned coorigination and the Middle Way. Beginning of the *sunyavāda* philosophy currently incorporated in Zen Buddhism.

ca. 250, Alexandria, Africa. Origen teaches quasi-cyclic time mentioned in the Bible, along with one-ness with God, both accepted by the ordinary people as well as the scholars of Alexandria.

ca. 325, Istanbul. Constantine convenes council of Nicaea to decide what good Christians ought to believe. Athanasius prevails over Arius who is declared a heretic; the calendar is standardised to fix the dates of Easter.

ca. 391, Alexandria. Burning down of the magnificent temple of Seraphis and the adjacent Great Library of Alexandria by rampaging Christian mobs, led by Bishop Theophilus who was later declared to be a saint.

ca. 400, Thagaste, Africa. Augustine's rejection of quasi-cyclic time through confusion with eternal recurrence. The birth of the dichotomy between 'linear' and 'cyclic' time, and the doctrine of the eternal estrangement of Man from God in Western Christianity.

ca 415, Alexandria. Hypatia lynched in a church by a Christian mob sent by Bishop Cyril of Alexandria, Theophilus' nephew. Cyril is subsequently sainted.

ca 460, Proclus of Alexandria composes a remarkable work explaining mathematics, especially geometry, as a religious discipline. Attributes authorship of some novel aspects of his work to a Euclid of Alexandria, who lived seven centuries before him but somehow remained unknown to *all* earlier commentators on geometry.

ca. 529, School of Alexandria shut down by Justinian's edict banning the teaching of philosophy throughout his empire. Many scholars flee to Iran.

542–553, Istanbul. Justinian curses 'cyclic' time. Convenes the 5th Ecumenical Council which concurs. This solidifies the stereotype identifying 'cyclic' time with 'pagans' and 'linear' apocalyptic time with Christianity.

499, Ujjain, India. Aryabhata completes his *Aryabhatīya*, accurately setting out the length of the sidereal year and the dimensions of the earth, and arguing that the earth revolved on its axis. Among very many other things, he also gave a table of 24 sine and cosine values, and a value of $\pi$ accurate to 5 decimal places.

ca. 500, University of Nalanda, India. Dinnāga teaches a new logic of the Wheel of Reason, introducing logical quantifiers in a way compatible with the Buddhist teaching of transitoriness and conditioned coorigination. Bhadrabahu the Junior formulates his ten-limbed syllogism.

ca. 750, North India. Decisive rejection of Creation by a variety of possible creators, including Time, reasserted by the Buddhists Śāntarakṣita and Kamalasīla.

ca. 750, India, especially South India. Rise of Advaita Vedanta. Reassertion of quasi-cyclicity by Adi Śankara of Kaladi.

ca. 750–850, Baghdad. Assertion of quasi-cyclicity and divine unity by Sūfī-s. Perhaps under Advaita Vedantic influence, Abu Yazīd al Bistāmī asserts 'I am God, so worship me'.

ca. 913, Baghdad. The Sūfī, al-Hallāj whipped, mutilated, crucified for 3 days, and then decapitated for asserting 'I am the Truth'. Composes beautiful verses on the gibbet.

ca. 750, Basra. Rise of Mu'tazilah school of Islamic rationalists. Seek to deduce everything from the two premises of divine unity and justice.

ca. 825, Baghdad. Attempt to enforce the Mu'tazilah line of thinking by the State.

ca. 900, Baghdad. al-Ashārī, atoms and accidents used to consolidate the tradition needed for Abbasid jurisprudence.

ca. 1000, Baghdad. Rise of philosophers in Islam. Ibn Sīnā (Avicenna) asserts helical quasi-cyclicity. Al-Razi (Rhazes) speaks of the 'Wheel of Birth'.

ca. 1100, Baghdad. Destruction of the philosophers in Islam by al-Ghazālī; assertion of ontically broken time. Rise of Sūfī doctrine of Grace. Baghdad falls to Moghuls.

ca. 1180, Seville. Ibn Rushd (Averröes) attempts to refute al-Ghazālī.

ca. 1200. Ibn 'Arabī and Rūmī poetically continue the idea of helical quasi-cyclicity, creative evolution, and mystic union with God.

ca. 1192, India. Sack of the University of Nalanda by Bakhtiyar-i-Khalji. Nalanda's seven storied library razed, and all manuscripts accumulated over a thousand years burnt; survivors flee to Tibet. Bakhtiyar-i-Khalji pursues them, but is defeated and returns with only a hundred men. Eclipse of Buddhism in India. Rise of Sufism and Bhakti.

ca. 1255, Paris. First universities commence in Europe. Censored form of Ibn Rushd's commentary on Aristotle accepted as a text at the University of Paris. Debate on Rationality and Providence inherited by Christian theology from Islam. Misrepresentation of al-Ghazālī. Thomas Aquinas repeats some of Ibn Rushd's arguments, in his tract against Averröes, and partially rejects Providence in trying to reconcile Averröes' 'Aristotle' with Augustine. Rise of Scholasticism in Europe.

1453, Istanbul. Fall of the Byzantine Empire. Church of St Sophia converted to a mosque. Greek translations of Arabic texts diffuse into Europe, inspiring the Copernican revolution.

ca. 1400. Mādhava of Sangamagrāma near Cochin, a member of the Aryabhata school of mathematics and astronomy, uses the 'Taylor-series' expansion of calculus to calculate sine tables to 9 decimal-place accuracy.

1498. Vasco da Gama, not knowing celestial navigation, reaches Calicut, near Cochin, from Melinde in Africa, with the help of an Indian pilot Malemo Cana.

1501. Neelkantha Somayaji, another follower of Aryabhata, completes his book *Tantrasangraha*. He used a 'Tychonic' model of planetary orbits.

ca 1530. Jyeshtadeva compiles the *Ganitayuktibhāsā*, setting forth the rationale used by Madhava.

ca 1540, Goa. All Hindu temples in Goa destroyed.

ca. 1555. Inquisition set up in India in the Portuguese territory of Goa.

1567. Spanish government offers a prize for anyone who can provide a reliable method of navigation.

1581. The Jesuits prepare a mission for Akbar's court, in the hope of controlling India by converting Akbar, a la Constantine. The Jesuit Matteo Ricci writes from India about his search for an 'intelligent Brahmin or an honest Moor', to explain the local ways of keeping time.

1582 (5 October). Gregorian calendar reform: Europe needs a good calendar to tell the latitude from measurement of solar altitude at noon. This requires a change in the date of Easter. Pope Gregory issues a bull based on the changes proposed by the committee headed by Christoph Clavius, which collected information on the calendar from various sources including India.

1598. The problem of determining longitude persists, and the Spanish government increases its reward. Galileo competes unsuccessfully for this reward for 15 years.

1636. The Dutch government offers a reward for a method of navigation at sea.

1640, Rome. Galileo forced to recant by the infallible pope.

1666. Colbert writes to leading scholars in Europe, offering rich rewards for a method of navigation. French Royal Academy formed from the replies he received. British Royal Society formed a little later.

ca. 1665. Cambridge. Isaac Barrow reasserts the dichotomy between 'linear' and 'cyclic' time.

1672. Picard redetermines the size of the earth, correcting Columbus' motivated rejection of the earlier accurate Indo-Arabic estimates. Solves the problem of determining longitude on land, using the telescope to improve the earlier Indo-Arabic method of eclipses.

ca. 1685, Cambridge. Newton publishes *Principia*. Thinks that God has revealed to him His Laws, and that providential interventions are still needed.

1711. British government declares a prize for determination of longitude at sea.

1762. With a chronometer (robust and accurate clock), a carpenter called Harrison claims the British prize for determining longitude at sea.

ca. 1800, Europe. Able to measure time accurately, and navigate, Europe first gains a lead in technology, and starts prospering. Rise of racism.

ca. 1800, Paris. Laplace proves the stability of the solar system; banishes Providence, and inadvertently gives birth to Laplace's demon.

ca. 1658, Delhi. Moghul prince and Sūfī, Dārā Shūkoh translates the Upanishads into Persian.

ca. 1808, Hamburg. Schopenhauer reads a retranslation of the Upanishads from Dārā Shūkoh's translation. Calls it the greatest comfort of his life.

ca. 1880, Germany. Nietzsche uses physics to prove statistical recurrence. Proposes a superman needed to transcend eternal recurrence.

1858 (1 July), London. Charles Darwin and Alfred Russel Wallace jointly communicate the theory of evolution to the Linnaean Society.

ca. 1885, England. The debate between T. H. Huxley and the Bishop Wilberforce on the theory of evolution. Karl Marx's *Capital*, Vol. II published.

ca. 1895, London. H. G. Wells' *Time Machine* published.

1898–1905 (5 June), Paris. Complete theory of relativity formulated, named, and published by Poincaré. Decisive rejection of Newtonian time.

1905 (September), Berne. Identical theory of relativity, with the same name, published by Einstein in *Annalen der Physik* (sent end-June 1905), then a patent clerk, who admitted seeing only some of Poincare's works, raising profound legal questions about priority in patenting. Einstein claimed he independently invented the theory in five weeks.

1915 (15 November), Gottingen. David Hilbert formulates the equations of the general theory of relativity and communicates this to Einstein, who announced the independent rediscovery of essentially the same equations five days later.

1931. Publication of Gödel's proof of the impossibility of Hilbert's metamathematical programme of mechanical proofs. Gives a definition of 'mechanical'.

1945, Japan. Atomic bomb dropped over the civilian population in Hiroshima, demonstrating a practical application of relativity. Claimed as a great success by the United States. Einstein responds indifferently.

1948. The first part of Wheeler and Feynman's article on the absorber theory published. (The second part of the article had already appeared in 1945.)

1948. Publication of Gödel's paper on cosmology presented in a symposium to celebrate the 40th anniversary of relativity.

1951. First resolution of the infinities of quantum electrodynamics.

1963. Publication of the Lorenz model for chaos.

ca. 1968. Experiments to detect tachyons.

ca. 1980. Scientists write popular accounts implicitly and explicitly bringing out the unity of science and 'religion' (= Western Christianity). Stephen Hawking's *A Brief History of Time* published. This new harmony requires an emphatic rejection of quasi-cyclicity and acceptance of creation with a bang in scientific theory.

1985. Publication of Thorne's paper claiming the possibility of time machines.

1990–91. End of the Cold War. Fall of the Berlin Wall. Collapse of the Soviet Union.

1993, Vatican. The Pope pardons the dead Galileo, signalling a remarriage between science and 'religion'.

# Glossary

**action by contact.** The belief that interacting particles must be in physical contact with each other.

**aether.** 1. An imaginary fluid whose particles provided contact between separated interacting bodies (like the moon interacting with the sea to produce tides). 2. By implication a reference to define absolute velocity.

**anathema.** The great curse of the church, excommunicating and damning a doctrine or person.

**anticipation.** The time-symmetric analogue of memory; future-dependence as opposed to history-dependence.

**apocalyptic time.** Time as supposedly revealed to 'prophets', especially of the doomsday kind. Apocalyptic time begins with creation, focuses on the doomsday—when God apocalyptically reveals himself to all creatures—and then bifurcates to heaven and hell.

**Arian.** A supporter of Arius, in the dispute between Arius and Athanasius in the Council of Nicea (First Ecumenical Council). By implication, one who rejects the Nicene creed, hence the Roman Catholic and Protestant churches, and would like to revert to the faith of early Christianity.

**bilking.** Cheating in the game of cribbage. By implication, producing something from nothing.

**capitalism.** A way of organising society so that means of production are privately owned. The traditional merchant only trades commodities produced by others; the capitalist controls the production process. Control of the production process allows him to enter into a systematically unequal exchange with labour: paying them the minimum needed for their subsistence and appropriating the surplus that they produce. Systematically unequal exchange leads to a concentration of wealth (capital), hence power, in the hands of a few individuals. While Karl Marx emphasised the unjust nature of this organisation, and its consequent instability, Max Weber, in a Machiavellian move, emphasised its harmony with the 'Protestant ethic': Protestants saw wealth, like caste, as a sign of divine grace. Ronald Reagan summarised the resulting system of 'morality': 'rich people are good because they have money'.

**causality.** 1. (Physics.) The belief that every event has a prior cause. This 'cause' is usually identified with initial data. 2. (Morality.) The belief that prior causes of events are the choices and actions of individual human beings.

**chance.** As in games of chance like roulette, where individual outcomes cannot be systematically calculated, but a large number of outcomes have a pattern regular enough to be measured by probability—so that the house is assured of its profit!

**chaos.** Sensitive dependence on initial conditions makes it difficult to predict the future state of a chaotic system. In some situations, a chaotic system may behave in an orderly way corresponding to the mythical emergence of order from chaos.

**Christianity, official.** *See* official Christianity.

**correlation.** Mutual relation or 'co-relation' (usually linear), distinct from a causal relation. For example, a student's marks in mathematics may correlate with her marks in language; but good marks in one subject are not the *cause* of better marks in another.

**complexity.** Specifically algorithmic complexity. For a sufficiently complex system, an algorithm (rule-based procedure) may need infinite time for successful execution.

**counterfactual.** The use of propositions contrary to fact to enable allocation of credits by implication, e.g., 'Had there been no British Empire, India wouldn't have been united.'

**diastema.** An interval or space between two successive musical notes, which could go unperceived. Hence, the unperceived, timeless gap between two discrete instants of time.

**declination.** Angle which measures the north-south displacement of a celestial body (sun, moon, stars) relative to the celestial equator. (The celestial equator is the circle in which a plane through the earth's equator cuts the celestial sphere.)

**deontic logic.** De-ontic logic concerns de-ontic or 'ought'-type statements (rather than ontic or 'is'-type statements). Hence, a logic suited to moral reasoning.

**dichotomy.** Division into a pair (of opposites), such as the moral dichotomy which divides people into 'good' and 'bad'. A bad dichotomy results in false similarities and conflicts: one may club as 'bad' an occasional liar with a mass murderer. A dichotomy between science and religion clubs all religions into one category. The dichotomy between 'linear' and 'cyclic' time clubs vaguely similar pictures of time into one class.

**ecumenical.** From the Greek *oikumene* meaning the inhabited world; hence something which includes the entire inhabited world. An ecumenical council, therefore, was one which supposedly had representatives from the entire inhabited world. In practice, since the church historian Eusebius, the term has always been used in a way that excluded most of the inhabited world.

**entropy.** A measure of disorder, explained in the text (Chapter 6).

**epistemic.** Pertaining to knowledge.

**epistemically broken time.** The belief that a connection between two successive states of the world may exist (e.g., in physical law or in the mind of God) but may not be known.

**eschatology.** From the Greek *eschaton* (= last) + *logos* (= knowledge). Hence, knowledge of last things, specifically the four last things in Christian theology: death, judgment, heaven, and hell.

**equinox.** From *equi* (= equal) + *noct* (= night), hence equal nights. 1. Either of the two times in the year when the Sun is directly above the equator, and days and nights are of equal duration. The vernal or spring equinox, around 21 March, occurs when the sun moves north across the equator, and the autumnal equinox around 23 September, when the sun crosses the equator, moving south. 2. Either of the two points in the sky where the path of the sun intersects the celestial equator. In this sense, the vernal equinox is also called the first point of Aries, and the autmnal equinox is also called the first point of Libra.

**exegesis.** Exposition of the intended meaning of a difficult passage of the Bible.

**finger measurements.** A traditional way of measurement, also used to determine latitude by measuring the (angular) altitude of the pole star above the horizon, using the fingers of one hand held at a distance of one span measured from the observer's nose.

**gee.** On the surface of the earth, freely falling bodies (neglecting air resistance, etc.) fall with a constant acceleration, traditionally represented by the symbol *g*. One gee is thus the normal acceleration experienced on earth, and two gees is twice that.

**gnomon.** From the Greek *gnomon* (= indicator). Stick stuck vertically on the ground to cast a shadow, usually to determine time as in a sundial.

**hermeneutics.** From the Greek *hermeneus* (= interpreter; in Greek mythology, Hermes carried messages between the gods). Hence, study of the principles used to interpret the Bible, as distinct from its practical exposition (= exegesis).

**homoiousian.** From the Greek *homoios* (= like) + *ousia* (= substance, essence). Hence, one who believes that Christ is of like substance, but *not* identical, with God.

**homoousian.** From the Greek *homos* (= same) + *ousia* (= substance, essence). Hence, one who believes that Christ is not only similar, but identical with God.

**immortality.** The meaning varies with the context. In Western Christian theology, 'immortality' refers to eternal existence in the flesh after the day of judgment. With quasi-cyclic time, 'immortality' means eternal cessation of existence in the flesh.

**instantaneity.** The belief that the state of the world at the next instant is decided by its state at this instant. Hence the belief that physical law must be a differential equation (as distinct from, e.g., a delay or functional differential equation).

**man.** Certainly includes woman, but usually used in a way that includes also all of life. The English language, being sexist, offers no appropriate alternative to this word.

**Merchant.** The Merchant is obviously a metaphor for a capitalist, despite the danger that this metaphor obfuscates the very important difference between the Merchant and the capitalist, namely that the capitalist, unlike the actual traditional merchant, controls the production process.

**metempsychosis.** From *metem* (= change) + *psyche* (= soul), hence a change of soul or rebirth. This euphemism is objectionable since bodies, not souls, are supposed to change at rebirth.

**modus ponens.** A basic rule of inference. Also the name of a syllogism of Aristotelian logic, explained in the text and appendix, and much used in current mathematics. *See also* **syllogism**.

**official Christianity.** It is easier to explain this in terms of who is *not* an 'official Christian'. Those who believe that poverty is both unjust and man-made, and do not ascribe to God various social hierarchies and power relations are NOT 'official Christians'. This new term is needed since current sectarian classifications—'Protestants', 'Catholics', etc.—do not capture the point of view of this book, and there are various shades even within, say, Liberation Theology. The term does *not* automatically exclude those who hold office: Paulos Mar Gregorios, for example, held high office, but was not an 'official Christian'.

**ontic.** Concerning what really is.

**ontically broken time.** The belief that (at times) there really is no connection between two successive states of the world.

**order.** The negative of entropy (= disorder).

**pagan.** Originally, a 'villager, rustic, civilian, non-militant'. Christians who called themselves 'enrolled soldiers' of Christ, members of his militant church, applied this term to non-Christians, particularly in the Roman empire. Despite theological denials, this is one of those words which spells out the character of Augustinian Christianity as an imperial and urban religion of the Roman empire.

**phlogiston.** European scientific theories of heat in the eighteenth century associated this imaginary substance with combustion (fire).

**photon.** Particle of light. Also a wave.

**pre-existence.** Another euphemism for rebirth. By referring only to past lives, this leaves open the possibility that the present existence may still be the last one before apocalypse, as theologically required.

**probans.** Presumably an alternative spelling of 'probands'. From the Latin *probare* (= to probe, to test, to examine, to prove). A proband is an individual proposition chosen to study some generic trait. This term indicates the kinds of obscurities that arise when a Pali text translated into Tibetan is translated into English, by an Indian or Chinese translator who understands them using the Greek organisation of logic, and the Latin vocabulary with which that was studied in medieval Europe.

**proof.** A valid argument according to Euclidean or modern Western logic, defined and explained in the text and appendix.

**providence.** The belief that God acts through direct divine intervention. The belief in miracles.

**quasi truth-functional logic.** A logic in which truth-values may not be prescribed at all, in contrast to a 3-valued logic where a sentence may be 'true', 'false', or 'indeterminate'.

**rational theology.** 1. (Islam.) The belief that one must exercise one's mental faculty (*aql*) to understand the word of God (*kalām*) in the K'urān. Opposed by those who believed that God may intervene directly in the world. Hence rational physicians deduced their line of treatment from general principles. 2. (Western Christianity.) Conceived as the attempt to convince by argument (reason) those who did not accept the authority of the scripture. Hence the belief that God runs the world through laws which the world is obliged to obey, and not through acts of direct intervention.

**refutability.** Also called falsifiability, and championed by Popper; has two senses. 1. (Logical refutability.) An assertion is physically meaningful only if there are some circumstances in which it could conceivably be false. 2. (Empirical refutability.) An assertion is empirically refutable if an actual experiment can be carried out to test whether the assertion is true or false.

**ROM.** Read Only Memory. A program burnt into the ROM is a program with which the computer comes to life, when it is switched on. Analogous to genetically programmed reflexive behaviour.

**seif dunes.** From the Arabic 'seif' meaning sword. Huge orderly chains of sand dunes, visible from space, and too large and unlike the dunes formed by wind action.

**SF.** Depending upon the context, this abbreviation denotes science fiction, or science fantasy, or speculative fiction.

**sidereal.** From the Latin *sidus* (= constellation, star). Relative to the stars. The sidereal year is the time taken by the sun to return to the same position relative to the stars. This is *more* than 365 ¼ days, being 365 days 6 hours 9 minutes and 10 seconds, while the tropical year is less than 365 ¼ days, The traditional Indian calendar uses the sidereal year, while the Indian calendar approved by the Government after Independence is the Gregorian calendar, based on the tropical year.

**singularity.** Widely regarded as a beginning or end of time, but may not actually be either.

**solstice.** 1. Either of the two times in a year when the sun is farthest north or farthest south. At summer solstice, around 22 June, the sun reaches its maximum declination of about 23 degrees 27 minutes, since the rotational orbit of the earth is inclined to its orbital plane at an almost constant angle of about 66 degrees 33 minutes. At this time, the sun is directly above the Tropic of Cancer (latitude 23 degrees 27 minutes north). At the winter solstice around 22 December, the sun is directly above the Tropic of Capricorn (so it is summer there). 2. Either of the two points in the sky representing the sun's maximum deviation north or south.

**spontaneity.** Causal inexplicability, in principle. Differs from chance, for no pattern need emerge even in a large number of cases. Further, spontaneity creates order while chance is believed to destroy order (create entropy).

**stochastic.** From the Greek *stochastikos* (= to aim, to guess). Hence, concerning chance in the sense of probability.

**struthious.** Ostrich-like.

**supercyclic time.** The belief that time may be pictured as a circle. Analogous to a closed chain of causes. Also analogous to exact, eternal return, or an exactly periodic cosmos. Cannot be described naturally in natural language for reasons explained in the text.

**superlinear time.** The belief that time may be represented by numbers on the real line.

**syllogism.** An argument (or template for an argument) expressed using a (fixed) number of propositions, including a premise, and a conclusion. In Aristotelian logic the syllogism had three propositions.

**tachyon.** From the Greek *tachys* (= fast). Hypothetical particle that travels faster than light. Tachyons have many strange properties: for example an infinite force is needed to slow a tachyon down to the speed of light.

**teleology.** From the Greek *telos* (= end), hence the study of ends or final causes, related in Western theology to God's design of the world. More generally, a teleological explanation explains from future causes or purposes: e.g., the purpose of survival.

**tilt.** Abbreviation of 'a tilt in the arrow of time'. A picture of time in which most physical processes are history-dependent, but some are anticipatory.

**transmigration.** The migration of the soul across bodies, hence rebirth. Connotes *transmutation*, or a change of species, hence the possibility of the soul migrating to animal bodies and vice versa. Also connotes *transmogrification*: a strange or grotesque transformation.

**tropical year.** The tropical year of 365 days 5 hours 48 minutes and 46 seconds is the time taken for two successive occurrences of the vernal equinox. This is the year used in the Gregorian calendar.

**utilitarianism.** Originally the doctrine that the greatest good of the greatest number should guide conduct; reinterpreted as a doctrine of the intelligent pursuit of self-interest; and nowadays often used as a doctrine of plain selfishness.

**vernal equinox.** The equinoxes are the two days in a year when day and night are of equal duration. Vernal refers to the arrival of spring. This occurs around March 21, and relates to the date of Easter.

**West.** On the earth, east and west are relative, and Rome was to the West of Constantinople (Istanbul), the shorter way round the earth. The Roman church followed Augustine's theology, creating a division between Western and Eastern Christianity—a division that later broadened into a division between Western Christianity and everyone else. According to Toynbee, every universal state must have a universal church, and Western Christianity is the religion associated with the only surviving universal state. This is the West for which capitalism is a cultural value according to Huntington.

**world.** A logical world is 'all that is the case': a collection of propositions declared to be true, so that either a proposition or its negation is true.

**wormhole.** A ‘tunnel’ through spacetime which links otherwise distant regions. The tunnel is comfortable enough for human beings to travel through, so the wormholes that concern us are also called TWISTs: Traversable Wormholes In Space Time.

# Notes

## CHAPTER 1

1. Translation modified from Swami Prabhavananda and Frederick Manchester, trans., *The Upanishads: Breath of the Eternal*, Mentor, New American Library, New York, 1957, pp. 15–16.
2. George Gallup Jr. and William Proctor, *Adventures in Immortality: A Look Beyond the Threshold of Death*, Coorgi Books, London, 1984. Samples were stratified geographically, and by community size. The belief in this 'great American superstition' declined from 77 per cent in 1952, to 75 per cent (non-whites 54 per cent, non-Christians 37 per cent, Jews 17 per cent) in 1965, to 67 per cent (scientists 32 per cent) in 1981.
3. T. W. Rhys-Davids, trans., *Dialogues of the Buddha*, vol. 2, London, 1910, pp. 346–74. Reprinted by the Pali Text Society, *Sacred Books of the Buddhists,* vol. 2, ed. F. Max Muller, Routledge and Keagan Paul, London, 1977. Reproduced in *Cārvāka/Lokāyata: An Anthology of Source Materials and some Recent Studies*, ed. Debiprasad Chattopadhyaya and Mrinal Kanti Gangopadhyaya, ICPR, New Delhi, 1990, pp. 8–31.
4. J. L. Head and S. L. Cranston, eds., *Reincarnation: An East-West Anthology*, Theosophical Publishing House, Wheaton, 1968, p. 102.
5. Codex Vaticanus. In *Antiquities of Mexico*, ed. Lord Kingsborough, London, 1833–48, p. 240.
6. H. A. Giles, trans., *Selections from the Upanishads and the Tao-Te-King*, Cunningham Press, Los Angeles, 1951, p. 91. The butterfly, incidentally, is not a substitutable symbol. The Chinese word for soul is *hun*, connoted by the Chinese word and symbol for 'butterfly' (*huj*). See N. J. Giradot, *Myth and Meaning in Early Taoism*, University of California Press, Berkeley, 1983, p. 308. For a more recent review of Chinese ideas of life after death, see Gary Arbuckle, 'Chinese Religions', in Harold Coward, ed., *Life after Death in World Religions*, Sri Satguru Publications, New Delhi, 1997, pp. 105–24.
7. As recorded by Plato, *Meno*, 81–83. *The Dialogues of Plato*, trans. B. Jowett, vol. 7 of *Great Books of the Western World*, R. M. Hutchins, ed. in Chief, Encyclopaedia Britannica Press, Chicago, p. 180. As

a firm believer in this theory, Socrates peacefully sipped hemlock, chiding his followers for their sorrow.

8. Proclus, *A Commentary on the First Book of Euclid's Elements*, trans. Glenn R. Morrow, Princeton University Press, 1992, 45, p. 37.
9. Proclus, *Commentary on Euclid's Elements*, 47, p. 38.
10. From E. Dowden, *The Life of Percy Bysshe Shelley*, vol. 1, London, K. Paul Trench & Co., 1886; anecdote quoted from his friend Hogg. As quoted in J. Head and S. L. Cranston, eds., *Reincarnation: An East-West Anthology*, cited earlier, p. 129.
11. J. Ducasse, *Nature, Mind, and Death*, Open Court, La Salle, Illinois, 1951.
12. T. W. Rhys-Davids, trans., *Dialogues of the Buddha*, cited earlier, vol. 1, pp. 73–74; quoted in D. P. Chattopadhyaya, *Lokāyata: a Study of Indian Materialism*, People's Publishing House, New Delhi, 1973, p. 510. See also, Maurice Walshe, *The Long Discourses of the Buddha: A Translation of the Dīgha Nikāya*, Wisdom Publications, Boston, 1995, p. 96. Incidentally, this outburst was unconnected with the question posed by the philosopher-king Ajātasattu, who stated that this reply was as relevant to his question as a man when asked about a mango responds by talking about a bread-fruit tree. Ajātasattu's question is taken up in more detail in Chapter 11.
13. Majid Fakhry, *History of Islamic Philosophy*, Columbia University Press, 1970, pp. 156–60.
14. Krishna Chaitanya, *A History of Arabic Literature*, Manohar Publications, New Delhi, 1983, pp. 98–99.
15. Krishna Chaitanya, cited above.
16. R. A. Nicholson, trans., *Translations of Eastern Prose and Poetry*, Curzon Press, London, 1987, p. 155. See also Henry Corbin, *Cyclical Time and Ismaili Gnosis*, Keagan Paul, London, 1983. A controversy exists about Sufi beliefs in transmigration; see, e.g., Margaret Smith, 'Transmigration and the Sufi-s', *Muslim World*, **30**, 1940, pp. 351–57; Jane I. Smith and Yvonne Y. Haddad, *The Islamic Understanding of Death and Resurrection*, SUNY, Albany, 1981; A. J. Arberry, *Reason and Revelation in Islam*, George Allen and Unwin, London, 1957, pp. 38–39. For more details and the pointlessness of this controversy, see C. K. Raju, 'Time in Medieval India', in D. P. Chattopadhyaya and Ravinder Kumar, eds., *Science, Philosophy and Culture*, part 2, PHISPC, New Delhi, 1997, pp. 253–78, reprinted in *Indian Horizons*, **46**(4) and **47**(1), October 1999–March 2000, pp. 40–71.
17. Farid al-din Attar, *Muslim Saints and Mystics*, trans. A. J. Arberry, Arkana, 1990, pp. 117–18.

18. R. A. Nicholson, trans., *Studies in Islamic Mysticism*, Cambridge University Press, 1921, p. 257, emphasis mine. The emphasis suggests that the rejection of the theory was only partial.
19. J. M. E. McTaggart, *Some Dogmas of Religion*, London, 2nd ed., 1930, p. 125.
20. Those who find this difficult should naturally consult the excellent description by Lewis Carroll!
21. This point about everything being *exactly* the same has been an endless source of confusion in the West, because of its ideological connotations. In particular, the following remark of Eudemus of Rhodes attributes this belief to Pythagoreans: 'Everything will eventually return in the self-same numerical order, and I shall converse with you staff in hand, and you will sit as you are sitting now, and so it will be in everything else; and it is reasonable to assume that time too will be the same.' [H. Diels and W. Kranz, *Fragmente der Versokratiker*, 6th ed., Berlin, 1951, 58B34; cited by Milic Capek in *Encyclopaedia of Philosophy*, article on 'Eternal Return'.]
22. One could estimate this 'long time' at around 80 billion years. The physical significance of such a large time-span is, however, unclear: for example, there may be no proper clock by which to measure it, even if time does not 'stop' or start running backward. Even less does this figure have any subjective significance: for there can be no conscious appreciation of the time elapsed between death and rebirth.
23. F. Nietzsche, *Eternal Recurrence*, 33. Translation adapted from O. Levy, ed., *The Complete Works of Friedrich Nietzsche*, vol. 16, Foulis, Edinburgh, 1911, p. 253.
24. The Buddhists doubt the continuation of identity across two instants of time; but such doubts are postponed to Chapters 11 and 12.
25. See, for example, C. K. Raju, *Time: Towards a Consistent Theory*, Kluwer Academic, Dordrecht, 1994 (Fundamental Theories of Physics, vol. 65), chap. 4. Or, 'On Time IV: Thermodynamic Time', *Physics Education*, **9**(1), 1992, pp. 44–62.
26. *The Bhagvad-Gita*, trans. Swami Prabhavananda and Christopher Isherwood, Martin Rodd, Hollywood, 1945.
27. *The Vishnu Purana*, trans. H. H. Wilson, London, 1840, reprint, with an introduction by R. C. Hazra, Punthi Pustaka, Calcutta, 1961, chap. 3, pp. 19–24. The reduction proceeds through equations of the type '1 year of mortals = 1 day of the gods'. Astronomers in the Indian tradition justified this equation by appealing to the picture of a spherical earth, 'surrounded on all sides by creatures just as the bulb of the kadamba flower is by blossoms'. They regarded day and night as due to rotation relative to the

cosmic sphere, on a north–south axis, so that day and night at the poles are six-months each. The gods were supposed to stay on Mount Meru, located at the north pole, so that one day and night of the gods quite literally amounted to one year of humans! 'The gods see the Sun, after it has risen, for half a solar year.' Āryabhata, *Āryabhatīya* (*Gola* 6–7, 17), trans. K. S. Shukla and K. V. Sarma, Indian National Science Academy, New Delhi, 1976, pp. 118, 127. Varāhamihīra, *Pancsiddhāntikā* (13.27 and 13.9–13), trans. G. Thibaut and Sudhakara Dvivedi, reprinted by, Chowkhamba Sanskrit Series, Varanasi, 1968, p. 72, p. 70. Āryabhata (b. 476) firmly thought the apparent rotation of the cosmic sphere was an illusion, 'Just as a man in a boat moving forward sees stationary objects [on the bank] moving backward'. He defined that 'The rotations of the earth are sidereal days', and gave the duration of a sidereal day as 23 hours, 56 minutes, and 4.1 seconds. He regarded all this as only a way to construct an accurate calendar to measure time, though he thought time itself to be 'without beginning and end'.

28. D. A. Mackenzie, *Pre-Columbian Mythology*, Gresham Publishing Co., London, c. 1920. (No date given.)
29. Prabhavananda and Manchester, trans., *The Upanishads*, cited earlier, p. 118.
30. Majid Fakhry, *Islamic Philosophy*, cited earlier, p. 120.
31. J. L. Henderson and M. Oakes, *The Wisdom of the Serpent: The Myths of Death, Rebirth and Resurrection,* New York, Brazilier, 1963; reprint, Princeton University Press, 1990, p. 36.
32. E. A. Wallis Budge, *The Egyptian Book of the Dead*, Keagan Paul, London, 1901, p. 278.
33. There are various other symbols, like the Sun. All these symbols suffer from a cultural bias: among the Yorubas, names reveal the belief in life after death. The Yorubas may name a boy Babatunde, meaning 'Father has returned', or a girl Yetunde (Iyatunde) signifying 'Mother has returned'. See E. G. Parrinder, *African Traditional Religion*, Society for Promotion of Christian Knowledge, London, 1962, pp. 138–40. In Ghana, the name Abaibo, 'He has come again', has the same significance.

    There is also, in African traditions, a more general sort of belief in life after death, related to a different belief in time. Death does not mark the end of life because the past has not ceased to exist. In these traditions, the future, by contrast, practically does not exist; time moves backwards from experienced time (Sasa) to remembered time (Zamani). Death marks the gradual removal of a person from the Sasa to Zamani; the person retains individuality till there are people alive who knew him personally. After that the dead person loses individuality and moves into the realm of collective memory. See John S. Mbiti, *African Religions and Philosophy*, Heinemann, London, 1969. In Chapter 11, we compare this belief in the continued existence of the past with the Buddhist belief that the past events do not cease to exist so long as they retain their causal efficacy: isn't the individual partly the cause of the memories of the individual?

34. The phrase 'eternal return' is a favourite with Western authors: this oxymoron seems to mean that there is a time quite independent of events (hence a metaphysical sort of time), which stretches to infinity in the future, in which events repeat endlessly.
35. F. Nietzsche, *The Gay Science*, 341. Quoted in *Friedrich Nietzsche: Selected Writings*, Srishti Publishers, Calcutta (in association with Creation Books, London), 1998 [1996], p. 205. See also, O. Levy, ed., *The Complete Works of Friedrich Nietzsche*, vol. X, *The Joyful Wisdom* ('La Gaya Scienza'), Edinburgh, 1910, 2nd ed., pp. 270–71; and R. J. Hollingdale, trans., *A Nietzsche Reader*, Penguin Books, London, 1977, pp. 249–50.

## Chapter 2

1. *Cambridge Medieval History*, vol. II, *The Foundation of the Western Empire*, p. 440. St. Sophia, or the 'Great church', dating back to Constantine, was rebuilt in 551, the principal architects being Isidore of Miletius and Anthemius of Tralles. The main novelty is its huge dome which, seen from inside, seems to float in the air. The building was again rebuilt after an earthquake in 568, and still stands. Plundered by Latin Crusaders in the 14th c., it was converted into a mosque in 1453, when Constantinople fell to Mehmet the Conqueror, and into a museum (Hagia-Sophia museum) in 1935 by Kemal Ataturk.
2. The Nika riots so called because the crowds collected at the hippodrome kept chanting 'Nika', meaning victory. A. H. M. Jones, *Constantine and the Conversion of Europe*, Collier Books, New York, 1962. George Ostrogorsky, *History of the Byzantine State*, trans. Joan Hussey, Rutgers Univ. Press, New Brunswick, N.J., 1969, pp. 68–79.
3. E. Gibbon, *History of the Decline and Fall of the Roman Empire*, vol. 1, chap. 40. Vol. 40 of *Great Books of the Western World*, ed. R. M. Hutchins, Encyclopaedia Britannica, Chicago, 1952, p. 649 and sequel. Theodora's son from a previous liaison was never again heard of, and Gibbon hints darkly that she had him murdered, an inference so offensive that to refute it Arthur Conan Doyle wrote a whole speculative fiction story. 'The Homecoming' in *The Great*

*Tales of Sir Arthur Conan Doyle*, Magpie Books, London, 1993, pp. 726–40.

4. Particularly, a powerful ecumenical politician, Theodore Askidas, Metropolitan of Caesarea in Cappadocia, and advisor to Justinian. Askidas, the Origenist, sought to out-manoeuvre those who held strictly to the creed declared at the Fourth Ecumenical Council at Chalcedon in 451. To attack the authority of Chalcedon, Askidas attacked the orthodoxy of the Three Chapters—the three bishops, Theodore of Mopsuestia, Ibas of Edessa, and Theodoret of Cyrrhus, the first of whom was accused as the father of Nestorianism, while the last two were rehabilitated at the Chalcedon council. In response to Justinian's anathemas against Origen, Askidas struck at the strict Chalcedonians by convincing Justinian to anathematise the Three Chapters, which he did. According to the Church historian Liberatus, Vigilius became Pope by promising Theodora that he would abandon the Chalcedon formula. Though Justinian did not at first envisage the need for any further confirmation of his anathemas (c. 543–545, now lost) against the Three Chapters, he eventually convened the Fifth Ecumenical Council to approve these anathemas. See Karl Baus, Hans-Georg Beck, Eugen Ewig, and Hermann Josef Vogt, *The Imperial Church from Constantine to the Early Middle Ages*, trans. Anselm Biggs, vol. II in *History of the Church,* ed. Hubert Jedin and John Dolan, Burns and Oates, London, 1980.
5. Origen, surnamed Admantius—the man of steel or diamond—was a teacher of teachers like Dionysius the Great, Didymus the Blind, and Plotinus at the Alexandrian school. His principal work is the *Peri Archon* (*On First Principles*) translated into the Latin as *De Principiis* by Rufinus. Long Greek fragments from it may be found in the *Philokalia* of Origen compiled by the Cappadocian fathers Basil, and Gregory Nazianzen. The dispute concerned his views on *apocatastasis* or the final restoration of all things. See *Encyclopaedia of Religion*, ed. Mircea Eliade, vol. 11, Macmillan, New York, 1987, p. 108; G. W. Butterworth, trans., *Origen on First Principles*, 1936, reprint, Harper & Row, New York, 1966; Jean Danielou, *Origen*, trans. W. Mitchell, Sheed & Ward, New York, 1955; Alexander Roberts and James Donaldson, eds., *The Ante-Nicene Fathers*, vol. 4, T&T Clark, Edinburgh, 1866–72, reprint Wm. Eerdman, Grand Rapids, Mich., 1965.
6. In interpreting this passage (Eccl. 1:9–12) from the Old Testament, it helps to keep in mind the following background. According to the historian Josephus Flavius, there were three sects among the Jews—the Essenes, the Pharisees, and the Sadducees—of which the first two believed in life after death, like the later Cabalists. The

Essene belief in the survival of disembodied souls is further found in Enoch and Jubilees, works prominent among the Qumran documents (Dead Sea Scrolls). *Whether* there is life after death was not the dispute in Christianity, for it is a fundamental tenet of Christian belief that Christ died on the cross and was later resurrected. It is equally clear that there were divergent opinions about the *sort* of life to be expected after death. Under these circumstances, the natural thing would have been to turn to other sources of knowledge, and we have already glimpsed in the preceding chapter how Indian, Persian, Egyptian, and Greek traditions related to cosmic recurrence.

7. Origen, *De Principiis*, as quoted in J. Head and S. L. Cranston, *Reincarnation: An East-West Anthology*, The Theosophical Publishing House, Wheaton, 1968, p. 36.
8. Origen, *De Principiis*, Book II, chap. 9. Frederick Crombie, trans., *The Writings of Origen*, vol. X in *Ante Nicene Christian Library*, ed. Alexander Roberts and James Donaldson, T&T Clark, Edinburgh, 1895, p. 136.
9. The similarity with Indian beliefs is not so surprising if we recollect that Alexandria, after all, is located in Egypt, where beliefs in life after death were similar to Indian beliefs. Trade between India and Egypt flourished from before the time of Alexander, whose general Nearchus travelled on this sea-route as described by Arrian. Moreover, in Origen's time, the Roman empire had a roaring trade with India, and some 120 ships sailed annually from India to Alexandria, so that the Roman historian Pliny complained that in no year did 'India absorb less than five hundred and fifty million sesterces of our surplus, sending back merchandise to be sold to us at hundred times its prime cost'. Alexandrian ('Greek') scholars of the Neoplatonist school to which Origen belonged, actively studied Indian systems of knowledge, and Augustine chided Porphyry for seeking salvation by studying the 'mores and disciplines of Indi'. Arrian, *Indika*, and Pliny, *Natural History,* Book VI, chap. 16, p. 63, cited by R. N. Saletore, *Early Indian Economic History*, Popular Prakashan, Bombay, 2nd ed., 1993, pp. 88, 296.
10. Henry R. Percival, ed., *The Seven Ecumenical Councils of the Undivided Church,* vol. 14 in *A Select Library of Nicene and Post-Nicene Fathers of the Christian Church*, ed. Philip Schaff and Henry Wace, Charles Scribner's Sons, New York, 1900, pp. 318–20. Also reproduced in J. Head and S. L. Cranston, *Reincarnation: An East-West Anthology*, The Theosophical Publishing House, Wheaton, 1968, Appendix.
11. There is no valid historical basis for the church propaganda that early Christians were persecuted and martyred in the Roman

empire. Gibbon, cited in note 3 above, argues that the church accounts of persecution are so wildly exaggerated as to be physically impossible. My reason for believing Gibbon is that no secular account even mentions the Christians prior to the third century: the Roman empire could hardly have persecuted early Christians if it was not even aware of their existence! Moreover, prior to Constantine there is no evidence of any Roman attempt to legislate religious beliefs.

12. It is well known that in 391 the temple of Seraphis and its adjacent great library of Alexandria were destroyed by a Christian mob. The magnificent temple of Dea Caelestis at Carthage remained open till c. 400. Under Catholic influence, many laws were passed against pagans and Donatists, and the synod of Carthage in 401 twice asked the State to implement these laws. Eventually, in 407, the Catholics took possession of Dea Caelestis, and Bishop Aurelius, Augustine's lifelong friend, triumphantly located his cathedra at the place occupied by the statue of the pagan goddess. In the countryside, there were bloody clashes between Catholics and pagans, and ultimately the latter were driven to carry their deities literally underground or into caves. See, *History of the Church*, ed. Jedin and Dolan, vol. II, cited earlier, p. 205. As a footnote to this footnote, the pagan prophecy of the collapse of Christianity in North Africa was fulfilled as Vandals attacked and destroyed churches in exactly the same way!

13. Starting as a pacifist of sorts, Augustine changed his tone after a taste of power. He argued that the Donatists were mistaken because the effect of baptism depended on the miraculous qualities with which Christ imbued the water. To talk of the moral qualities of the priest performing the baptism was, therefore, a heresy against which the use of State power guided by a Catholic emperor was justified, because it was intended to be good, holy, and just. If this was persecution by the State, then it was persecution as the workers practised it in the gospel when they were sent by their master to the highways with the order 'to coerce' the poor 'to come in'(Luke 14:23); it was the persecution of the shepherd who 'persecutes' the lost sheep, bringing it back to the flock, even against its will, and thus saves it (Matt. 18:12–14). 'Why should not the Church compel its lost sons to return, if the lost sons compel others to their ruin?' Augustine letters 93 and 185, Ep. 185, 6, 123, cited in *History of the Church*, ed. Jedin and Dolan, vol. II, cited above.

14. More examples can be found in F. Cavallera, *Saint Jérome*, Université Catholique de Louvain, Louvain-Paris, 1926, pp. 115–26, and J. N. D. Kelly, *Jerome. His Life, Writings, and Controversies*, Duckworth, London, 1975. Jerome's about turn (c. 393) on Origen involved

also a revolt against his bishop and a bitter fight with his bosom friend Rufinus. They were reconciled, and Rufinus returned to Rome to translate *Apologia for Origen*, adding an essay, *On the Falsification of the Works of Origen*, arguing that all theologically doubtful opinions of Origen were interpolations by falsifiers. In a similar vein of theological correctness, he translated Origen's *Peri Archon*, stating prefatorily that he was only continuing the work of that great man (Jerome) who had already translated more than 70 of Origen's homilies. Rufinus' unfinished work was somehow forwarded to Jerome, who produced a literal translation 'to hand over the heretical author to the Church'. Subsequently, he translated anti-Origenist propaganda which talked of the 'blasphemous' 'madness' and 'criminal error of Origen, this Hydra of all heresies'. Rufinus defended himself, and, in response, Jerome dashed off three books, including the *Apologia contra Rufinum*, which begins with some rather warm polemics against Rufinus, and unscrupulously questions his honesty. Rufinus wrote a last letter, now lost, and remained silent for the remaining eight years of his life. When he died, Jerome gloated that now the scorpion lies pressed flat under the earth of Sicily; now finally the many-headed Hydra ceased to hiss. See *History of the Church*, ed. Jedin and Dolan, vol. II, cited earlier.

15. J. Head and S. L. Cranston, *Reincarnation in World Thought*, Julian Press, New York, 1967.
16. Origen, *De Principiis*, Book II, chap. 9. Frederick Crombie, trans., *The Writings of Origen*, vol. X in *Ante Nicene Christian Library*, ed. Alexander Roberts and James Donaldson, T&T Clark, Edinburgh, 1895, p. 132.
17. Thus, in neighbouring Iran (Persia), where the Magi aspired to make Zoroastrianism a state religion, the followers of Mazdak were massacred in 528 by the leader of the Magi, reportedly in association with crown prince Khusrau. Mazdak taught not only equity, he regarded ownership of property as the root of all evils, and advocated the common ownership of property as the solution. He was patronised by Khusrau's father, Kavadh, for Mazdak's teaching's appealed to the people, though they clearly threatened the rich and the powerful. The Magi persecuted the followers of various religions, at various times, starting from Karter and his liquidation of Mani, as proclaimed in Karter's edicts at Ka'be-ye Zardusht. But it is noticeable that among the religions with a sizeable following in Iran, only the more egalitarian—viz. Mazdakism and Buddhism—were completely eliminated, while Manichaeism and Christianity continued to exist, despite the fact that Christians were viewed with suspicion as potential traitors loyal to the Roman enemy. The Magi

eventually failed to assert their control, perhaps because, unlike their Christian counterparts, they stopped at physical liquidation, and do not seem to have gone on to adapt their ideology to state purposes.

18. Augustine, *City of God*, XI.23, says that Origen was 'justly blamed', and 'cannot sufficiently express [his] astonishment', for example, about Origen's 'foolish assertion' that better souls should be reborn in better bodies (pp. 334–35). In the popular translation, Augustine says that Origen was 'rightly reproved', and is 'inexpressibly astonished' that Origen should be so 'stupid' (pp. 230–31). On the other hand, Jerome had objected that Origen's ideas meant that better souls may be reborn in worse circumstances! Augustine, who commented on the quarrel between Jerome and Rufinus, presumably knew about this. Augustine's arguments were, thus, directed against the idea that bodies were neither worse nor better, but remained the same. See, Augustine, *The City of God*, in *Augustine*, trans. Marcus Dods, vol. 18 in *Great Books of the Western World*, ed. R. M. Hutchins, Encyclopaedia Britannica, Chicago, 1952. Popular translation: Vernon J. Bourke, ed., *Saint Augustine, The City of God*, abridged from the translation by Gerald G. Walsh, Demetrius B. Zema, Grace Monahan, and D. J. Honan, Image Books, New York, 1958.
19. Augustine cites M. Aurelius (11.14): 'All things from eternity are of like form and come round in a circle'.
20. W. R. Inge, *The Philosophy of Plotinus*, vol. II, Greenwood Press Publishers, Westport, Connecticut, 1968, p. 19.
21. Augustine, *City of God*, XI.13, trans. Marcus Dods, cited earlier, p. 350, emphasis mine.
22. Unlike the millenarists, Augustine did not prophecy the precise extent of the future, or an exact date for the end of the world. But he vigorously denied pagan beliefs about the extent of the past, maintaining that the world was not more than 6000 years old, on his interpretation of the scriptures. 'Reckoning by the sacred writings, we find that not 6000 years have yet passed'. Augustine, *City of God*, cited earlier, XII.10, pp. 348–49. This portion is skipped in the popular translation.
23. Modern theologians have found technical room to argue that the curse against cyclic time is not part of the official doctrine of the Church. One claim is that Pope Vigilius, who was in Constantinople, did not sign the anathemas. Another is that the anathemas concerned an obscure chapter of ecumenical politics. Undoubtedly one can find various local elements and human dimensions in the formal condemnation of Origen, but these would have been insubstantial without the changed political role of the Church after

acquiring a State-approved monopoly. As for Vigilius, he was summoned to Constantinople in 547, and remained there till 555. He vacillated during this period, excommunicating people and being himself excommunicated. To recover his reputation, he claimed that his earlier *Judicatum* abandoning the Three Chapters (see note 4 above) was issued under duress, but secretly gave a written and sworn assurance in 550 that he would cooperate with all his power in condemning the Three Chapters, and would undertake nothing without consulting Justinian. In his *Constitutum* of 14 May 553, he took a weaker stand on the Three Chapters. This became public, upon which Justinian also made public the signed minutes of the Pope's secret oath of 550, and the Pope's letter defending his earlier *Judicatum*. The Pope's name was expunged from the diptychs, without excommunicating him. On 2 June 553, the last day of the Council, Justinian's anathemas against the Three Chapters were accepted. To balance matters, Justinian had also proposed the anathemas against Origen about which 'it is certain that the bishops made no difficulties…and Vigilius seems to have assented without much hesitation' (Jedin and Dolan, eds., *History of the Church*, vol. II, cited earlier, p. 454). The Origenists were expelled from Palestine, and some bishops from their sees. But perhaps some more manipulations were carried out by Theodore Askidas, for there still seems to be some ambiguity about these anathemas. As for Vigilius, he again changed his mind and agreed to condemn the Three Chapters unequivocally by December 553, and published a new Constitutum in March 554. He left Constantinople for Rome in 555, but died en route.

The precise theological interpretation of the actions of Vigilius—whether Protestants or Roman Catholics too should believe in the curse on cyclic time—is of marginal interest. The undeniable fact is that the Western Church accepted Augustine and rejected Origen, and the curse isolates the key issues involved in this fundamental ideological shift. The consequent long-term religious stigma attached to any beliefs about 'cyclic' time prepared the cultural predisposition which results in so many people who 'find time-travel profoundly repugnant' (J. F. Woodward, *Foundations of Physics Letters,* **8**, 1995, 1–39, p. 2).

24. Henry R. Percival, ed., *The Seven Ecumenical Councils of the Undivided Church,* cited earlier, pp. 318–20. Also reproduced in J. Head and S. L. Cranston, *Reincarnation: An East-West Anthology*, cited earlier', Appendix.
25. Augustine, *Confessions*, XI.26, trans. E.B. Pusey, in *Augustine*, ed. Hutchins, cited earlier, p. 95.

26. C. K. Raju, *Time: Towards a Consistent Theory*, Fundamental Theories of Physics, vol. 65, Kluwer Academic, Dordrecht, 1994, especially chap. 8: 'Mundane Time'.
27. More recently he has introduced the *chronology protection conjecture*, which makes closed timelike curves illegal: *the laws of physics do not allow the appearance of closed timelike curves*. No time machines. See Chapter 7, for Hawking's latest position, and S.W. Hawking, *Physical Review D*, **46**, 1992, pp. 603–11. Chapter 7 also explains why the exact opposite of the claim made by Augustine and Hawking is valid: closed loops in time are *exactly* the way to allow spontaneity or 'free will' in current physics.
28. S. W. Hawking and G. F. R. Ellis, *The Large Scale Structure of Space-Time*, Cambridge University Press, paperback edition, 1974, p. 189.
29. One could, for example, eliminate these naive features, and use a more sophisticated formulation like Popper's record postulate. That postulate says simply that there is no upper limit to the length of the records one can keep. But on going round a closed time loop, every record must be destroyed for consistency. Hence there are no closed timelike curves. Incidentally, this, too, is an approach to banish 'cyclic' time by fiat. K. R. Popper, *The Open Universe: An Argument for Indeterminism*, vol. 3 of *Postscript to Logic of Scientific Discovery*, Hutchinson, London, 1982.
30. 'For, to confess that God exists and at the same time to deny that He has foreknowledge of future things, is the most manifest folly.' Augustine, *City of God*, V.9, cited earlier, p. 123. Alternatively, '…one who does not foreknow the whole of the future is most certainly not God', *Augustine*, ed. Bourke, cited earlier, p. 108.
31. '…if I should choose to apply the name of fate to anything at all, I should rather say that fate belongs to the weaker of two parties, will to the stronger…than that the freedom of our will is excluded by that order of causes which, by an unusual application of the word peculiar to themselves, the Stoics call Fate.' (Augustine, *City of God* V.9, cited earlier, p. 215.) '…if I wanted to use the word "fate" for anything at all, I should prefer to say that "fate" is the action of a weak person, while "choice" is the act of the stronger man, rather than to admit that the choice of our will is taken away by that order of causes which the Stoics arbitrarily call fate.' (*Augustine*, ed. Bourke, cited earlier, pp 108–9.)
32. F. J. Tipler, *Nature*, **280**, 1979, pp. 203–5, and 'General Relativity and the Eternal Return' in F.J. Tipler, ed., *Essays in General Relativity*, Academic Press, New York, 1980, pp. 21–37.
33. F. J. Tipler, *The Physics of Immortality. Modern Cosmology, God and the Resurrection of the Dead.* Macmillan, London, 1995.

# CHAPTER 3

1. A. N. Whitehead, *Science and the Modern World*, Lowell Lectures, 1925, The Free Press, New York, 1967, p. 181.
2. Isaac Asimov, 'The Threat of Creationism', in *Creations: The Quest for Origins in Story and Science*, ed. Isaac Asimov, George Zebrowski, and Martin Greenberg, Harrap, London, 1984, p. 186.
3. Friedrich Nietzsche, *The Anti-Christ*, [1895], in *The Twilight of the Idols and The Anti-Christ*, trans. R. J. Hollingdale [1968], Penguin Books, 1990, sec. 48, pp. 175–76. (Italics original.)
4. Jürgen Renn and Robert Schulman, eds., *Albert Einstein/Mileva Marić: The Love Letters*, Princeton University Press, New Jersey, 1992, p. xix. See also Document No. 115 in *The Collected Papers of Albert Einstein*, vol. 1: *The Early Years, 1879–1902*, ed. John Stachel, Princeton University Press, New Jersey, 1987, and a companion volume with the same title, trans. Anna Beck.
5. The withdrawal of the strictures against Galileo was no trifling matter: it was preceded by a 13-year study by the Vatican (see, e.g., *The Times of India,* 26 October 1996, front page). The commissioning of the 13-year study presumably followed from the deliberations of the Second Vatican Council (1962–65), which explicitly sought to change the inflexibility that had characterised Catholic thought since the Protestant Reformation.
6. There remains, of course, the freedom of interpretation, or exegesis, to find the intended meaning of the Bible. At a more abstract level, there is the further freedom to choose the hermeneutic, i.e., the principles used to interpret the Bible. (We note in passing that Jerome, who used Origen's notes to prepare the version of the Bible, now regarded as authoritative, subscribed to the literal hermeneutic—that the Bible was the literal truth—while Origen subscribed to the moral and allegorical hermeneutic: that the Bible should be interpreted allegorically.) However, few politicians in the USA, today, would be ready to reject altogether the authority of the Bible by relegating it to, say, the status of an obsolescent text.
7. The name derives from a series of 12 pamphlets that they wrote and circulated, called *The Fundamentals*.
8. Ian Plimer, *Telling Lies for God—Reason versus Creationism*, Random House, 1994.
9. A. D. White, *A History of the Warfare of Science with Theology in Christendom*, 2 vols, 1896; reprinted, Dover, New York, 1960.
10. Nicolaus Copernicus, *De Revolutionibus,* preface and Book 1, trans. J. F. Dobson and S. Brodetsky, Royal Astronomical Society, Occasional Notes, No. 10, 1947, pp. 3–6.

11. For example, in Brooke's book of 419 pages, all references to Buddhism and Islam would easily fit in one page (and it is not as if that page contains terse comments of great depth). J. H. Brooke, *Science and Religion: Some Historical Perspectives*, Cambridge University Press, Cambridge, 1991.
12. The notion of 'proof' in the claim actually appeals to certain Platonic ideas of what constitutes a convincing demonstration. It is facile to suppose that this notion of 'proof' is universal, for the Buddha's idea's of a four-fold negation incorporated a logic quite different from the two-valued logic underlying the later Neoplatonic ('Euclidean') notion of 'proof'. The current Western notion of 'proof' is considered in greater detail in Chapter 6, and in the Appendix, and traditional notions of proof in Chapter 11. The current Western notion also assumes a two-valued logic, which is neither culturally universal nor empirically certain. Chapters 8 and 9 explain the possible incompatibility of two-valued logic with the structure of time in a quantum mechanical world.
13. *The Tantrasamgraha of Śāntarakṣita, With the Commentary of Kamalaśīla*, trans. Ganganath Jha, reprinted Motilal Banarsidass, Delhi, 1986, vol. I, chapter VI, pp. 132–38. The Tibetan text and translation may be found in Hajime Nakamura, *A History of Early Vedanta Philosophy* (English translation by Trevor Leggett et al), Motilal Banarsidass, Delhi, 1983, Part 1, pp. 232–35. The notion of 'cause' involved here should *not* be assumed to be identical with the notion of 'cause' used in debates in traditional Christian theology, for the notion of cause, like logic, depends upon the underlying picture of time.
14. The differences between science and Buddhism could, however, relate to (a) the *kind* of reason or logic underlying inference (see note 12 above), and (b) whether this logic is forever Plato-given or whether the nature of logic may itself be decided by recourse to the empirical.
15. J.C. Polkinghorne, 'A revived natural theology', in *Science and Religion*, Papers presented at the Second European Conference on Science and Religion, March 10–13, 1988, ed. Jan Fennema and Iain Paul, Kluwer Academic Publishers, Dordrecht, 1990, p. 87.
16. Oswald Spengler, *The Decline of the West*, vol. I, *Form and Actuality*, trans. C. F. Atkinson, George Allen & Unwin, London, 1926, p. 18. (Italics original in both quotes.) It goes without saying that talk of a Copernican revolution is itself part of a Eurocentric scheme of things!
17. For Spengler, Cultures (rather than nations) are the appropriate entities to be studied in history: '*Higher history*, intimately related

to life and to becoming, *is the actualizing of possible Culture*.' Spengler, cited above, p. 55, italics original.

18. Spengler, cited above, p. 4. Spengler devotes a whole volume to explain that his analogies are not superficial. In the ancient Nyāya tradition, analogy was regarded as one of the means of right knowledge.
19. Arnold J. Toynbee, *A Study of History*, abridgement in 2 vols. by D.C. Somervell, Oxford University Press, 1957.
20. Samuel P. Huntington, *The Clash of Civilizations and the Remaking of World Order*, Viking, New Delhi, 1997, p. 166.
21. In a book called *1984*, published in 1948, George Orwell had used Spengler's projection to visualise a future world divided into 3 zones perpetually at war with each other.
22. Joseph S. Nye, Jr, 'The Changing Nature of World Power', *Political Science Quarterly*, **105**, 1990, pp. 181–82.
23. Copernicus' book, cited earlier, may have been a revolution in European thought, but the theory was that of Ibn as Shatir, from the Maragheh observatory, and heliocentrism was a part of Arabic astronomy for centuries before that. See, Otto Neugebauer, 'On the Planetary Theory of Copernicus', *Vistas in Astronomy*, **10**, 1968, pp. 89–103, and George Saliba, 'Arabic Astronomy and Copernicus', chapter 15 in *A History of Arabic Astronomy*, New York University Press, New York, 1994, p. 291. With the rise of Baghdad, in the early 9th c., Greek and Sanskrit texts were imported and translated into Arabic. By the time Baghdad fell to Hulegu, Arabic texts were being translated into Byzantine Greek. After the fall of the Byzantine empire, in 1453, many Greek translations of Arabic originals came to Europe. Copernicus translated one such book from Greek to Latin. While the mutual sharing of information is as it ought to be, the depiction of this process by Western historians of science has turned Copernicus into a heroic innovator, by transferring all credit to him. This sort of history has made science seem like a uniquely Western enterprise, and has hence made the West seem as the *legitimate* recipient of benefits flowing to it by force of a technological advantage—an advantage derived by monopolising information initially acquired through mutual sharing.
24. In pre-Sassanid times, Buddhism had spread to Syria, and al Bīrūnī, the scholarly emissary of Mahmud of Ghazni, thought the Buddhists were refugees in India! Al Bīrūnī, *Kitab al Hind*, translated by E. C. Sachau as *Alberuni's India*, [Keagan Paul, 1910], Munshiram Manoharlal, New Delhi, 1992, p. 21. Nietzsche, influenced by Schopenhauer in his youth, speaks of Buddhism as a 'kindred religion' which he 'should not like to have wronged', for 'Buddhism is the only really *positivistic* religion history has to show us...it no

longer speaks of "the struggle against *sin*" but…"the struggle against *suffering*"…it already has…the self-deception of moral concepts behind it…it is *beyond* good and evil…Buddha…demands ideas which produce repose or cheerfulness…*Prayer* is excluded, as is *asceticism*; no categorical imperative, no *compulsion* at all…his teaching resists nothing *more* than it resists the feeling of revengefulness, of antipathy, of *ressentiment* (—"enmity is not ended by enmity": the moving refrain of the whole of Buddhism…)….The precondition of Buddhism is…*no* militarism.' (Italics original.) Friedrich Nietzsche, *The Anti-Christ*, cited earlier, sec. 20, pp. 141–42.

25. See, e.g., A. H. M. Jones, *Constantine and the Conversion of Europe*, Collier Books, New York, 1962.
26. E. Gibbon, *History of the Decline and Fall of the Roman Empire*, vol. I, chap. 16. Vol. 40 in *The Great Books of the Western World*, ed. R. M. Hutchins, Encyclopaedia Britannica, Chicago, 1952, p. 233.
27. According to an empirical survey that I conducted, 100 per cent of a sample of 166 people who used the word 'communism' could not correctly discriminate between communism and socialism, in the sense of Marx, and could not explain why the Soviet Union called itself a socialist republic. The difference, incidentally, is this: 'communism' is a utopian situation where the state withers away, and there prevails, as in a family, the situation of 'to each according to his needs, and from each according to his capacity'. Socialism is a transitional state between capitalism and communism.
28. See note 12, Chapter 2.
29. Chapter 42 of Gibbon, *Decline and Fall of the Roman Empire*, cited earlier.
30. Bertrand Russell, *A History of Western Philosophy*, George Allen and Unwin, London, 1947, p. 387.
31. P. S. S. Pissurlencar, 'Govyache Khristikarana', Shri Santadurga Quatercentenary Celebration Volume, Shaka 1488–1818, published by Durgarao Krishna Borkar, Bombay, 1966, pp. 91–122. English summary in B. S. Shastry and V. R. Navelkar, eds., *Bibliography of Dr Pissurlencar Collection*, part I, Goa University Publication Series, No. 3, pp. 67–69.
32. See note 13, Chapter 2. There is, of course, no dearth of current-day apologias, e.g., H. A. Drake, 'Lambs into Lions: Explaining Early Christian Intolerance', *Past and Present*, **153**, 1996, pp. 3–36.
33. Gallup poll cited in Chapter 1, note 2. Wald points out that the USA is an outlier, an exception to the general rule that prosperity makes religion unimportant. That, however, is not relevant to the current perspective which is civilisational rather than national. Kenneth D. Wald, *Religion and Politics in the United States*, Popular

Prakashan, Bombay, 1992. See also, G. Holton, *Science and Anti-Science*, Harvard University Press, Cambridge, Mass., 1994; J. C. Burnham, *How Superstition Won and Science Lost*, Rutgers University Press, New Brunswick, 1987. A Spenglerian parallel in Greece may be found in E. R. Dodds, *The Greeks and the Irrational*, Beacon University Press, Boston, 1957.

34. B. Russell, 'What is Science', in *Science Speaks*, ed. H. Dow, Melbourne, Cheshire, 1955.
35. E. Gilson, *Philosophie du Moyen Age*, p. 218, translation cited in Spengler, *Decline of the West*, cited earlier, p. 502.
36. M. Adas, *Machines as the Measure of Men*, Oxford University Press, New Delhi, 1991.
37. For example, only 7 per cent of the US adults can be called scientifically literate. See Gerald Holton, *Science and Anti-Science*, cited earlier, p. 147.
38. This is generally true of any capitalist society. In India, for example, the Department of Atomic Energy got ten times the total funding given to the University Grants Commission, which concerns higher education, and higher education itself received far more funds than primary education. This is generally true of any capitalist society because profit maximisation requires constant increases in productivity, and dramatic increases in productivity can only come from technological innovation. On the other hand, the expenses on education only serve to reproduce the scientific labour which produces the innovation, and it is well understood why a capitalist society focuses on production (of commodities such as technological innovation) rather than reproduction (of scientific labour needed to produce the innovation).
39. This, incidentally, is another reason why soft power has become important. Hard power obtained by increasing technical sophistication is more prone to sabotage by disgruntled elements. Workers in a more sophisticated system cannot be managed by an overseer with a whip, for the simple reason that the overseer may be unable to judge what is happening, so that the typical manager clings to people he thinks he can trust. This strategy may be all right with car-mechanics, where the final result at least is transparent, but it usually fails at the level of a more abstract state enterprise, such as one devoted to the development of science and technology.
40. Arnold J. Toynbee, *A Study of History*, abridgement of vols. vii–x by D. C. Somervelle, Oxford University Press, 1957; reprint, Dell Publishing Co., vol. 2, p. 112.
41. Pope John Paul II has himself told the faithful to believe that faith and science can coexist. See *The Times of India*, 26 October 1996.

42. See, e.g., Asimov, 'The Threat of Creation', in *Creations: The Quest for Origins*, ed. Asimov et al. cited earlier.
43. Friedrich Nietzsche, *Twilight of the Idols and The Anti Christ*, cited earlier, p. 135. (Italics original.)
44. The 'Award of Constantine', or the 'Donation of Constantine' (*Donatio Constantini*) was a document, allegedly under the signature of Emperor Constantine, which granted the Vatican to the church, along with its special status as a state within a state. The document which the church at first claimed to have discovered (in the 8th c.) was later (in the 15th c.) shown to be a forgery. But this realisation did not change the status of the Vatican. See, e.g., E. F. Henderson, *Select Historical Documents of the Middle Ages*, George Bell, London, 1910, pp. 319–29, or *The Penguin Atlas of World History*, vol. 1, Penguin Books, New York, 1974, pp. 140, 212.
45. *The Times of India*, 26 October 1996.
46. Stephen Hawking, *A Brief History of Time: From the Big Bang to Black Holes*, Bantam, New York, 1988, p. 122.
47. That is, no one else has actually solved the classical electrodynamic two-body problem for an electron and a proton, while theorising about the structure of the atom.
48. The idea is that the two-body problem of electrodynamics involves functional differential equations (FDE), rather than the ordinary differential equations (ODE) that Bohr took to be the case, and which have been used by physics texts ever since. For the exact equations of motion, and for the fundamental differences between FDE and ODE, see C. K. Raju, *Time: Towards a Consistent Theory*, Fundamental Theories of Physics, vol. 65, Kluwer Academic, Dordrecht, 1994, chap. 5b. A preliminary solution of the equations was presented in, C. K. Raju, 'Simulating a tilt in the arrow of time: preliminary results', Seminar on *Some Aspects of Theoretical Physics*, Indian Statistical Institute, Calcutta, 14–15 May 1996; and C. K. Raju, 'The Classical Electrodynamic 2-Body Problem and the Origin of Quantum Mechanics', International Symposium on *Uncertain Reality*, India International Centre, New Delhi, 5–9 January 98, but is yet to be finalised and submitted for publication. The theory behind these calculations is explained in general terms in Chapter 9.
49. Paul Davies, *God and the New Physics*, Penguin Books, London, 1990, p. 7.
50. I cannot say what, if anything, Davies means by the term 'Oriental cosmology'. Possibly he has in mind one of the usual utterly confused (or deliberate) misrepresentations so popular with some theologians. See, e.g., Stanley L. Jaki, *Science and Creation*, Scottish Academic Press, Edinburgh and London, 1974. Davies

cites Jaki's later work, *Cosmos and Creator*, Scottish Academic Press, Edinburgh, 1981, as part of his select bibliography.

51. There is, of course, an old dispute about what the Old Testament actually says about creation. Origen, cites the earlier Greek version of the Old Testament (the Septuagint), particularly Isaiah lxvi.22, and Ecclesiastes, in support of 'the ages which have been before us'. He, then, goes on to point out that 'the holy Scriptures have called the creation of the world by a new and peculiar name, calling it καταβολη, which…signifies…to cast downwards—a word which has been…very improperly translated into Latin by the phrase "constitutio mundi"…in which καταβολη is rendered by beginning (*constitutio*)…'. Origen, *De Principiis*, Book III, chap. V, p. 256, in A. Roberts and J. Donaldson, *Ante Nicene Christian Library*, vol. X, Edinburgh, 1895.
52. Isaac Asimov in *Creations*, ed. Asimov et al., cited earlier, p. 6.
53. I have translated the Sanskrit *sat* as 'being', which is the primary meaning assigned to it by, e.g., Monier-Williams' dictionary, though it has earlier been translated as 'existent', and may well be translated as 'truth' or 'real'. My reason is, roughly, that 'real' can be a confusing philosophical category, as is clear in the contemporary context of the debate on quantum mechanics. 'Truth' being logically prior seems a strong contender. But to *say* that something is true needs the verb 'is'. M. Monier-Williams, *A Sanskrit English Dictionary*, reprint, Motilal Banarsidass, Delhi, 1990.
54. But see H. A. Wolfson, 'The identification of *ex nihilo* creation with emanation in Gregory of Nyssa', *Harvard Theological Review*, **63**, 1970, pp. 53–60; R. Sorabji, *Time, Creation and the Continuum*, London, Duckworth, 1983, p. 294. For the radical political difference that this makes, and for a fuller account of Gregory of Nyssa, see Paulos Gregorios, *Cosmic Man*, Sophia Publications, New Delhi, 1980, especially pp. 223–33. As summarised by Inge, 'Gregory of Nyssa is an Origenist (in many of his doctrines) who has never been condemned'. W. R. Inge, *The Philosophy of Plotinus*, vol. 1, Greenwood Press Publishers, Westport, Connecticut, reprint, 1968, p. 103.
55. *The Vishnu Purana*, trans. H. H. Wilson, cited in Chapter 1, note 27.
56. Various concrete medieval representations of this creator in poetry and cathedral art have been examined in great detail by A. D. White, *Warfare of Science with Theology*, cited earlier, pp. 4–11.
57. A. D. White, *Warfare of Science with Theology*, cited earlier, p. 6.
58. As pointed out in Chapter 1, this is not entirely an 'Oriental' figure, for the West also measured the duration of an ordinary day and night cycle in 86,400 seconds. Note that the figure of 8.64 billion

years corresponds to the duration of a cosmic cycle, and not to the age of the cosmos within the present cosmic cycle.

59. W. R. Inge, *The Philosophy of Plotinus*, vol. II, Greenwood Press Publishers, Westport, Connecticut, reprint, 1968.
60. Augustine, *City*, cited earlier, XII.10, pp. 348–49, 'reckoning by the sacred writings, we find that not 6000 years have yet passed'. This portion is skipped in the popular translation.
61. See note 50, this chapter. Jaki's book on 'pagan' cosmologies is cited as the authority by Davies. More recently, this book has been cited by Paul Halpern in another excessively ill-informed but supposedly authoritative account of 'pagan' views of time. Paul Halpern, *The Cyclical Serpent*, Pergamon, 1995.
62. I think it is quite irrelevant to the issue here that a couple of people, Fred Hoyle, and his disciple Jayant Narlikar, mistakenly marketed the steady-state theory of Bondi and Gold as the theological antithesis of the big bang. As already pointed out earlier, the steady state theory requires continuous creation, which provides more scope for divine intervention.
63. A. D. White, *Warfare of Science with Theology,* p. 18.
64. E. R. Harrison, in *Galactic and Extragalactic Background Radiation*, ed. S. Bowyer and Ch. Lienert, Proceedings of the International Astronomers Union, No. 139, Kluwer Academic, Dordrecht, 1989, pp. 3–17.
65. Frank E. Manuel, *The Religion of Isaac Newton*, Clarendon Press, Oxford, 1974.
66. S. W. Hawking and G. F. R. Ellis, *The Large Scale Structure of Space-Time*, Cambridge University Press, 1974.
67. Stephen Hawking, *A Brief History of Time*, pp. 52–54.
68. More precisely, the 'evolutionary path of a particle' refers to a worldline.
69. I do not recall the source which was in an anthology of SF someone borrowed from me (and never returned). This remark is attributed to Larry Niven, a former mathematician, in *Black Holes*, ed. Jerry Pournelle, Futura Publications, London, 1978, p. 333. 'As we drove away from Pasadena, Larry [Niven] remarked that if we ever had proximity to a singularity, he could well imagine people praying to it. After all, their prayers probably wouldn't influence what came out of it—but they might, and certainly nothing else would.'
70. Hawking still maintains this point of view as regards classical general relativity. In a recent publication he has stated: '…according to general relativity, there should be a singularity in our past. At this singularity the field equations could not be defined. Thus classical general relativity brings about its own downfall: it predicts that it can't predict the universe.' Stephen Hawking and Roger

Penrose, *The Nature of Space and Time*, Oxford University Press, Delhi, 1997, p. 75.

71. Stephen Hawking, *A Brief History of Time*, cited earlier, pp. 183–84.
72. On universal rotation, see, further, Chapter 7, note 16. On classical dynamics, rotation would make the initial configuration quite literally egg-shaped rather than spherical.
73. More precisely, Hawking and Ellis, *The Large Scale Structure of Space-Time*, cited earlier, p. 362, speculate that the singularity might create *information* (or negative entropy as defined in Chapter 6): 'It might be that the set of geodesics which hit these singularities (i.e. which are incomplete) was a set of measure zero. Then one might argue that the singularities would be physically insignificant. However this would not be the case because the existence of such singularities would produce...a breakdown of one's ability to predict the future. In fact this could provide a way of overcoming the entropy problem in an oscillating world model since at each cycle the singularity could inject negative entropy.'
74. Merely punching a hole will not do, since the geodesic incompleteness could then be remedied by patching up the hole. But the idea can be suitably modified. See, C. J. S. Clarke, *The Analysis of Space-Time Singularities*, Cambridge University Press, Cambridge, 1993, pp. 141–53. For simplicity, we may imagine here that this hole extends inside or outside in such a way that geodesics that hit the hole are inextendible. What the external observer would 'see' is only a sphere with a hole amiss, as in the case of a black-hole with a small surface area, in a vast cosmos. The point of the example is only this: one tends to think of a geodesic as the path taken by a particle, but it is fallacious to suppose that every geodesic corresponds to an actual particle, so that geodesic inextendability does not mean the actual creation or destruction of a particle. The correspondence between actual particles and geodesics is far from clear in relativity; it does not seem to be one to one, for in spacetime there are an uncountable infinity of geodesics, but there may be only a finite number of actual particles. Technical difficulties have prevented the construction of a relativistic statistical mechanics so there is no clear correspondence in general relativity between the continuum and the particle description of matter.
75. The description of matter in the theory is through the matter tensor, and no one has shown that in the presence of a Hawking–Penrose singularity some terms appear or disappear in the matter tensor. Indeed, the connection of geometry to the matter tensor is through the 'laws of physics'—the equations of general relativity—that allegedly fail in the presence of curvature divergences that

Hawking feels ought to be generically associated with incomplete geodesics.

76. 'There are examples in which geodesic incompleteness can occur with the curvature remaining bounded, but it is thought that generically the curvature will diverge along incomplete geodesics.' Stephen Hawking and Roger Penrose, *The Nature of Space and Time*, Oxford University Press, Delhi, 1997, p. 15. For the examples, see C. J. S. Clarke, *Analysis of Space-Time Singularities*, cited earlier.
77. Mathematically, the assumption is that the metric tensor should remain smooth (continuously differentiable, say) all the way to the singularity, without which assumption the geometric approach of singularity theory fails, and one has to shift to analytical techniques. The curvature relates to the second derivative of the metric tensor, so if the metric tensor has a kink (as in a V-shape) its first derivative would be discontinuous, and the second derivative would blow up. For shock waves in perfect fluids, these difficulties could be handled by shifting to an integral formulation of the basic equations, and deducing what happens *at* the point of blow-up from what happens *around* it. Worse divergences can arise, involving the square of the delta function, which cannot be handled so easily. These cases may arise because viscosity has a sharpening instead of a smoothing effect (see note 81, this chapter); they could also arise in the more exotic situation where the metric tensor itself becomes discontinuous, in the presence of exotic matter, say, as in the case of a 'gravitational screen'.
78. The exact technical meaning of this term from the theory of (hyperbolic) partial differential equations is not relevant here. Roughly speaking, these are paths along which sound travels, so that the analogy to null geodesics is exact, and does not depend on the geodesic hypothesis. Technically, the intersection of characteristics must be interpreted as indicating a shock wave; see P. D. Lax, *Hyperbolic Systems of Conservation Laws and the Mathematical Theory of Shock Waves*, SIAM Regional Conference Series in Appl. Math., **11**, Society for Industrial and Applied Mathematics, Philadelphia, 1973.
79. The fluid particles are hypothetical particles used in the continuum approach, and should not be confused with the molecules of the air, used in the discrete approach. In general relativity, as formulated today, only the continuum approach is available.
80. That is, singularities have no empirical consequences that are distinct from the empirical consequences of a dense past state of the cosmos.
81. Those interested in the technical details may consult the following of my papers. The general background papers are: 'Products and

Compositions with the Dirac Delta Function', *J. Phys. A: Math. Gen.*, **15**, 1982, pp. 381–96, 'Junction Conditions in General Relativity', *J. Phys. A: Math. Gen.*, **15**, 1982, pp. 1785–97; 'Distributional Matter Tensors in Relativity', in *Proc. MG5*, ed. D. Blair et al. World Scientific, Singapore, 1989, pp. 421–24. The relation to quantum infinities is taken up explicitly in 'On the Square of $x^{-n}$', *J. Phys. A: Math. Gen.*, **16**, 1983, pp. 3739–53. Note that it does not help to talk of the smoothing properties of viscosity: on the contrary, with viscosity, the infinities involve the square of the delta function; see, 'Navier-Stokes Shocks', preprint, Centre for Development of Advanced Computing, Pune.

82. In terms of singularity theory, the statement would be that the spacetime manifold can be extended, and 'there is no absolute criterion for what sorts of extensions are 'legitimate', and hence no absolute criterion for what is and what is not a singularity'. C. J. S. Clarke, *Analysis of Space-Time Singularities*, p. 145. For the actual reinterpretation of physical law in distributional terms, see particularly my articles on the Dirac delta function, and on distributional matter tensors, cited above. It is true that uniqueness breaks down, and some further physical condition, such as the entropy law, may be needed. That, however, is in the nature of things.
83. For a quick overview, see Stephen Hawking, 'Classical Theory', chap. 1 in Stephen Hawking and Roger Penrose, *The Nature of Space and Time*, Oxford University Press, New Delhi, 1997. For a rather more technical—and balanced—account, see C. J. S. Clarke, *Analysis of Space-Time Singularities*, cited earlier.
84. Closing sentence of Hawking and Ellis, *The Large Scale Structure of Space-Time*, cited earlier, p. 364.
85. Jerry Pournelle in *Black Holes*, ed. Jerry Pournelle, cited earlier, p. 333.
86. Stephen Hawking, *Black Holes and Baby Universes and Other Essays*, Bantam Books, London, 1993, p. 158.
87. A relativistic correction to Leibniz is needed: since spacetime is an attribute of the cosmos, God cannot also be at any time in any place!
88. Stephen Hawking, *Black Holes and Baby Universes*, cited earlier, p. 85.
89. But see F. J. Tipler, *The Physics of Immortality*, Macmillan, London, 1995, p. 256.
90. Freeman J. Dyson, 'Time without end: physics and biology in an open universe', *Rev. Mod. Phys.,* **51**, 1979, pp. 447–60. Also, *Infinite in All Directions*, Harper and Row, New York, 1988.

91. A popular account of the respective claims of Dyson and Tipler about the end of the world may be found in Paul Davies, *The Last Three Minutes*, Basic Books, New York, 1994.
92. Vladimir Nabokov, *The Defence*, trans. Michael Scamell in collaboration with the author, Panther Books, 1967.
93. Frederic Brown, 'Answer', in *The Stars and Under, A Selection of Science Fiction*, ed. Edmund Crispin, Faber and Faber, London, 1968, p. 110.
94. Spengler, *Decline of the West*, pp. 502–4.
95. Tipler, *Physics of Immortality*, pp. 256–57.

## CHAPTER 4

1. Richard S. Westfall, *Never at Rest: A Biography of Isaac Newton*, [1980], Cambridge University Press, paperback edition, 1983, p. 49. Conduitt's memorandum of a conversation with Newton, 31 August 1726 (Keynes MS 130.10).
2. Manuel recalls 'Voltaire's wicked quip about the assurance of Newton's doctor that he died a virgin'. Frank E. Manuel, *Isaac Newton, Historian*, Harvard University Press, Cambridge, Mass., 1963, p. 253.
3. A Freudian view may be found in Frank E. Manuel, *Portrait of Isaac Newton*, Cambridge, Mass., 1968, and is extended in Frank E. Manuel, *Religion of Isaac Newton*, Oxford University Press, Oxford, 1974.
4. Westfall, *Never at Rest*, p. 319.
5. 'Having searched after knowledge in the prophetic scriptures, I have thought myself bound to communicate it for the benefit of others, remembering the judgment of him who hid his talent in a napkin.' H. McLachlan, ed., *Sir Isaac Newton, Theological Manuscripts*, Liverpool University Press, Liverpool, 1950, p. 1. The scriptural allusion is to Luke xix, 20f; Matthew xxv, 25f. The wording has been modernised, changing 'prophetique' to 'prophetic' and 'my self' to 'myself', and 'remembring' to 'remembering'. See also, Appendix A of Frank E. Manuel, *Religion of Isaac Newton*, p. 107.
6. John Greaves, *Miscellaneous Works*, ed. Thomas Birch, vol. 2, London, 1737, pp. 405–33.
7. The implication of this for the credibility of authoritative historians of science should not be overlooked: for centuries, historians of science have put foward their fabrications, and concealed the elementary truth about Newton.
8. The complete quote reads: 'a wealthy Palestinian Jew, who took his degree in Arabic studies in Germany, became Royal Professor of Medieval Rabbinics in Spain, then professr of Arabic in Germany,

a lecturer in England in the 1930's and a refugee scholar in America from 1940 until his death in 1951.' Richard H. Popkin, 'Biblical Theology and Theological Physics', in *Newton's Scientific and Philosophical Legacy*, ed. P.B. Scheuer and G. Debrock, Kluwer Academic, Dordrecht, 1988, pp. 81–97.

9. *Isaac Newton*, *Theological Manuscripts*, selected and edited with an introduction by H. McLachlan, Liverpool, 1950. According to Westfall, cited in note 1, 'this misbegotten volume' 'takes great liberty with the originals', such as introducing paragraphs. More to the point, Newton's theological manuscripts in Keynes' possession were not representative, since Keynes appears to have focused on Newton's alchemy, often swapping the theological manuscripts he had for alchemical one's. The Yahuda collection gives a better account of Newton's theological views.
10. Popkin, in *Newton's Legacy*, ed. Scheuer and Debrock, p. 87.
11. Popkin, in *Newton's Legacy*, ed. Scheuer and Debrock, p. 82; original correspondence in Yahuda MS, var. 1, box 42.
12. Westfall, *Never at Rest*, p. 876.
13. Popkin, in *Newton's Legacy*, ed. Scheuer and Debrock, p. 85, states that in the Bodmer MSS 'Newton presented his…theory of how the Church became corrupt, how it falsified the true doctrine of Christianity, and in part, how it accomplished this by tinkering with the texts of the New Testament'. That Newton's theological writing included a completed history of the church was indicated by the will of Newton's niece, Catherine Conduitt, which mentions a 'church history compleat'; see Frank E. Manuel, *Isaac Newton, Historian*, Harvard University Press, 1964, p. 254. It now appears that the Bodmer MSS is part of the Sotheby lot No. 249, an incomplete 425 page treatise 'Of the Church', which corresponds to a later draft of the church history in Yahuda MS, var. 1, 15. See M. Goldish, 'Newton's *Of the Church*: its Contents and Implications', in *Newton and Religion: Context, Nature and Influence*, ed. J. Force and R. H. Popkin, International Archives of the History of Ideas 129, Kluwer, Dordrecht, 1999, pp. 145–64.
14. An easily accessible list of the Sotheby lots may be found at the website of the Newton Project at http://www.newtonproject.ic.ac.uk/. This project, started at the Imperial College, London, in 1998, aims to end centuries of secrecy and make available all the Newton manuscripts in digital format.
15. 'A society of would-be clerics intent on preferment and constrained by the principle of seniority did not allow the ladder all must climb to be clogged with non-clerics who could hold their fellowships forever.' Westfall, *Never at Rest*, p. 330.

16. Barrow's argument was in response to one Francis Aston's attempt to obtain such a royal dispensation. Westfall, *Never at Rest*, p. 332.
17. Ibid., p. 333.
18. Ibid., p. 869; Keynes MSS, 130.6, Book 1; 130.7, sheet 1.
19. More details may be found in the references in note 5, and in Frank Manuel, *Isaac Newton Historian*, Harvard University Press, Cambridge, Mass., 1963; I. Bernard Cohen and Robert E. Schofield, eds., *Isaac Newton's Papers and Letters on Natural Philosophy*, Harvard University Press, Cambridge, Mass., 1958, rev. ed. 1978; Richard S. Brooks, 'The Relationships between Natural Philosophy, Natural Theology and Revealed Religion in the Thought of Newton and their Historiographic Relevance', dissertation, Northwestern University, 1976; William H. Austin, 'Isaac Newton on Science and Religion', *Journal of the History of Ideas*, **31**, 1970, pp. 521–40; Leonard Trengrove, 'Newton's Theological Views', *Annals of Science*, **22**, 1966, pp. 277–94; Margaret Jacob, *The Newtonian and the English Revolution 1689–1720*, Cornell University Press, Ithaca, New York, 1976.
20. Westfall, *Never at Rest*, pp. 312–13.
21. As specific examples, Newton wrote that Athanasius had misrepresented the 3rd-century church Father, Dionysius of Alexandria, to make it appear that he accepted a term (*homoousios*) which, in fact, he considered heretical (Westfall, *Never at Rest*, p. 314, original in Yahuda MS, 2.5b, ff. 40v–41); and that words were 'foisted in' in the epistles of the 2nd-century Ignatius in support of trinitarianism (ibid., Yahuda MS, 14, f. 61v).
22. Westfall, *Never at Rest*, p. 314; original in Keynes MS, 2, p. 77. The synod of Serdica (Sofia) met in 342 or 343 to patch a division between the eastern part of the Roman empire ruled by Conantius, and the western part ruled by his brother Constans. he eastern delegation left within a day, conemning Pope Julius and Hosius of Cordoba through whom '...Athanasius, and the other criminals' had been 'again received into the ecclesiastical community'. Jedin and Dolan, eds., *History of the Church*, vol. II, cited in note 4, Chapter 2, p. 38. The source of the quote is Hilary of Poitiers. In his 'Paradoxical Questions Concerning the Morals and Actions of Athanasius and his Followers', Newton, of course, quotes the reference to 'the most wretched Athanasius, convicted of the most foul crimes, for which he can never be sufficiently punished—no, not though he should be ten times killed...'. McLachlan, ed., *Theological Manuscripts*, p. 111.
23. After early training in Syrian Antioch, Arius was a pastor in the Church at Baucalis in Alexandria. From 318 to 319 he taught about the Logos and its relation to the Father. His bishop, Alexander,

suggested a theological discussion in which the special views of Arius could be debated. Arius stated that 'the Son of God was created out of non-being that there was a time when he did not exist, that, according to his will, he was capable of evil as well as of virtue, and that he is a creature and created'. His opponents insisted on the consubstantiality and eternity of the Son with the Father. Alexander praised both sides for their theological zeal, accepted the second opinion, and ordered Arius never again to propound his opinion. When Arius refused to accept this verdict, he and his adherents were excommunicated. Arius moved out of Egypt to Nicomedia whose Bishop Eusebius, a 'Collucian' (i.e., follower of the school started by Arius' teacher, Lucian, at Antioch), supported him. He coined the term *homoousios* as a heretical, intolerable consequence of the anti-Arian position.

24. Nestor was branded a heretic nominally for calling Mary 'Mother of Christ' because his congregation was debating whether to call her 'Mother of God' (Theotokos) or 'Mother of Man' (Anthropotokos)!
25. Newton did think, 'That Religion and polity, or the laws of God and the laws of man, are to be kept distinct', McLachlan, ed., *Theological Manuscripts*, p. 58.
26. Westfall, *Never at Rest*, p. 350; original in Yahuda MS, 9.2, ff. 99–99v.
27. Westfall, *Never at Rest*, p. 318.
28. Ibid., p. 313.
29. Ibid., p. 350; original in Yahuda MS, 9.2, ff. 99–99v.
30. Westfall, *Never at Rest*, p. 315.
31. Ibid., p. 349.
32. More to Sharp, 16 August 1680 in *Conway Letters. The correspondence of Anne, Viscountess Conway, Henry More, and Their Friends 1642–1644*, ed. Marjorie Hope Nicolson, Yale University Press, New Haven, 1930, pp. 478–79.
33. Westfall, *Never at Rest*, p. 356; original in Yahuda MS, 9.2, f.157. (Emphases mine.)
34. Westfall, *Never at Rest*, p. 330; original in Yahuda MS, 1.2, f. 30v. (Emphases mine.)
35. Westfall, *Never at Rest*, p. 327.
36. Westfall, *Never at Rest*, pp. 323–24; original in Yahuda MS, 1.4, ff. 67–68.
37. Westfall, *Never at Rest*, p. 313; original in Yahuda MS, 14, f. 57v; Keynes MS, 2, pp. 19–20.
38. Isaac Barrow, *Lectiones geometricae*, pp. 4–15. Lecture 1, reproduced as 'Absolute Time', in *The Concepts of Space and Time: their Structure and their Development*, ed. Milic Capek, vol. XXII of Boston Studies

in the Philosophy of Science, ed. Robert S. Cohen and Marx W. Wartofsky, D. Reidel, Dordrecht, 1976, pp. 203–8.

39. Barrow, in *Space and Time*, ed. Capek, p. 204. Capek points out that Gassendi, in his polemic against Descartes in 1644, had already stated, 'Whether things exist or not, whether they move or are at rest, time always flows at an equal rate'. Milic Capek, 'What Survives from Absolute Time', in *Newton's Legacy*, ed. Scheuer and Debrock, pp. 309–19, 311.
40. 'Magnitudes themselves are absolute *Quantums* Independent on all Kinds of Measure tho' indeed we cannot tell what their Quantity is, unless we measure them; so Time is likewise a *Quantum* in itself, tho' in Order to find the Quantity of it, we are obliged to call in Motion to our Assistance.' Barrow, cited above, p. 204.
41. Barrow, in *Space and Time*, ed. Capek, p. 205. As Capek points out, Giordono Bruno had advanced a similar argument to make time (duration) independent of motion: 'Now if it happened that all things are at rest, would this mean that they would not endure? Indeed, they would endure, they would all endure by one and the same duration.' Capek in *Newton's Legacy*, p. 310
42. The 'Parts of Time' corresponded to the 'Parts of an equal Motion', time was 'alike in all its Parts', and since it could be thought of as the continual 'Flux of one Moment', it had length alone. Barrow in *Space and Time,* ed. Capek, p. 205.
43. Isaac Newton, *The Mathematical Principles of Natural Philosophy*, A. Motte's translation, revised by Florian Cajori, University of California Press, Berkeley and Los Angeles, 1962, vol. 1, pp. 6, 7–8. Reproduced in *Concepts of Space and Time*, ed. Capek, p. 209.
44. H. Poincaré, *Science and Hypothesis* [1902], Eng. trans. (1905); reprint, Dover, New York, 1952, p. 141.
45. Newton related elliptic orbits to the inverse square law using the calculus, where 'Newton's basic discovery was that everything had to be expanded in infinite series....Newton, although he did not strictly prove convergence, had no doubts about it....What did Newton do in analysis? What was his main mathematical discovery? Newton invented Taylor series, the main instrument of analysis.' V. I. Arnol'd, *Barrow and Huygens, Newton and Hooke,* trans. E. J. F. Primrose, Birkhauser Verlag, Basel, 1990, pp. 35–42. Taylor was a pupil of Newton whose paper dates from 1715. These infinite expansions were to analysis as decimal fractions to arithmetic. It is another matter that these infinite series expansions were not only in use, but were also explained at length in a 1501 manuscript that was in wide circulation in coastal South India in the sixteenth century, when Jesuits were busily gathering information from India. For more details, see C. K. Raju, 'Computers, Mathematics

Education, and the Alternative Epistemology of the Calculus in the *Yuktibhāṣā*', *Philosophy East and West,* **51**(3), 2001, pp. 325–362. Basically, the Indian calculus-related texts were imported into Europe in connection with the European navigational problem, and the related Gregorian calendar reform of 1582. These diffused into Europe through the works of Cavalieri, Fermat, etc., who had access to Jesuit sources. See further Chapter 10 and C. K. Raju, 'The Infinitesimal Calculus: How and Why it Was Imported into Europe', paper presented at the International Conference on East-West Transitions, National Institute of Advanced Studies, Indian Institute of Science, Bangalore, December 2000 (submitted for publication).

46. 'Planet Fakery Exposed. Falsified Data: Johannes Kepler'. *The Times* (London) 25 January 1990, 31a. The article includes large excerpts from the article by William J. Broad, 'After 400 Years, a Challenge to Kepler: He Fabricated Data, Scholars Say', *New York Times*, 23 January 1990, C1, 6. The key background article is William Donahue, 'Kepler's Fabricated Figures: Covering Up the Mess in the *New Astronomy*', *Journal for the History of Astronomy,* **19**, 1988, p. 217–37.
47. The poem was written c. 1730, and published in 1730. John Butt, ed., *The Poems of Alexander Pope*, Methuen, London, 1968, p. 808. The poem has been cited so often that it cannot possibly be spoilt by explaining that apart from the allusion to creation, 'Light' alludes also to Newton's work on light (optics), and that 'light' is, in a way, the opposite of gravity.
48. Arab philosophy was systematically studied along with the medicine of Ibn Sīnā (called Avicenna), as part of the university syllabus for centuries in Europe. It is well documented how the scholastic philosophers, like Thomas Aquinas were deeply influenced by this philosophy, together with the works of Aristotle that it brought back to the West. It is, therefore, very likely that this dispute between rationality and providence entered Christian theology from Islamic theology.
49. John Duns Scotus, d. 1308, was also known as Dr Subtilis, for his subtlety, and his works were used as texts until about the 16th century. Instead of subtlety, his followers developed a reputation for cavil and sophistry, and even this soon degenerated into a reputation for plain dull obstinacy.

## CHAPTER 5

1. Remark to his biographer Moszkowski. Roger Highfield and Paul Carter, *The Private Lives of Albert Einstein*, Faber and Faber, London, 1993, p. 100.

2. Highfield and Carter, *Private Lives*, p. 57. Original in Jürgen Renn and Robert Schulmann, eds., *Albert Einstein/Mileva Marić, the Love Letters*, Princeton University Press, Princeton, 1992, p. 19; Anna Beck and Peter Havas, trans., *The Collected Papers of Albert Einstein*, vol. 1, Princeton University Press, Princeton, 1987, p. 141.
3. Highfield and Carter, *Private Lives*, p. 79.
4. After getting the job at the Patent office, Einstein married Mileva in 1903, but only after his father gave him permission to do so on his deathbed. 'She hatched another chick', and another. The younger son was apparently mentally disturbed, while the older son remained permanently embittered from his father. The two divorced in 1919, just before Einstein became very famous, and after many years of 'carrying on' with his cousin Elsa, whom he later married. Physical violence is reported to have been one of the grounds for the divorce. Einstein continued his daily philanderings (including with Mileva) which were behind Elsa's back only in the sense that she deliberately went out in the morning and returned in the evening. The point of the marriage was not clear, at least not to Einstein. When asked whether the object of smoking a pipe was to clean it, he said that the object is to smoke, this gets in the way, like marriage. As she lay dying in the other room, Einstein calmly continued working, though her shrieks unnerved his collaborator P. W. Bridgman. Shortly after her death, Einstein wrote to Max Born that he had settled down splendidly at the Institute of Advanced Study. See Highfield and Carter, *Private Lives,* especially, p. 216.
5. There was an attempt to do genetic matching on at least one other claim, using the preserved portions of Einstein's brain. But the tissue did not permit such matching to be carried out. See, Highfield and Carter, *Private Lives*, p. 284.
6. A. Einstein, 'How I Created the Theory of Relativity', translated from the Japanese by Yoshimasa A. Ono, in *History of Physics*, ed. Spencer R. Weart and Melba Phillips, Amer. Inst. Phys., 1985, p. 244. (Based on a talk given at Kyoto on 14 December 1922, when Einstein was unable to attend the Nobel prize ceremony at Stockholm, as he had already proceeded to Japan.)
7. A. Einstein, 'On the Electrodynamics of Moving Bodies', in *The Principle of Relativity*, by H. A. Lorentz, A. Einstein, H. Minkowski, and H. Weyl, with notes by A. Sommerfeld, trans. W. Perrett, and G. R. Jeffrey, 1923; reprinted, Dover Publications, New York, 1952, p. 37. (Reprinted from *Ann. Phys.* **17**, September 1905.)
8. I do not know what significance to attach to these contradictory answers since Einstein clearly had selective recall. He denied having had anything to do with the military, when, in fact, he

worked for the US Navy on explosions, from 31 May 1943 to 30 June 1946, at a consultant's rate of twenty five dollars a day. Highfield and Carter, *Private Lives*, p. 245. See also, Abraham Pais, *'Subtle is the Lord…': The Science and the Life of Albert Einstein*, Oxford University Press, Oxford, 1982, p. 529.

9. E. T. Whittaker, *A History of the Theories of Aether and Electricity*, vol. II: *The Modern Theories*, [1951–53], American Institute of Physics, New York, 1987.
10. Ibid., p. 30.
11. Ibid., p. 48.
12. *Comptes rendus Acad. Sci.*, Paris, **140**, 1905 (5 June), p. 1504.
13. Whittaker, *History of Aether and Electricity*, vol. II, p. 40.
14. H. Poincaré, *Bull. des Sci. Math.*, (2) **28**, 1904, p. 302; trans. G. B. Halstead, *The Monist*, **15**, (January) 1905, pp. 1–24; reprinted as 'The Principles of Mathematical Physics', in *The Value of Science*, [1905] by H. Poincaré; reprint Dover, New York, 1958.
15. This ought to be easy to decide, in principle, since a record is maintained by the University about the discussions held there.
16. E. T. Whittaker and G. Robinson, *The Calculus of Observations: A Treatise on Numerical Mathematics*, Blackie & Son, London, [1924], 4th ed., reprinted 1965. Though a bit dated, the book contains nuggets like the following (p. 138): *show that the sum of the 7th and 5th powers of the first n whole numbers is double the square of the sum of their cubes.* [Hint: This is easy if you *know* how to calculate log (79!) on a computer!]
17. Kip S. Thorne, *Black Holes & Time Warps: Einstein's Outrageous Legacy*, W. W. Norton, New York, 1993.
18. Why did Lorentz take the experiment seriously? The experiment was never designed to disprove the existence of the aether. It was meant to discriminate between the theories of Fresnel and Stokes, both of which accepted the aether. The experiment was cited in favour of Stokes' theory which was based on a mathematical impossibility, so that any hypotheses was preferable to it. For further details, see C. K. Raju, 'The Michelson–Morley Experiment', chap. 3a in *Time: Towards a Consistent Theory*, Kluwer Academic, Dordrecht, 1994.
19. A micron is a millionth part of a meter, or one thousandth of a centimeter, so the change in length amounts to one part in 200 million.
20. Abraham Pais, *'Subtle is the Lord…'*, p. 167.
21. Translator's introduction to Poincaré, *The Value of Science*.
22. Sir Edmund Whittaker, in *Biographical Memoirs of Fellows of the Royal Society*, London, 1955, p. 42.

23. H. Poincaré, *Science and Hypothesis*, [1902], Eng. Trans., Dover, New York, 1952, p. 111.
24. For those familiar with elementary calculus at the school level, the reason is simply that acceleration is the derivative of velocity; so adding a constant (vector) to the velocity does not change the acceleration.
25. That is, a law of motion formulated as a first order differential equation. The solution would then be uniquely fixed by specifying the initial *positions* of all interacting particles.
26. Poincaré, *The Value of Science*, cited earlier, p. 46. (Emphasis mine.)
27. Poincaré, *Science and Hypothesis*, pp. 171–72.
28. Ibid., p. 171,
29. Poincaré, *The Value of Science*, p. 108.
30. Ibid., p. 98.
31. Poincaré, *Science and Hypothesis*, p. 243, pp. 175–76.
32. Ibid., pp. 175–176.
33. 'The task was not easy, and if Lorentz has got through it, it is only by accumulating hypotheses'. H. Poincaré, *The Value of Science*, p. 99.
34. Poincaré, *Science and Hypothesis*, p. 175.
35. H. A. Lorentz, in *Relativity*, by Lorentz et al, p. 24.
36. Einstein, in *Relativity*, by Lorentz et al, p. 63.
37. Ibid., p. 38.
38. Poincaré, *The Value of Science*, cited in note 13, p. 104.
39. Ibid. (Emphasis mine.) Is this waffling?
40. Ibid., p. 111.
41. Reproduced as chapter II, in Poincaré, *The Value of Science*, pp. 26–36.
42. Ibid., p 27.
43. Ibid., p. 30.
44. Ibid., p. 35.
45. W. Kaufmann, *Ann. Physik*, **19**, 1906, p. 495: 'The measurement results are not compatible with the Lorentz–Einsteinian fundamental assumption. Pais states that 'Einstein was unmoved': is he looking for the reaction of a scientist or a prophet? Pais, *Subtle is the Lord…*, p. 159.
46. G. Holton, *Amer. J. Phys.*, **28**, 1960, pp. 627–36.
47. G. Scribner, Jr., *Amer. J. Phys.*, **32**, 1964, pp. 672–78.
48. S. Goldberg, *Amer. J. Phys.*, **35**, 1967, pp. 934–44. See also, A. P. French, ed., *Einstein: A Centenary Volume*, Heinemann (for the International Commission on Physics Education), London, 1979, p. 80.
49. Paul A. Schlipp, ed., *Albert Einstein: Philosopher-Scientist*, Library of Living Philosophers, Evanston, Illinois, 1949; including

Autobiographical Notes by A. Einstein. P. Frank, *Einstein: His Life and Times*, Alfred A. Knopf, New York, 1947.

50. R. W. Clark, *Einstein: The Life and Times*, World Publishing Co., New York, 1971. A. Pais, cited in note 7, and Banesh Hoffmann, with Helen Dukas, *Albert Einstein: Creator and Rebel*, Hart-Davis, MacGibbon, London, 1973.
51. Hoffmann and Dukas, cited in note 49, p. 68. Poincaré's second paper, submitted in July 1905, appeared in *Rend. Circ. Mat. Palermo*, **21**, 1906, p. 129.
52. A. Pais, *Subtle is the Lord…*, p. 134.
53. H. Poincaré, *The Value of Science*, pp. 98–99.
54. C. K. Raju, *Time: Towards a Consistent Theory*, Appendix to chapter 3b.
55. Poincaré, *The Value of Science*, p. 91.
56. Cited in Jagdish Mehra, *Einstein, Hilbert and the Theory of Gravitation*, D. Reidel, Dordrecht, 1974, p. 82. Wigner briefly worked with Hilbert.
57. Stephen Hawking, *Black Holes and Baby Universes, and other Essays*, Bantam Books, New York, 1993, p. 62.
58. Jagdish Mehra, *Einstein, Hilbert, and the Theory of Gravitation*, cited earlier.
59. C. Reid, *Hilbert*, Springer, New York, 1970, p. 142.
60. Letter to Arnold Sommerfeld, of 15 July 1915, cited in Jagdish Mehra, p. 25.
61. For more details, see Jagdish Mehra, pp. 25, 30, and C. Reid *Hilbert*, cited above.
62. Reid, *Hilbert*, p. 142, Jagdish Mehra, *Einstein, Hilbert, and the Theory of Gravitation*, p. 25, cited above.
63. Abraham Pais, *Subtle is the Lord…*, pp. 260–61.
64. P. A. Schlipp, *Albert Einstein: Philosopher Scientist*, Library of Living Philosophers, 1959, p. 47. Einstein's three papers in 1902–1904 on the foundations of statistical mechanics dealt with 'the definitions of temperature and entropy for thermal equilibrium conditions and with the equipartition theorem…, the second one with irreversibility…, the third one with fluctuations and new ways to determine the magnitude of the Boltzmann constant.' Pais, p. 58. Einstein did not, however, submit these clearly important rediscoveries in statistical mechanics to claim his Ph.D. in 1905.
65. P. A. Schlipp, *Albert Einstein: Philosopher Scientist*, p. 47; L. Infeld, *Albert Einstein*, Scribner's, New York, 1950, pp. 97–98.
66. Highfield and Carter, *Private Lives*, p. 116.
67. Everyone refers to this as Poincaré's lecture, but the lecture was published in 1904 itself. Einstein knew French, and the English translation of the paper was published in January 1905. To my

knowledge, no one seems to have asked Einstein directly whether he knew of Poincaré's work. Given Einstein's authority, this would have seemed insulting. But let us recall Einstein's remarks on authority.

68. Einstein's denial that he had read the paper at that time could have been just as much a case of selective recall, as his remarks on the Michelson–Morley experiment, or on working for the military.
69. Editorial in *The Times of India*, 12 August 93, on the book by Highfield and Carter.
70. **A personal account.** My prejudices in the matter are as follows. As an undergraduate, I was thrilled to stumble upon Einstein's paper (on Brownian motion) while browsing through old tomes in my college library, though only the formula for Avogadro's number made a little sense to me. My first scientific paper was presented at a symposium to celebrate Einstein's centenary. The praise that I heard there convinced me that Einstein was a super-genius. I appropriated a photograph of Einstein from a notice board of the Physics Department of the Indian Institute of Technology in Delhi, and hung it above my table as a source of inspiration. As a scientist I was unconcerned with history. But in 1989 I started writing a series of articles for the journal *Physics Education*. I wanted to explain that the text-book version of the discovery of relativity theory was wrong, and that Einstein had arrived at it by analysing the notion of time. I read Whittaker's book for the history of the Michelson–Morley experiment, and was struck by the lucidity of the book. I relied heavily on this book to draft the third article in this series. (At this time, I did not doubt that Einstein had carried out the analysis about time. That Einstein reportedly came up with a relatively low [for a super-genius] IQ of 135 was an argument I used against IQ tests.)

    To make the article more interesting for students, I wanted to put in some biographical details. I picked up Pais' book. I was horrified by his description of Whittaker, whose book I had just read. As a mathematician I was aware of Poincaré, and I found Pais's description of Poincaré a little offensive, though I believed him at this point.

    Fortunately, I found Poincaré's two volumes in the library, and was fascinated by what I read. Poincaré had put, very much more clearly and thoroughly, exactly the argument that I wanted to present, the argument missing from the textbooks. What I had thought to be implicit in Einstein was explicit in Poincaré. I concluded that Pais was misrepresenting Poincaré. I was not absolutely sure of what had happened, but every time I looked at Einstein's photograph, the doubts assailed me. I could not bear to look anymore at the photograph which was now kept on a cupboard adjacent to my table. I turned its face to the wall.

Five years later, I thought that I might have misjudged the situation. I found Einstein's photograph (I had shifted to a new house), dusted it and hung it in a corner. Subsequently, I managed to get Whittaker's second volume. I read the naming objection between the lines. After reading other literature, I found that others had the same reading. Many have argued for Einstein in ways that are not at all offensive, but I am beyond caring: I have now permanently dismounted the photograph.

71. A naive but frequently asked question is this: why didn't Poincaré object? Several reasons can be offered. First, like Hilbert, Poincaré simply remained unaware (until his death in 1912) that he would be deprived of credit for his insights—for Poincaré then was famous, Einstein was largely unknown. Second, for Poincaré, science related more to the subtler aesthetics of nature than to social recognition, which he already had. Third, Poincaré was generous in giving credit to others; he understood that his work was based on that of others; probably, under no circumstances would he have brawled, like Newton with Leibniz over calculus, for credit that he could hardly claim singlehanded.
72. We shall see that in the case of relativity, the wrong understanding of the theory relates, as in Newton's case, to the pressure of political beliefs about time.

## Chapter 6

1. Stephen Hawking, *Black Holes and Baby Universes and Other Essays*, Bantam, London, 1994, p. 62.
2. Ever since Descartes introduced his aether (=sky), probably adapted from the corresponding concepts of *akāsa* (sky), in the Nyāya-Vaiśeṣika system of Indian philosophy, physics has stuck to the associated ideas of action by contact. In Indian traditions, this notion of contact was long ago recognised as a linguistic matter, by, for example, the tenth century philosopher Udyotkara, who, in his arguments against Buddhism, refutes the argument that atoms must have parts for they are capable of contact. This did not happen in Western philosophy, with a lengthy debate on the above argument from the time of Leibniz and Kant to the present debate on Bell and non-locality. For a general outline of the debate see the following. Mary Hesse, *Forces and Fields: The Concept of Action at a Distance in the History of Physics*, Philosophical Library, New York, 1962; reprint Greenwood Press, Westport, 1970. C. K. Raju, 'Time in Indian and Western Traditions, and Time in Physics',

in *Mathematics, Astronomy and Biology in Indian Traditions,* ed. D. P. Chattopadhyaya and Ravinder Kumar, PHISPC Monograph Series on History of Philosophy, Science and Culture in India, No. 3, Munshiram Manoharlal, New Delhi, 1995, pp. 56–93; C. K. Raju, 'The Electromagnetic Field', chapter 5a in *Time: Towards a Consistent Theory*, Kluwer Academic, Dordrecht, 1994, pp. 102–115 (first published in *Physics Education*, **9**, 1992, pp. 251–65), and references cited therein; and 'Bell and Non-Locality', chapter 6a in *Time: Towards a Consistent Theory*, pp. 139–160 (first published in *Physics Education*, **10**, 1993, pp. 55–73).

3. H. Poincaré, *Science and Method*, [1908], Dover Publications, New York, 1952.
4. The term 'statistical' derives from the need to collect data to apply the laws of large numbers, and the fact that collection of data was, and still is, considered very important for purposes of the state. See, e.g., Ian Hacking, *The Taming of Chance*, Cambridge University Press, Cambridge, 1990.
5. Jeremy Rifkin (with Ted Howard), *Entropy: A New World View*, Bantam, New York, 1981, p. 39.
6. N. Georgescu-Roegen, Afterword in *Entropy*, by Rifkin, p. 267.
7. One may want to multiply by the Boltzmann constant, and add another constant.
8. Most texts prove this theorem for special cases, assuming Newtonian mechanics, for example. For a proof of the general case, see C. K. Raju, 'Thermodynamics Time', chapter 4 and its appendix in *Time: Towards a Consistent Theory*, pp. 79–101 (first published in *Physics Education*, **9**, 1992, pp. 44–62). The general proof helps to understand the various ways to avoid recurrence.
9. *Complete Works of Friedrich Nietzsche*, ed. O. Levy, Foulis, Edinburgh, 1911, vol. XVI, *Eternal Recurrence*, No. 5, p. 239.
10. 'The law of conservation of energy demands *eternal recurrence*'. F. Nietzsche, *The Will to Power As Art*, No. 1063, trans. W. Kaufmann and R. J. Hollingdale, ed. W. Kaufmann, 1967; reprint Vintage Books, 1968; see also, *The Complete Works of Nietzsche*, ed. O. Levy, vol. IX, 1909.
11. Nietzsche, *Will to Power*, No. 1066, ed. Kaufmann, and also *Complete Works of Nietzsche*, ed. O. Levy, vol. IX.
12. For a proof, see any standard textbook on Markov chains, or C. K. Raju, 'Thermodynamic Time', chap. 4 in *Time: Towards a Consistent Theory*.
13. Nietzsche, *Will to Power*, No. 1066.
14. Nietzsche's argument is essentially correct, notwithstanding claims that it has been refuted by some simple-minded arguments. For the alleged refutation, see W. Kaufmann, *Nietzsche: Philosopher,*

*Psychologist, Antichrist*, Princeton University Press, New Jersey, 1974, p. 327.

15. Nietzsche, *Eternal Recurrence*, No. 8.
16. 'This conception is not simply a mechanistic conception; for if it were that, it would not condition an infinite recurrence of identical cases, but a final state. *Because* the world has not reached this, mechanistic theory must be considered an imperfect and merely provisional hypothesis.' Nietzsche, *Will to Power*, No. 1066, cited earlier.
17. What is required is a manifold with constant negative curvature.
18. That is, the trajectories locally diverge exponentially. They cannot, however, run off to infinity for the trajectories are *confined* to a finite region: the billiards table.
19. H. Poincaré, *Science and Method*, [1908], reprinted, Dover, New York, 1952, chapter 4.
20. *Dīgha Nīkāya*, trans. Maurice Walshe, *The Long Discourses of the Buddha*, Wisdom Publications, Boston, 1995, pp. 68–72,
21. The plots of the Lorentz model shown here were obtained using Calcode, a programme for all calculations with ordinary differential equations.
22. Strictly speaking the figures do not show phase portraits, for phase trajectories never intersect: they are 2-dimensional projections of the phase portraits.
23. K. R. Popper, *The Open Universe: an Argument for Indeterminism*, Postscript to the *Logic of Scientific Discovery*, vol. 3, Hutchinson, London, 1982.
24. Stephen Hawking, *Black Holes, Baby Universes, and other Essays*, Bantam, 1994.
25. Roger Penrose, *The Emperor's New Mind: Concerning Computers, Minds and the Laws of Physics*, Vintage Books, London, 1990. Roger Penrose, *Shadows of the Mind: A Search for the Missing Science of Consciousness*, Oxford University Press, 1994. Roger Penrose, Abner Shimony, Nancy Cartwright, and Stephen Hawking, *The Large, the Small and the Human Mind*, ed. Malcolm Longair, Cambridge University Press, 1997.
26. The following is based on my talk during a debate with Roger Penrose. C. K. Raju, 'Penrose's Theory of the Mind: a Rebuttal', *The Matter of the Mind*, 22–23 December, India International Centre, New Delhi, 1997.
27. One of the first machine learning programs, which could learn to converse was naturally called ELIZA. Joseph Weizenbaum, *Computer Power and Human Reason: from Judgment to Calculation*, [1976], Penguin Books, London, 1993. This made some people (Colby et al.) believe that computers could be used in psychological therapy!

28. M. Minsky, as cited by Weizenbaum, *Computer Power and Human Reason*, p. 235. First published as 'Why Programming is a Good Medium for Expressing Poorly Understood and Sloppily Formulated Ideas', in *Design and Planning* II, ed. M. Krampen and P. Seeitz, Hastings House, New York, 1967, p. 121.
29. The problem was the listing of all simple finite groups. See J. H. Conway, 'Monsters and Moonshine', *The Mathematical Intelligencer*, **2**, 1980, pp. 165–71.
30. K. Appel and W. Haken, 'The solution of the four-color-map problem', *Scientific American*, October 1977, pp. 108–21; 'The four color proof suffices', *The Mathematical Intelligencer*, **8**, 1986, pp. 10–20.
31. School geometry changed in the 1960's, after the recommendations of the US School Mathematics Study Group. School Mathematics Study Group, *Geometry*, Yale University Press, 1961.
32. This confusion was specific to the cultural assimilation of the calculus in Europe, after its import by Jesuits in the 16th c. The confusion did not exist in the original Indian context because Indian mathematics had a different understanding of number, from the days of the Sulba Sūtra-s. Furthermore, in the Indian context the empirically manifest was accepted as a source of proof also in mathematics. Accordingly, the Indian approach to calculus used not 'infinitesimals' but 'indivisibles' in the sense of atomicity: the process of subdividing a circle must stop when the subdivisions reached atomic proportions. However, when the Jesuit Cavalieri, a student of Galileo, whose access to Jesuit sources in Collegio Romano is well documented, first used the same term 'indivisible' in exactly the same context, this invited a storm of protest in Europe. See, further, C. K. Raju, 'Computers, Mathematics Education, and the Alternative Epistemology of the Calculus in the Yuktibhāsā', *Philosophy East and West*, **51**(3), 2002, pp. 325–62. W. A. Wallace, *Galileo and His Sources: The Heritage of the Collegio Romano in Galileo's Science*, Princeton University Press, Princeton, 1984.
33. Proclus, *A Commentary on the First Book of Euclid's Elements*, trans. Glenn R. Morrow, Princeton University Press, 1992, p. 37
34. The key change introduced into the Elements by Hilbert et al. was to change the Side-Angle-Side 'theorem' (proposition 1.4 of the *Elements*) into a postulate, since it was unprovable from the other postulates, and its original proof involved the empirical procedure of picking and carrying one triangle to place it on top of another.
35. Richard's paradox. For an easy exposition see, e.g., R. R. Stoll, *Set Theory and Logic*, Eurasia Publishing House, New Delhi (by arrangement with W. H. Freeman & Co.), 1961, p. 446 and sequel. The

barber paradox, by the way, has the tacit sexist assumption that the barber, and all the 'people' are all adult males.

36. This is a slight correction of the game presented by Weizenbaum, *Computer Power and Human Reason*, pp. 51–53.
37. For example, Penrose asserts in *Emperor's New Mind*, p. 539: '…the terms 'algorithm' and 'algorithmic' refer to anything that (in effect) can be simulated on a general purpose computer. This certainly includes "parallel action"…' Or again, in *Shadows of the Mind*, p. 20, 'It is always possible to simulate parallel action serially.'
38. The parallel computing paradigm referred to here is that of Communicating Sequential Processes, as first implemented some 15 years ago in a computing chip called the Transputer, and in the computing language called OCCAM, which has an indeterministic construct going under the name ALT. For the knowledgeable, the formal semantics in terms of tense logic is similar to that of Schrödinger's cat: there is a PAR construct corresponding to branching, while ALT corresponds to an *indeterministic* selection, so that the collapse of the wavefunction faithfully implements the ALT construct. This, of course, is a parallel computer one can engineer here and now, though it would not be commercially viable. Such a parallel computer corresponds to the chocolate–ice cream machine discussed later on. For more details on the relation of OCCAM to quantum mechanics, see C. K. Raju, 'Quantum Mechanical Time', chap. 6b in *Time: Towards a Consistent Theory*. For quantum computation, see David P. DiVincenzo, 'Quantum Computation', *Science* **270** (1995) pp. 255–261. For the experimental realization, see D. P. DiVincenzo, *Nature* **393** (1998) pp. 113–114, and I. L. Chuang et al, *Nature* **393** (1998) pp. 143–146.
39. During the debate, 'The Matter of the Mind', India International Centre, New Delhi, 22–23 December 1997, cited earlier, Penrose argued that the parallel computer of the preceding note could be simulated by something 'random' in the sense of 'pseudo-random' or 'ensemble' as considered in *Shadows of the Mind*, section 3.18, pp. 168–169. In response to my question, he further clarified that the 'ensembles' under consideration were finite. However, pseudo-random numbers are generated algorithmically, while a finite ensemble of Turing machines is equivalent to a single Turing machine. Thus Penrose's response amounts to saying that parallel computers are algorithmic—even if the parallelism is implemented using the collapse of the wave-function in quantum mechanics. Not only is this not in accordance with existing quantum mechanics, this is not consistent with Penrose's theory of the mind which introduces a non-algorithmic element in the human

brain exactly by this process of wavefunction collapse. Moreover, asserting that wavefunction collapse can be mechanically replicated would force Penrose into a hidden-variable interpretation of quantum mechanics, hence into various questions such as those about non-locality and Bell's inequalities.

40. We need, here, a slightly different definition of 'information', related to what is called the Kolmogorov–Chaitin entropy or complexity. The Kolmogorov–Chaitin entropy of a string is the length in bits of the shortest computer program that will produce that string as an output. See, G. J. Chaitin, *Algorithmic Information Theory*, Cambridge University Press, Cambridge, 1987.
41. David Ruelle, *Chance and Chaos*, Penguin Books, 1993. This refers again to the Kolmogorov–Chaitin complexity.
42. In his *Tahāfut al Falāsifā* ('Destruction of the Philosophers'), his arguments were directed against the theology of reason (*aql-i-kalām*), and against earlier philosophers such as Al Farābi and Ibn Sīnā (Avicenna). S. A. Kamali, *Al-Ghazālī, Tahāfut al-Falāsifā*, Pakistan Philosophical Congress, Lahore, 1958. S. van den Bergh, *Averroes' Tahāfut al-Tahāfut* (incorporating al-Ghazālī's *Tahafut al-Falasifa*) translated with introduction and notes, 2 vols, Luzac, London, 1969. H. A. Wolfson, *The Philosophy of the Kalām*, Harvard University Press, Cambridge, Mass, 1976. Literally, *kalām* means word or Word of God, and the rationalists maintained that one must apply the faculty of reason/intelligence (*aql*) to interpret the contentious passages in the Ku'rān. As interpretations proliferated, al-Ashārī maintained that these passages must be accepted 'without asking how'.
43. *Al-Ghazālī's Tahāfut al-Falāsifā*, trans. S. A. Kamali, p. 189.
44. The chocolate–ice cream (CHIC) machine, by the way, is a real machine which can be constructed today. It is possible to build a quantum-mechanical measuring apparatus, and it is possible to link the output of this apparatus to a digital computer which does the rest. The output of this ana-digi machine is algorithmically uncomputable, so that the criterion of uncomputability does not discriminate between human and machine. Though not a Turing machine, the chocolate–ice cream machine is, in fact, a parallel computer which faithfully implements the ALT construct of OCCAM discussed in an earlier note.
45. M. Dummett, 'Bringing about the past,' *Philosophical Review*,**73**, 1964; reprinted in *The Philosophy of Time*, ed. R. M. Gale, Macmillan, London, 1968, pp. 252–274. For a more detailed review of the exact context of this paradox, see C. K. Raju, 'Philosophical Time', chapter 1 in *Time: Towards a Consistent Theory*, pp. 11–31.

46. The quote continues, 'Then, which of the virtually possible events are to be called possible under the auspices of free will? I would say, just the one that actually follows.' This sentence is fallacious; for it easily degenerate into a tautology. E. Schrödinger, 'Indeterminism and free will', *Nature*, July 4, 1936, pp. 13–14.

# CHAPTER 7

1. Paul J. Nahin, *Time Machines: Time Travel in Physics, Metaphysics and Science Fiction*, American Institute of Physics, New York, 1993. The difficulty that the biological clock need not be a proper clock is relevant also to time dilation due to velocity, since achieving large relative velocities would require subjecting the astronaut to prolonged periods of large accelerations, that may well speed up aging, exactly like extra weight. The need to distinguish between biological time and proper time motivated the conceptual division of time dilation as being 'due to velocity', and 'due to acceleration', in the present book. Though the biological clock cannot be affected by relative velocity, nothing guarantees that a biological clock will behave like a proper clock, when subjected to large accelerations. (In fact, the very existence of a proper clock is suspect, for nothing guarantees that any physically realizable process behaves like a proper clock over very long periods of time.)
2. A. Einstein, 'Electrodynamics of Moving Bodies', in H. A. Lorentz, A. Einstein, H. Minkowski, and H. Weyl, *The Principle of Relativity*, trans. W. Perrett and G. B. Jeffrey, Dover Publications, New York, 1952, pp. 63–64.
3. O. M. P. Bilaniuk, V. K. Deshpande, and E. C. G. Sudarshan, ' "Meta" Relativity', *Amer. J. Phys.*, **30**, 1962, pp. 718–23. O. M. Bilaniuk and E. C. G. Sudarshan, 'Particles Beyond the Light Barrier', *Physics Today*, 1969, pp. 43–51. O. M. Bilaniuk and E. C. G. Sudarshan, 'Causality and Space-like Signals', *Nature*, **223**, 1969, pp. 386–87. G. Feinberg, 'Possibility of Faster than Light Particles', *Physical Review* **159**, 1967, pp. 1089–105.
4. Hence also, it is irrelevant that the rest mass of a tachyon is a complex number, for a tachyon can never be brought to rest (all frames of reference are assumed to be subluminal).
5. Bilaniuk, Deshpande, and Sudarshan, cited above, and Bilaniuk and Sudarshan, cited above.
6. R. C. Tolman, *The Theory of Relativity of Motion*, University of California Press, Berkeley, 1917, pp. 54–55.
7. G. A. Benford, D. L. Book, and W. A. Newcomb, 'The Tachyonic Antitelephone', *Physical Review* D, **2**, 1970, pp. 263–65. The logic

does not apply to single tachyons, nor does it apply to a collection of tachyons which cannot be used to signal to the past.

8. Oswald Spengler, *The Decline of the West*, cited earlier in Chapter 3, p. 500.
9. Strictly speaking, the surface of a photograph is 3-dimensional, and not 2-dimensional, because the photograph endures in time.
10. M. Dummett, 'Causal Loops', in *The Nature of Time*, ed. R. Flood and M. Lockwood, Basil Blackwell, Oxford, 1986.
11. Nahin, however, has a section on why Wells' machine won't work, because it doesn't move through space, Paul J. Nahin, *Time Machines*, p. 13.
12. M. Cook, 'Tips for Time-Travel', in *Philosophers Look at Science Fiction*, ed. N. D. Smith, Nelson-Hall, Chicago, 1982, pp. 47–55.
13. Nahin says, 'Wells, fortunately, never has his characters stick a hand into the space where the time machine was last seen.' (Nahin, *Time Machines*, note 1 to chapter 4, p. 274.) This is incorrect. As the authority called in to support Wells' idea of 'diluted presentation', the Psychologist 'passed his hand in the space in which the machine had been. "You see?" he said, laughing.' Wells has skillfully constructed his story, and its cast of characters. The asymmetry between the presentation of the world to the time traveller, and presentation of the time traveller to the world could also plausibly be put down in SF to psychological factors. H. G. Wells, *The Time Machine*, reprint, UBS Publishers, New Delhi, 1995, p. 10.
14. See, e.g., John Earman, 'Recent Work on Time Travel', in *Time's Arrows Today*, ed. Steven F. Savitt, Cambridge University Press, 1995, pp. 268–310.
15. The calculation is, however, suspect because it is not clear that 'energy' can be assigned an unambiguous meaning in the Gödel cosmos (because the Gödel cosmos is not asymptotically flat).
16. There seem to be two common errors here. One is that a paper published by Birch, suggesting empirical evidence for universal rotation, was later shown to be wrong, but the later paper has not been noticed (e.g., Nahin, *Time Machines*). The other is that the 'accepted' analysis of the amount and *kind* of anisotropy (quadrupole anisotropy) one should look for has itself been more recently shown to be wrong. For further details, see C. K. Raju, 'Cosmological Time', chapter 7 in *Time: Towards a Consistent Theory*, Kluwer Academic, Dordrecht, 1994, pp. 190–211. What this means is that present-day observation may not rule out rotation of the cosmos, hence some peculiar behaviour of the cosmological arrow of time.

17. Kip S. Thorne, *Black Holes and Time Warps: Einstein's Outrageous Legacy*, W. W. Norton & Co., New York, 1994. A more quantitative account may be found in M. S. Morris and K. S. Thorne, 'Wormholes in Spacetime and their use of Interstellar Travel: A Tool for Teaching General Relativity', *Amer. J. Phys.*, **56**, 1988, pp. 395–412.
18. Carl Sagan, *Contact*, Simon and Schuster, New York, 1985. The novel was written after consultation with Kip Thorne on the question of time travel.
19. That is, the journey should take at most one year as measured by both the traveller, and the observer stationed at the mouth of the wormhole.
20. R. H. Price, *Amer. J. Phys.*, **61**, 1993, pp. 216–17.
21. C. K. Raju and N. K. Dadhich, 'Is Gravitational Screening Possible?' in *General Relativity and Gravitation (Proceedings of the Xth International Conference on General Relativity and Gravitation, Padova 1983)*, ed. B. Bertotti, F. de Felice, and A. Pascolini, D. Reidel, Dordrecht, 1984. A gravitational screen corresponds to a discontinuity in the metric tensor, which invalidates typical assumptions used in singularity theorems. A side effect of such a gravitational screen would be a large redshift.
22. S. W. Hawking, 'Chronology protection conjecture', *Physical Review*, **D 46**, 1992, pp. 603–11. Subsequently, Hawking has changed his views on time travel in two respects. The above paper had concluded that there is excellent empirical evidence against time travel since we have not been swamped by 'hordes of tourists' from the future. He has now acknowledged a weakness of this argument: 'A possible way to reconcile time travel, with the fact that we don't seem to have had any visitors from the future, would be to say that it can occur only in the future.' The key change, however, is the restriction of his conjecture to macrophysics: 'the Chronology Protection Conjecture: the laws of physics conspire to prevent time travel, *on a macroscopic scale*.' (Emphasis added.) S. W. Hawking, 'Space and Time Warps by S. W. Hawking as at 18/10/95', personal communication of 16 December 1997.
23. Except in the cases of cosmologies like the Gödel cosmology, where spacetime behaves peculiarly at infinity (it is not asymptotically flat); or in cases like black holes, where there is a singularity; or in cases where negative energy is present, so that there is a discontinuity (in the metric tensor), and Hawking's technique entirely breaks down even in the classical domain!
24. Stephen Hawking, *A Brief History of Time*, Bantam Books, New York, 1988, 'About the Author'.

25. For a differing point of view, see, e.g. Paul Horwich, 'Closed causal chains', in *Time's Arrows Today*, ed. Steven F. Savitt, Cambridge University Press, Cambridge, 1995, pp. 259–67.
26. Frederic Brown, 'Experiment', in *Honeymoon in Hell*, Bantam, New York, 1958. The presentation that follows does not faithfully stick to Brown's story, but uses it only to illustrate a paradox set up by Wheeler and Feynman. The point of the paradox is, of course, that any way of telling the story is wrong!
27. J. A. Wheeler and R. P. Feynman, *Rev. Mod. Phys.*, **21**, 1949, p. 425.
28. Some philosophers have argued that it is meaningless to speak of 'changing' the past, and this argument is given prominence in Nahin's book, cited earlier. I consider this argument to be a meaningless quibble over the meaning that *ought* to be assigned, in natural language, to the word 'change'. One could speak, instead of 'bringing about' the past, in the same way as one speaks of 'bringing about' the future. Even more formally, one could speak of past-branching as opposed to past-linear temporal logic. Such linguistic difficulties also arise in the case of 'cyclic' time, which must be described by a four-place relation, rather than the binary before-after relation assumed in natural language; these difficulties are considered in Chapter 8. But as shown by the Appendix and assumption 3, the virtues associated with formalism are not above suspicion. Ultimately, meaning has to be grasped intuitively.
29. I have *not* investigated this matter myself, and I am definitely sceptical about the alleged facts. But the allegation concerns Morgan Robertson's novel *Futility*, first published in 1898, and then republished *in revised form* under the title *The Wreck of the Titan*, in 1912, allegedly a short while before the sinking of the *Titanic* in 1912. It is, for instance, quite conceivable, that there was some chance similarity between the event and its description in the earlier novel, which chance similarity was brushed up after the event, and the publication of the book backdated, to make it seem like a prophecy.
30. J. W. Dunne, *An Experiment with Time*, Faber & Faber, London, 1934; reprint, Macmillan, London, 1981.
31. C. G. Jung, *Synchronicity: an Acausal Connecting Principle*, trans. R. F. C. Hull, ARK Paperbacks, Routledge, London 1985 [1955]. Based on Volume 8 of the *Collected Works of C. G. Jung*, *The Structure and Dynamics of the Psyche*, and an earlier essay, 'Uber Synchronizitat', *Eranos-Jahrbuch*, 1951.
32. See, for example, J. B. Priestley, *Man and Time*, Aldus Books, London, 1964.
33. Physiologically, these bursts of dreaming are associated with rapid eye movements (REM), and enhanced cerebral activity (especially

in the region of the pons). By monitoring the eye movements and the EEG, one can therefore tell when a person is dreaming. REM sleep occurs five to six times in a normal night's sleep.

## CHAPTER 8

1. Cited in P. J. Nahin, *Time Machines: Time Travel in Physics, Metaphysics, and Science Fiction*, American Institute of Physics, New York, 1993, p. 168. The view is from John Varley's novel, and later movie, *Millennium*.
2. Methyl Iso-CyanatE, the chemical released in Bhopal, by the Union Carbide factory, resulting in the worst industrial disaster in history, the compensation claims of which are yet to be settled. Union Carbide used the symbol of a cat with nine lives for its batteries.
3. There is a traditional nomenclature of 'inductive' and 'deductive' logic, which was used to denote what would today be called inductive and deductive inferences. Inductive inferences follow from empirical observations, but deductive inferences have been believed to be *a priori*, and independent of empirical facts. In this book, the term 'logic' everywhere refers to deductive logic. For inductive inferences, I have suggested the use of maximum likelihood estimation (or some similar principle of statistical inference) explained in the appendix.
4. A fuller account may be found in Martin Bernal, *Black Athena: The Afroasiatic Roots of Classical Civilization, Vol. 1: The Fabrication of Ancient Greece*, Vintage, London, 1991. There are many more dimensions to this than meet the eye, e.g., the wholesale appropriation of a variety of technologies, or the appropriation of the infinitesimal calculus, for which last see C. K. Raju, 'Computers, Mathematics Education, and the Alternative Epistemology of the Calculus in the Yuktibhāṣā,' *Philosophy East and West*, **51** (3), 2001, pp. 325–62; and 'The Infinitesimal Calculus: How and Why it was Imported into Europe', paper presented at the International Seminar on East-West Transitions', National Institute of Advanced Study, Bangalore, December 2000 (submitted for publication). Even 'Euclidean' geometry is probably such an appropriation, C. K. Raju, 'How Should "Euclidean" Geometry be Taught', in *History of Science: Implications for Science Education,* ed. G. Nagarjuna, Homi Bhabha Centre, 2002, pp. 241–60. For a popular account of better known cases, see George Geverghese Joseph, *The Crest of the Peacock: Non-European Roots of Mathematics*, Penguin, London, 1991.
5. This is too long a story to get into here. Some more details in this regard are in Chapter 10. See also note 4 above, and C. K. Raju,

'Computers, Mathematics Education, and the Alternative Epistemology of the Calculus in the Yuktibhāṣā', *Philosophy East and West*, **51**, 2002, pp. 325–62.

6. This 'wrapping around' applies only to integers or whole numbers. However, this analogy might have been taken as seriously as the analogy of time to the real line, had physics developed computationally, and had the calculus continued to be done in the traditional Indian way of computational mathematics, where floating point calculations are done using large integers and a notion of 'zeroing' the insignificant. This would also have made 'discreteness' seem as natural a feature of time as continuity is today.
7. If one chooses to quibble, one cannot 'change' the future either, one can only 'bring it about'.
8. For more details on the temporal relation, see N. Rescher and A. Urquhart, *Temporal Logic*, Springer, Wien, 1971, and A. N. Prior, *Past, Present, and Future*, Clarendon, Oxford, 1967.
9. A more detailed account may be found in W. H. Newton-Smith, *The Structure of Time*, Routledge and Keagan Paul, London, 1974.
10. These are worlds exactly in the sense of Wittgenstein's famous statement: 'The world is all that is the case.' L. Wittgenstein, *Tractatus Logico-Philosophicus*, German with English Translation by D. F. Pears and B. F. McGuinness, with an introduction by Bertrand Russell, Routledge and Keagan Paul, London, 1961.
11. It is possible to present this paradox in a slightly different way. A theory is called physical if it is refutable or falsifiable. Refutability depends on the mundane ability to conceive of a bird which is like a swan in all respects except that it is black. This ability presupposes mundane time. This is the primary consistency problem addressed in my book, *Time: Towards a Consistent Theory*, Kluwer Academic, Dordrecht, 1994.
12. C. K. Raju, 'Quantum Mechanical Time', chapter 6b in *Time: Towards a Consistent Theory*, pp. 161–89
13. W. H. Newton-Smith, *The Structure of Time*, cited above.
14. C. K. Raju, 'Quantum-Mechanical Time', chap. 6b, in *Time: Towards a Consistent Theory*, pp. 161–89.
15. Technically, the difference is that the distributive law between *and* and *or* fails. For more details, see C. K. Raju, 'Quantum Mechanical Time', cited above.
16. This is something of a technical matter, and those interested in the technical details may refer to my book cited earlier.

## CHAPTER 9

1. C. K. Raju, 'The Electromagnetic Field', chap. 5a in *Time: Towards a Consistent Theory*, Kluwer Academic, Dordrecht, 1994.
2. The *Nyāya Sūtra* (IV.2.17) asserts that 'atoms are not further divisible', and then states the objection (*pūrva pakṣa*) that this is impossible since 'atoms are pervaded by aether' (IV.2.18), 'else aether would not be all-pervasive' (IV.2.19). The reply is that the aether is 'all pervasive by contact' (IV.2.20). *The Nyāya Sūtra of Gotama*, trans. S. C. Vidyabhuṣaṇa, Panini Office, Allahabad, 1930; reprint Munshiram Manoharlal, New Delhi, 1977, pp. 131–32. Kanāda ('atom-eater'), the founder of the ancient Vaiśeṣika system, however stated the maxim: 'there must be neither contact nor disjunction between cause and effect'. *Vaiśeṣika Sùtra*, II.2.6–11, Eng. translation in *Encyclopaedia of Indian Philosophy*, ed. K. H. Potter, vol. 2, Motilal Banarsidass, Delhi, 1977, p. 218.
3. Mary Hesse, *Forces and Fields*, reprint Greenwood Press, Westport, CT, 1973, p. 95.
4. What does 'contact' mean? Does it mean that the atoms of one object are in contact with the atoms of another object? And if atoms are capable of contact, do they have parts? This was stated as an ante-thesis (*purva paksha*) by Gautam, founder of the ancient Nyāya system, which believed in atomism. A linguistic resolution was proposed by Udyotkara, after a thousand-year long debate with Buddhists, but centuries before the same debate was taken up in Europe by Leibniz, Kant and others, after Descartes adopted and adapted this philosophy. A linguistic resolution would seem to create a new difficulty: what does it mean to say that two particles are *not* in contact? For the original statement of the paradox see, *Nyāya Sūtra,* IV.2.24, in *The Nyāya Sūtra of Gautama,* trans. Ganganath Jha, vol. 4, reprint, Motilal Banarsidass, Delhi, 1984. For Udyotkara's linguistic resolution, see *Nyāya Varttika,* trans. Ganganath Jha [1919], reproduced in K. H. Potter, *Encyclopaedia of Indian Philosophy,* vol. II, Motilal Banarsidass, Delhi, 1977, pp. 334–35. For the debate on the same question in Europe, see, Mary Hesse, *Forces and Fields,* pp. 160–67.
5. C. K. Raju, 'Newton's Time', chap. 2 in *Time: Towards a Consistent Theory*, Kluwer Academic, Dordrecht, 1994, pp. 33–48.
6. Ironically, in the priority dispute between Einstein and Poincaré, credit for relativity has been given to Einstein on the ground that he rejected the aether, while Poincaré 'waffled'. Specifically, the term aether has two meanings in physics. The first is as a container, a reference frame with respect to which absolute velocity may be defined. The second is as an all-pervasive substratum, which ensures 'contact' and a 'chain of causes' between interacting distant

objects. This is the original meaning, as used in Nyāya-Vaiśeṣika system or by Descartes. The first meaning derived from the posited all-pervasiveness of the aether. Einstein initially rejected the aether only in the first sense, while Poincaré at least stated the consequences of rejecting the aether in the Cartesian sense, namely that 'the state of the world would depend not only on the moment just preceding, but also on much older states'. General relativity also seemed to restore in the spacetime manifold, the other sense of the aether as an absolute reference frame. F. Selleri (personal communication) informs me that Einstein believed in the aether at least from 1916 onwards as described in the book by Ludwig Kostro, *Einstein and the Ether*, Apeiron, Montreal, 2000.

7. H. Poincaré, *Science and Hypothesis*, [1902], Eng. Trans., Dover, New York, 1952, p. 169.
8. More precisely, what I mean here is the following. It is impossible to capture the qualitative features of the solutions of a (retarded) functional differential equation (FDE) by means of ordinary differential equations (ODEs). Hence, it is mathematically impossible to reduce FDEs to an equivalent system of ODEs, through a more complicated description of the state. On the other hand, it *is* mathematically possible to replace a system of FDEs by an equivalent system of partial differential equations (PDE) plus a system of ODEs, together with some ad hoc stipulations. (For example, the 2-particle FDEs of retarded electrodynamics may be replaced by Maxwell's equations for fields, plus ODEs of motion of each particle, given all other fields, together with the ad hoc stipulation that the fields in question are retarded.) But this results in a system so complicated and misleading that no one has actually solved the electrodynamic 2-body problem, and its qualitative properties have been misunderstood for a century. C. K. Raju, 'Simulating a Tilt in the Arrow of Time: Preliminary Results', invited paper presented at the Seminar on *Some Aspects of Theoretical Physics*, Indian Statistical Institute, Calcutta, 14–15 May 1996. 'The Tachyonic Anti-Telephone and Tolman's Grandfather', invited talk delivered at the *Heisenberg Colloquium,* Indian Institute of Advanced Study, Shimla, August 1997. 'The Electrodynamic 2-Body Problem and the Origin of Quantum Mechanics', paper presented at the International Symposium on *Uncertain Reality*, India International Centre, New Delhi, 5–9 January 1998, 'Relativity: History and History Dependence', paper presented at the *On Time* Seminar, British Society for History of Science, and Royal Society for History of Science, Liverpool, August 1999. 'Time Travel', invited talk at the International Seminar, *Retrocausality Day*, University of Gronningen, September 1999.

9. To be more precise, Einstein's mathematical error was that he tried to reduce a system of retarded FDEs for the relativistic many-body problem to a system of ODEs by 'Taylor'-expanding in powers of the delay. A. Einstein, L. Infeld, and B. Hoffmann, 'The Gravitational Equations, and the Problem of Motion', *Ann. Math.*, **39**, 1938, pp. 65–100; H. P. Robertson, 'Notes on the Preceding Paper: The Two Body Problem in General Relativity', *Ann. Math.*, **39**, 1938, pp. 101–4. This procedure is known to be incorrect. For mathematical details, see C. K. Raju, 'Electromagnetic Time', chap. 5b in *Time: Towards a Consistent Theory*, pp. 116–35.
10. P. A. M. Dirac, 'Classical Theory of the Radiating Electron', *Proc. R. Soc.* **A167**, 1938, pp. 148–68.
11. K. R. Popper, 'The Arrow of Time;, *Nature*, **177**, 1956, p. 538; 'Irreversibility and Mechanics', *Nature*, **178**, 1956. p. 382; 'Irreversible Processes in Physical Theory', *Nature*, **179**, 1957, p. 1297; 'Irreversibility and Entropy since 1905', *Brit. J. Phil. Sci.*, **8**, 1957, pp. 151–55; 'Time's Arrow and Entropy', *Nature*, 207, 1965, pp. 233–34 *The Open Universe*, Hutchinson, London, 1982.
12. K. R. Popper, personal communication, letter dated 4 May 1990.
13. P. A. M. Dirac, cited above.
14. J. A. Wheeler and R. P. Feynman, 'Interaction with the Absorber as the Mechanism of Radiation', *Rev. Mod. Phys.* **17**, 1945, pp. 157–81; **21**, 1949, pp. 425–33.
15. That is, that the mean free path of a photon is of the order of the Hubble radius. J. E. Hogarth, 'Cosmological Considerations of the Absorber Theory of Radiation', *Proc. R. Soc.* **A267**, 1962, pp. 365–83.
16. P. C. W. Davies, *Proc. Camb. Phil. Soc.* **68**, 1970, pp. 751–64; *J. Phys. A,* **4**, 1971, pp. 836–45; 'Extension of Wheeler-Feynman Quantum Theory to the Relativistic Domain', *J. Phys. A*, **5**, 1972, pp. 1025–36.
17. F. Hoyle and J. V. Narlikar, 'Time Symmetric Electrodynamics and the Arrow of Time in Cosmology', *Proc. R. Soc.,* **A277**, 1964, pp. 1–23; *Ann. Phys.* **54**, 1969, pp. 207–39; **62**, 1971, pp. 44–97.
18. C. K. Raju, 'Classical Time-Symmetric Electrodynamics', *J. Phys. A*, **13**, 1980, pp. 3303–17.
19. R. B. Partridge, 'Absorber Theory of Radiation and the Future of the Universe', *Nature*, **244**, 1973, pp. 263–65.
20. M. L. Heron and D. T. Pegg, *J. Phys. A*, **7**, 1974, pp. 1965–69.
21. The Poincaré recurrence theorem, in its most general form, fails with history-dependence, and it would be more correct to say that history-dependent processes increase entropy. See, C. K. Raju, *Time: Towards a Consistent Theory*, cited earlier, appendix to Chapter 4, and Chapters 5a and 5b.

22. No doubt the process suggested above involves what has come to be known as reductionism. But I presume that most anti-reductionists chew their food, and don't gulp it down whole. Currently, the reductionist's real objection is to the mechanisation of life that results from reductionism (with instantaneity) and not to the mere reduction of a problem to a more manageable size.
23. E. Schrödinger, *What is Life?*, reprint Cambridge University Press, Cambridge, 1992.

## CHAPTER 10

1. E. P. Thompson, 'Time, Work-Discipline and Industrial Capitalism', *Past and Present* **38**, 1967, pp. 56–97; Lewis Mumford, *Technics and Civilization*, Harcourt Brace, New York, 1934; Sebastian de Grazia 'Time and Work' in *The Future of Time*, ed. Henn Yakes, Garden City, New York, 1971. Georges Gurvitch, *The Spectrum of Social Time*, D. Reidel, Dordrecht, 1964.
2. John Hassard, ed., *The Sociology of Time*, Macmillan, London, 1990.
3. David S. Landes, *Revolution in Time: Clocks and the Making of the Modern World*, Harvard University Press, Cambridge, Mass., 1983, pp. 59–66.
4. These were the lauds, prime, tierce, sext, none, vespers, and compline; the night prayer was called the vigil, and later the matins.
5. See, e.g., Suzan Rose Benedict, *A Comparative Study of the Early Treatises Introducing into Europe the Hindu Art of Reckoning* (Ph.D. Thesis, University of Michigan), Rumford Press, 1914. 'Algorismus' is a Latinisation of al Khwarizmi, who translated into Arabic the mathematical texts of Brahmagupta. There was a protracted conflict between the algorismus texts and abacus texts. The eventual victory of algorismus over abacus was depicted by a smiling Boethius using Indian numerals, and a glum Pythagoras to whom the abacus technique was attributed. This picture first appeared in the *Margarita Philosophica* of Gregor Reisch, 1503, and is reproduced, for example, in Karl Menninger, *Number Words and Number Symbols: A Cultural History of Numbers*, trans. Paul Broneer, MIT Press, Cambridge, Mass., 1970, p. 350. According to the periodisation suggested by Menso Folkerts, the abacus period commenced by the 12th century, though the use of the abacus is obviously much older. Menso Folkerts, Lecture at the Second Meeting of the International Laboratory for the History of Science, Max Planck Institute for the History of Science, Berlin, 19–26 June 1999.

6. E. C. Phillips, 'The proposals of Father Christopher Clavius, S. J. for improving the Teaching of Mathematics', *Bulletin of the American Association of Jesuit Scientists* (Eastern Section) vol. XVIII, May 1941, No. 4, pp. 203–6. The document was written before ca. 1575, when its recommendations were actually implemented in the Collegio Romano.
7. According to Whitrow, the 'verge-and-folio' escapement which made possible the mechanical clock was invented between 1280 and 1300. G. J. Whitrow, *Time in History*, Oxford University Press, Oxford, 1989, p. 103. This type of clock was inaccurate because the balance controlling the frequency of oscillations had no natural period of its own. Later this was linked to the oscillations of a pendulum, and then a cycloidal pendulum, which measured 'equal intervals of time' according to Newtonian mechanics.
8. G. J. Whitrow, *Time in History*, p. 102; emphasis mine.
9. Douglas Peck, 'Columbus Used Dead Reckoning Navigation in His 1492 Voyage of Discovery to the new World', *Encounters: A Quincentenary Review*, 1990 (Summer), pp. 18–21.
10. C. K. Raju, 'Kamāl or Rāpalagai', Paper presented at the Xth Indo-Portuguese Conference on History, Indian National Science Academy, New Delhi, 1998. To appear in Proc.
11. J. W. Norie, *Norie's Nautical Tables,* London, 1864, pp. 59–60.
12. See, for example, K. S. Shukla, ed. and trans., *Bhāskara I and his Works,* Part III: *Laghu Bhāskarīya*, Department of Mathematics and Astronomy, Lucknow University, 1963. The *Laghu Bhāskarīya* was a widely used 6th or 7th century *jyotiṣa* text.
13. The exact relation is $\sin \delta = \sin \phi \sin a$, where $\delta$ is the declination, $\phi$ is the local latitude, and $a$ is the solar altitude on the prime vertical. *Laghu Bhāskarīya* iii 22–23 et. seq., *Maha Bhāskarīya*, iii 37–38. *Bhāskara I and His Works,* Part III, and Part II respectively, ed. and trans. K. S. Shukla, Department of Mathematics and Astronomy, Lucknow University, 1963. Hence, to determine latitude, accurate sine tables were also needed, in addition to an accurate calendar, and Clavius, for example, produced these sine tables.
14. To reiterate, since the church retained the equinoctial cycle as the basis of the calendar, it did not intend to ignore natural cycles altogether. Thus, by continuing to ignore the natural cycle of the moon, and retaining the unequal months, the church was presumably demonstrating its commitment to the state, through its continuing reverence for the petty egos of Roman dictators, together, perhaps, with its commitment to inequity even with regard to the duration of months! Curiously, historians like Whitrow have called this 'a uniform calendar corresponding to the

needs of a universal society and based upon the Christian year.' Whitrow, *Time in History*, p. 70.

15. 'Com tudo não me parece que sera impossivel saberse, mas has de ser por via d'algum mouro honorado ou brahmane muito inteligente que saiba as cronicas dos tiempos, dos quais eu procurarei saber tudo.' Letter by Matteo Ricci to Petri Maffei on 1 December 1581, Goa **38** I, ff. 129r–130v, corrected and reproduced in *Documenta Indica*, **XII**, pp. 472–77. (The quote is from p. 474.) Also reproduced in Tacchi Venturi, *Matteo Ricci S.I., Le Lettre Dalla Cina 1580–1610*, vol. 2, Macerata, 1613.
16. Martin Bernal, *Black Athena: The Afroasiatic Roots of Classical Civilization. Volume 1: The Fabrication of Ancient Greece 1785–1985*, Vintage, London, 1987. Alexandria was located in Egypt, in the continent of Africa. Most early scientific discoveries today attributed to Greeks (Eratosthenes, 'Euclid', Archimedes, Ptolemy, etc.) relate to Alexandria, not Athens, and were earlier attributed to the knowledge of the Egyptians, accumulated in the Great Library of Alexandria. Present-day knowledge of most of the science and philosophy attributed to Greeks relates to medieval Latin translations of Arabic works, or of Byzantine Greek texts which translated Arabic works. The story of 'Greek' origins is thus a racist appropriation carried out with the help of colonial historians. Likewise, the story of a purely European origin of 'modern science' involved numerous appropriations from India and China.
17. Otto Neugebauer, 'On the Planetary Theory of Copernicus,' *Vistas in Astronomy*, **10**, 1968, pp. 89–103. George Saliba, 'Arabic Astronomy and Copernicus', chap. 15 in *A History of Arabic Astronomy*, New York University Press, New York, 1994, p. 291. The heliocentric theory was one of the competing theories in Indo-Arabic astronomy for several centuries prior to Copernicus, and references to it may be found even in the poetry of Amir Khusrau, a 14th century CE poet of Delhi.
18. C. K. Raju, 'Computers, Mathematics Education, and the Alternative Epistemology of the Calculus in the Yuktibhāṣā', *Philosophy East and West*, **51**(3), 2001, pp. 325–62; C. K. Raju and Dennis Almeida (Aryabhata Group) 'The Transmission of the Calculus from Kerala to Europe, Part I: Motivation and Opportunity', and 'Part II: Documentary and Circumstantial Evidence'. Paper presented at the Aryabhata Conference, Trivandrum, January 2000. C. K. Raju 'The Infinitesimal Calculus: How and Why it Was Imported into Europe', paper presented at an International Seminar on East-West Transitions, National Institute of Advanced Study, Bangalore, December 2000 (submitted for publication).

19. For detailed quotations, etc., see C. K. Raju, 'Kamāl or Rāpalagai' cited earlier. Briefly, the *Laghu Bhāskarīya* II.8 gives a rule for determining the local longitude using a clepsydra. *Bhaskara I and his works, Part II: Laghu-Bhāskarīya*, ed. and trans., K. S. Shukla, Department of Mathematics and Astronomy, Lucknow University, 1963, p. 53.
20. E. S. Kennedy, *A Commentary upon Bīrūni's Kitab Tahdid al-Amakin: An 11th Century Treatise on Mathematical Geography*, Beirut, 1973, p. 164.
21. For Fermat's challenge problem see D. Struik, *A Sourcebook of Mathematics 1200–1800*, Harvard University Press, Cambridge, Mass., 1969, p. 29. For the Brahmagupta–Bhaskara equation, see T. S. Bhanu-Murthy, *A Modern Introduction to Ancient Indian Mathematics*, Wiley Eastern, New Delhi, 1992, Chapter 3, p. 121. For Fermat's access to Jesuit sources, and for details on why it is unlikely that Fermat independently rediscovered this, see the paper by C. K. Raju and Dennis Almeida, cited earlier. For Fermat's access to Bombelli's preface to his translation of Diophantus, acknowledging Indian contributions, see C. K. Raju, 'How and Why the Calculus was Imported into Europe', cited earlier.
22. C. K. Raju, 'Computers, Mathematics Education and the Alternative Epistemology of the Calculus in the Yuktibhāṣā', *Philosophy East and West*, **51** (3), 2001, pp. 325–62.
23. Cavalieri, a student of Galileo, waited for five years for his teacher to publish first on the calculus. Galileo's access to the Collegio Romano is well documented. See William Wallace, *Galileo and his Sources: The Heritage of the Collegio Romano in Galileo's Science*, Princeton University Press, 1984.
24. The navigational unit of zam incorporates exactly the Indian method of measuring the radius of the earth, as documented by al Bīrūnī. Al Bīrūnī's accurate results agreed with Caliph al Mamun's measurements (early 9th century), and the earlier Indian estimates of the radius of the earth, whose exact basis is not recorded. See C. K. Raju 'Kamāl or Rāpalagai' cited earlier.
25. Whitrow, *Time in History*, p. 141.
26. Nigel Thrift, 'The Making of a Capitalist Time-Consciousness', in *The Sociology of Time*, ed. J. Hassard, cited earlier, pp. 105–29.
27. This was similar to the traditional Indian astronomical technique of using the meridian through Ujjain—another one of those little facts that Western historians of science have forgotten.
28. Bronislaw Malinowski, 'Tie-reckoning in the Trobriands', in *The Sociology of Time*, ed. J. Hassard, cited earlier, pp. 203–18. (Extracted from 'Lunar and seasonal calendar in the Trobriands', *J. Anthropological Institute of Great Britain and Ireland*, **56–57**, 1926–27.)

29. Karl Marx, *Capital*, vol. I; reprint, Progress Publishers, Moscow, 1974, p. 392.
30. H. -J. Voth, 'Time and Work in Eighteenth-Century London', *Journal of Economic History,* **58**, 1998, pp. 29–58.
31. In India, for example, this is calculated by fixing the minimum wage as the poverty line: the cost of purchasing enough food to maintain the basal metabolic rate (1800 KCal) + light physical activity (sitting or standing), to give a figure of 2400 Kcal (though the poor are typically involved in hard labour). The most well-known (though not the first) attempt to calculate it this way was by the economists V. M. Dandekar and N. Rath. The study, conducted on behalf of the Ford Foundation, did not take into this calculation the needs of the poor for clothes, or housing, or medicine etc., on the grounds that they spent very little on these things anyway! Even this miserable figure was found to be too high, and P. V. Sukhatme's theory was used to bring this down. The theory relied on a malapropism: confusing autoregression with autoregulation to call stunted growth 'homeostasis'. From the point of view of physics (conservation of energy) and statistics, Sukhatme's theory was as befuddled as he was when I repeatedly asked him to show me even the data on the 5 persons on which he claimed to have based his theory. (He never did.) The theory was adopted by the Government of India, and internationally by the Food and Agricultural Organization, to bring down the poverty line, and reduce poverty estimates. The real point of these calculations by Dandekar et al. is not to ensure that the poor get a minimum wage: for the state does not devote resources to ensure that. The real point is that poverty is the capitalist substitute for slavery; without poverty, the capitalist cannot negotiate an unfair exchange. In the US, slaves sold 'down the river' died soon because they were overworked and underfed; and the aristocracy found this to be the most profitable course since the cost of replacing slaves was lower than the cost of maintaining them. Thus, the work of Dandekar et al. served the hidden agenda of calculating how the poor can be most profitably starved. Now, perhaps, the only hope for the poor seems to be to rely on the process which broke the slave trade: the north of North America fought with the south because they produced goods cheaper in the south with slave labour. The first sign of this is the recent US concern for child labour in India. See Jaya Mehta, 'Nutritional norms and the measurement of malnourishment and poverty', *Economic and Political Weekly*, 14 August 1982; 'Poverty data', *State of India's Economy,* Public Interest Research Group, New Delhi, 1995; 'Concern for child labour'. In: *My Name is Today*,

Butterflies Programme of Street and Working Children, excerpted in *The Times of India*, 30 March 1994.

32. Max Weber, *The Protestant Ethic and the Spirit of Capitalism*, [1930], George Allen and Unwin, London, 1968, pp. 60–61.
33. Nigel Thrift, in *The Sociology of Time*, ed. J. Hassard, cited earlier, p. 112.
34. Pierre Bourdieu, 'The Attitude of the Algerian Peasant Towards Time', *Mediterranean Countryman*, **6**, 1963, pp. 55–72. However, they started working harder when their wages were tripled.
35. M. Adas, *Machines as the Measure of Men. Science, Technology and Ideologies of Western Dominance*, reprint, Oxford University Press, New Delhi, 1990, pp. 242–45.
36. Ibid., p. 225.
37. Ibid., p. 226.
38. A. Giddens, *The Class Structure of Advanced Societies*, Hutchinson, London, 1973.
39. *The Times of India*, December 94, op. ed. page.
40. As with the equation *time=money*, this temporal assumption was also a source of racist comment when the temporal beliefs of an industrial society collided with those of an agricultural society during colonialism. 'By the late nineteenth century…lack of "prevoyance" or "ability to anticipate" was considered a clear sign of the primitive state of African societies…Edmund Ferry claimed that the peoples of Sudan had no verb forms to express the past tense and in fact made no distinction between past, present, and future…H. L. Duff compared Africans to "intelligent animals" because of their presentist orientations.' See Adas, *Machines as the Measure of Men*, in the place cited earlier.
41. For a review, see, e.g., D. K. Wood, *Men Against Time*, University of Kansas Press, 1982.
42. A. & B. Bel, 'Polychronie—une approache nouvelle du travail choregraphique et des interactions dans-musique', Actes du Colloque International pour la Danse et la Recherche Choregraphique Contemporaines (Paris: GERMS)(to appear).
43. David Wood, *The Deconstruction of Time*, Humanities Press International, Atlantic Highlands, NJ, 1989.
44. Mircea Eliade, *Cosmos and History: The Myth of the Eternal Return*, trans. W. Trask, Harper, New York, 1959, p. 153.
45. T. S. Eliot, *Essays Ancient and Modern,* Harcourt Brace, New York, 1932, p. 138; 'The idea of a Christian Society', in *The Idea of a Christian Society* and *Notes Towards the Definition of Culture*, Harvest, New York, 1940, pp. 14–19.

# CHAPTER 11

1. See, e.g., Stephen E. Hanson, *Time and Revolution*, University of North Carolina Press, Chapel Hill, 1997, p. 15. Hanson cites Mircea Eliade's *Cosmos and History*, cited in Chapter 10.
2. As recorded in the *Sāmanna Phala Sutta* of the *Dīgha Nikāya*. T. W. R. Rhys-Davids, trans., *Dialogues of the Buddha* (3 vols), London, 1899–1921, vol. I, pp. 68–69. Parallel records are available amongst the Jains. The term 'recluse' is not properly translated, since these six had not run away to the Himalaya. 'Homeless wanderer' is a more accurate if clumsier term, since they did not live the married life of an ordinary householder either.
3. This 'natural' inclination should be distinguished from the reflex or habitual inclination to survive.
4. In the *Viṣṇu Purāṇa*, the reduction proceeds through equations of the type 1 year of mortals = 1 day of the gods and so on up to a day and night of Brahmā. Perhaps this reduction is to be seen in terms of subjective time, as determined by the life span, say. But the justification offered is rather curious in places. For instance, see note 27 of Chapter 1.
5. The *Brahmajāla Sutta* of the *Dīgha Nikāya* of the *Sutta Pitaka*. See, e.g., T. W. Rhys Davids, trans., *The Dialogues of the Buddha*, vol. 1; or the more easily available, Maurice Walshe, trans., *The Long Discourses of the Buddha: A Translation of the Dīgha Nikāya*, Wisdom Publications, Boston, 1995.
6. The use of a quibble was, however, considered acceptable as a means of destroying those who had become too powerful and supported evil. For example, in the same battle, the venerable Bhishma, who had the boon that he could be killed neither by man nor by woman, was killed by a hermaphrodite, Shikhandin, against whom he refused to fight.
7. Like the Stoics, we hear of *Lokāyata* or *Cārvāka* only from their opponents, but the relation here is marked by mutual contempt and explicit abuse. There are two meanings of 'Lokāyata'. The first is *lokesu* (people) + *āyatah* (prevalent) = people's philosophy; the second, attributed to a 5th century CE Buddhist commentator Buddhaghosha, is *loka* ([this] world) + *āyatana* (basis) = this-worldly philosophy or materialism. In all likelihood, both meanings apply—the people's philosophy was materialistic—as supposed in D. P. Chattopadhyaya, cited earlier. There is a small probability, however, that the two meanings may be a bit like there being simultaneously two D. P. Chattopadhyaya-s (both Debi Prasad) in one philosophy department of the same university (Jādavpur), both of whom are cited earlier in this book, it being assumed that the one referred to is clear from the context!

8. T. W. Rhys-Davids, trans., *Dialogues of the Buddha*, cited earlier, vol. 1, pp. 73–74; quoted in D. P. Chattopadhyaya, *Lokāyata: A Study in Ancient Indian Materialism*, Peoples Publishing House, New Delhi, 1959, p. 510; cf. *Dīgha Nikāya*, trans. Maurice Walshe, cited above.
9. Debiprasad Chattopadhyaya and M. K. Gangopadhyaya, eds., *Cārvāka/Lokāyata: An Anthology of Source Materials and Some Recent Studies*, ICPR, New Delhi, 1990, pp. 246–54. Mādhava and his brother Sāyana were ministers in the Vijayanagar empire which sent Vasco da Gama into ecstasies over the wealth in India. *Sarva Darṣana Sangraha of Madhavacarya*, ed. K. L. Joshi, trans. E. B. Cowell and A. E. Gough, Parimal Publications, Delhi, 1986.
10. S. N. Dasgupta, *A History of Indian Philosophy*, vol. 3; reprint Orient Books, New Delhi, 1975, p. 533.
11. D. P. Chattopadhyaya, *Lokāyata*, cited earlier. He also examines in depth the related bias of patriarchy.
12. D. P. Chattopadhyaya, in *Lokāyata*, also argues at length that triangles used in the *yantra*-s of Tantra are esoteric symbols of female genitalia, and that similar esoteric symbols were used in Egypt. These fertility symbols were presumably related to agriculture.
13. D. R. Shastri, *A Short History of Indian Materialism, Sensationalism and Hedonism*, Calcutta, p. 36; cited in Chattopadhyaya, *Lokāyata*, p. 18. Reproduced in*Cārvāka/Lokāyata*, ed. Debiprasad Chattopadhyaya and M. K. Gangopadhyaya, pp. 394–431.
14. D. P. Chattopadhyaya, *Lokāyata*, p. 31. This is an old saying, attributed to the Cārvāka mentor Brhaspati by Madhava in his *Sarva Darṣana Samgraha*; see *Cārvāka/Lokāyata*, ed. Debiprasad Chattopadhyaya and M. K. Gangopadhyaya, p. 254.
15. The 'learned' Western pundits who so facilely refer to Buddhism as Hindu heterodoxy, should first locate at least one heterodox Christian sect which rejects the Bible in toto or one heterodox Islamic sect which similarly rejects the Ku'rān.
16. Quoted by S. N. Dasgupta in *A History of Indian Philosophy*, vol. 3, Cambridge, 1922–55, p. 539.
17. Manibhadra was a commentator on the 8th century Haribhadra's *Sat Darssna Samuccaya*. D. P. Chattopadhyaya, *Lokāyata*, pp. 29–30. *Cārvāka/Lokāyata*, ed. Debiprasad Chattopadhyaya and M. K. Gangopadhyaya, p. 260.
18. Dasgupta, *Indian Philosophy*, vol. 3, p. 536.
19. The elite hostility to Lokāyāta is well known. But even the Buddha rejected the teaching of Lokāyata doctrines as a *dukkata* offence; D. P. Chattopadhyaya, *Lokāyāta*, pp. 38–39; F. Max Mueller, ed., *Sacred Books of the East*, Oxford, 1859, vol. 20, pp. 151–52.

20. *Dhammapada*, trans. E. W. Burlingame, *Buddhist Legends*, (Harvard Oriental Series, vol. 30), Harvard University Press, Cambridge, Mass., 1921. Reprinted by Pali Text Society, Routledge and Kegan Paul, London, 1977, p. 128.
21. B. M. Baruah, *A History of Pre-Buddhistic Indian Philosophy*, Calcutta, 1921; reprint Motilal Banarsidass, Delhi, 1970.
22. *Yoga Bhāsya* 3.52. J. H. Woods, trans., *The Yoga System of Patañjali*… (Harvard Oriental Series, vol. 17), Harvard University Press, Cambridge, Mass., 1927, pp. 287–88; here reproduced from the modified translation by C. K. Raju, 'Time in Indian and Western Traditions and Time in Physics', in *Astronomy, Mathematics, and Biology in Indian Tradition* (PHISPC Monographs, No. 3), ed. D. P. Chattopadhyaya and Ravinder Kumar, PHISPC, New Delhi, 1995, p. 68.
23. Th. Stcherbatsky, *Buddhist Logic*, vol. I, Dover, New York, 1962, p.106.
24. The Buddha's answer involved graded pedagogy. At the zeroth level, he points out (through a counter-question) that if Ajātasattu's slave became a Buddhist monk, the king would treat him with respect. Seeing that the king understands, he proceeds to give him the answer.
25. Lewis Carroll, *The Annotated Alice*, with an introduction and notes by Martin Gardner, Penguin, 1984, p. 67.
26. Friedrich Nietzsche, *The Anti-Christ*, 20, in *Twilight of the Idols and the Anti-Christ,* trans. R. J. Hollingdale, Penguin Books, 1990, pp. 141–42.
27. In fact, since existence did not continue for more than an instant, one acts *not* out of self interest (for future rewards, etc.) but out of compassion for those (including oneself) coming later.
28. One cannot justify inter-temporal comparisons of utility on the grounds that there are only 'slight' changes over time, since the term 'slight' is a cardinal notion, and the very point in question is the existence of a cardinal utility function.
29. F. Max-Mueller, *Sacred Books of the East*, vol. 13, pp. 84–85.
30. *Kaccāyanagotta-Sutta, Samyukta Nīkāya*, 2.17.
31. We recall from Chapter 1 how Kassapa responded to Pāyāsi with the allegory of a pregnant woman who died with her child because she cut open her womb to check whether the child was a boy or a girl, to decide her share in the inheritance.
32. D. D. Kosambi, *An Introduction to the Study of Indian History*, Popular Prakashan, Bombay, 1956.
33. This association of monasteries with trade routes enabled Kosambi to uncover Buddhist sites in the mountains around the Karla caves. While Kosambi's ideas are insightful, not all of them are quite

convincing. Thus, it does make sense to say that beef-eating was prohibited because a shift from a pastoral to an agricultural economy made animals too valuable to be given up easily for sacrifice; but one wonders why a similar shift in other parts of the world failed to produce similar prohibitions against beef-eating. Similarly, this logic does not explain the sudden stress on animal rights (even Aśoka prohibited needless slaughter of cocks and hens in his kitchen) or the insistence of numerous wanderers to go about naked—these were not uniquely the Jain ascetic extremes against which the Buddha preached moderation. Similarly, the current association of Jainism with trade was surely not what Mahavira had preached. Likewise, what accounts for the sudden interest in animal rights in the West today?

34. D. P. Chattopadhyaya, *Lokāyata*, cited earlier.
35. *The Reader's Digest Great World Atlas*, First Edition, Sixth Revise, Reader's Digest Association, London and Cape Town, 1962, p. 131.
36. D. D. Kosambi, *Indian History*, for example, p. 136.
37. *Vaiśeṣika Sutra* 2.10. K. H. Potter, ed., *Encyclopaedia of Indian Philosophy*, vol. 2, Motilal Banarsidass, Delhi 1987, p. 218.
38. *Vaiśeáika Sutra* 1.15. Potter, ed., *Encyclopaedia of Indian Philosophy*, vol. 2, p. 216.
39. The *Nyāya Sūtra* (IV.2.17) asserts that 'atoms are not further divisible', and then states the objection (*pūrva pakṣa*) that this is impossible since 'atoms are pervaded by aether' (IV.2.18), 'else aether would not be all-pervasive' (IV.2.19). *The Nyāya Sūtra of Gautama,* trans. Ganganath Jha, vol. 4, reprint, Motilal Banarsidass, Delhi, 1984, pp. 131–32.
40. *Nyāya Sūtra*, IV.2.20. Ibid.
41. *Nyāya Sūtra*, IV.2.24. Ibid.
42. Mary Hesse, *Forces and Fields,* pp. 160–67.
43. Udyotkara gave a linguistic resolution of the problem: ' "contact" qualifies the two atoms in contact; it is not a physical property'. *Nyāya Varttika,* trans. Ganganath Jha [1919], reproduced in *Encyclopaedia of Indian Philosophy*, ed. Potter, vol. 2, pp. 334–35. For more details, in relation to fields and particles, see C. K. Raju, 'The Electromagnetic Field', chap. 5a in *Time: Towards a Consistent Theory*, Kluwer Academic, Dordrecht, 1994, pp. 102–15.
44. The African belief (Chapter 1, note 33) is that the dead are not quite dead, but retain their individuality till such time as there are people alive who personally knew them. Memories of the dead may sometimes arise in the minds of such people, and the dead surely are partly the cause these memories—the dead, though past, *hence*

may be regarded as continuing to exist. John S. Mbiti, *African Religions and Philosophy,* Heinemann, London, 1969.

45. Hajime Nakamura, *A History of Early Vedanta Philosophy*, trans. Trevor Leggett et al., Motilal Banarsidass, Delhi, 1983, p. 237.
46. R. A. Nicholson, *A Literary History of the Arabs*, T. Fisher Unwin, London, 1907. Krishna Chaitanya, *A History of Arabic Literature*, Manohar Prakashan, New Delhi, 1983.
47. This was similar to the Neoplatonic intention of Proclus, the earliest actual source of the *Elements*; the term 'equality' was replaced by the term 'congruence' only by Hilbert and others, in the 20th century CE.
48. See, e.g., R. C. Taylor in *Neoplatonism and Islamic Thought*, ed. Parviz Morewedge, SUNY, Albany, 1992.
49. Krishna Chaitanya, *History of Arabic Literature*, pp. 98–99. This sort of thing has with facility been dubbed pantheism.
50. Maimonides, *Guide of the Perplexed*, part 1, chaps 73–76, trans. S. Pines, University of Chicago Press, Chicago, 1974. (Also, Maimonides, *Guide for the Perplexed*, trans. M. Friedlander, Dover, New York, 2000.)
51. *Futuhat*, II, p. 523; cited by Mahmoud al-Ghorah, in *Muhyiddin Ibn 'Arabī*, ed. Stephen Hirtenstein and Michael Tiernan, Element, Shaftesbury, 1993, p. 208.
52. In Islam there is no *institution* like a church, and no scriptural recognition of a division between the temporal and the spiritual ('Give unto God what is God's and unto Caesar what is Caesar's'). In India, the linkage between orthodoxy and the state started appearing very late, with the last effective Moghul emperor Aurangazeb who slew his Sufi step-brother Dara Shūkoh. With the collapse of the Moghul empire, this tendency dissipated before it could take hold.
53. For example, Shaikh Ahmad Sirhindi, *Maktūbāt* (*Letters*), ff. 52–53b, in *Sources of Indian Tradition*, trans. Wm. Theodore de Bary et al.; reprint, Motilal Banarsidass, Delhi, 1972, p. 449. Sirhindi, who regarded Akbar as a thorn in the side of Islam, died in Jehangir's time.
54. Farid al-din Attar, *Muslim Saints and Mystics*, trans. A. J. Arberry, Arkana, London, 1990, p. 119.
55. Max Weber, *The Protestant Ethic and the Spirit of Capitalism* [1930], George Allen and Unwin, London, 1968. A detailed critical examination of his thesis would be out of place here.
56. To call as 'capitalist' one who rationally maximises profit with a religious zeal would reduce Weber's thesis to an irrefutable circularity.

57. Statement attributed to Mother Teresa's successor, Sister Nirmala, as reported in various newspapers. See the discussion on the editorial page of *The Times of India*, 17 September 1997. It should be observed that their concern is not with the removal of poverty—for which man-made condition they appeal to divine sanction—but with alleviating the *suffering* of the poor. Hope has always served as a means of control, as in the lotteries used to tax the poor. Therefore, offering hope to the poor, without wanting to remove poverty, is regarded as a socially laudable objective.
58. The technical difference is that class permits some individual mobility, while caste, except in very extraordinary cases, permits only group mobility. Hence caste loyalties are stronger than class loyalties, for the system ties the benefit of the individual to that of the group.
59. For some more details, see C. K. Raju, 'Computers, Mathematics Education, and the Alternative Epistemology of the Calculus in the Yuktibhāṣā', *Philosophy East and West*, **51**(3), 2001, pp. 325–62; 'Mathematics and Culture', in *History, Culture and Truth: Essays Presented to D. P. Chattopadhyaya*, ed. Daya Krishna and K. Satchidananda Murthy, Kalki Prakash, New Delhi, 1999, pp. 179–93. Reprinted in *Philosophy of Mathematics Education* **11**. Available at www.ex.ac.uk/~PErnest/pome/art18.htm.
60. P. C. Mahalanobis, 'The Foundations of Statistics (A Study in Jaina Logic)', *Dialectica* **8**, 1954, pp. 95–111; reproduced in *Sankhya, Indian Journal of Statistics,* **18**, 1957, pp. 183–94; reproduced as Appendix IV B in *Formation of the Theoretical Fundamentals of Natural Science* vol. 2 of *History of Science and Technology in Ancient India*, by D. P. Chattopadhyaya, Firma KLM, Calcutta, 1991, pp. 417–32.
61. J. B. S. Haldane, 'The *Syadavada* system of Predication', *Sankhya, Indian Journal of Statistics*, **18**, 1957, pp. 195–200; reproduced as Appendix IV C in *Theoretical Fundamentals of Natural Science*, by D. P. Chattopadhyaya, cited above, pp. 433–40.
62. D. S. Kothari, 'Modern Physics and Syadavada', Appendix IV D in *Theoretical Fundamentals of Natural Science*, by D. P. Chattopadhyaya, cited above, pp. 441–48.
63. Sadly, Mahalanobis refers to the Buddhist doctrine of flux, in this context as 'one well-known school of Buddhist philosophy which holds that reality consists of an infinite sequence of [atomistic] or completely independent [moments] which have no connexion with one another.' Footnote 24 there actually relates to footnote 25 in the text, and the footnote 1 referred in it is actually footnote 22 in the text. Mahalanobis, cited above, pp. 424–25.
64. Rhys-Davids, trans., *Dialogues of the Buddha*, cited earlier, vol. 1, p. 75.

65. *Dīgha Nikāya*, trans. Maurice Walshe, p. 97.
66. S. C. Vidyabhuṣaṇ, *A History of Indian Logic*, Calcutta, 1921, reprint Munshiram Manoharlal, New Delhi, 1977.
67. That is, if Bhadrabāhu really was the brother of the astronomer Varāhamihīra, roughly a contemporary of Āryabhata, whose work on astronomy, cited in Chapter 1, note 27, is securely fixed at 498.
68. J. B. S. Haldane, cited earlier.
69. D. S. Kothari, cited earlier, and his advisors, strangely seem to have been unaware of the work of Reichenbach, done nearly forty years earlier. For details of Reichenbach's work, and an exposition of three valued logic see C. K. Raju, 'Philosophical Time', chap. 1 in *Time: Towards a Consistent Theory*, Kluwer Academic, Dordrecht, 1994. In view of the unsuccessfulness of this approach, it seems to me that using a three valued logic as the foundation of statistics, as suggested by Mahalanobis, leads neither to classical nor to quantum statistics!
70. The Jaina units of time suggest that this time atom is linked to human perception of sound, which has a cutoff at 18KHz (or the next octave).
71. C. K. Raju, 'Quantum-Mechanical Time', chap. 6b and its appendix in *Time: Towards a Consistent Theory*, cited earlier.
72. B. M. Barua, D. Litt. Thesis, University of London, 1921, cited earlier. In Barua's view this was modified to a five-fold negation by Sañjaya Belaṭṭhaputta.
73. *Dīgha Nikāya*, trans., Maurice Walshe, p. 541, footnote 62 to Sutta 1.
74. Ibid. pp. 78–79.
75. *Mulamādhymakakārika* 18.8. David J. Kalupahana, trans., *Nagarjuna*, SUNY, New York, 1986, p. 269.
76. *Dīgha Nikāya*, trans. Maurice Walshe, pp. 80–81
77. For this reason, I am doubtful of the translation of Nagarjuna's *prasang* into reductio *ad absurdum*. Though it is Nagarjuna's objective to bring out the absurdity of certain beliefs, *reductio* has a specific meaning today (and in Euclid's *Elements*) in the context of two-valued logic.
78. G. N. Ramachandran, Tech. Report, Dept. of Mathematical Biology, Indian Institute of Science, Bangalore (198?).
79. This means that we have eight truth values, the negation of the first being the second, the negation of the second being the third, and so on, with the negation of the last being the first. For more details on cyclic negation, see the text of N. Rescher, *Many-Valued Logic*, McGraw Hill, New York, 1969.
80. Hsueh-li Cheng, *Empty Logic: Mādhyamika Buddhism from Chinese Sources*, Motilal Banarsidass, Delhi, 1991, p. 36. An interesting

attempt to interpret dependent coorigination from the viewpoint of systems theory may be found in Joanna Macy, *Mutual Causality in Buddhism and General Systems Theory*, SUNY, Albany, 1991.

81. Trans. D. Chatterji, *'Hetucakranirnaya'*, *Indian Historical Quarterly*, **9**, 1933, pp. 511–14.

82. Dignāga clearly has the last word in S. C. Vidyabhuśaṇ's, *Indian Logic*, cited earlier, p. 299 and pull-out diagram annexed as the last page of the book!

83. R. S. Y. Chi, *Buddhist Formal Logic*, The Royal Asiatic Society, London, 1969; reprint Motilal Banarsidass, Delhi, 1984, p. 5. The claim is in the ellipsis which expand to read, 'In fact, the so-called "similar" and "dissimilar" instances refer to the likeness to the major term but not to the middle term [reason, *hetu*]'. See, however, Vidyabhuśaṇ, *Indian Logic*, p. 291. In addition, there are some minor discrepancies which I am not competent to comment upon.

84. Nothing can possibly be redundant in a text as brief as the *Hetucakra*, and the Sanskrit formulae of the *Nyāyavarttika* clearly does not cover the last stanza of the *Hetucakra*, a point which Udyotkara also overlooks in his arguments against the Buddhist notion of instant of time. B. K. Matilal, *Logic, Language, and Reality*, Motilal Banarsidass, Delhi, 1985, p. 146, expresses the same opinion, 'My own feeling is that to make sense of the use of negation in Buddhist philosophy in general, one needs to venture outside the perspective of the standard notion of negation.' See also, H. Herzberger, 'Double Negation in Buddhist Logic', *Journal of Indian Philosophy*, **3**, 1975, pp. 1–16.

85. See, e.g., A. N. Prior, *Past, Present, and Future*, Clarendon, Oxford, 1967.

86. See, e.g., E. Mendelson, *Introduction to Mathematical Logic*, Van Nostrand Reinhold, New York, 1964.

87. To the above points, one could add the following. (3) Udyotkara's *Nyāyavarttika* is implicitly, explicitly, and polemically against Buddhist philosophy; so I see no reason to regard Udyotkara's as the last word on Dignāga, especially since that last word is positioned at such a peculiar moment in the history of Buddhism in this country, when no Buddhist was left to respond to Udyotkara. (4) Dignāga's logic, in his *Pramānasamuccaya*, cannot be instantly formalised, because he explicitly rejected tautological inferences as trivial, while Western logic admits only such inferences. Thus, to infer fire from smoke was a trivial inference. Nor from a smoky hill should one infer a fire on the hill (for the *connection* between fire and hill could not be inferred—the apparent connection between smoke and hill may be only an illusion). Hence, from a smoky hill

one inferred a fiery hill—from an apparently smoky hill one inferred an apparently fiery hill.

## CHAPTER 12

1. To be quite precise, the 'is' here refers to an existential 'is' and not a tensed 'is'. Also, the 'is' is not a metaphysical 'is' as in the statement 'God is', which, though syntactically an existential statement, may be rejected as semantically void on the grounds that the claimed existent is inconsistent, irrefutable, and redundant. The statement asserting the existence of a moral law could, with some justification, be treated similarly to the statement 'God is'. The difference arises from the undisputedly physical beliefs underlying values (irrespective of their validity).
2. A. Prior, *Deontic Logic*, Oxford University Press, Oxford, 1966. For a review of the is/ought dichotomy in Kant and Hegel, see, for example, R. P. Singh, *Dialectic of Reason*, Intellectual Publishing House, New Delhi, 1995.
3. Bertrand Russell, *History of Western Philosophy*, George Allen and Unwin, London, 1946, p. 164.
4. Ibid., p. 111. Russell continues by contrasting this with Western Christianity: 'In Christian ethics, a pure heart is the essential, and is at least as likely to be found among the ignorant as among the learned. This difference between Greek and Christian ethics has persisted down to the present day.'
5. This elaborates my earlier article, 'Reconstruction of Values: The Role of Science', in *Cultural Reorientation in Modern India*, ed. Indu Banga and Jaidev, Indian Institute of Advanced Study, Shimla, 1996, pp. 369–92.
6. To be sure, one could still say, for example, that from the fact that this man *is* drunk it does not follow that this man *ought* to be drunk. But this kind of quibbling is not germane to the point.
7. Konrad Lorenz, *On Aggression*, Methuen, London, 1968, p. 24.
8. In von Neumann's formalistic tradition, one would say that the input–output matrix is irreducible (no non-trivial invariant subspaces).
9. *The Dunkel Draft of Uruguay Round of GATT Negotiations*, p. 73, and part III, p. 76 and sequel, and Sections S and T.
10. This term is used in the sense of Paul M. Sweezy, *Post-Revolutionary Society*, Monthly Review Press, New York, 1980.
11. Jaya Mehta, 'Plan and Market' (unpublished).
12. E. O. Wilson, *Sociobiology The New Synthesis*, Harvard University Press, Cambridge, Mass., 1975; E. O. Wilson, *On Human Nature*, Harvard University Press, Cambridge, Mass., 1978; C. Lumsden

and E.O. Wilson, *Genes, Mind, and Culture,* Harvard University Press, Cambridge, Mass., 1981. R. Dawkins, *The Selfish Gene*, Oxford University Press, Oxford, 1976. P. Kitcher, *Vaulting Ambition*, MIT Press, Cambridge, Mass., 1985. M. Rose, *Sociobiology: Sense or Nonsense?*, D. Reidel, Dordrecht, 1979. A. Caplan, ed., *The Sociobiology Debate*, Harper and Row, New York, 1978. J. Maynard Smith, *Evolution and the Theory of Genes*, Cambridge University Press, Cambridge, 1982. *Biology as a Social Weapon*, ed. Sciences for the People Collective, Burgess, Minneapolis, 1977. R. S. Lewontin, S. Rose and L. Kamin, *Not in Our Genes*, Pantheon, New York, 1984. S. J. Gould, *Ever Since Darwin*, Norton, New York, 1977, pp. 251–59,

13. H. Tetrode, *Zeit. Phys.* **10**, 1922, p. 317, as quoted by J. A. Wheeler and R. P. Feynman, *Rev. Mod. Phys.*, **17**, 1945, p. 159. A more detailed quote reads: 'The sun would not radiate if it were alone in space and no other bodies could absorb its radiation…If for example I observed through my telescope yesterday evening that star which let us say is 100 light years away, then not only did I know that the light which it allowed to reach my eye was emitted 100 years ago, but also the star or individual atoms of it knew already 100 years ago that I, who then did not even exist, would view it yesterday evening at such and such a time…' In the sense in which this quote is used here, the references to knowledge, etc., are to be put down to bad expression. A similar idea is attributed by them to G. N. Lewis, *Proc. US Nat. Acad. Sci.*, **12**, 1926, p. 22.
14. N. Georgescu-Roegen, *The Entropy Law and the Economic Process*, Harvard University Press, Cambridge, Mass., 1971. J. Rifkin with T. Howard, *Entropy: A New World View*, Bantam, 1980.

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