

Schroeder, Gerald, L. The Science of God: The Convergence of Scientific and Biblical Wisdom (New York: The Free Press), pp. xii, 226, US\$25.00

The main thesis of this book—as the subtitle suggests—is that there is a *convergence* between modern scientific discoveries and the ancient wisdom of the Old Testament. While Schroeder does not claim either “that current scientific opinion can explain the workings of all the events described in [the Old Testament]” or “that [Old Testament] wisdom foresaw all the modern science has discovered”, he does claim that “in biology, paleontology, cosmology, among a sweep of topics, the *confluence* is remarkable”. (p.17, my italics) These claims about “convergence” and “confluence” are rather vague—and Schroeder nowhere attempts to make them more precise—but there is no vagueness in many of the subsidiary pronouncements which Schroeder makes, apparently in support of them: (i) the first thirty-one chapters of *Genesis* provides a succinct summary of the main elements of Big Bang cosmology (70), complete with mention of inflation (66), quark confinement (65), and various other esoteric physical doctrines; (ii) the first chapter of *Genesis* tells us that life appeared on earth *immediately* after the appearance of liquid water, just as the fossil record confirms (28–29, 86); (iii) archaeopteryx is referred to in *Leviticus* (95–6); (iv) dinosaurs are mentioned in the first chapter of *Genesis* (193–4); (v) pre-human hominids are referred to indirectly in several passages in the Bible (140–3); (vi) quantum indeterminacy explains how freedom of the will is possible (146–57, 173–4); (vii) the theory of relativity explains how God can be outside of time (56–7, 161–5); (viii) the theory of relativity explains how the six days of *Genesis* are in fact fifteen billion earth years (41–71); (ix) difficulties which face standard evolutionary accounts of the origins of life strongly indicate that the evolution of life was pre-programmed by an intelligent designer (83–124); and so on.

There are things to admire in this book. Schroeder writes well, and his views are always made perfectly clear. Although he is sometimes banal (“For someone who waits until age sixty to ask the meaning of life ... the awakening can be frightening” (1)), sometimes both sententious and absurd (“[The] erosion of biblical understanding is tragic, and we’ve paid a price for it. ... Our 60% divorce rate and the double locks on our doors provide a succinct summary of the effect”), and occasionally given to grand, undefended—and I think indefensible—claims (“The genesis described in the first chapter of the Bible broke the pessimism of the pagan world” (81)), he more often writes with verve and charm. Moreover, he has assembled material which presents genuine challenges to non-theists. Much of the book can be read as an extended development of the claim that the universe appears to have been incredibly finely tuned for human life. Part of the evidence for this claim comes from recent work on the early history of the universe; and part of the evidence comes from difficulties which have recently confronted orthodox neo-Darwinian accounts of the origins of life on earth. It seems to me that this evidence cannot be simply dismissed, and that non-theists do have an obligation to develop responses to the argument for fine-tuning. On the other hand—though I shall not attempt to argue for this here—I think that it is quite clear that there are adequate responses available.

There is also plenty more to disagree with in this book. While it is clear that Schroeder knows some areas of science well, and while it is also plain that he has an extensive knowledge of some areas of biblical interpretation, it seems to me that some of his claims about science and biblical interpretation can be contested. Moreover, it is obvious that Schroeder has quite limited knowledge of recent treatments of some of the philosophical and theological questions which he takes up. I shall try to defend these claims by pointing to problematic

aspects of the defences which Schroeder gives for claims (i)–(ix) mentioned in the opening paragraph of this review.

One crucial part of Schroeder's attempt to reconcile the Bible with recent science involves his claim that the six days of creation mentioned in *Genesis* are measured from the perspective of the wave frequency of the cosmic microwave background radiation. On his account, day one corresponds to the time between the moment of quark confinement and the formation of the disk of the Milky Way (from 15.75 billion years ago to 7.75 billion years ago); day two corresponds to the time between the formation of the disk of the Milky Way and the appearance of liquid water on a cool earth (from 7.75 billion years ago to 3.75 billion years ago); day three corresponds to the time between the appearance of liquid water on a cool earth and the era in which the earth's atmosphere became transparent to radiation at optical frequencies (from 3.75 billion years ago to 1.75 billion years ago); day four corresponds to the time between the era in which the earth's atmosphere became transparent to radiation at optical frequencies and the appearance of the first multicellular animals (from 1.75 billion years ago to 750 million years ago); day five corresponds to the time between the appearance of the first multicellular animals and the massive extinction towards the very end of the Palaeozoic era (from 750 million years ago to 250 million years ago); and day six corresponds to the time between the massive extinction towards the very end of the Palaeozoic era and the appearance of properly human beings (from 250 million years ago to 5, 759 years ago). Even if we take on trust Schroeder's claim that the cosmic microwave background radiation provides a clock which measures the history of the universe in this way, there are many reasons to be sceptical about the suggestion that the account in *Genesis* is an account of a Big Bang universe of the kind in which we now suppose ourselves to live. Perhaps the most obvious consideration is that it is far more plausible to suppose that the account in *Genesis* is myth: the people who wrote that account did not have the slightest inkling of twentieth century cosmology, and there is no serious way to make sense of the idea that they intended to refer to it. Indeed, it seems to me pretty clear that general problems about translation and interpretation—and the absence of any attempt to address these problems in a systematic, theoretical way—make it more or less impossible to take Schroeder's project seriously. However, there are also more 'internal' difficulties with Schroeder's account, and it is on these which I shall focus here.

Schroeder claims that *Genesis* 1:1 refers to the era prior to quark confinement, i.e. the first hundred-thousandth second of the universe; and he claims that this era precedes the first day of *Genesis*. Moreover, he claims that the line which says that the Spirit of God was moving over the face of the waters (*RSV*) refers to the inflationary expansion of the universe prior to the era of quark confinement. The interpretative links here are incredibly tenuous: any one-time phenomenon which occurs before the era of quark confinement could, with equal plausibility—or better, with equal implausibility—be taken to be under description: for example, according to standard theory, at the end of the Planck era, gravitational radiation comes out of thermal equilibrium with the rest of the universe; and there is also a symmetry-breaking phase which shatters the electroweak force well before the era of quark confinement. (Of course, there are also delicate questions about the correct translation of the original texts which need to be discussed: if—as my *RSV* version of the Bible has it—*Genesis* 1:1 is committed to the existence of water in the earliest phase of the universe, then there is no question of trying to reconcile this with Big Bang cosmology. Given the role that water played in other early cosmological myths and speculations, it seems very plausible to suppose that the references to water in *Genesis* 1:1 and 1:6–1:7 are intended literally. A similar problem arises with the very first sentence of *Genesis*: if heaven and earth really are created

in the beginning—i.e. in the era prior to quark confinement—then they exist at that time. On p.8, Schroeder reads the opening sentence in a way which makes it clear that he takes ‘the earth’ here to refer to our planet. Yet later, when he gives the mapping onto Big Bang cosmology, it is clear that he can’t understand the reference to ‘the earth’ in the opening sentence in this way. If you allow yourself unconstrained and inconsistent interpretation of a text, you can read anything you like into it ...)

Schroeder claims that *Genesis* 1:11 tells us (correctly) that life appeared *immediately after* the appearance of liquid water. (The most recent evidence is that life appeared 3.8 billion years ago, almost immediately at the time that liquid water appeared.) Even by his lights, this claim must surely appear dishonest. After all, it does not say in the account of the third day that God made vegetation *immediately after* he made the dry land appear; all that we are given is a list of things in the order in which they were done on the third day. On his account, the third day covers a time span of 2 billion years; as far as I can see, his interpretation leaves it open that vegetation could have appeared at any time in that 2 billion year period. Note, in particular, that there is just as much reason to hold that God made the birds—or, as Schroeder would have it, the flying insects—*immediately after* he made the sea creatures on day four—but that is in sharp disagreement with the evidence. (The same point also applies to the creation of man on day five; that it would be inconsistent with other aspects of Schroeder’s interpretation to say that God made man *immediately after* he made the other animals is surely evidence that he should not say that *Genesis* 1:11 tells us that life appeared *immediately after* the appearance of liquid water.)

Schroeder claims that dinosaurs are mentioned in *Genesis* 1:21, since there is a reference there to big reptiles. (The RSV says ‘great sea monsters’, but I’m prepared to accept that Schroeder has the translation right.) How is this a reference to dinosaurs? Well, “the biggest reptiles were the dinosaurs”! This is pretty dire. Why not argue as follows: there are references in *Genesis* to animals; dinosaurs were animals; so there are references to dinosaurs in the Bible?! Or as follows: throughout the Bible, there are references to the things of this world; dinosaurs are among the things of this world (in the relevant atemporal sense); so these are references to dinosaurs in the Bible?! (Surely it is far more plausible to think that the ‘big reptiles’ which the writers of this text had in mind are crocodiles, large lizards, and the like! Indeed, a list which seems to say exactly this is given in *Leviticus* 11:30.) Schroeder’s claim that archaeopteryx is mentioned at *Leviticus* 11:18 and *Leviticus* 11:30 is no more plausible, but also for a different reason: why on earth would anyone bother to proscribe the eating of something which had been extinct for around 150 million years?

Schroeder claims that pre-human hominids are referred to—or, at any rate, *alluded to*—in several places in the Bible. Questions about interpretation come up in every case. At *Genesis* 12:5, Schroeder takes “... Abraham took ... the souls they had made ...” to entail that possession of a soul requires belief in a universal, non-corporeal God. (Why not just read it as “... Abraham took ... the people they had converted ...”? This is much closer to the RSV version, and would surely fit within permissible bounds of translation.) Schroeder notes that *Genesis* 1:26 talks about ‘making’ mankind, whereas *Genesis* 1:27 says that God ‘created’ man, and insists that, since both verbs characterise our origins, there *must* be an essential difference in their import. (But why not think that the words are interchangeable, and chosen for purely stylistic reasons, or for no reason at all? After all, it is not *unusual* for many words to be interchangeable in a given context.) Schroeder notes that an exact translation of *Genesis* 2:7 would give “... man became to a living soul”, and then observes that Nahmanides speculated that the redundant ‘to’ might indicate that the addition of soul transforms one kind

of complete creature into a quite different kind of complete creature. (But why rest weight on Nahmanides opinion? There are, after all, other possible explanations of the origins of that redundant 'to' during early transcriptions of the text. Why suppose that it has any significance at all?) Schroeder claims that a careful reading of *Genesis* 4:25 and *Genesis* 5:3 reveals that there was a period in which Adam had sexual relations with non-human creatures. The allegedly crucial point is the appearance of the word 'again' in *Genesis* 4:25: "Adam knew his wife *again* and she bore a son ..." Isn't the "again" superfluous, and doesn't it tell us that Adam had been playing the field? (I can't see it. We might just as well infer that they'd been struggling for 130 years to have a child to replace the one they had lost. They tried yet *again* ...) And so on. It is very hard to resist the conclusion that Schroeder is trying desperately hard to find anything at all which can be twisted to support the case that he wants to make.

So much for the kinds of questions which I might raise about Biblical interpretation. Since I have no claims to expertise on these matters, I shall not put any more weight upon them. At the very least, I think that it is clear that many of Schroeder's claims stretch credulity—and also that it is hard to find a good motivation for them. Given the concession that the text cannot be given a straightforward literal interpretation—not least because, as Schroeder points out (pp.10–11), it is multiply inconsistent—what harm could there be in supposing that much of it is best interpreted as myth? *Reconciling* science and Bible does not require finding science in the Bible; rather, it requires reading the Bible in ways which generate no inconsistencies with the well-established teachings of science. Moreover, this position is consistent with—though it does not require—the further claim that the teachings of the Bible are morally authoritative. (Schroeder assumes without argument that morality must have a Biblical foundation—see, e.g., pp. 1, 2, 4, 18, 40, 81–2, 137. This seems to me quite wrong; but I shan't try to dispute it here.)

Be all of the above as it may, some of the most problematic parts of Schroeder's book are those in which he appeals to scientific theories in order to try to resolve longstanding philosophical and theological puzzles. I shall now turn to consider a few of these cases:

In his chapter on free-will, he claims that quantum mechanics explains how free-will is possible. In this discussion, he assumes without argument that freedom is incompatible with determinism—indeed, he provides not the slightest hint that he is aware of the existence of compatibilist accounts of human freedom—and then argues that quantum mechanics has demonstrated that the future is unpredictable and hence indeterministic. Even leaving aside compatibilist scruples, there is much to contest in this argument. Although quantum mechanics 'has a sixty-year track record of predicting correctly the outcome of experiments' (149), it may be that quantum mechanics will one day cease giving uniformly accurate predictions—Newtonian mechanics had an equally impressive track record for a couple of hundred years, but we now know that it is only approximately right. Even if quantum mechanics never comes into conflict with observation, it may be that the theory is not a complete description of the world—perhaps there are some kinds of 'hidden variables' which form part of the complete and deterministic world. And even if quantum mechanics is a true theory, it may be that it is deterministic—not all interpretations of quantum mechanics hold that it is an indeterministic theory. (In particular, it seems to me that many worlds interpretations of quantum mechanics are entirely deterministic; that there are at least some versions of Bohm theory which are deterministic; and that transactional interpretations in the style of Cramer and Price leave no room for the kind of indeterministic freedom which Schroeder prizes.) Since the moves from 'unpredictable in terms of quantum mechanics' to

‘unpredictable’ and from ‘unpredictable’ to ‘indeterministic’ can both be questioned, it is clear that Schroeder’s argument is highly doubtful. But, even if these transitions are allowed to stand, a far more formidable difficulty remains: namely, that the kind of indeterminism which it is alleged makes room for freedom actually seems to be inconsistent with it. If my ‘choices’ are simply the results of indeterministic quantum transitions, then it is hard to see how I can be free in virtue of them. The best that Schroeder offers is the claim that there is an only “partly random, nondeterministic surfacing of subconscious thoughts into the conscious ... what might be described as a quantum wave function includes the range of an individuals’ subconscious information” (173) But, since all of the indeterminism here is simply randomness—and since the difficulty is precisely in conceiving what else it could be—this suggestion is no help at all. Schroeder also has a chapter on, *inter alia*, the problem of evil. Given what he says about freedom and determinism, his line is entirely predictable—and quite inadequate to explain why God could not have created a world people with free creatures who always freely choose the good. (There are other things which Schroeder says about quantum mechanics which can also be contested. For example, he claims that the Copenhagen interpretation of quantum mechanics ‘forms much of the basis of the theory’ (149), where, in fact, it is just one highly contested interpretation of the theory. However, I shall not pursue these kinds of worries here.)

In the chapter on free-will, Schroeder also appeals to the theory of relativity in order to reconcile divine foreknowledge and human freedom (161–5). He claims—with Boethius, Aquinas, and many others, none of whom he acknowledges—that, if God is outside of time, then there is no puzzle about divine foreknowledge: God sees the past, present and future ‘all at once’. He then claims that the theory of relativity can be used to explain how it is possible for God to see the past, present and future all at once. “At the speed of light .. time ceases to flow altogether. The time of all events becomes compressed into the present, an unending now. The laws of relativity have changed timeless existence from a theological claim to a physical reality. ... Light .. is outside time, a fact proven in thousands of experiments at hundreds of universities. I don’t pretend to understand how tomorrow and next year exist simultaneously with today and yesterday. But at the speed of light they actually and rigorously do. Time does not pass.” (162–4) I am pretty sure that this just gets the physics wrong. In special relativity, the velocity of light is invariant across all inertial frames. Consequently, there are no inertial frames which ‘travel along’ with light. So—I think—there is no sense to be made of the question of the passage of time in the inertial frame of a photon. But it doesn’t follow from this that photons are outside time and that, for them, time ceases to flow altogether. Photons take about eight minutes to travel from the sun to the earth. Photons can be emitted from a source at one time and absorbed by a receiver at a later time. Nothing which is outside time could do this! (Notice Schroeder’s curious use of the words ‘at the speed of light’. When he says ‘at the speed of light .. time ceases to flow altogether’, he can’t mean that things which move relative to us at the speed of light are outside of time. But then what does he mean?) Can Schroeder’s position be rescued by moving to general relativity? I don’t think so. After all, it remains true in general relativity that photons are in time, and that a single photon can be at different places at different times. In general relativity, photons can be emitted from a source at one time and absorbed by a receiver at a later time. So, of course, light is not ‘outside time’, and time does not ‘cease to flow’ for it. Moreover, it remains true in general relativity that no ordinary material particles can be accelerated to the velocity at which light travels in a vacuum; consequently—I think—there is still no sense to be made of the question of the passage of time in the rest-frame of a photon. (Even if we could make sense of the idea of the rest-frame of a photon, it seems clear that the conclusions which Schroeder wants to draw would not follow: for, from the standpoint of the photon,

there will be a clear distinction between before and after even if there are problems associated with the measure of time. But, from the standpoint of eternity there can be no distinction between before and after. At best, Schroeder's considerations are metrical; but the proposal which Boethius makes is topological. No doubt there is more to be said about this argument of Schroeder's; I hope I have done enough to show that it is unsustainable. Note, too, that it *may* be that Schroeder's account of a clock based on the wave frequency of the cosmic microwave background radiation is subject to similar kinds of difficulties to the ones raised above. I don't know enough physics to be sure.)

An even larger problem for Schroeder's views is raised by the attitude which he takes to quantum mechanics and general relativity. Schroeder claims that general relativity is law rather than theory (47)—i.e. he commits himself to the claim that general relativity is correct. (His use of relativity in reconciling divine foreknowledge with human freedom would make no sense unless he supposed that general relativity is true.) Similarly, Schroeder claims that quantum mechanics is true—he emphasises in several places its long and distinguished track record of making extraordinarily accurate experimental predictions (24, 149). (Again, his use of quantum mechanics in rejecting determinism would make no sense unless he supposed that quantum mechanics is true.) But—as is quite well-known—quantum mechanics and general relativity are mutually inconsistent: they cannot both be true! General relativity is a local theory; quantum mechanics is not. Either the world obeys local laws or it does not. Something has to give—and when it does, at least something important in the story which Schroeder tells will have to be given up. (Schroeder displays an extraordinary faith that the physics which we have now is correct and complete. Even aside from the fact that this faith is actually ill-founded, there are various grounds for concern. There have been various occasions in the past when people have announced that physics is correct and complete—why should we think that we are any more likely to be right? Who knows what secrets the universe may have in store for us in succeeding centuries? And—most importantly—if the Bible really is closely tied to current physics—as Schroeder would have it—then isn't it overwhelmingly likely that it will be shown to be false at some time in the future? Surely theists should not look with too much fondness on Schroeder's attempts to reinterpret the opening chapters of Genesis in terms of current science—for that just opens the door to the likely empirical refutation of that kind of theism!)

As I mentioned earlier, apart from these worries about some of the philosophical and theological details of Schroeder's account, there are also general methodological worries. The account of the first thirty-one chapters of Genesis is very brief, and, with enough imagination, you can probably read into it just about whatever you like. For instance, I don't see why you couldn't hold that the very first verse tells us that the universe is infinitely old, and that it has always been creatively sustained in existence by God. Had some kind of steady state theory prevailed, I'm sure that there would have been counterparts of Schroeder arguing this very case. Indeed, in the early decades of this century, there were a number of very well-known scientists who argued that a kind of steady-state cosmology was far more consonant with Christian belief than alternative theories (MacMillan in the teens; Millikan, Nernst, and Wiechert in the twenties; Milne (sort of) in the thirties; Kapp in the early forties). Had they wished, I am sure that they could have written books like Schroeder's supporting *their* views.

There are some things in the book which I found irritating. For example, on p.72, Schroeder writes: "The god an atheist does not believe in is usually not the God of the Bible." On the contrary, the gods in which an atheist does not believe certainly number among their ranks the God of the Bible. Or, to put the point less contentiously: Atheists hold that there are no

gods. *A fortiori*, they hold that the God of the Bible does not exist. And so, manifestly, atheists do not believe in the God of the Bible. (I am reminded here of Ayer's complaint that Heidegger and the early Sartre supposed that 'nothing' is a name. While Ayer's complaint is not supported by a reading of either Heidegger or Sartre, it does seem that Schroeder has fallen into something like this trap.) Perhaps it could be objected to this criticism that the point which Schroeder wants to make is that atheists often do not have a very complete picture of what the Bible says about God, and hence cannot be said to be explicitly and directly rejecting the existence of that being; however, provided that atheists have fastened onto some uniquely identifying essential properties which are attributed to God in the Bible, it will be straightforwardly the case that they explicitly reject the existence of the God of the Bible. And there seems to be little doubt that most atheists do this much (if anyone does).

For another example, on p.19, Schroeder writes: "The Science of God deals with the Book of Genesis, the heritage of all Western religions. Because of the book's nonsectarian nature, it employs the abbreviations B.C.E. for 'before the Common Era', instead of B.C. and C.E. for 'during the Common Era' instead of A.D." Aside from the fact that these abbreviations make no appearance in the text, there are various ways in which the book is manifestly sectarian. Not all Christian sects hold that God is outside time (159); not all Christian sects hold that the world is more than 6,000 years old (41–71); not all Christian sects hold that we are free to choose life or death—some hold that this is pre-ordained, and that the most we can hope for is evidence about what is ordained for us (166–75); and so on. Moreover, the reliance on Maimonides, Nahmanides and the Talmud for interpretations of the Old Testament leads to interpretations—and methods of interpretation—of scriptural passages which many Christian sects would find unacceptable; for instance, I doubt very much that Schroeder's approach to Biblical interpretation is compatible with High Anglicanism.

A third example is provided by Schroeder's repeated insistence—e.g. at pp.19, 51, 52, 58—that he only appeals to 'scientific opinions appearing in leading science journals' and to 'peer-reviewed data accepted in physics laboratories of leading universities'. Clearly, there is a way of reading these claims which allows that the opinions and data are controversial (and, indeed, likely false). However, it is also clear that Schroeder does not intend this reading: his (tacit) claim is that these are the prevailing opinions and data, which we should be loathe to contest. Yet, when we check for the sources he actually cites, what we find mostly are: newspapers and popular magazines (*New York Times*, *Time*, *National Geographic*); popular scientific journals (*Scientific American*); well-known popular physics books (by Penrose, Davies, Weinberg, Pagels, Hawking, Silk, etc.); well-known popular biology books (Gould, Maynard-Smith, Dawkins); and the journals *Science* and *Nature*. There are a couple of references to standard—and rather dated—texts (Peebles; Weinberg; Misner, Thorne and Wheeler; Taylor and Wheeler), and one or two references to journals (e.g. *American Journal of Physics*), but there are no citations from *leading* physics journals—i.e. from journals like *Physics Review*—and I suspect that the same is true of the *leading* biology journals as well. If Schroeder does present current majority opinions amongst physicists and biologists, this is only because popular journals and books give a fair representation of those opinions; however, it seems to me to be questionable to try to give authority to these opinions in the way that Schroeder does.

There are also passages in the book which I found worse than irritating. For example, on p.143: "Science has also confirmed the biblical assertion that [only] less-than-human creatures with human-like bodies and brains existed [more than 5759 years ago]." We have already seen that Schroeder insists that all proper humans have a common ancestor who lived

less than 6,000 years ago, and before whom there were no properly human beings. But there have been people in Australia for more than 40,000 years; and they existed in geographical isolation for more than the 6,000 years which Schroeder mentions. So it follows, on his view, that when Europeans first came to Australia in the eighteenth century, they encountered beings which were less-than-human. This is offensive rubbish, made worse by the claim that it is said to be confirmed by science. (Could Schroeder reply that, since all he means by 'properly human' is 'possessing the concept of a transcendental, non-corporeal God', there is no harm in the claim that there were many less-than-human beings on the planet only a few hundred years ago? I don't think so: he makes it clear that only properly human beings are moral beings (137), and he also strongly suggests that invention of writing and developments in metalwork required the existence of properly human beings (130). Moreover, he says quite clearly that the less-than-human beings lack *the* factor which distinguishes men from beasts (139). In any case, since there are no doubt still people who do not possess the concept of a transcendental, non-corporeal God, it will follow that even today there are less-than-human people of normal intelligence—and that is surely a suggestion which is completely at odds with the expected connotations of the expression 'properly human'.)

The problems raised in this review do no more than gesture at the range of criticisms which one might lodge against Schroeder's book. Leaving many controversial matters untouched, I shall conclude with a couple of observations about Schroeder's treatment of orthodox neo-Darwinian accounts of evolution. Schroeder claims that the kinds of arguments which he gives provide compelling reasons for thinking that the evolution of life was pre-programmed by an intelligent designer. These arguments mostly take the form of calculations which show that certain kinds of complex structures could not have arisen as the result of random events in the time-spans available (e.g. that chimpanzees and Cro-magnon man could not have evolved from a common ancestor as a result of random genetic mutations in seven million years (116–124); that the convergence observed in convergent evolution—e.g. invertebrate and vertebrate eyes—could not have been the result of independent random reactions in the time available (93–4, 101–114); and that the explosion of life at the time of the appearance of liquid water on the surface of the earth could not have been the result of independent random reactions in the brief period of time in which an astonishing diversity of forms of life appeared (29–33, 34–40, 83–94). The kinds of calculations which Schroeder gives are familiar: du Nouy's 1947 calculation of the probability of the spontaneous assemblage of a protein molecule from its constituent atoms is of the same type. Moreover, the kinds of responses which one might make are also well-known. On the one hand—as Schroeder admits—there are various uncertainties in the calculations, which might make the figures slightly unreliable (though there is reason to think that Schroeder's figures are quite conservative). On the other hand—and far more importantly—the obvious conclusion to draw in each case is that mistaken assumptions have been made about the mechanism of evolution. It should not be part of standard evolutionary theory to suppose that the first protein molecule was randomly assembled for its constituent atoms—as Hoyle observed (in a slightly different context), calculations like the one made by du Nouy show that construction of a protein molecule in this way is as likely as the assemblage of a 747 by a tornado whirling through a junkyard. But all that is required is some intermediate steps in the passage from atoms to protein (steps which need not all proceed linearly in time, and each of which can be expected to happen in quite small amounts of time with sufficient frequency to make it probable that there will eventually be plenty of protein molecules). Of course, it remains for the evolutionary theorist to give an account of those steps—but there is no reason to suppose that there is any difficulty of principle here. The same kinds of considerations apply to Schroeder's arguments. Given that the early explosion of life on the cool earth cannot be

explained according to Darwin's 'warm little pond' hypothesis, evolutionary theorists need to look for some other account. Various suggestions have been made—e.g. Cairns-Smith's clay-based theory and Hoyle's theory of intergalactic origins—though all remain rather speculative. Most recently, there has been considerable interest in the idea that life may have begun deep under the earth's crust, in rather warmer conditions than has thus far been supposed. The crucial point—for present purposes—is that these remain theories in which life starts by chance. None of Schroeder's calculations establish that certain things cannot be the result of chance; at best, they show that some further mechanism remains to be identified which shows how these things can be the result of chance. (Of course, the considerations offered here do not address the cosmic fine-tuning arguments; there, I take it, a quite different response is needed. But that is something which I have discussed elsewhere; I shall not repeat myself here.)