Chapter 10

THE ANTHROPIC PRINCIPLES AND THEORIES OF EVERYTHING

1. THE SEARCH FOR UNITY

Modern physics was born of the union of the "terrestrial physics" and the "celestial physics." In the Aristotelian paradigm of science there was a rigid demarcation between the "sublunary world" and the "supralunary world." The former was the domain of a physics of changeability and destruction; in the latter eternal motion about circular paths were proceeding with neither loss nor expenditure. The work of Copernicus, Kepler and Galileo shook this dualism severely, and Newton's synthesis finally laid it to rest: the same force of gravity made the apple fall to the ground and held the planets in their orbits around the Sun. This search for unity was inscribed into the progress made in modern science. The next milestone on the road to unification was the work accomplished by Maxwell, who unified the electric and magnetic phenomena, hitherto known as separate, in a single theory of electromagnetism. The first overt formulation of the programme to unify the whole of physics was expressed by Albert Einstein, who said that gravitation and electromagnetism should not be treated as two independent interactions and right until the end of his life continued to search for a theory which would unify them. Unfortunately his attempt was bound to fail; as it later turned out, there are two other fundamental interactions apart from gravitation and electromagnetism: the strong nuclear (hadron) force, and the weak nuclear (lepton) force. The final unification could not be partial; it had to encompass all the interactions. The road to unification turned out much more difficult than had been supposed. Currently all we have

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achieved is the unification of the electromagnetic and the weak nuclear force, into what is known as the electroweak force. We have managed to do this thanks to the Salam-Weinberg theory. The electromagnetic and weak nuclear forces unite at energies higher than ca. 100 GeV (gigaelectron-volts); at lower energies they act as separate forces. We have managed to achieve energies of this order in the elementary particle accelerator at CERN near Geneva, and the Salam-Weinberg theory has been confirmed experimentally. Energies of this order were typical in the universe when it was 10^{-11} s old.

Extrapolating back from this success, we may infer that at energies of the order of 10^{15} GeV the electroweak and the strong nuclear interactions will unite. Energies of this order were prevalent in the universe when its age was 10^{-35} s. Obtaining such energies is at present well beyond the capacity of the laboratories we have on Earth. There are several theoretical models for the unification of the electroweak and strong nuclear forces (referred to as the Grand Unification), but so far we have no means of telling which is the right model.

On the grounds of theoretical premises we may assume that at energies of the order of 10^{19} GeV, characteristic for Planck's threshold, all the interactions including gravitation will be unified (and this is referred to as the superunification). The ultimate unification in physics will have been achieved when the same theory unites all the fundamental interactions and integrates them with a unified theory of gravitation (general theory of relativity) and quantum physics, viz. when a theory of quantum gravitation is devised. This as yet non-existent, fully integrated theory of physics is sometimes referred to as the Theory of Everything. The path taken by many of the research programmes being conducted now is oriented towards the achievement of this Theory.

The question arises whether this kind of trend to unify is not in opposition to the concept of a multiverse, or at least to some of its versions. As we recall, in many of them the birth of a new universe is attended by perturbations of the values of the fundamental physical constants and/or other parameters characteristic of the universe, or even by the modification of some of the laws of physics. Is this not a tendency towards the proliferation of variety, going in the opposite direction to unification? In this chapter we shall try to consider this question more closely.

2. CAN THE STRUCTURE OF THE UNIVERSE BE CHANGED?

At the foundation of practically all the mechanisms for the "generation of universes" there is a (tacit) assumption that if we perturb our universe's initial conditions slightly, we shall obtain a slightly different history of the universe, but one which may also develop in time. By analogy, if we perturb a parameter characteristic of our universe, we will get a universe that works, but in a somewhat different way. And finally, if we introduce a small perturbation into a physical constant or slightly modify a law of physics, we will obtain an equally good, though somewhat different set of physical laws. The formulations of these three (tacit) assumptions should, however, be regarded only as an approximation. For the universe appears to be far too integrated to allow of a distinction of its characteristic parameters from its initial conditions or the laws of physics. From the methodological point of view it's even better if the parameters characteristic of the universe are not determined a priori but are a consequence of the laws of physics, in other words are an integral part of their structure. Also the laws of physics may determine the initial conditions. As we remember, there is a tendency in cosmology for cosmological models not to require initial conditions but instead to be fully defined by the laws of physics (cf. the Hartle-Hawking model in Chap. 7). On the other hand, we cannot rule out the situation in which the initial conditions applicable to the entire universe would perform the functions of the laws of physics. So we see that drawing a distinction between the laws of physics and the initial conditions is not so obvious as it might seem at first glance. These methodological difficulties show that the universe is much more of an integrated entity structurally than our terminological conventions might suggest.

At present the only distinction that seems to be uncontroversial is that of the fundamental physical constants. They differ sufficiently clearly from the initial conditions. They are part of the laws of physics, but not in themselves the laws of physics. But even here we encounter a hint pointing to the "integrated nature" of the structure of the universe. Just as for the universe's other characteristic parameters, there is a prevalent opinion that it would be a good thing if all the physical constants could be deduced from some more fundamental principles. Attempts to do this are being undertaken. For instance, people are trying to deduce the value of the fine structure constant, the elementary electric charge, the masses of the elementary particles. These attempts seem to conflict with the practice of the creation of "other universes" by means of perturbing the various physical magnitudes. The only chance for a successful deduction of the values of the physical constants is to show that they are a consequence of the structure of the universe in such a manner that any perturbation whatsoever of that structure would eradicate the possibility of such a consequence.

The situation is similar to one we often experience in our everyday lives. If we have a fine and fairly complicated mechanism we know all too well that even a slight perturbation in a detail will make the whole mechanism stop working. And we shall have to call in an expert to set it right.

3. RIGID STRUCTURES

The exposition of these arguments does not, of course, disprove the possibility of the existence of many universes, nonetheless it does show that we should proceed very carefully. Let's make our discussion somewhat more rigorous.

Let *S* be a mathematical structure determined by parameters $p_1, p_2, p_3 \ldots$ Let us assume that there is a mathematician who wants to generalise the structure of *S* by manipulating with some of the parameters. There is a method in mathematics which may be used to do this. It involves the *deformation* of the structure by a change in the value of one or more of the parameters, which leads to a generalisation of the structure. The term "deformation" denotes a certain technique the details of which we shall not go into. We shall only give two informal examples to illustrate just a few of the aspects of deformation. As we know, classical mechanics has a well-defined mathematical structure with two physical constants: Planck's constant, which takes the value of zero; and the speed of light, which in classical mechanics takes the value of infinity. We may deform the structure of classical mechanics by changing the value of Planck's constant, ascribing a non-zero, positive value to it. Thereby we obtain the structure of quantum mechanics. Or we may deform the structure of classical mechanics by ascribing a positive, finite value to the speed of light, and thereby obtain the structure of the special theory of relativity. It need not be added that this role played by the two constants in question did not come to light until the appearance of quantum mechanics and the special theory of relativity. What we are concerned with here, however, are not the historical facts but the properties of this method.

Deforming the structure of a theory of physics is, then, in a certain sense, the opposite of a method which is well-known and much discussed in the philosophy of science – the *reduction* of a new theory to an earlier theory. For example, quantum mechanics reduces to classical mechanics as Planck's constant tends to zero; and the special theory of relativity reduces to classical mechanics as the speed of light tends to infinity. In such cases we speak of a principle of *correspondence* between the new theory and the earlier theory. By applying this principle it may be shown that the development of physics is not random: a new theory does not invalidate the theory in use hitherto but merely "absorbs" it as its limiting case. On the other hand, by applying the deformation method we may predict the direction new developments in physics will take: if we deform the structure of the current theory we will be able to anticipate the structure of the forthcoming theory. However, the snag is that deformation does not, in general, yield an unambiguous result: the same structure may be deformed with respect to various parameters and in various ways.

However, there exist some structures which are particularly "permanent." Let's consider a structure S and try to deform it with respect to a parameter p. It may happen that any change at all in p will produce the same, undeformed structure S. Such a structure is called a *rigid* structure with respect to parameter p.[1]

When we consider the prospective ultimate theory of physics, the Theory of Everything as some like to call it, we want it to have a rigid mathematical structure with respect to all the parameters. Indeed, as some authors stress, the Theory of Everything should be necessary – that is, the only possible theory. The only reasonable constraint on this rather general postulate would seem to be the requirement of rigidity in the structure of such a theory with respect to all of its parameters. Such a theory would indeed be the "only possibility" in its class. Is this requirement realistic? Can it be accomplished? It remains to be seen.

4. IMAGINATION AND RATIONALISM

In the light of the above reflections we need to investigate two possibilities. According to the first, the perturbation of any component of the structure of the universe gives rise to the destruction of the entire structure. This would indeed hold if the structure of the universe were rigid in every respect (with respect to all of its parameters). In that case the universe in which we live would be the only possible universe and there would be no chance of the production of new universes on the disturbance of its structure. And the "anthropic coincidences" would be encoded in the initial conditions of our universe, since presumably the structure of the entire universe would have required this. Any other initial conditions would break up the structure. Perhaps one day (soon?), when we succeed in developing a Theory of Everything, we shall be able to observe that they are not "coincidental," but necessary elements of the entire structure.

The second possibility is that a disturbance (perhaps only a perturbation that was not large, but what does "not large" mean?) of the structure of the universe would not bring about its utter destruction, but merely cause a variety of "adaptations" within it. We may imagine such a structure as logically coherent to the highest degree possible, but within that level of coherence there would be room for the manipulation of some of its parameters; for instance, in such a way that a (slight) change in one parameter would have to be "compensated for" by a change in some other parameter. It might be that a certain structural change would preclude the possibility of life of the kind that exists in our universe, but would not rule out the possibility of life operating on different principles. For example, in their monograph on the anthropic principle John Barrow and Frank

Tipler cite work which shows that the solutions to Schrödinger's equation (supplemented with certain analyses based on the special theory of relativity) rule out the existence of stable atomic orbits for spaces of more than three dimensions. Since stable atoms are indispensable for "the chemistry of life" Barrow and Tipler see the fact that space in our universe is three-dimensional as an "anthropic coincidence."[2] This conclusion is based on the strong assumption that a change in the dimensionality of space would not affect "the rest of physics." But of course, in line with our hypothesis of a "maximally coherent" structure of the universe, it could be that in a space with a different number of dimensions some other equation could perform the functions presently performed by Schrödinger's equation, as a result of which we would have different stable atoms, a different biochemistry, and life based on different principles.

This is borne out by the detailed research carried out by Gordon McCabe.[3] He has examined the standard model of elementary particles and shown that disturbances of the geometrical structure of space-time (its signature or number of dimensions) do not lead to the destruction of the standard model for free elementary particles, but produce different sets of particles. If we assume that universes with a disturbed space-time structure are not just a useful mental tool for the mathematics but describe other universes that really exist, then different sets of elementary particles may occur in such universes. We have to bear in mind, however, that McCabe's analysis concerns only the standard model for particles and does not say anything about the prospective Theory of Everything on this issue.

5. OUR ANTHROPOCENTRISM?

Are we not perhaps being too anthropocentric ourselves in our discussion on the anthropic principles? Can we not imagine a different biology than the one which has grown up on our planet? Perhaps we do not want to admit the idea (or maybe it just doesn't occur to us) that there might exist an atomic physics governed by an equation other than the one discovered by Schrödinger? And maybe that is why the multiverses we are conjuring up are too close to our own measure?

Such deliberations are, of course, highly speculative, but their aim is to throw light upon the equally speculative notion of the existence of "parallel worlds."

Nevertheless I would not like to go to the other extreme and deny the multiverse idea any cognitive value. Strictly speaking, the concept does not meet the criteria of science, since by very definition we have no experimental control whatsoever over other worlds, and the chances of indirectly testing their existence are negligible and based on probabilistic speculation. But the history of science teaches us that the hard core of science has always been enveloped by a ring of more or less philosophical speculations which have often played a heuristic role, suggesting valuable ideas and encouraging progress in previously unexpected directions. Today the concept of the multiverse is performing a similar role, which will be fulfilled to an even higher degree if the creative imagination is combined with rational criticism.