12. Accident or design?

> 'Whence arises all that order and beauty we see in the world?'
>
> Isaac Newton

> 'Man at last knows that he is alone in the unfeeling immensity of the universe… Neither his destiny nor his duty have been written down.'
>
> Jacques Monod in *Chance and Necessity*

In his book *Natural Theology* William Paley (1743–1805) articulated one of the most powerful arguments for the existence of God:

> In crossing a heath, suppose I pitched my foot against a *stone*, and were asked how the stone came to be there: I might possibly answer, that, for anything I knew to the contrary, it had lain there for ever; nor would it, perhaps, be very easy to show the absurdity of this answer. But suppose I found a *watch* upon the ground, and it should be inquired how the watch happened to be in that place. I should hardly think of the answer I had given before — that, for anything I knew, the watch might always have been there. Yet why should not this answer serve for the watch as well as for the stone?[1]

The intricate and delicate organization of a watch, with its components dovetailing accurately, is overwhelming evidence for design. Someone who had never seen a watch before would conclude that this mechanism was devised by an intelligent person for a purpose.

Paley went on to argue that the universe resembles a watch in its organization and complexity — though on a vastly greater scale. Surely, therefore, there must exist a cosmic designer who has arranged the world this way for a purpose: 'the contrivances of nature surpass the contrivances of art, in the complexity, subtlety and curiosity of the mechanism'.

The argument from design came to be associated with the concept of *teleology*: the idea that the universe has been programmed to evolve towards some final goal. In its broadest form the teleological argument encompassed both the order of simplicity and the order of complexity. It is an old idea. Aquinas wrote that 'an orderedness of actions to an end is observed in all bodies obeying natural laws, even when they lack awareness… which shows that they truly tend to a goal, and do not merely hit it by accident'. Though Aquinas knew nothing about the mathematical simplicity of the fundamental laws of physics, he spotted the striking fact of the compliance of material bodies with orderly laws and used that fact as evidence for a designer God.

The teleological argument was so savagely attacked that it is treated today with circumspection by theologians. Nevertheless it does have some modern proponents. 'The existence of order in the universe', writes Swinburne, 'increases significantly the probability that there is a God.'[2] But Swinburne bases his argument on the order of simplicity rather than the order of complexity. The idea that complex natural structures provide evidence for a cosmic designer seems to have fallen into disrepute.

The main objection to the argument from design involving complexity is that many systems which display complex order and structure can, in fact, be explained as the end result of perfectly ordinary natural processes. This does not, of course, prove that *all* ordered systems have arisen naturally, but it makes us cautious about inferring the existence of a designer purely on the rather superficial grounds that something looks too complicated to have arisen by chance. One must also have some understanding of the processes whereby complex order can develop.

The classic conflict between these opposing philosophies came with Charles Darwin's publication of *The Origin of the Species*. The exquisite organization of living creatures seems to offer the best possible demonstration of a supernatural designer, yet the evidence of biology and geology provide an adequate explanation for the extraordinary characteristics of biological organisms. Evolution of biological order by mutation and natural selection is now accepted virtually unanimously by scientists and theologians alike. Though Darwin's original theory is by no means established in its entirety, the basic principles and mechanisms of evolution are no longer seriously in doubt.

The essential feature of Darwinian evolution is its accidental nature. Mutations occur by blind chance, and as a result of these purely random alterations in the characteristics of the organisms nature is provided with a wide range of options from which to select on the basis of suitability and advantage. In this way, complex organized structures can arise from the accumulation of vast numbers of small accidents. The corresponding increase in order (fall in entropy) occasioned by this trend is more than paid for by the much greater number of damaging mutations which are weeded out by natural selection. There is thus no conflict with the second law of thermodynamics. Today's beautifully fashioned creatures sit atop a family tree festooned with genetic disasters.

Whether one is prepared to accept that the Darwinian mechanism of evolution is the whole story, it cannot be denied that mutation and natural selection must be a major contributory factor in the development of biological order. The essential principle that physical systems can spontaneously organize themselves into intricate complexity is an empirical fact. In Chapter 5 we saw how many simpler examples of self-organization in the laboratory have been studied by physicists and chemists in recent years. Indeed, so important have these studies become that a new word — synergetics — has been coined to describe them. The conclusion must be that the presence of order in a system, however remarkable and complex it might be, is in itself no guarantee that a designer is necessary. Order can, and does, occur spontaneously.

These observations still, however, leave open a vital issue. Though the spontaneous appearance of order will not conflict with the second law of thermodynamics so long as compensatory disorder is generated elsewhere, it is clear that no order at all could exist unless the universe as a whole started out with a considerable stock of negative entropy. If total disorder always increases, in accordance with the second law, then the universe must, it seems, have been created in an orderly condition. Does this not provide strong evidence in favour of a creator-designer? After all, even if natural processes can generate localized order unaided, a fund of negative entropy is still needed to drive those processes in the first place. True, this could only constitute evidence of a designer-by-proxy, a creator who winds up the machine and then lets it crank out whatever structures it will, but even that strategy would involve supernatural dexterity of an astonishing degree, for the following reason.

Entropy, or disorder, is closely related to the concepts of probability and arrangement. A high-entropy, or disordered system, is one that can be achieved in a large variety of ways. Consider, for example, a box of gas in equilibrium at some uniform temperature and density; this is the condition of maximum possible entropy for the gas. Under these circumstances the molecules of gas could be rearranged in a huge variety of ways (for example, by being moved to different positions, or having their velocities altered) without affecting the large-scale properties of the gas. On the other hand, consider a very low entropy state, where all the molecules are moving on parallel trajectories, or another in which every molecule is crowded into one end of the box. These ordered configurations are exceedingly sensitive to any minute rearrangement of the molecules, and can only be achieved by a very limited fraction of the total available number of molecular arrangements. It follows that ordered (low-entropy) states are highly improbable and unstable. They require the careful cooperation of vast numbers of individual molecules. In disordered (high-entropy) states, all the molecules can move about randomly without regard for the others.

Now if you were asked to pick an arrangement of molecules at random, it is overwhelmingly likely that you would choose one that corresponds to maximum entropy, simply because there are vastly more possible disorderly arrangements than orderly ones. It is rather like the monkey who tinkers at random on a piano. The chances of his playing a well-known tune rather than a chaotic sequence of notes is minute. A mathematical investigation shows that order is exponentially sensitive to rearrangements. That is to say, the probability of a random choice leading to an ordered state declines exponentially with the degree of negative entropy. An exponential relation is characterized by its rapid rate of growth (or decline). For example, a population that grows exponentially doubles its size in a fixed interval of time: 1, 2, 4, 8, 16, 32…

The exponential factor implies that the odds against randomly-generated order increase astronomically. For example, the probability of a litre of air rushing spontaneously to one end of a box is of the order $10^{10^{20}}$ to one, where the number $10^{10^{20}}$ stands for one followed by 100,000,000,000,000,000,000 zeros! Such figures indicate the extreme care with which low-entropy states must be selected from the vast array of possible states.

Translated into a cosmological context, the conundrum is this. If the universe is simply an accident, the odds against it containing any appreciable order are ludicrously small. If the big bang was just a random event, then the probability seems *overwhelming* (a colossal understatement) that the emerging cosmic material would be in thermodynamic equilibrium at maximum entropy with zero order. As this was clearly not the case, it appears hard to escape the conclusion that the actual state of the universe has been 'chosen' or selected somehow from the huge number of available states, all but an infinitesimal fraction of which are totally disordered. And if such an exceedingly improbable initial state was selected, there surely had to be a selector or *designer* to 'choose' it?

A useful image here is that of a creator equipped with a pin. Before him is a vast 'shopping list' of universes, each characterized by their initial state. If the creator picks a universe by sticking in a pin at random, there is an overwhelming probability that the choice will be a highly disordered cosmos with no appreciable structure or organization. Indeed, to find an ordered universe, the creator would have to scour a selection of 'models' that is so vast its number could not be written down on a sheet of paper as big as the entire observable universe.

The mystery of how the universe got into its low-entropy state has exercised the imagination of several generations of physicists and cosmologists, many of whom have been reluctant to appeal to divine selection. The pioneer of statistical thermodynamics, Ludwig Boltzmann, preferred to fall back on blind chance. He suggested that the cosmic order had arisen spontaneously as a result of a collaboration of unbelievably rare fluctuations from equilibrium. The basis of his argument is the fact that, even in equilibrium, the molecules of a gas do not remain inert, but are continually rushing about in a random sort of way. From time to time, purely by chance, a few molecules will find themselves in unwitting cooperation, and a tiny enclave of order will arise, fleetingly, amid an ocean of chaos. Exponentiate the time scale and one can be persuaded that still larger regions of cooperation will eventually accidently occur. If the universe has enough time available then, sooner or later, one might suppose, whole stars, whole galaxies, will simply happen to form — accidentally. The fact that the time for such an absurdly improbable accident is inconceivably long (at least $10^{10^{80}}$ years) is, in principle, no problem if one is prepared to believe that the universe is of infinite age.

According to this view, the universe spends the overwhelming majority of its time in total chaos, with no organization whatever. But from time to time, after intervals of mind-numbing duration, there occurs a few billion years of accidental order. The reason that we — humanity — are present to witness one such occurrence of staggering improbability is simply because, in the absence of such a 'miracle', life could not exist. Because life feeds on negative entropy (see Chapter 5) conscious observers will only exist in the epochs of 'miraculous' fluctuations.

An interesting by-product of Boltzmann's reasoning is its assurance of a form of immortality. The continual molecular reshuffling which is responsible for the universe 'winding itself up' can be proved, mathematically, to possess the following curious property. As the molecules mill around, the universe visits state after state. Eventually, every possible state that can ever exist will be visited: anything at all that can happen, will happen, sooner or later. After this, the shuffling continues, and the universe starts *revisiting* states that have previously occurred. Eventually, every state will have been revisited, and so the process continues. This phenomenon of unlimited repetition and duplication is known as the Poincaré cycle, after the mathematical physicist Henri Poncaré who proved the result (at least, he proved it for an idealized model). Taken at face value, the Poincaré theorem implies that, in the fullness of time, planet Earth, long since disappeared, will be reconstituted, together with all its inhabitants! Moreover, this will happen infinitely often. But for every instance of more or less exact duplication there will be untold numbers of cases in which there are departures from the present arrangement. The closer the 'fit' the smaller the probability of reconstitution and the longer the wait.

Few physicists would take Boltzmann's explanation of cosmic order seriously. The basic mechanism of Poincaré recycling is not in doubt, however it is now known that the universe is not simply sitting there, shuffling away, but is in a state of global expansion. It is generally assumed that this expansion forces the universe to be of finite age. Its multi-billion-year lifetime is but an insignificant drop in the ocean of time needed to bring about all but a trifling decrease in entropy.

Boltzmann's argument does, however, bring out one vital feature of enduring value. The universe we perceive is, necessarily, selected *by us*, from the elementary requirement that life, and hence consciousness, can only develop under the appropriate physical conditions. By definition, we cannot observe an uninhabitable cosmos. This simple fact has, as we shall shortly see, been used to argue by some that the extraordinarily improbable, low-entropy universe that we observe has indeed been selected from a vast array of possible universes (nearly all of which are disordered); but the selection has been made by us, not by God.

Adopting, therefore, the big bang scenario, it would seem that we have little choice but to assume that the universe went bang in a remarkably orderly way, even though an accidental creation would, with a probability that is a virtual certainty, produce a totally disordered universe. This fundamental paradox of cosmology has stimulated several different responses:

1. So what?

Many scientists incline to the view that it is meaningless to discuss the concepts of probability, randomness and likelihood on an a *posteriori* basis. If you pick up a pebble on a beach at random, and carefully measure its size and shape you could correctly conclude it was wildly improbable that you had selected a pebble of those exact dimensions. But you would not be justified in proceeding to claim it must have therefore been a miracle that you made the choice you did, or that some supernatural or occult agency had been responsible for guiding your selection. Such arguments carry no conviction *after the event*. Amazement would have been justified had the pebble's dimensions been specified in advance, of course. In the same vein it could be argued that, given the existence of the universe, its particular structure need occasion no surprise: it simply is the way it is.

A related difficulty is that, at least according to one conception, probability is only defined in relation to a collection of trials. To say that, for example, the toss of a die will produce the result ‘two’ with a probability one-sixth is to say that, after many, many such tosses, roughly one-sixth of them will have produced a ‘two’. The greater the number of trials the closer the proportion converges on the value one-sixth. At the very least, the subject to which our discussion of probability is directed must be a member of a collection or ensemble of similar things. The face of a die, for example, has five neighbours; the pebble on the beach had millions of neighbours. If, then, there is but one universe, what meaning can be attached to discussions of its likelihood?

This argument is not completely convincing though. If the selected pebble had turned out, for example, to be exactly spherical, surprise would indeed have been justified, even if its spherical nature had not been specified in advance. A sphere is a very special sort of shape with the property that it is mathematically highly regular. Even after the event the random selection of an exactly spherical pebble would be regarded as a remarkable circumstance deserving some sort of explanation. Likewise, a universe that is suitable for human habitation has a special significance for us that is absent for the vast majority of other possible universes: those that are uninhabitable.

At this point the ‘so what' proponents reply that, had the universe not been arranged in the way it is, we should not be here to marvel at it. Indeed, any universe in which intelligent creatures can frame philosophical and mathematical questions is, by definition, a universe of the sort we observe, however remarkable that universe would otherwise have been a *priori*. In other words, they maintain, there is not, after all, anything very extraordinary or mysterious about the highly ordered universe we perceive, because we could not (obviously) perceive it otherwise.

This type of reasoning receives some support from the philosophy of logical positivism which argues, crudely speaking, that it is meaningless to talk about what can never be observed. What does it mean to discuss a universe that has no conscious observers within it? As such a universe could never be verified or refuted by observation, its existence would seem to have no meaning or significance for conscious individuals.

A related argument is that of the so-called strong anthropic principle, first articulated in detail by the astrophysicist Brandon Carter, and much discussed in recent years by physicists and astronomers. According to this principle ‘The universe must be such as to admit conscious beings in it at some stage’ [3] (my italics). This amounts to saying that, far from being astonishingly unlikely, the universe had *no choice* about appearing with the appropriate degree of order required for life to appear.

These two positions — logical positivism and the strong anthropic principle — hinge on the paramountcy of human (or extraterrestrial) intelligent observers. The theologian could counter, however, that God is an observer, who moreover does not require special physical conditions for his existence. So universes that never produce life are still meaningful if observed by God.

2.The many-universes theory.

According to this point of view, there is an ensemble of universes of which ours is but one member. The universe we perceive is only one of a huge, perhaps infinite, collection of universes, each differing from the other members of the ensemble in some way. Somewhere among this collection is an example of every possible arrangement of matter and energy. Although the overwhelming majority of these universes are unsuitable for life, and lie very close to the totally chaotic conditions of maximum entropy (thermodynamic equilibrium), nevertheless there will be a minute fraction in which, accidentally, the conditions came out just right, and life develops. Obviously it is only those accidental universes that will be perceived by living organisms, who will write books about how incredibly improbable their world is.

Boltzmann's hypothesis, mentioned above, is logically identical to the many-universes theory. His universes occur sequentially, but the organized phases are separated by such enormous chasms of time that they are all but physically independent. A modern variant of the sequential scenario is the oscillating universe theory. As we shall see (in Chapter 15) the present expansion of the universe might not continue indefinitely. If it does not, the universe will eventually begin to contract, falling back on itself in a gigantic cataclysm known as the ‘big crunch’. Some physicists have speculated that the highly compressed cosmos, rather than imploding to oblivion at a spacetime singularity, will ‘bounce' at some enormous density, and thereafter embark on a new cycle of expansion and eventual contraction. In this scenario, then, the universe continues indefinitely in a cyclical fashion, oscillating between collapsed ‘crunch-bangs' and distended, low-density states, like a balloon being successively inflated and deflated.

The oscillating universe suffers from the physical problems associated with all infinitely old universes which were discussed briefly in Chapter 2. However, the uncertainties surrounding the physics of the extremely collapsed state widen the scope for speculation, and one suggestion, due to Wheeler, is that the ‘crunch-bangs' have the effect of ‘reprocessing' the cosmos. What this means is that each new cycle of expansion and contraction is a sort of ‘new deal' in which the physical conditions are re-scrambled randomly. No attempt is made to explain how this might happen, but if it did it would clearly enable the universe to explore all possibilities open to it after a sufficient number of cycles — which would, of course, have to be astronomically large. Once again, only in those cycles where, by accident, the cosmos scrambler got it just right, would cosmologists evolve to speculate about it.

An alternative to assuming an ensemble of universes in time is to suppose that there is only one universe, which is infinite in spatial extent. Almost all of the cosmos would be close to equilibrium (no structure or organization) but, here and there, oases of order would appear spontaneously out of the chaos, by chance fluctuations. The distances between the oases would be inconceivably great, of course, but life and conscious observers could only form within an oasis, so all observers of this universe would necessarily perceive order.

Perhaps the most popular version of the many-universes idea comes, however, from Everett's interpretation of the quantum theory. In this theory *all possible* quantum worlds are actually realized, and coexist in parallel with each other. Thus, every time an electron faces two choices *both* alternatives occur, and the entire universe divides into two. Each universe is complete with inhabitants (whose brains and presumably minds have also bifurcated) each set of which believes that the electron has abruptly opted for one of the alternatives. The two universes are disconnected from each other in the sense that it is not possible to travel from one to the other through ordinary space or time. They exist 'side-by-side' or 'in parallel' in some abstract sense. And because there are as many universes as there are quantum choices, every possible arrangement of matter and energy will occur somewhere among the infinite array of parallel worlds.

This pattern of reasoning — that observers select a highly atypical universe from among a vast number of alternatives — is known as the weak anthropic principle. The idea has been attacked on a number of philosophical and physical grounds. First it is, in a sense, too successful. By allowing nature to realize all possibilities, anything at all might be 'explained'. Indeed, we might need no science at all. It is merely necessary to make a case that such-and-such a feature is indis-pensible to human existence and, hey presto, it is explained.

Another weakness of the anthropic argument is that it seems the very antithesis of Occam's razor, according to which the most plausible of a possible set of explanations is that which contains the simplest ideas and least number of assumptions. To invoke an infinity of other universes just to explain one is surely carrying excess baggage to cosmic extremes, not to mention the fact that all but a minute proportion of these other universes go unobserved (except by God perhaps). 'Not a bit of it,' counter the anthropic proponents. 'The Everett interpretation of the quantum theory may be expensive in universes but it is extremely cheap in epistemology. Consider the convoluted and implausible assumptions that are made in the alternative explanations of the quantum measurement problem. In the many-universes theory, the interpretation just drops out of the formalism with no additional metaphysical hypotheses.'

Nevertheless, the many-universe theorists concede that the 'other worlds' of their theory can never, even in principle, be inspected. Travel between quantum 'branches' is forbidden. Moreover, the ordered regions in the infinite or oscillating model universes are separated by such huge expanses of space or time that no observer can ever verify or refute empirically the existence of the many universes. It is hard to see how such a purely theoretical construct can ever be used as an *explanation*, in the scientific sense, of a feature of nature. Of course, one might find it easier to believe in an infinite array of universes than in an infinite Deity, but such a belief must rest on faith rather than observation.

The scientific basis of both the weak and strong anthropic principles has also been challenged. The appeal to the concept of probability, upon which the whole anthropic argument turns, has been used to argue against it. The issue concerns the relative likelihood of small versus large fluctuations. Imagine the chimpanzee on the piano again, tinkering randomly. After an exceptional wait we might reasonably expect to hear a three or four note sequence of a familiar tune. The wait for, say, a six note sequence would be immensely longer. The improbability rises sharply with the degree of order involved. To take another example, a shuffled pack of cards might well result in each of four players receiving an ace. Less likely is for each to receive an ace, two and three of the same suit. The odds against each player being dealt a whole suit are colossal. Small coincidences are relatively much more likely than big ones.

In the context of cosmology, a random accident which produces, say, one star, is exceedingly more probable (less improbable) than one which produces a whole galaxy. And the chances of billions of galaxies forming this way would be infinitesimal compared to the chances for a single galaxy. But, it has been reasoned, surely only one galaxy — perhaps only one star — would be sufficient for life to form and observers to arise? Why, then, do we observe an entire universe filled with orderly structure? In the many-universes theory for example, there would be untold billions of universes with just one galaxy for every universe which had two; when more galaxies are involved the proportional discrepancy escalates rapidly. If observers exist in all these universes, the overwhelming majority will, therefore, inhabit a one-galaxy as opposed to a many-galaxy cosmos. How, then, do we account for the existence of so many galaxies in *our* universe?

The only conceivable answer to his criticism is that, for some as yet unknown reason, the formation of a galaxy is somehow linked to the large scale structure of the universe. Perhaps galaxies can only form when some special global condition is realized, and then when this is the case, they form everywhere. In other words, universes either have galaxies everywhere, or no galaxies. Linking principles of this type are known in physics but the mechanism of galaxy formation is still too obscure for a realistic evaluation of such a possibility.

3. Order out of chaos.

The third response to the mystery of the origin of cosmic order is an attempt to demonstrate that it has somehow arisen out of an initially chaotic state as a result of natural physical processes (not merely inconceivably rare fluctuations). (This idea has already been discussed in detail in Chapter 4; only a brief summary will be given here.) At first sight such an approach seems doomed to failure. Does the second law of thermodynamics not state that (fluctuations aside) order can give way to chaos but not vice versa?

It does indeed, but one has to look at the small print. Strictly stated, the second law is intended to apply only to completely isolated systems. Obviously any portion of the universe, however large, is not isolated, because it is in contact with the surrounding portions. More important, the entire universe is subject to the famous expansion, and this external disturbance can make all the difference.

A good analogy here is the humble piston and cylinder of the type found in ordinary petrol-driven engines. Imagine a gas confined in the cylinder beneath the piston. If the piston is at rest, the gas will be in equilibrium at a uniform temperature and pressure —

a condition of maximum entropy. No further change can be expected: the gas is devoid of any ordered structure or organized activity. Suppose now that the piston is abruptly raised, allowing the gas to expand. Suddenly the gas is no longer uniform. The density is lower near the retreating piston where more available space is opening up. Turbulent motions occur as the gas flows forward into this space. If the piston should then reverse and return to its starting position the gas would eventually settle down again into a new state of thermodynamic equilibrium, but the entropy will have risen as a consequence of this disturbance. Temporarily the gas will have grown a structure and organization as the piston moved.

Have we found a loophole in the second law? No. The entropy of the gas still rises after a complete cycle of motion (it is hotter). The initial state of equilibrium *was* the maximum entropy state consistent with the external constraints on the system. When the piston moved, however, those constraints changed, allowing the gas to seek a still higher entropy state. In short, the initial state of equilibrium was only a relative, not an absolute maximum.

In the cosmological case the expansion of the universe plays a similar role to the piston as a changing external constraint. Cosmologists point out that, far from being in an orderly state, the primeval universe was close to thermodynamic equilibrium. None of the familiar structures we now observe — galaxies, stars, atoms — were present in the big bang. Indeed, before about one minute or so after the beginning, the temperature was too hot even for atomic nuclei to exist. Somehow the present orderly structure has arisen from the primeval chaos. How?

Most of the complex organization with which we are familiar on Earth, such as biosystems and weather patterns, are generated by sunlight, the vital source of negative entropy on which we all feed. The sun's store of negative entropy is its nuclear fuel (mainly hydrogen). The most relaxed, high-entropy form of nuclear matter consists of medium-mass elements, such as iron. The production of sunlight represents the entropy produced by the sun's attempt to convert hydrogen into iron through a succession of nuclear reactions. The secret of the sun's order (negative entropy), and that of most other stars, is to be found in the explanation for its hydrogen content. About three-quarters of the mass of the universe is made of hydrogen, nearly all the rest consisting of the next lightest element, helium. Why is it not all made of iron?

The answer to this question was given in Chapter 4. The primeval universe was simply too hot for iron to exist, and its subsequent cooling was too rapid to allow significant nuclear transmutation to take place. The primeval material thus remained trapped in the form of low-entropy hydrogen, unable to achieve its goal of high-entropy iron until the stars appeared.

By appealing to an explanation along these lines, it is evidently unnecessary to suppose that the universe was created in a remarkably ordered state after all. The primeval material was actually in a condition of total disorder (maximum entropy). Such a state can be realized in the greatest number of ways, and the creator-with-the-pin would merely need to stab the 'shopping list' at random. The mystery of the origin of the cosmic order is solved.

Or is it?

The nuclear condition of the cosmic material is certainly a crucial factor in generating the observed structure and organization, but it is not the whole story. The larger structures — stars and galaxies — are shaped by gravity. Moreover, the crucial cosmic expansion is also controlled by gravity. What can be said about the gravitational organization of the cosmos? Do we live in a highly ordered, or a disordered universe, from the gravitational point of view? These questions will form the subject of the next chapter.