2. Genesis

> 'In the beginning God created the heaven and the earth.'
>
> Genesis 1: 1

> 'But no one was there to see it.'
>
> Steven Weinberg in *The First Three Minutes*

Was there a creation? If so, when did it occur and what caused it? Nothing is more profound or more baffling than the riddle of exis-tence. Most religions have something to say about how things got started; so does modern science. In this book I shall address the enigma of genesis in the light of recent cosmological discoveries. This chapter deals with the origin of the universe as a whole. Some people have used the word 'universe' to mean the solar system or the Milky Way galaxy. I shall use it in the more conventional sense of 'every physical thing that exists', by which I mean all matter distributed among and between all the galaxies, all forms of energy, all non-material things such as black holes and gravity waves, and all of space as well, stretching (if indeed it does) right out to infinity. Sometimes I shall use 'world' to mean the same thing.

Any system of thought that claims to provide an understanding of the physical world must make some statement about the origin of the world. At its most basic, the choice is stark. Either the universe has always existed (in one form or another) or it began, more or less abruptly, at some particular moment in the past. Both alternatives have long been a source of perplexity to theologians, philosophers and scientists, and both present obvious difficulties for the layman.

If the universe had no origin in time — if it has always existed — then it is of infinite age. The concept of infinity leaves many people reeling. If there has been an infinite number of events already, why do we find ourselves living now? Did the universe remain quiescent for all of eternity only to spring into action relatively recently, or has there been some activity going on for ever and ever? On the other hand, if the universe *began*, that means accepting it appeared suddenly out of nothing. This seems to imply that there was a first event. If so, what caused it? Is such a question even meaningful?

Many thinkers baulk at these issues, and turn instead to the scientific evidence. What can science tell us about the origin of the universe?

These days most cosmologists and astronomers back the theory that there was indeed a creation, about eighteen billion years ago, when the physical universe burst into existence in an awesome explosion popularly known as the 'big bang'. There are many strands of evidence to support this astonishing theory. Whether one accepts all the details or not, the essential hypothesis – that there was some sort of creation – seems, from the scientific point of view, compelling. The reason stems directly from a large body of scientific evidence that is encompassed by the most universal law of physics known – the second law of thermodynamics. In its widest sense this law states that every day the universe becomes more and more disordered. There is a sort of gradual but inexorable descent into chaos. Examples of the second law are found everywhere: buildings fall down, people grow old, mountains and shorelines are eroded, natural resources are depleted.

If all natural activity produces more disorder (measured in some appropriate way) then the world must change *irreversibly*, for to restore the universe to yesterday's condition would mean somehow reducing the disorder to its previous level, which contradicts the second law. Yet at first sight there seem to be many counter-examples of this law. New buildings are erected. New structures grow. Isn't every new-born baby an example of order arising out of disorder?

In these cases you have to be sure you are looking at the total system, not merely the subject of interest. The concentration of order in one region of the universe is always paid for by increasing disorder somewhere else. Take the construction of a new building, for example. The materials used inevitably deplete the world's resources, while the energy expended in the building process is also lost irretrievably. When a full balance sheet is drawn up, disorder always wins.

Physicists have invented a mathematical quantity called entropy to quantify disorder, and many careful experiments verify that the total entropy in a system never decreases. If the system is isolated from its surroundings, any changes that occur within it will remorselessly drive up the entropy until it can go no higher. After that there will be no further change: the system will have reached a condition of thermodynamic equilibrium. A box containing a mixture of chemicals provides a good example. The chemicals will react, some heat may be produced, the constituent substances will alter their molecular form and so on. All these changes increase the entropy inside the box. Eventually, the contents settle down at a uniform temperature in their final chemical form and nothing further happens. To return the contents to their former state is not impossible, but it would mean opening the box and expending energy and materials to reverse the changes that had occurred. This manipulation would produce more than enough entropy to offset the entropy reduction within the box.

If the universe has a finite stock of order, and is changing irreversibly towards disorder — ultimately to thermodynamic equilibrium — two very deep inferences follow immediately. The first is that the universe will eventually die, wallowing, as it were, in its own entropy. This is known among physicists as the ‘heat death’ of the universe. The second is that the universe cannot have existed for ever, otherwise it would have reached its equilibrium end state an infinite time ago. Conclusion: the universe did not always exist.

We see the second law of thermodynamics at work in all the familiar systems around us. The Earth, for example, cannot have existed for ever, or its core would have cooled down. From radioactivity studies the Earth can be dated to about 4½ billion years, which is similar to the age of the moon and of various meteorites.

As far as the sun is concerned, it clearly cannot continue burning away merrily ad infinitum. Year by year its fuel reserves decline, so that eventually it will cool and dim. By the same token its fires must have been ignited only a finite time ago: it does not have unlimited sources of energy. Estimates place the age of the sun at a little greater than that of the Earth, which accords well with current astronomical theories that the solar system formed together as a single unit. Nevertheless, the solar system is only a minute component of the universe, and it would be rash to draw sweeping conclusions from considerations of the Earth and sun alone. The sun, however, is a typical star, and our galaxy alone contains many billions of other stars whose life cycles can be studied by astronomers. Stars exist that have reached various stages in their evolution, enabling us to build up a detailed picture of stellar birth, life and death.

Stars form, along with planets, as a result of the gradual contraction and fragmentation of huge, tenuous clouds of inter-stellar gas which consist mainly of hydrogen. Today it is easy to find regions of the galaxy where starbirth is taking place. One of these, the Great Nebula in Orion, is visible to the naked eye. The stars were not simply made once and for all. Our sun, for example, at about five billion years old, is at most only half the age of the oldest stars in the galaxy. The formation of the solar system would have been just one further product of a continuing process that has occurred hundreds of billions of times in the Milky Way alone, and will continue in the future. Thus, as far as the formation of stars and planets are concerned, there was no real creation as such at all, merely a sort of cosmic assembly line steadily turning the raw material — hydrogen, helium, and a minute fraction of heavier elements — into stars and planets.

Given that stars are continually burning out while others are being formed to replace them, might this cycle of birth and death have continued endlessly? Alas, no, as the second law of thermodynamics assures us. The material of burnt-out stars can never be fully recycled. The energy needed dissipates away into space in the form of starlight radiated over the aeons. Some of the star stuff is lost irretrievably down black holes.

There is, however, a more direct reason for believing that the entire cosmic system has not been recycling away for all eternity. Isaac Newton, one of the founders of modern science, established that gravity is a universal force, acting between all material bodies in the cosmos: every star, every galaxy, pulls on every other with a gravitational force. Because astronomical bodies float freely in space there seems to be no reason why they do not fall together as a result of this ubiquitous gravitational attraction. In the solar system, gravitational collapse of the planets on to the sun is avoided by centrifugal effects: the planets are revolving around the sun. Likewise the galaxy is rotating. But there is no evidence that the universe as a whole is rotating. Clearly the galaxies can't just hang there for ever. So the universe cannot always have enjoyed its present arrangement.

Although this cosmic conundrum had been appreciated since the time of Newton, it was not until the 1920s that the resolution was discovered. The American astronomer Edwin Hubble found that the galaxies are not falling together because they are rushing apart instead. Hubble noticed that galactic light is slightly distorted in colour ('red shifted' to use the jargon), a circumstance that suggests rapid recession. The reason is that light consists of waves, so a moving light source can stretch or shrink the waves, just as a moving vehicle stretches or shrinks the sound waves it emits. The tone of a car engine, or the whistle of a train, drops dramatically in pitch as it rushes by. In the case of light, read 'colour' for 'pitch' and you have the Hubble red shift. The speeds involved, however, are vastly greater. Distant galaxies recede at many thousands of miles per second.

Hubble's discovery is sometimes misinterpreted to mean that our galaxy is at the centre of this headlong rush, with all the other galaxies flying directly away from us. That is quite wrong. Because the distant galaxies recede faster than the nearby ones, the gaps between the galaxies also expand, so in fact every galaxy is moving away from every other one. This is the famous 'expanding universe'. The pattern of galactic dispersal would appear very much the same from wherever in the cosmos you looked.

The expanding universe accords very well with modern thinking on the nature of space, time and motion. Albert Einstein, who carries the same status in the scientific community as St. Paul does among Christians, revolutionized our conception of these matters with his mind-bending theory of relativity. Although it has taken sixty years for Einstein's spacewarps and timewarps to impinge on the popular imagination, physicists have long accepted his ideas of curved space-time as an explanation of gravity.

The force of gravity powers all large-scale cosmic phenomena. In objects of astronomical size, gravity far outweighs all other forces such as magnetism or electricity. It shapes the galaxies and controls the intergalactic motions. When it comes to explaining the expanding universe, gravity is the key.

Einstein argued convincingly that gravity stretches or distorts space and time, and the idea can be checked directly by watching the sun's gravity bend starbeams that graze its surface. The sky behind the sun appears from Earth to be slightly, but distinctly, bent. The elasticity of time can also be demonstrated, most directly by flying clocks in space. Time runs faster in the gravity-free environment up there than it does on the Earth's surface.

If the sun can stretch space so can the galaxy, which is made of many suns. So rather than thinking of the galaxies as moving apart *through* space, astronomers prefer to think of the space between the galaxies as stretching. If intergalactic space is being 'inflated', then each day every galaxy will find itself with more and more elbow room. In that way the universe expands, without having to expand *into* some external void.

Setting aside for now the concepts of elastic space and time, which many people find hard to understand, it is plainly obvious that a universe which is growing bigger must have been smaller in the past. If the present expansion rate had been maintained throughout history, then twenty or thirty billion years ago the whole observable universe would have been shrivelled up into an unrecognizable blob with no identifiable astronomical bodies at all. In fact, astronomers have discovered that the expansion rate is decellerating somewhat, so this highly compressed condition in fact occurred rather more recently, perhaps fifteen or twenty billion years ago. (Compare the sun's age of five billion years.) Because the expansion rate was much higher then, the early stages of the galactic dispersal resembled an outburst rather than a slow expansion.

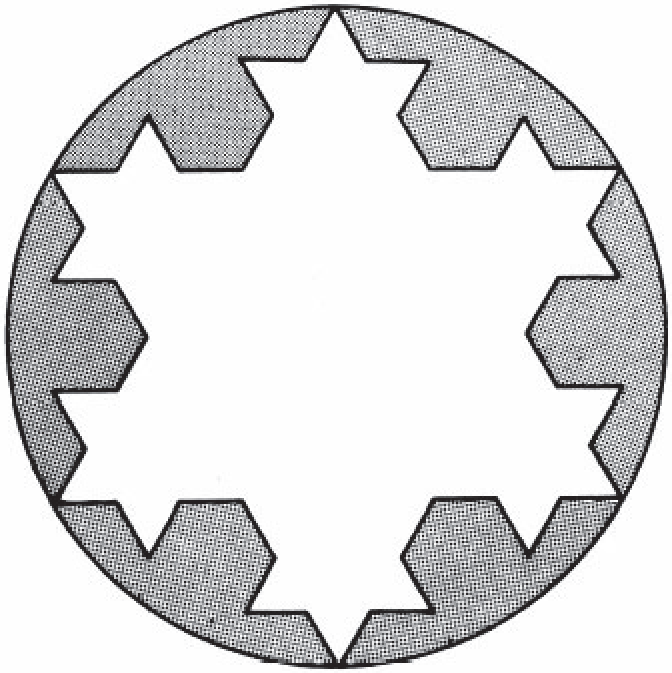
It is sometimes said that the universe as we now know it was created by the explosion of a sort of primeval ‘egg’, the galaxies being fragments of the explosion that are still hurtling through space. It is a picture that captures some correct features but it can also be misleading. The thing that exploded was shrunken because space was shrunken. It is wrong to think in terms of an ‘egg’ surrounded by a void. An egg has a surface and a middle. Astronomers believe, however, that there is no edge or surface to the universe, and no privileged centre.

We are tangling here with the delicate subject of infinity. It is a topic full of pitfalls for the unwary. In view of its importance not only for the expanding universe, but for the broader issues of science and religion, it is worth a short digression at this stage.

Scientists have long recognized the need to base all their considerations of infinity on precisely formulated mathematical steps, for measuring the infinite can produce all sorts of paradoxes. Consider, for example the famous ‘hare and tortoise’ paradox due to Zeno of Elea (fifth century B.C.) In a race, the tortoise has a head start, but the hare, running faster, soon overtakes him. Clearly, at every moment of the race the hare is at a place and the tortoise is at a place. As both have been running for the same length of time — for an equal number of moments — then presumably they have passed through an equal number of places. But for the hare to overtake the tortoise he must cover a greater distance in the same time, and so pass through a greater number of places than the tortoise. How then can the hare ever overtake the tortoise?

The resolution of this paradox (one of several due to Zeno) involves a proper formulation of the concept of infinity. If time and space are infinitely divisible then both the hare and the tortoise run for an infinity of moments through an infinity of places. The essential feature of infinity here is that a part of infinity is as big as the whole. Although the tortoise's journey is shorter in distance than the hare's, he still covers as many places as the hare (i.e. infinity) — even though we know the hare passes through all the same places as the tortoise, and more!

Many surprises of this sort emerge from a study of the infinite, and it has taken mathematicians centuries of logical construction to fully comprehend the rules for the proper manipulation of infinity. An odd feature is that there exists more than one sort of infinity. There is the infinity of things that can be labelled by whole numbers (1, 2, 3… without end) and a bigger infinity for which even the whole numbers in their entirety are inadequate.



1 The irregular perimeter in this figure is constructed by raising equilateral triangles on the sides of larger triangles in a sequence of steps. The third step is shown in the figure. As the number of steps increases, so the perimeter becomes longer and more 'spikey'. The length of the perimeter grows without limit as the number of steps is increased indefinitely, but the perimeter never protrudes outside the enclosing circle. The area enclosed by the irregular perimeter is therefore finite, even though the length of the perimeter approaches infinity in the limit of an infinite number of steps.

When it comes to geometry, intuition can lead you badly astray. Consider for example the length of a fence that surrounds a field of given area. It is easy to see that a long thin field requires more fence for a given area than a square field. A round field uses the minimum length offence. But just how long can the perimeter of a field become? Figure 1 shows a rather eccentrically shaped perimeter consisting of triangles built upon triangles in a sequence of steps. With each step the perimeter fence gets longer, and the area enclosed increases a bit. But the perimeter will never protrude beyond the enclosing circle, so the area will always remain finite, yet the perimeter can grow without limit as the number of additional triangular wedges is increased. It is thus possible to conceive of an *infinitely* long fence enclosing a *finite* area of field (see Fig. 1).

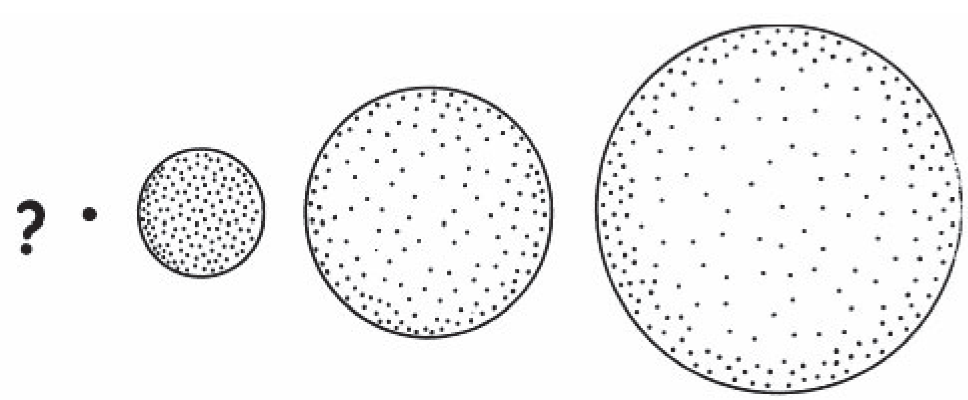
What has all this got to do with the creation of the universe? First, it illustrates that ideas like 'infinity' should not be used sloppily or they are likely to produce nonsense. Secondly, it demonstrates that the results obtained often run counter to common sense and intuition. This is one of the great lessons of science. It is often necessary to resort to the abstract — to formal mathematical manipulations — to make sense of the world. Ordinary experience alone can be an unreliable guide.

Is the universe infinite in size? If space has an infinite volume we can envisage an infinity of galaxies populating it with roughly uniform density. Many people then worry about how something that is infinite can expand. What is there for it to expand into? There is no problem: infinity can be boosted in magnitude and still remain the same size. (Remember what the 'tortoise taught us'.) But visualization problems set in when we wind this model backwards to the 'cosmic egg' phase. If the galaxies are everywhere, there could never have been a *finite* egg, with a surface beyond which there was no matter. So eggs are out.

Imagine, in such an infinite universe, a huge sphere enclosing an enormous volume of space containing many galaxies. Now picture space everywhere rapidly shrinking, like Alice in Wonderland after eating the magic cake. The sphere contracts to a smaller and smaller radius; but however shrunken it becomes there is still unending space and an infinity of galaxies outside it. If the sphere shrinks to literally nothing, then we have the mathematically delicate problem of an infinite universe which is infinitely shrunken. There is still no centre or edge, but the contents of any sphere, however large it started out, would be crushed together into a single point. Astronomers believe that it was from such an infinitely shrunken, yet unbounded, state that the universe exploded.

There is, in fact, another possible model for the universe that avoids the competition of infinities; it was proposed by Einstein himself in 1917. Based on the fact that space can bend, Einstein argued that space can connect up to itself in a variety of unexpected ways. The curved surface of the Earth can be used as an analogy. The Earth's surface is finite in area, but unbounded: nowhere does a traveller meet an edge or boundary. Similarly space could be finite in volume, but without any edge or boundary. Few people can really envisage such a monstrosity, but mathematics can take care of the details for us. The shape is called a hypersphere. If the universe is a hypersphere an astronaut could, in principle, circumnavigate it like a cosmic Magellan by always pointing his rocket in the same direction until he returned to his starting point.

Although it is finite, Einstein's hyperspherical cosmos still has no centre or edge (just as the surface of the Earth has no centre or edge), so when shrunken it does not resemble a cosmic egg either. One can imagine the hypersphere shrivelling away to nothing, its volume vanishing, analogous to the surface of a sphere being shrunk to zero radius (see Fig. 2).



2 If three-dimensional space is represented by a two-dimensional surface, then one model of the expanding universe is reminiscent of a balloon that inflates from nothing. In this model space is finite, but unbounded: an observer in the space could travel freely all around the universe. The dots represent galaxies (or clusters of galaxies). As the universe expands, space stretches, so all the dots move farther apart from all their neighbours. An observer on any one of the dots would see the other dots receding in a systematic pattern, and would seem to be at the centre of this outward migration.

The study of elastic space has led cosmologists to propose a theory of the creation which differs greatly in detail from the biblical version. The most startling feature of the scientific theory is the suggestion that space itself was created in the big bang, and not merely matter. If the 'shrivelling balloon' model is envisaged instead as an expanding balloon – expanding out of nothing – then you obtain a rough idea of the story of Genesis as told by modern physics. The important point is that continuation of the concept of space back through the infinitely shrunken phase is impossible, and this is true whether or not the universe resembles Einstein's hypersphere (balloon model) or is infinite in size. The first instant of the big bang, where space was infinitely shrunken, represents a boundary or edge in time at which space ceases to exist. Physicists call such a boundacy a *singularity*.

The idea of space being created out of nothing is a subtle one that many people find hard to understand, especially if they are used to thinking of space as already being 'nothing'. The physicist, however, regards space as more like an elastic medium than as emptiness. Indeed, we shall see in later chapters that, because of quantum effects, even the purest vacuum is a ferment of activity and is crowded with evanescent structures. To the physicist 'nothing' means 'no space' as well as no matter.

More peculiarities lie in wait. Space is inextricably linked to time, and as space stretches and shrinks, so does time. Just as the big bang represents the creation of space, so it represents the creation of time. Neither space nor time can be extended back through the initial singularity. Crudely speaking, time itself began at the big bang.

These bizarre ideas can only be fully grasped by appeal to mathematics. Human intuition is an inadequate guide — which illustrates one of the principal reasons for the success of the scientific method. By employing mathematics as a language, science can describe situations which which are completely beyond the power of human beings to imagine. Indeed, most of modern physics falls into this category. Without the abstract description provided by mathematics, physics would never have progressed beyond simple mechanics. Of course, physicists, like everybody else, carry around mental models of atoms, light waves, the expanding universe, electrons, and so on, but the images are often wildly inaccurate or misleading. In fact, it may be logically impossible for anyone to be able to correctly visualize certain physical systems, such as atoms, because they contain features that simply do not exist in the world of our experience (as we shall see when we come on to look at the quantum theory in Chapter 8).

Failure of the human imagination to grasp certain crucial features of reality is a warning that we cannot expect to base great religious truths (such as the nature of the creation) on simple-minded ideas of space, time and matter, gleaned from daily experience.

Intellectual difficulties over the origin of time are not new. Aristotle in the third century B C rejected the idea of time being created, for that would imply there was a first event. What caused the first event? Nothing, for there was no prior event.

The finitude of time, in fact, need not imply that there was a first event. Imagine events labelled by numbers, with zero corresponding to the singularity. The singularity is not an event, it is a state of infinite density, or something like it, where spacetime has ceased. If one now asks, 'What is the first event *after* the singularity?', this is the same as the question, 'What is the smallest number greater than zero?' There is no such number, for every fraction, however small, can always be halved. Likewise, there is no first event.

The trouble is that infinite time is equally perplexing, as Immanuel Kant later emphasized:

> If we assume the world has no beginning in time, then up to every given moment an eternity has elapsed, and there has passed away in the world an infinite series of successive states of things. Now the infinity of the series consists of the fact that it can never be completed through successive synthesis. It thus follows that it is impossible for an infinite world series to have passed away, and that a beginning of the world is therefore a necessary condition of the world's existence.[1]

Remembering Zeno, however, we must be wary of manipulating infinity. According to Kant's reasoning, the hare could never complete the infinite series of steps 'through successive synthesis' necessary for him to overtake the tortoise. Yet we all know that he will. Nor is it a valid objection to point out that in the Zeno case the elapsed time is finite, while Kant refers to the passage of an infinite duration. In both cases there is an infinity of moments involved. Any mathematician can demonstrate that there are no more moments in all of eternity than there are in, say, one minute. In both cases there is an infinite number, and this infinity can be made no bigger by 'infinite stretching'.

Another objection to Kant's reasoning is the assumption that time 'elapses', which implies a flowing or moving time. Few physicists would concede that time does flow or move. It is simply *there*, like space (a topic that we shall return to in Chapter 9).

In conclusion, there seems to be nothing terribly wrong with either an eternal universe, or one that is of a finite age, bounded in the past by a singularity. Assuming the latter to be correct, does this mean that science supports the biblical version of the creation?

There is no agreement among Christians on the weight to be placed on the biblical narrative of Genesis. In 1951, Pope Pius XII, addressing the Pontifical Academy of Sciences in Rome on the implications of modern scientific cosmology, [2] alluded to the big bang theory, and the fact that 'everything seems to indicate that the universe has in finite times a mighty beginning'. His remarks provoked a fierce reaction (not least among scientists), and contemporary theologians are still divided over whether the big bang is the creation event supposedly revealed to the Bible writers. Thus, Ernan McMullin of Notre Dame University in the United States, writing recently under the title, 'How should cosmology relate to theology?', concludes that: 'What one cannot say is, first, that the Christian doctrine of creation "supports" the Big Bang model, or second, that the Big Bang model "supports" the doctrine of creation.'[3] Nevertheless, many laymen, compelled these days to dismiss so much of the Old Testament as fiction, find comfort in the apparent support that modern scientific cosmology brings to the Genesis story.

If we accept that space and time really did erupt out of nothing in the big bang, then clearly there was a creation and the universe has a finite age. The paradox of the second law of thermodynamics is therefore immediately solved. The universe has not reached thermodynamic equilibrium yet because it has only been disordering itself for eighteen billion years or so, and that is nowhere near long enough to complete the process. Moreover, we can now understand why all the galaxies have not fallen together. The explosive violence has flung them apart, and even though their rate of separation is slowing, there has not yet been enough time for them to fall back on themselves.

If the big bang theory rested on the work of Hubble and Einstein alone, it would not command the widespread support that it does. Fortunately, there is some persuasive confirmatory evidence.

The searing violence which accompanied the birth of the cosmos must have left many imprints on the structure of the universe, and we might expect some relics of the primeval phase to survive today. Searching for relics from the creation is now one of the most popular scientific enterprises and, incredible though it may seem, there are good financial reasons for this. The primeval universe provided an ideal natural laboratory in which physical conditions of such extremity were realized that they cannot be simulated on Earth with even the most elaborate scientific equipment. To test their theories about the behaviour of matter under these extreme conditions physicists must appeal to the cosmology of the newly-created universe. The hope is that the universe today may contain traces or clues about the physical processes that occurred during that first brief flash of existence. Calculations may then be used to see if those processes accord with what the theorists expect for the behaviour of matter under extreme conditions.

By far the most important relic of the primeval universe was discovered by accident in the mid-1960s. Two physicists working for the Bell Telephone Company stumbled across some mysterious radiation coming from space. A careful analysis has revealed that this radiation, which bathes the whole universe, is a relic of the primeval heat, the last fading glow of the fiery birth of the universe. The big bang, like any explosion, generated huge quantities of heat. Indeed, it took 100,000 years for the cosmic gases to cool to the sort of temperatures found at the surface of the sun. Now, eighteen billion years on, the temperature has dropped to the very depths, a mere three degrees above absolute zero (–273°C). Nevertheless there is still a vast amount of energy locked up in the heat radiation.

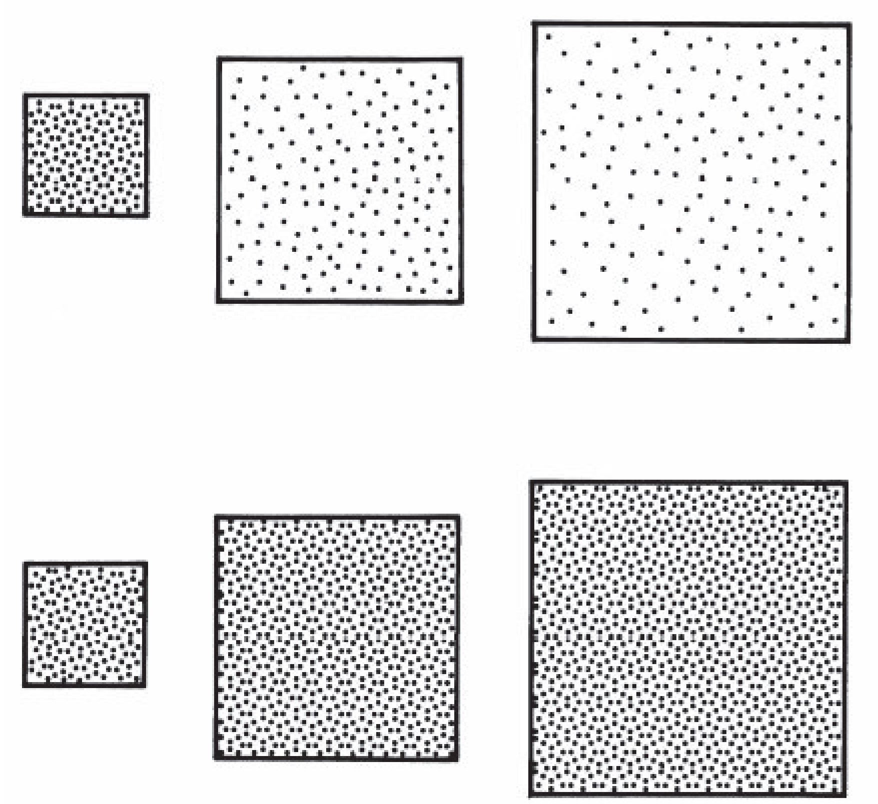
Knowing the present temperature of the relic heat radiation, it is a simple matter of scaling to compute its value at all epochs. Every time a typical region of the universe doubles in size, the temperature falls by fifty per cent. Working backwards, it is readily deduced that, for example, at one second after the creation, the temperature was ten billion degrees. This may seem pretty hot, but it is well within the range of laboratory experience. Indeed, using modern particle accelerators to generate high energy collisions, it is possible to simulate for a fleeting instant the conditions in the primeval explosion at a mere million-millionth of a second after the beginning, when the temperature was a staggering million billion degrees. It is therefore with some confidence that astrophysicists can model many of the physical processes that must have occurred after that first searing instant.

Using such models it is possible to compute the form of the cosmic material at each epoch as the universe erupted into existence. For example, between about one second and five minutes conditions would have been suitable for nuclear reactions to have occurred. The major process would have been the fusion of hydrogen nuclei to form helium and some deuterium. Calculations predict that the final ratio of helium to hydrogen should be about twenty-five per cent by mass, which is very close to what is observed to be the relative cosmic abundances of these two elements today. (Hydrogen and helium together constitute over ninety-nine per cent of the material in the universe.) Such remarkable agreement gives us confidence that the basic ideas of the hot big bang theory are correct.

The epochs before one second, being so hot, involved some very high energy physics. At these temperatures matter is broken completely apart, and its primary constituents (to be discussed in Chapter 11) would have been exposed. This very early phase – the first one second of existence – is now the subject of intense study by theoretical physicists, some of whom believe that many of the features of the universe can be explained by processes that occurred then. In the next chapter some of these more recent developments will be described.

The big bang theory is now taken very much for granted by astrophysicists, and the helium abundance calculations have long become part of standard cosmology. It is therefore easy to overlook the remarkable nature of these early successes. Had a nineteenth-century archaeologist claimed to have discovered the Garden of Eden and produced a relic showing unmistakable evidence of God's handiwork during the first day, the claim would have produced a sensation. Helium may not be very familiar to most people, but it can readily be purchased from industry. It is an extraordinary thought that this commonplace laboratory substance was fashioned in the primeval furnace, not just during the first day, but in the first few minutes of existence.

Though present scientific opinion lends strong support to the creation theory, it is important to realize that there is no logical reason why the universe cannot be infinitely old. The chief physical difficulty is, as we have seen, the second law of thermodynamics. However, from time to time mechanisms have been proposed to overcome this difficulty. One of these is the steady-state theory, due to Hermann Bondi, Thomas Gold and Fred Hoyle. In all versions of this theory the universe is infinite in age, but the thermodynamic heat death is avoided by postulating that new low-entropy matter is continually being created. Thus, rather than matter appearing all in one go in a primeval explosion, it arises gradually, or perhaps sporadically in mini-bangs, over the aeons. The average rate of appearance of new matter is adjusted (perhaps by a feedback mechanism) so that, as the universe expands and the density of existing matter is diluted, the newly-created matter fills in the gaps and maintains a roughly constant density. The dispersal of the galaxies is thereby compensated by the creation of new galaxies in the widening void in such a way that the overall aspect of the universe remains much the same from epoch to epoch. Globally, nothing changes (see Fig. 3). In contrast, in the big bang model, the density of galaxies steadily declines, and the universe



3 The figure contrasts three successive ‘snapshots’ of a region of expanding space in the big bang and steady-state models of the universe. In the big bang case (upper) the number of galaxies (dots) remain unchanged in a given volume of space. Thus, the density of dots declines as the expansion proceeds. In the steady-state case (lower) the density of galaxies remains unchanged from epoch to epoch, so that new galaxies must be continuously created to fill in the gaps made by the expanding space.

evolves in structure and arrangement.

Hoyle attempted to explain the continual creation of matter by inventing a new type of field that carries negative energy. The steady enhancement of this field pays for the positive energy necessary to create the matter. (The creation of matter from energy will be described in the next chapter.) Thus, God is abolished from the steady-state model altogether. First, the primary energy necessary to create matter need not be created; it is simply paid for by depositing *negative* energy into some other system. Secondly, space and time are not created, but have always existed.

The steady-state model had great philosophical appeal for many scientists, who were attracted by its elegance and simplicity. However, advances in astronomy put paid to any simple version of the theory, and the discovery of the cosmic background heat radiation in 1965 was really the last nail in its coffin. It remains an important idea, though, for it demonstrates the logical possibility of a universe with neither abrupt creation nor heat death, in which all processes, including the appearance of matter, are attributed to natural mechanisms.

The fact that modern cosmology has provided hard physical evidence for the creation is a matter of great satisfaction to religious thinkers. However, it is not enough that a creation simply occurred. The Bible tells us that God created the universe. Can science throw any light at all on what caused the big bang? This will form the subject of the next chapter.