4. Why is there a universe?

'There is a reason in Nature why something should exist rather than not.'

Leibniz

'The more the universe seems comprehensible, the more it also seems pointless.'

Steven Weinberg

The idea of God-the-creator, who caused the universe to come into being of his own free will, is firmly rooted in the Christian-Judaic culture. Yet we have seen how such an assumption raises more problems than it solves, and has been seriously questioned by theologians for centuries. The difficulty involves the nature of time. Today we know that time is linked inseparably to space, and that space-time is as much a part of the physical universe as matter. As we shall see in Chapter 9, time has its own laws of change and behaviour; it is demonstrably part of physics.

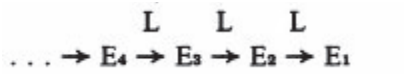
If time belongs to the physical universe, and is subject to laws of physics, it must be included in the universe that God is supposed to have created. But what does it mean to say that God *caused* time to come into existence, when by our usual understanding of causation a cause must precede its effect? Causation is a temporal activity. Time must already exist before anything can be caused. The naive image of God existing *before* the universe is clearly absurd if time did not exist — if there was no 'before'.

These difficulties were already apparent, as we have seen, to St. Augustine in the fifth century. They were articulated especially by Boethius a century later, and developed into a concept of 'creation' that is far more abstract and subtle than the one which is still familiar to most laymen. According to this refined viewpoint, God exists entirely outside space and time; in some sense 'above' nature, rather than before it. The concept of a timeless God is not an easy one, and I shall defer the main discussion of this topic until Chapter 9 which deals with the nature of time in more depth.

The God who is outside time is regarded as 'creating' the universe in the more powerful sense of 'holding it in being at every instant'. Instead of God simply starting the universe off (a belief known as deism rather than theism), a timeless God acts at all moments. The remote cosmic creator is thus given a greater sense of immediacy — he is acting here and now — but at the expense of some obscurity, for the idea of God being above time is a subtle one.

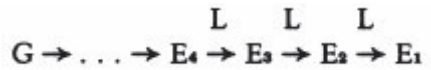
The alternative roles of God in time, causing the creation, and a timeless God holding the universe (including time) in being, are sometimes illustrated schematically in the

following way.[1] Imagine a sequence of events, each one causally dependent on the preceding one. They can be denoted as a series... E^3, E^2, E^1, stretching back in time. Thus, E^1 is caused by E^2, which in turn is caused by E^3 and so on. This causal chain can be denoted as follows:

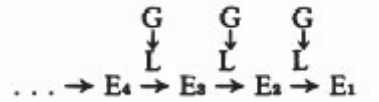


where the 'L's remind us that one event causes the next through the operation of the laws of physics, L.

The concept of a causal God (which we considered in detail in the previous chapter) can then be illustrated by making God, denoted G, the first member of this series of causes:



By contrast, if God is outside time, then he cannot belong to this causal chain at all. Instead, he is above the chain, sustaining it at every link:



and this picture could apply equally well whether the chain of causes has a first member (i.e. a beginning in time) or not (as in an infinitely old universe). With this picture in mind, we may say that God is not so much a cause of the universe as an *explanation*.

These ideas are not easy to grasp. Roughly speaking, the laws of physics are apparent to us as regularities in the way things happen: the precision motion of the planets in their orbits, the orderly pattern of lines in the spectrum of an element, and so on. When we press the brake pedal in a moving car we expect the car to slow down. When we ignite gunpowder we expect it to explode. We expect a hot flame to melt a block of ice, or a hard floor to smash a falling vase. The world is not haphazard and chaotic but, at least to a certain extent, predictable and orderly.

From our limited perspective within spacetime we interpret these regularities in terms of cause and effect: the sun's gravity causes the Earth's orbit to curve, and so on. But there is an alternative possibility — that every event is actually caused by God, operating on our universe from outside, carefully arranging the events to display the regularities.

There is a helpful analogy here. Imagine a machine-gunner facing a target screen. As he fires the gun, he sweeps his aim at a steady rate from side to side. The end result is a pattern of equispaced bullet holes. Now a two-dimensional creature obliged to live permanently in the flatland of the screen would perceive this sequence of events as the regular appearance of holes in his world. With careful observation he would deduce that the holes are not formed at random, but periodically, and moreover they are arranged in a geometrically simple way, with equal distance between them. Confidently this flatlander would proclaim a new law of flatland physics: the law of hole creation. He

would conclude that the appearance of each hole *causes* the appearance of the next in line, in a regular way. After all, one hole is always followed by another in a simple sequence. From the limited perspective of his two-dimensional world, the flatlander misses entirely the fact that the holes are actually *completely independent* of each other, and the regularity in their arrangement is due entirely to the activity of the machine-gunner. In the same way, the orderly operation of the cosmos can be explained by God creating each event in spacetime in an organized way from some wider perspective. A higher dimensional space? A physical structure which is not space? An entirely non-physical structure (whatever that may mean) ?

What is the justification for this belief? Look around you. See the complex structure and elaborate organization of the universe. Puzzle over the mathematical formulations of the laws of physics. Stand perplexed before the arrangement of matter, from the whirling galaxies to the beehive activity of the atom. Ask why these things are the way they are. *Why this* universe, *this* set of laws, *this* arrangement of matter and energy? Indeed, why anything at all?

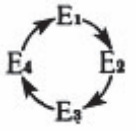
Every thing and every event in the physical universe must depend for its explanation on something outside itself. When a phenomenon is explained, it is explained in terms of *something else*. But if that phenomenon is all of existence – the entire *physical* universe – then clearly there is nothing physical outside the universe (by definition) to explain it. So any explanation must be in terms of something non-physical and supernatural. That something is God. The universe is the way it is because God has *chosen* it to be that way. Science, which by definition deals only with the physical universe, might successfully explain one thing in terms of another, and that in terms of another and so on, but the totality of physical things demands an explanation from *without*.

This line of reasoning, which takes as its basis the assertion that all physical things are contingent upon something else, is known as the contingency argument and is the second version of the cosmological argument for the existence of God. It is open to some of the criticisms which have been deployed against the other version of the cosmological argument (the causal argument considered in the previous chapter).

In a sense that contingency argument falls a victim of its own success, for suppose we enlarge the definition of ‘universe’ to include God. What, then is the explanation for the total system of God plus the physical universe of space, time and matter? In short, what explains God? The theologian answers: ‘God is a *necessary* being, without need of explanation; God contains within himself the explanation of his own existence.’ But does this mean anything? And if it does, why can't we use the same argument to explain the universe: The universe is *necessary*, it contains within itself the reason for its own existence? Indeed, that seems to be Wheeler's position described in the last chapter.

The idea of a physical system containing an explanation of itself might seem paradoxical to the layman but it is an idea that has some precedence in physics. While one may concede (ignoring quantum effects) that every event is contingent, and depends for its explanation on some other event, it need not follow that this series either continues endlessly, or ends in God. It may be closed into a loop. For example,

four events, or objects, or systems, E^1, E^2, E^3, E^4, may have the following dependence on each other:



A theory of precisely this sort was once popular with some particle physicists in their attempts to explain the structure of matter. Here there is a well-known chain of explanation: matter is made of molecules, which are made of atoms, which are made of electrons and nuclei, which are made of protons and neutrons. There has been a widespread belief (since ancient Greece) that this chain of explanation will have an end; that there exists a small number of truly elementary particles that have no internal parts and which are the building blocks of all matter. If we can but probe into ever smaller regions within the atom, sooner or later these fundamental, structureless particles will be discovered. At present, this theory receives strong experimental support in the shape of the so-called quark theory (see Chapter 11).

An alternative picture, permitted by the weird properties of the quantum theory, is that (in a subtle sense to be clarified in later chapters) there are no elementary particles at all. Instead, every particle (at least every subnuclear particle) is made up of every other. No particle is elementary or primitive, but each contains something of the identity of all the others. The idea of a system of particles generating themselves in a self-consistent loop of explanation is reminiscent of the story of the boy who fell into a bog and hauled himself out by pulling on his own bootstraps, so physicists call such modes of explanation ‘bootstrapping’. One could envisage a ‘bootstrap universe' containing its own explanation entirely in terms of natural, physical interactions.

But surely, counters the theologian, God, who is infinitely powerful and infinitely knowledgable and hence the *simplest* being that one can evisage, is more likely to contain the reason for his own existence than is the universe, which is *complicated* and *special* in its many particular features:

> There is quite a chance that if there is a God he will make something of the finitude and complexity of a universe. It is very unlikely that a universe would exist uncaused, but rather more likely that God would exist uncaused. The existence of the universe is strange and puzzling. It can be made comprehensible if we suppose that it is brought about by God. This supposition postulates a simpler beginning of explanation than does the supposition of the existence of an uncaused universe, and that is grounds for believing the former supposition to be true.[2]

This counter is very persuasive. It takes a lot to believe that this intricate universe with so many characteristic, contingent features, just happens to be. Can we really accept it as a brute, inexplicable fact? Yet a single, simple, infinite mind (though the logic of even its existence may be perplexing to us) seems an altogether more plausible candidate for something that exists of necessity.

The scientist, however, may wish to challenge the assumption that an infinite mind

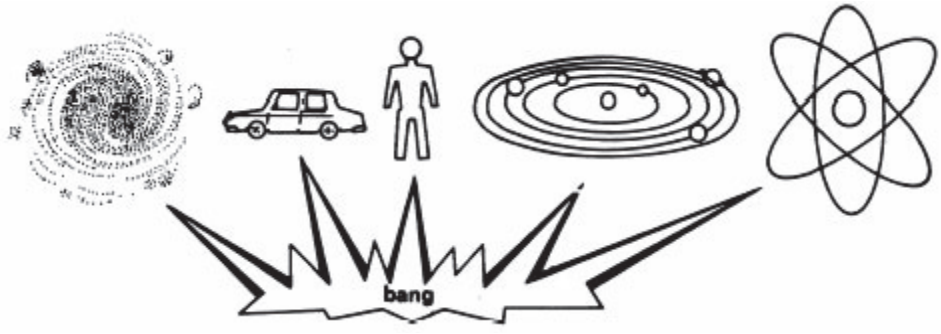
(God) is simpler than the universe. In our experience, mind only exists in physical systems that are above a certain threshold of complexity. The brain is a highly complicated system. (In Chapter 6 we shall see that mind must be regarded as a 'holistic' concept — a pattern of activity.) While it is possible to imagine a disembodied mind, there must be some means of expression of the pattern, and the pattern itself is complex. So it could be argued that an infinite mind is infinitely complex and hence far less likely than a universe, many parts of which are far too short on complexity to support a mind.

Perhaps, then, God is not a mind, but something simpler? Does it in any case make sense to talk about a mind existing timelessly? Aren't thoughts, decisions, and so on things that take place in time? But if God cannot *decide* (or hope, or judge, or converse) in what sense is he responsible for the nature and existence of the universe? Is such a being anything that we would recognize as a God at all? Despite these doubts, we are still left with the complexity and specificity of the universe to account for. Why *this* universe?

This is the question I shall take up more fully in Chapter 12, but here we may note what I believe to be the central issue in assessing the relative plausibility of a self-caused universe as against requiring God for its explanation. In the foregoing discussion it was taken for granted that the universe is very complicated, and that God provides a ready explanation for its features. But has the universe always been complicated? Could this complexity not have arisen naturally as a result of perfectly ordinary physical laws?

According to our best scientific understanding of the primeval universe it does indeed seem as though the universe began in the simplest state of all – thermodynamic equilibrium – and that the currently-observed complex structures and elaborate activity only appeared subsequently. It might then be argued that the primeval universe is, in fact, the simplest thing that we can imagine. Moreover, if the prediction of an initial singularity is taken at face value, the universe began in a state of infinite temperature, infinite density and infinite energy. Is this not at least as plausible as an infinite mind?

The success of the above argument depends crucially on whether it can be demonstrated that cosmic complexity and order really have arisen spontaneously from the simple primeval state. At first sight this claim seems to be in flagrant contradiction with the second law of



6 Mystery surrounds how order has emerged out of chaos in the universe. The present orderly structures and complex activity has somehow arisen from the featureless ferment of the big bang, in apparent defiance of the second law of thermodynamics which requires that order decreases, rather than increases, with time. The resolution of the paradox

thermodynamics, which requires just the opposite — that order gives way to disorder, so that complex structures tend to decay to a final state of disorganized simplicity. Thus, E.W. Barnes wrote in the 1930s:

> In the beginning there must have been a maximum organization of energy… In fact, there was a time when God wound up the clock (i.e. the cosmic mechanism) and a time will come when it will stop if He does not wind it up again.[3]

We now know that this is wrong. The primeval state was not one of maximum organization but one of simplicity and equilibrium. The apparent conflict of this fact with the second law has only recently been resolved.

The problem is that the second law strictly applies only to isolated systems. Now it is physically impossible to isolate anything from gravity — there are no gravity shields, and even if there were the system concerned could not escape its own gravity. In the expanding universe, the cosmic material comes under the influence of the cosmological gravitational field — the cumulative gravity of the rest of the universe. This coupling to gravity opens the way to the injection of order into the cosmic material by the gravitational field. We know that, given an external supply of energy, order can be created in one system at the expense of disorder in another. Thus the flux of heat and light from the sun generates the highly complex order of the Earth's biosphere, but only by sacrificing irreversibly the limited fuel resources of the solar core. In the same way, an expanding universe can generate order in the cosmic material.

A very simple example can be given of how the expansion of the universe can be used in place of God to ‘wind up the clock’. It has already been remarked that the primeval cosmic substance was very hot, but the expansion of the universe caused it to cool. An elementary scaling argument yields the temperature of the substance at each stage of the expansion. However, the temperature will depend to some extent on the nature of the substance itself. In the case of radiant heat (electromagnetic energy), the temperature declines in proportion to the size of a typical expanding region of space: double the size and the temperature is halved. On the other hand, material substance, such as hydrogen gas, cools much faster, like the square of the size. This implies that, so long as hydrogen gas is decoupled from radiant heat, the expanding universe will cause a temperature difference to open up between these two components of the cosmic substance. As any engineer knows, a temperature differential is an ideal source of useful energy, and is in essence the secret of the sun's power to generate life on Earth. Thus, the expansion of the universe is capable of creating order where none existed before.

Using analyses like this, it is possible to trace, step by step, the origin of most of the orderly structure that we observe in the universe today back to the expansion of the universe in the primeval era.[4] The above cited example is actually not the most important. By far the greatest source of organized energy today is the highly reactive hydrogen gas which constitutes about seventy-five per cent of the cosmic material. Hydrogen provides the fuel for all normal stars. When it is burned (in nuclear fusion

reactions) it is ultimately converted to heavier elements such as iron. Iron is just nuclear ash; it has no useful nuclear energy locked up inside. We therefore owe the existence of the stellar order to the preponderance of hydrogen over iron.

This circumstance can be explained by the cosmic expansion. In the primeval phase it was too hot for any composite nuclei (such as iron) to exist. Only hydrogen nuclei (individual protons) — the simplest substance — could survive. With the continual expansion and cooling, the way lay open for the conversion of hydrogen into heavier elements and, as discussed in the previous chapter, the cosmic material made some progress down this road. It did not, however, get very far. About twenty-five per cent reached helium (the next simplest element) and only a minute fraction beyond. The blame for the aborted journey can be laid at the door of the expansion. It was far too rapid to give the material enough time to undergo all the complex nuclear reactions necessary before heavy, composite, nuclei like iron can be synthesized. After only a few minutes of 'cooking' the temperature had sunk below the threshold needed for nuclear reactions to ignite. The nuclear fire went out, leaving most of the material 'frozen' in the form of hydrogen or helium. Only with the formation of stars, which occurred much later on, were local hot-spots created in which the journey could be resumed.

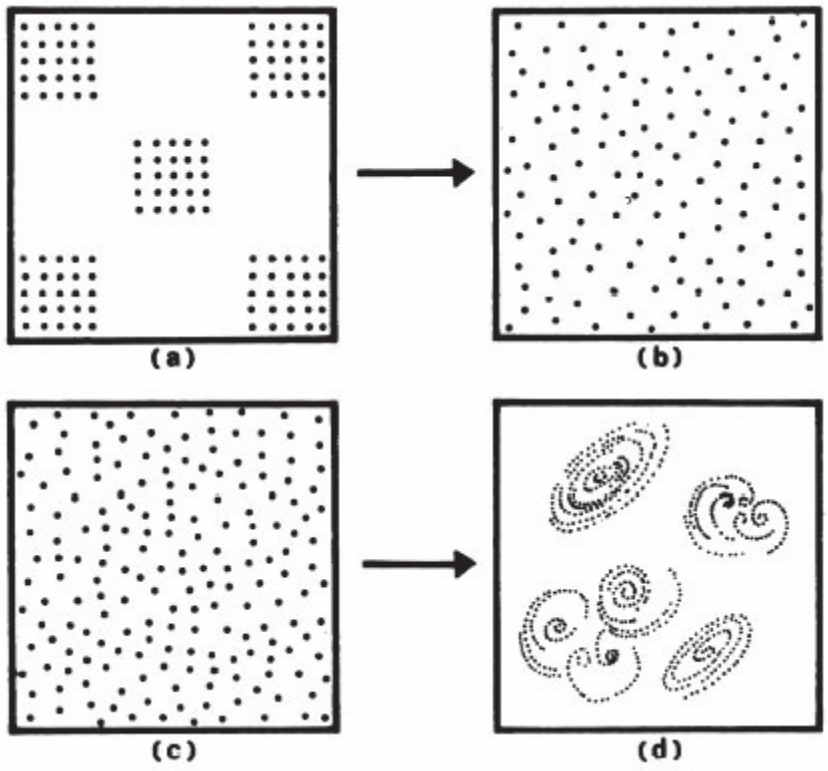
In conclusion, it appears that in an expanding universe organized energy can appear spontaneously, without the necessity for it being present at the outset. There is then no need to attribute the cosmic order (low entropy) either to the activity of a Deity or to the input of organization at the initial singularity. The singularity could have coughed out totally random and chaotic energy, which then organized itself spontaneously into the present arrangement under the influence of the expanding universe. Notice that now we not only have attributed the origin of matter to expanding space (see page 32), but also the origin of its organization.

This cannot, however, be the whole story. The gravitational field, which is ultimately responsible for generating order via the cosmic expansion, presumably suffers some disordering tendency as a result. Thus we can explain the order of material things by shifting the responsibility on to gravity, but then we have to explain how the order appeared in the gravitational field in the first place. Where does the buck stop?

The issue turns on whether or not the second law of thermodynamics applies to gravity as well as to matter. Nobody really understands this. Recent work on black holes suggests that it does, but different physicists have drawn opposite conclusions (see Chapter 13). Some, such as Roger Penrose, conclude that the large scale cosmic gravitational field is in a very low entropy (highly ordered) state which therefore requires an input of order at the creation. Others, such as Stephen Hawking, claim that the cosmic gravity is highly disordered, and is the expected result of purely random and unstructured influences emerging from the initial singularity. Because no one yet knows how to quantify the orderliness of a spacewarp (i.e. gravity) the issue remains undecided. Nevertheless, the debate illustrates an important point. Future progress in theoretical physics might well clarify the concepts involved, and enable a definitive statement to be made as to whether the universe was created with or without order.

Thus may science come one day to answer a question that has long occupied the attention of theologians and philosophers.

Whatever the outcome of the debate about quantifying the entropy of gravity, one curious thing has already emerged. In systems such as boxes of gas, where gravity is so small it can be ignored, low entropy (ordered) states are complicated, while high entropy (disordered) states are simple. For example, a box in which all the gas molecules are crowded into the corners clearly involves a more complicated arrangement than the equilibrium (maximum entropy) state in which the gas is distributed uniformly throughout the box. By contrast, a low entropy gravitating system is geometrically much *simpler* than one in a high entropy state. Gravity has a tendency to grow structures spontaneously.



7 The concept of order depends crucially on whether gravity can be ignored. Box (a) contains a gas for which gravity is negligible. Its highly ordered molecular arrangement soon gives way to featureless disorder (maximum entropy) as a result of molecular agitation and collisions. The final state is shown in (b). By contrast, a gravitating 'gas', for example a system of stars, will do just the opposite. The initial uniform configuration (c) will tend to fragment and become clumpy as the stars fall together and organize themselves into clusters (c.f. galaxies). The ultimate result of this clumping would be a number of black holes.

Thus, a uniform distribution of matter (stars, or gas) will tend to grow clumpy with time, forming into clusters and dense accumulations. In summary, for non-gravitating systems order means complexity and disorder means simplicity. For gravity it is the other way round (see Fig. 7).

If the universe really did start out with a highly ordered, low entropy, gravitational field, then this field would have been smooth and uniform. So we see that it is possible, in the special case of gravity, to satisfy both the requirement of simplicity, and the requirement of low initial entropy (order). This means we can regard the *simplest*

universe (a uniform one) as containing immense potential for generating complexity later. This is surely a pleasing result. If we were expected to believe that the universe appeared uncaused, what better than for it to have the simplest possible arrangement of matter and gravity, yet without compromising its ability to develop into a complex and interesting form subsequently?

In spite of this success, there is more to the world than just the *state* of the universe. What about the *laws*? Granted that, initially at least, the universe was in a very simple state, there can be no doubt that the laws of physics are still rather numerous and special. Are these laws not contingent? Could we not envisage a host of alternatives? Furthermore, what about the *constituents* of the universe — the protons, neutrons, mesons, electrons, and so on. Why *those* particles? Why do they have the masses and charges that they do? Why are there not more, or less, types of such subatomic particles? The theologian has a ready answer. God made it that way. God, who is infinite simplicity, chose to create the laws of physics and the constituents of matter in complex variety, in order to produce an interesting universe.

Now it is only very recently that the scientist has also begun to perceive an answer to this point. The new developments arise from a programme of theoretical work aimed at unifying the forces of nature into a single descriptive scheme. According to this theoretical scheme, which will be described more fully in a later chapter, the present profusion of physical laws is purely a low-temperature phenomenon. As the temperature of matter is raised, so the varied forces that act upon it begin to merge their identity until, at the staggering temperature of 10^{32}K (that is a hundred thousand billion billion billion degrees absolute) all the forces of nature should merge into a single superforce with a remarkably simple mathematical form. Furthermore, all the many disparate subatomic particles lose their identities too, their varied characteristics disappearing in the searing heat. Evidence for this convergence to simplicity comes from years of study of high-energy physics (high energy is the same as high temperature in this context). Physicists tend to find that as the energy is raised, so complex subatomic structures break apart to reveal simpler constituents, and complicated forces become simpler in operation.

If these ideas are right — and it is premature to conclude more than that the signs are encouraging — then they have profound implications for the big bang theory. In the unlimited temperatures of the creation, only the superforce would have operated, with a handful of simple particle species. The current differentiated forces and particles would only have emerged as the universe cooled. Thus, the state of the universe, the laws of physics and the constituents of matter all seem to have started out in an exceedingly simple form.

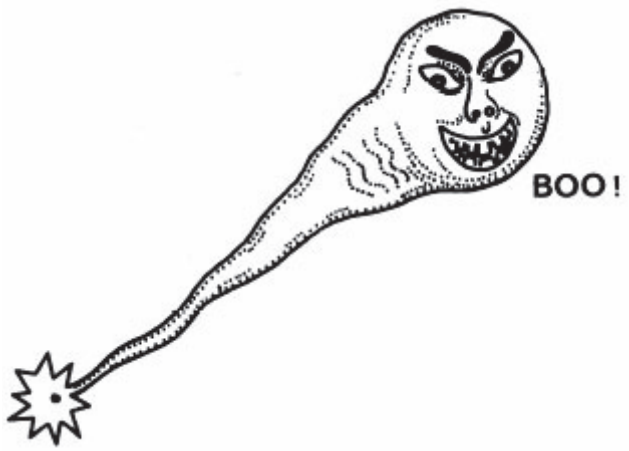
Still, the sceptical theologian will reply, even a single superforce and a handful of simple particles require an explanation. Why that particular superforce? In fact, why any *law* at all?

This is a point that we shall return to in the final chapter. Some physicists, inspired by the simplicity of nature's fundamental laws, have argued that perhaps the ultimate law

(in this case the superforce) has a mathematical structure which is uniquely defined as the only logically consistent physical principle. That is to say, physics is proclaimed 'necessary' in the same way that God is proclaimed necessary by theologians. Should we then conclude that *God is physics* as some philosophers seem to have done?

A few physicists, notably Stephen Hawking, have argued that a remarkably simple primeval state of the universe is, in fact, to be expected.[5] The reason for this concerns the initial singularity, discussed briefly in Chapter 2. The essential feature of a singularity is that it is rather like an edge or boundary to spacetime and hence, one supposes, to the physical universe. An example of a singularity is the infinitely dense, infinitely compact state that marked the beginning of the big bang. Singularities are also expected to occur inside black holes and perhaps elsewhere as well.

Because all our physical theories so far are formulated in the context of space and time, the existence of a boundary to spacetime suggests that natural physical processes cannot be continued beyond such a thing. In a fundamental sense a singularity represents, according to this view, the outer limits of the natural universe. At a singularity, matter may enter or leave the physical world, and influences may emanate therefrom that are totally beyond the power of physical science to predict, even in principle. A singularity is the nearest thing that science



8 A singularity (dot) represents the ultimate unknowable in science. It is an edge or boundary of spacetime at which matter and influences can enter or leave the physical universe in a totally unpredictable fashion. If a singularity is 'naked' then anything can apparently come out of it without prior physical causation. Some cosmologists believe that the universe emerged without cause from a type of naked singularity. If these ideas are correct, a singularity is the interface between the natural and the supernatural.

has found to a supernatural agent.

For many years it was thought that singularities were an artefact due to over-idealization in the gravitational model used. Then, in a series of brilliant and embracing mathematical theorems, Penrose and Hawking proved that singularities were quite general and, under all reasonable physical conditions, unavoidable, once gravity becomes strong enough. It was certainly strong enough in the big bang.

Since they had to be taken seriously a lot of thought was expended on how singularities might behave. The choices boil down to this. What comes out of a singularity is either totally chaotic and unstructured, or it is coherent and organized. In

the former case, the big bang singularity simply coughs out a randomly arranged universe displaying no particular order, and in the latter case the universe emerges with a degree of organization present wound up and ready for action.

Hawking has proposed a ‘principle of ignorance' which says that the singularity is the ultimate unknowable, and therefore should be totally devoid of information (in physics, information is roughly the same as order — the negative of entropy).[6] Hence, anything that emerges from a singularity is totally random and chaotic. This accords well with the belief that the primeval universe was in a state of maximum disorder (thermodynamic equilibrium).

Many of these ideas are at the frontier of modern theoretical physics and will only be clarified by future developments. There is no unanimous agreement among physicists about the status of spacetime singularities, or even about the precise state of the primeval universe. Yet the flow of ideas generated by recent advances in scientific cosmology has undoubtedly regenerated and given a new slant to the debate about God and the existence of the universe.