RICHARD DAWKINS

THE GOD DELUSION

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THOMAS JEFFERSON

THE ULTIMATE BOEING 747

The argument from improbability is the big one. In the traditional guise of the argument from design, it is easily today's most popular argument offered in favour of the existence of God and it is seen, by an amazingly large number of theists, as completely and utterly convincing. It is indeed a very strong and, I suspect, unanswerable argument - but in precisely the opposite direction from the theist's intention. The argument from improbability, properly deployed, comes close to proving that God does *not* exist. My name for the statistical demonstration that God almost certainly does not exist is the Ultimate Boeing 747 gambit.

The name comes from Fred Hoyle's amusing image of the Boeing 747 and the scrapyard. I am not sure whether Hoyle ever wrote it down himself, but it was attributed to him by his close colleague Chandra Wickramasinghe and is presumably authentic.[58] Hoyle said that the probability of life originating on Earth is no greater than the chance that a hurricane, sweeping through a scrapyard, would have the luck to assemble a Boeing 747. Others have borrowed the metaphor to refer to the later evolution of complex living bodies, where it has a spurious plausibility. The odds against assembling a fully functioning horse, beetle or ostrich by randomly shuffling its parts are up there in 747 territory. This, in a nutshell, is the creationist's favourite argument - an argument that could be made only by somebody who doesn't understand the first thing about natural selection: somebody who thinks natural selection is a theory of chance whereas - in the relevant sense of chance - it is the opposite.

The creationist misappropriation of the argument from improbability always takes the same general form, and it doesn't make any difference if the creationist chooses to masquerade in the politically expedient fancy dress of 'intelligent design' (ID).* Some observed phenomenon - often a living creature or one of its more complex organs, but it could be anything from a molecule up to the universe itself - is correctly extolled as statistically improbable. Sometimes the language of information theory is used: the Darwinian is challenged to explain the source of all the information

Intelligent design has been unkindly described as creationism in a cheap tuxedo.

in living matter, in the technical sense of information content as a measure of improbability or 'surprise value'. Or the argument may invoke the economist's hackneyed motto: there's no such thing as a free lunch - and Darwinism is accused of trying to get something for nothing. In fact, as I shall show in this chapter, Darwinian natural selection is the only known solution to the otherwise unanswerable riddle of where the information comes from. It turns out to be the God Hypothesis that tries to get something for nothing. God tries to have his free lunch and be it too. However statistically improbable the entity you seek to explain by invoking a designer, the designer himself has got to be at least as improbable. God is the Ultimate Boeing 747.

The argument from improbability states that complex things could not have come about by chance. But many people *define* 'come about by chance' as a synonym for 'come about in the absence of deliberate design'. Not surprisingly, therefore, they think improbability is evidence of design. Darwinian natural selection shows how wrong this is with respect to biological improbability. And although Darwinism may not be directly relevant to the inanimate world - cosmology, for example - it raises our consciousness in areas outside its original territory of biology.

A deep understanding of Darwinism teaches us to be wary of the easy assumption that design is the only alternative to chance, and teaches us to seek out graded ramps of slowly increasing complexity. Before Darwin, philosophers such as Hume understood that the improbability of life did not mean it had to be designed, but they couldn't imagine the alternative. After Darwin, we all should feel, deep in our bones, suspicious of the very idea of design. The illusion of design is a trap that has caught us before, and Darwin should have immunized us by raising our consciousness. Would that he had succeeded with all of us.

NATURAL SELECTION AS A CONSCIOUSNESS-RAISER

In a science-fiction starship, the astronauts were homesick: 'Just to

think that it's springtime back on Earth!' You may not immediately see what's wrong with this, so deeply ingrained is the unconscious northern hemisphere chauvinism in those of us who live there, and even some who don't. 'Unconscious' is exactly right. That is where consciousness-raising comes in. It is for a deeper reason than gimmicky fun that, in Australia and New Zealand, you can buy maps of the world with the South Pole on top. What splendid consciousness-raisers those maps would be, pinned to the walls of our northern hemisphere classrooms. Day after day, the children would be reminded that 'north' is an arbitrary polarity which has no monopoly on 'up'. The map would intrigue them as well as raise their consciousness. They'd go home and tell their parents - and, by the way, giving children something with which to surprise their parents is one of the greatest gifts a teacher can bestow.

It was the feminists who raised my consciousness of the power of consciousness-raising. 'Herstory' is obviously ridiculous, if only because the 'his' in 'history' has no etymological connection with the masculine pronoun. It is as etymologically silly as the sacking, in 1999, of a Washington official whose use of 'niggardly' was held to give racial offence. But even daft examples like 'niggardly' or 'herstory' succeed in raising consciousness. Once we have smoothed our philological hackles and stopped laughing, herstory shows us history from a different point of view. Gendered pronouns notoriously are the front line of such consciousness-raising. He or she must ask himself or herself whether his or her sense of style could ever allow himself or herself to write like this. But if we can just get over the clunking infelicity of the language, it raises our consciousness to the sensitivities of half the human race. Man, mankind, the Rights of Man, all men are created equal, one man one vote - English too often seems to exclude woman. * When I was young, it never occurred to me that women might feel slighted by a phrase like 'the future of man'. During the intervening decades, we have all had our consciousness raised. Even those who still use 'man' instead of 'human' do so with an air of self-conscious apology - or truculence, taking a stand for traditional language, even deliberately to rile feminists. All participants in the *Zeitgeist*

* Classical Latin and Greek were better equipped. Latin *homo* (Greek *anthropo-)* means human, as opposed to *vir (andro-)* which means man, and *fetnina (gyne-)* which means woman. Thus anthropology pertains to all humanity, where andrology and gynecology are sexually exclusive branches of medicine.

have had their consciousness raised, even those who choose to respond negatively by digging in their heels and redoubling the offence.

Feminism shows us the power of consciousness-raising, and I want to borrow the technique for natural selection. Natural selection not only explains the whole of life; it also raises our consciousness to the power of science to explain how organized complexity can emerge from simple beginnings without any deliberate guidance. A full understanding of natural selection encourages us to move boldly into other fields. It arouses our suspicion, in those other fields, of the kind of false alternatives that once, in pre-Darwinian days, beguiled biology. Who, before Darwin, could have guessed that something so apparently *designed* as a dragonfly's wing or an eagle's eye was really the end product of a long sequence of non-random but purely natural causes?

Douglas Adams's moving and funny account of his own conversion to radical atheism - he insisted on the 'radical' in case anybody should mistake him for an agnostic - is testimony to the power of Darwinism as a consciousness-raiser. I hope I shall be forgiven the self-indulgence that will become apparent in the following quotation. My excuse is that Douglas's conversion by my earlier books - which did not set out to convert anyone - inspired me to dedicate to his memory this book - which does! In an interview, reprinted posthumously in *The Salmon of Doubt,* he was asked by a journalist how he became an atheist. He began his reply by explaining how he became an agnostic, and then proceeded:

> And I thought and thought and thought. But I just didn't have enough to go on, so I didn't really come to any resolution. I was extremely doubtful about the idea of god, but I just didn't know enough about anything to have a good working model of any other explanation for, well, life, the universe, and everything to put in its place. But I kept at it, and I kept reading and I kept thinking. Sometime around my early thirties I stumbled upon evolutionary biology, particularly in the form of Richard Dawkins's books *The Selfish Gene* and then *The Blind Watchmaker,* and suddenly (on, I think the second

> reading of *The Selfish Gene)* it all fell into place. It was a concept of such stunning simplicity, but it gave rise, naturally, to all of the infinite and baffling complexity of life. The awe it inspired in me made the awe that people talk about in respect of religious experience seem, frankly, silly beside it. I'd take the awe of understanding over the awe of ignorance any day.[59]

The concept of stunning simplicity that he was talking about was, of course, nothing to do with me. It was Darwin's theory of evolution by natural selection - the ultimate scientific consciousness-raiser. Douglas, I miss you. You are my cleverest, funniest, most open-minded, wittiest, tallest, and possibly only convert. I hope this book might have made you laugh - though not as much as you made me.

That scientifically savvy philosopher Daniel Dennett pointed out that evolution counters one of the oldest ideas we have: 'the idea that it takes a big fancy smart thing to make a lesser thing. I call that the trickle-down theory of creation. You'll never see a spear making a spear maker. You'll never see a horse shoe making a blacksmith. You'll never see a pot making a potter.'[60] Darwin's discovery of a workable process that does that very counter-intuitive thing is what makes his contribution to human thought so revolutionary, and so loaded with the power to raise consciousness.

It is surprising how necessary such consciousness-raising is, even in the minds of excellent scientists in fields other than biology. Fred Hoyle was a brilliant physicist and cosmologist, but his Boeing 747 misunderstanding, and other mistakes in biology such as his attempt to dismiss the fossil *Archaeopteryx* as a hoax, suggest that he needed to have his consciousness raised by some good exposure to the world of natural selection. At an intellectual level, I suppose he understood natural selection. But perhaps you need to be steeped in natural selection, immersed in it, swim about in it, before you can truly appreciate its power.

Other sciences raise our consciousness in different ways. Fred Hoyle's own science of astronomy puts us in our place, metaphorically as well as literally, scaling down our vanity to fit the tiny stage on which we play out our lives - our speck of debris from the

cosmic explosion. Geology reminds us of our brief existence both as individuals and as a species. It raised John Ruskin's consciousness and provoked his memorable heart cry of 1851: 'If only the Geologists would let me alone, I could do very well, but those dreadful hammers! I hear the clink of them at the end of every cadence of the Bible verses.' Evolution does the same thing for our sense of time - not surprisingly, since it works on the geological timescale. But Darwinian evolution, specifically natural selection, does something more. It shatters the illusion of design within the domain of biology, and teaches us to be suspicious of any kind of design hypothesis in physics and cosmology as well. I think the physicist Leonard Susskind had this in mind when he wrote, 'I'm not an historian but I'll venture an opinion: Modern cosmology really began with Darwin and Wallace. Unlike anyone before them, they provided explanations of our existence that completely rejected supernatural agents . . . Darwin and Wallace set a standard not only for the life sciences but for cosmology as well.'[61] Other physical scientists who are far above needing any such consciousness-raising are Victor Stenger, whose book *Has Science Found God?* (the answer is no) I strongly recommend, and Peter Atkins, whose *Creation Revisited* is my favourite work of scientific prose poetry.

I am continually astonished by those theists who, far from having their consciousness raised in the way that I propose, seem to rejoice in natural selection as 'God's way of achieving his creation'. They note that evolution by natural selection would be a very easy and neat way to achieve a world full of life. God wouldn't need to do anything at all! Peter Atkins, in the book just mentioned, takes this line of thought to a sensibly godless conclusion when he postulates a hypothetically lazy God who tries to get away with as little as possible in order to make a universe containing life. Atkins's lazy God is even lazier than the deist God of the eighteenth-century Enlightenment: *deus otiosus* - literally God at leisure, unoccupied, unemployed, superfluous, useless. Step by step, Atkins succeeds in reducing the amount of work the lazy God has to do until he finally ends up doing nothing at all: he might as well not bother to exist. My memory vividly hears Woody Allen's perceptive whine: 'If it turns out that there is a God, I don't think that he's evil. But the

worst that you can say about him is that basically he's an under-achiever.'

IRREDUCIBLE COMPLEXITY

It is impossible to exaggerate the magnitude of the problem that Darwin and Wallace solved. I could mention the anatomy, cellular structure, biochemistry and behaviour of literally any living organism by example. But the most striking feats of apparent design are those picked out - for obvious reasons - by creationist authors, and it is with gentle irony that I derive mine from a creationist book. *Life - How Did It Get Here?,* with no named author but published by the Watchtower Bible and Tract Society in sixteen languages and eleven million copies, is obviously a firm favourite because no fewer than six of those eleven million copies have been sent to me as unsolicited gifts by well-wishers from around the world.

Picking a page at random from this anonymous and lavishly distributed work, we find the sponge known as Venus' Flower Basket *(Euplectella),* accompanied by a quotation from Sir David Attenborough, no less: 'When you look at a complex sponge skeleton such as that made of silica spicules which is known as Venus' Flower Basket, the imagination is baffled. How could quasi-independent microscopic cells collaborate to secrete a million glassy splinters and construct such an intricate and beautiful lattice? We do not know.' The Watchtower authors lose no time in adding their own punchline: 'But one thing we do know: Chance is not the likely designer.' No indeed, chance is not the likely designer. That is one thing on which we can all agree. The statistical improbability of phenomena such as *Euplectella's* skeleton is the central problem that any theory of life must solve. The greater the statistical improbability, the less plausible is chance as a solution: that is what improbable means. But the candidate solutions to the riddle of improbability are not, as is falsely implied, design and chance. They are design and natural selection. Chance is not a solution, given the high levels of improbability we see in living organisms,

and no sane biologist ever suggested that it was. Design is not a real solution either, as we shall see later; but for the moment I want to continue demonstrating the problem that any theory of life must solve: the problem of how to escape from chance.

Turning Watchtower's page, we find the wonderful plant known as Dutchman's Pipe *(Aristolochia trilobata),* all of whose parts seem elegantly designed to trap insects, cover them with pollen and send them on their way to another Dutchman's Pipe. The intricate elegance of the flower moves Watchtower to ask: 'Did all of this happen by chance? Or did it happen by intelligent design?' Once again, no of *course* it didn't happen by chance. Once again, intelligent design is not the proper alternative to chance. Natural selection is not only a parsimonious, plausible and elegant solution; it is the only workable alternative to chance that has ever been suggested. Intelligent design suffers from exactly the same objection as chance. It is simply not a plausible solution to the riddle of statistical improbability. And the higher the improbability, the more implausible intelligent design becomes. Seen clearly, intelligent design will turn out to be a redoubling of the problem. Once again, this is because the designer himself (/herself/itself) immediately raises the bigger problem of his own origin. Any entity capable of intelligently designing something as improbable as a Dutchman's Pipe (or a universe) would have to be even more improbable than a Dutchman's Pipe. Far from terminating the vicious regress, God aggravates it with a vengeance.

Turn another Watchtower page for an eloquent account of the giant redwood *(Sequoiadendron giganteum), a* tree for which I have a special affection because I have one in my garden - a mere baby, scarcely more than a century old, but still the tallest tree in the neighbourhood. 'A puny man, standing at a sequoia's base, can only gaze upward in silent awe at its massive grandeur. Does it make sense to believe that the shaping of this majestic giant and of the tiny seed that packages it was not by design?' Yet again, if you think the only alternative to design is chance then, no, it does not make sense. But again the authors omit all mention of the real alternative, natural selection, either because they genuinely don't understand it or because they don't want to.

The process by which plants, whether tiny pimpernels or

massive wellingtonias, acquire the energy to build themselves is photosynthesis. Watchtower again: ' "There are about seventy separate chemical reactions involved in photosynthesis," one biologist said. "It is truly a miraculous event." Green plants have been called nature's "factories" - beautiful, quiet, nonpolluting, producing oxygen, recycling water and feeding the world. Did they just happen by chance? Is that truly believable?' No, it is not believable; but the repetition of example after example gets us nowhere. Creationist 'logic' is always the same. Some natural phenomenon is too statistically improbable, too complex, too beautiful, too awe-inspiring to have come into existence by chance. Design is the only alternative to chance that the authors can imagine. Therefore a designer must have done it. And science's answer to this faulty logic is also always the same. Design is not the only alternative to chance. Natural selection is a better alternative. Indeed, design is not a real alternative at all because it raises an even bigger problem than it solves: who designed the designer? Chance and design both fail as solutions to the problem of statistical improbability, because one of them is the problem, and the other one regresses to it. Natural selection is a real solution. It is the only workable solution that has ever been suggested. And it is not only a workable solution, it is a solution of stunning elegance and power.

What is it that makes natural selection succeed as a solution to the problem of improbability, where chance and design both fail at the starting gate? The answer is that natural selection is a cumulative process, which breaks the problem of improbability up into small pieces. Each of the small pieces is slightly improbable, but not prohibitively so. When large numbers of these slightly improbable events are stacked up in series, the end product of the accumulation is very very improbable indeed, improbable enough to be far beyond the reach of chance. It is these end products that form the subjects of the creationist's wearisomely recycled argument. The creationist completely misses the point, because he (women should for once not mind being excluded by the pronoun) insists on treating the genesis of statistical improbability as a single, one-off event. He doesn't understand the power of *accumulation.*

In *Climbing Mount Improbable,* I expressed the point in a parable. One side of the mountain is a sheer cliff, impossible to

climb, but on the other side is a gentle slope to the summit. On the summit sits a complex device such as an eye or a bacterial flagellar motor. The absurd notion that such complexity could spontaneously self-assemble is symbolized by leaping from the foot of the cliff to the top in one bound. Evolution, by contrast, goes around the back of the mountain and creeps up the gentle slope to the summit: easy! The principle of climbing the gentle slope as opposed to leaping up the precipice is so simple, one is tempted to marvel that it took so long for a Darwin to arrive on the scene and discover it. By the time he did, nearly three centuries had elapsed since Newton's *annus mirabilis,* although his achievement seems, on the face of it, harder than Darwin's.

Another favourite metaphor for extreme improbability is the combination lock on a bank vault. Theoretically, a bank robber could get lucky and hit upon the right combination of numbers by chance. In practice, the bank's combination lock is designed with enough improbability to make this tantamount to impossible - almost as unlikely as Fred Hoyle's Boeing 747. But imagine a badly designed combination lock that gave out little hints progressively- the equivalent of the 'getting warmer' of children playing Hunt the Slipper. Suppose that when each one of the dials approaches its correct setting, the vault door opens another chink, and a dribble of money trickles out. The burglar would home in on the jackpot in no time.

Creationists who attempt to deploy the argument from improbability in their favour always assume that biological adaptation is a question of the jackpot or nothing. Another name for the 'jackpot or nothing' fallacy is 'irreducible complexity' (IC). Either the eye sees or it doesn't. Either the wing flies or it doesn't. There are assumed to be no useful intermediates. But this is simply wrong. Such intermediates abound in practice - which is exactly what we should expect in theory. The combination lock of life is a 'getting warmer, getting cooler, getting warmer' Hunt the Slipper device. Real life seeks the gentle slopes at the back of Mount Improbable, while creationists are blind to all but the daunting precipice at the front.

Darwin devoted an entire chapter of the *Origin of Species* to 'Difficulties on the theory of descent with modification', and it is

fair to say that this brief chapter anticipated and disposed of every single one of the alleged difficulties that have since been proposed, right up to the present day. The most formidable difficulties are Darwin's 'organs of extreme perfection and complication', sometimes erroneously described as 'irreducibly complex'. Darwin singled out the eye as posing a particularly challenging problem: 'To suppose that the eye with all its inimitable contrivances for adjusting the focus to different distances, for admitting different amounts of light, and for the correction of spherical and chromatic aberration, could have been formed by natural selection, seems, I freely confess, absurd in the highest degree.' Creationists gleefully quote this sentence again and again. Needless to say, they never quote what follows. Darwin's fulsomely free confession turned out to be a rhetorical device. He was drawing his opponents towards him so that his punch, when it came, struck the harder. The punch, of course, was Darwin's effortless explanation of exactly how the eye evolved by gradual degrees. Darwin may not have used the phrase 'irreducible complexity', or 'the smooth gradient up Mount Improbable', but he clearly understood the principle of both.

'What is the use of half an eye?' and 'What is the use of half a wing?' are both instances of the argument from 'irreducible complexity'. A functioning unit is said to be irreducibly complex if the removal of one of its parts causes the whole to cease functioning. This has been assumed to be self-evident for both eyes and wings. But as soon as we give these assumptions a moment's thought, we immediately see the fallacy. A cataract patient with the lens of her eye surgically removed can't see clear images without glasses, but can see enough not to bump into a tree or fall over a cliff. Half a wing is indeed not as good as a whole wing, but it is certainly better than no wing at all. Half a wing could save your life by easing your fall from a tree of a certain height. And 51 per cent of a wing could save you if you fall from a slightly taller tree. Whatever fraction of a wing you have, there is a fall from which it will save your life where a slightly smaller winglet would not. The thought experiment of trees of different height, from which one might fall, is just one way to see, in theory, that there must be a smooth gradient of advantage all the way from 1 per cent of a wing to 100 per cent. The forests are replete with gliding or parachuting animals

illustrating, in practice, every step of the way up that particular slope of Mount Improbable.

By analogy with the trees of different height, it is easy to imagine situations in which half an eye would save the life of an animal where 49 per cent of an eye would not. Smooth gradients are provided by variations in lighting conditions, variations in the distance at which you catch sight of your prey - or your predators. And, as with wings and flight surfaces, plausible intermediates are not only easy to imagine: they are abundant all around the animal kingdom. A flatworm has an eye that, by any sensible measure, is less than half a human eye. *Nautilus* (and perhaps its extinct ammonite cousins who dominated Paleozoic and Mesozoic seas) has an eye that is intermediate in quality between flatworm and human. Unlike the flatworm eye, which can detect light and shade but see no image, the *Nautilus* 'pinhole camera' eye makes a real image; but it is a blurred and dim image compared to ours. It would be spurious precision to put numbers on the improvement, but nobody could sanely deny that these invertebrate eyes, and many others, are all better than no eye at all, and all lie on a continuous and shallow slope up Mount Improbable, with our eyes near a peak - not the highest peak but a high one. In *Climbing Mount Improbable,* I devoted a whole chapter each to the eye and the wing, demonstrating how easy it was for them to evolve by slow (or even, maybe, not all that slow) gradual degrees, and I will leave the subject here.

So, we have seen that eyes and wings are certainly not irreducibly complex; but what is more interesting than these particular examples is the general lesson we should draw. The fact that so many people have been dead wrong over these obvious cases should serve to warn us of other examples that are less obvious, such as the cellular and biochemical cases now being touted by those creationists who shelter under the politically expedient euphemism of 'intelligent design theorists'.

We have a cautionary tale here, and it is telling us this: do not just declare things to be irreducibly complex; the chances are that you haven't looked carefully enough at the details, or thought carefully enough about them. On the other hand, we on the science side must not be too dogmatically confident. Maybe there is something out there in nature that really does preclude, by its *genuinely*

irreducible complexity, the smooth gradient of Mount Improbable. The creationists are right that, if genuinely irreducible complexity could be properly demonstrated, it would wreck Darwin's theory. Darwin himself said as much: 'If it could be demonstrated that any complex organ existed which could not possibly have been formed by numerous, successive, slight modifications, my theory would absolutely break down. But I can find no such case.' Darwin could find no such case, and nor has anybody since Darwin's time, despite strenuous, indeed desperate, efforts. Many candidates for this holy grail of creationism have been proposed. None has stood up to analysis.

In any case, even though genuinely irreducible complexity would wreck Darwin's theory if it were ever found, who is to say that it wouldn't wreck the intelligent design theory as well? Indeed, it already *has* wrecked the intelligent design theory, for, as I keep saying and will say again, however little we know about God, the one thing we can be sure of is that he would have to be very very complex and presumably irreducibly so!

THE WORSHIP OF GAPS

Searching for particular examples of irreducible complexity is a fundamentally unscientific way to proceed: a special case of arguing from present ignorance. It appeals to the same faulty logic as 'the God of the Gaps' strategy condemned by the theologian Dietrich Bonhoeffer. Creationists eagerly seek a gap in present-day knowledge or understanding. If an apparent gap is found, it is *assumed* that God, by default, must fill it. What worries thoughtful theologians such as Bonhoeffer is that gaps shrink as science advances, and God is threatened with eventually having nothing to do and nowhere to hide. What worries scientists is something else. It is an essential part of the scientific enterprise to admit ignorance, even to exult in ignorance as a challenge to future conquests. As my friend Matt Ridley has written, 'Most scientists are bored by what they have already discovered. It is ignorance that drives them on.' Mystics exult in mystery and want it to stay mysterious. Scientists

exult in mystery for a different reason: it gives them something to do. More generally, as I shall repeat in Chapter 8, one of the truly bad effects of religion is that it teaches us that it is a virtue to be satisfied with not understanding.

Admissions of ignorance and temporary mystification are vital to good science. It is therefore unfortunate, to say the least, that the main strategy of creation propagandists is the negative one of seeking out gaps in scientific knowledge and claiming to fill them with 'intelligent design' by default. The following is hypothetical but entirely typical. A creationist speaking: 'The elbow joint of the lesser spotted weasel frog is irreducibly complex. No part of it would do any good at all until the whole was assembled. Bet you can't think of a way in which the weasel frog's elbow could have evolved by slow gradual degrees.' If the scientist fails to give an immediate and comprehensive answer, the creationist draws a *default* conclusion: 'Right then, the alternative theory, "intelligent design", wins by default.' Notice the biased logic: if theory A fails in some particular, theory B must be right. Needless to say, the argument is not applied the other way around. We are encouraged to leap to the default theory without even looking to see whether it fails in the very same particular as the theory it is alleged to replace. Intelligent design - ID - is granted a Get Out Of Jail Free card^ a charmed immunity to the rigorous demands made of evolution.

But my present point is that the creationist ploy undermines the scientist's natural - indeed necessary - rejoicing in (temporary) uncertainty. For purely political reasons, today's scientist might hesitate before saying: 'Hm, interesting point. I wonder how the weasel frog's ancestors *did* evolve their elbow joint. I'm not a specialist in weasel frogs, I'll have to go to the University Library and take a look. Might make an interesting project for a graduate student.' The moment a scientist said something like that - and long before the student began the project - the default conclusion would become a headline in a creationist pamphlet: 'Weasel frog could only have been designed by God.'

There is, then, an unfortunate hook-up between science's methodological need to seek out areas of ignorance in order to target research, and ID's need to seek out areas of ignorance in order to claim victory by default. It is precisely the fact that ID has

no evidence of its own, but thrives like a weed in gaps left by scientific knowledge, that sits uneasily with science's need to identify and proclaim the very same gaps as a prelude to researching them. In this respect, science finds itself in alliance with sophisticated theologians like Bonhoeffer, united against the common enemies of naive, populist theology and the gap theology of intelligent design.

The creationists' love affair with 'gaps' in the fossil record symbolizes their whole gap theology. I once introduced a chapter on the so-called Cambrian Explosion with the sentence, 'It is as though the fossils were planted there without any evolutionary history.' Again, this was a rhetorical overture, intended to whet the reader's appetite for the full explanation that was to follow. Sad hindsight tells me now how predictable it was that my patient explanation would be excised and my overture itself gleefully quoted out of context. Creationists adore 'gaps' in the fossil record, just as they adore gaps generally.

Many evolutionary transitions are elegantly documented by more or less continuous series of gradually changing intermediate fossils. Some are not, and these are the famous 'gaps'. Michael Shermer has wittily pointed out that if a new fossil discovery neatly bisects a 'gap', the creationist will declare that there are now twice as many gaps! But in any case, note yet again the unwarranted use of a default. If there are no fossils to document a postulated evolutionary transition, the default assumption is that there was no evolutionary transition, therefore God must have intervened.

It is utterly illogical to demand complete documentation of every step of any narrative, whether in evolution or any other science. You might as well demand, before convicting somebody of murder, a complete cinematic record of the murderer's every step leading up to the crime, with no missing frames. Only a tiny fraction of corpses fossilize, and we are lucky to have as many intermediate fossils as we do. We could easily have had no fossils at all, and still the evidence for evolution from other sources, such as molecular genetics and geographical distribution, would be overwhelmingly strong. On the other hand, evolution makes the strong prediction that if a *single* fossil turned up in the *wrong* geological stratum, the theory would be blown out of the water. When challenged by a

zealous Popperian to say how evolution could ever be falsified, J. B. S. Haldane famously growled: 'Fossil rabbits in the Precambrian.' No such anachronistic fossils have ever been authentically found, despite discredited creationist legends of human skulls in the Coal Measures and human footprints interspersed with dinosaurs'.

Gaps, by default in the mind of the creationist, are filled by God. The same applies to all apparent precipices on the massif of Mount Improbable, where the graded slope is not immediately obvious or is otherwise overlooked. Areas where there is a lack of data, or a lack of understanding, are automatically assumed to belong, by default, to God. The speedy resort to a dramatic proclamation of 'irreducible complexity' represents a failure of the imagination. Some biological organ, if not an eye then a bacterial flagellar motor or a biochemical pathway, is *decreed* without further argument to be irreducibly complex. No attempt is made to *demonstrate* irreducible complexity. Notwithstanding the cautionary tales of eyes, wings and many other things, each new candidate for the dubious accolade is assumed to be transparently, self-evidently irreducibly complex, its status asserted by fiat. But think about it. Since irreducible complexity is being deployed as an argument for design, it should no more be asserted by fiat than design itself. You might as well simply assert that the weasel frog (bombardier beetle, etc.) demonstrates design, without further argument or justification. That is no way to do science.

The logic turns out to be no more convincing than this: 'I [insert own name] am personally unable to think of any way in which [insert biological phenomenon] could have been built up step by step. Therefore it is irreducibly complex. That means it is designed.' Put it like that, and you immediately see that it is vulnerable to some scientist coming along and finding an intermediate; or at least imagining a plausible intermediate. Even if no scientists do come up with an explanation, it is plain bad logic to assume that 'design' will fare any better. The reasoning that underlies 'intelligent design' theory is lazy and defeatist - classic 'God of the Gaps' reasoning. I have previously dubbed it the Argument from Personal Incredulity.

Imagine that you are watching a really great magic trick. The celebrated conjuring duo Penn and Teller have a routine in which

they simultaneously appear to shoot each other with pistols, and each appears to catch the bullet in his teeth. Elaborate precautions are taken to scratch identifying marks on the bullets before they are put in the guns, the whole procedure is witnessed at close range by volunteers from the audience who have experience of firearms, and apparently all possibilities for trickery are eliminated. Teller's marked bullet ends up in Penn's mouth and Penn's marked bullet ends up in Teller's. I [Richard Dawkins] am utterly unable to think of any way in which this could be a trick. The Argument from Personal Incredulity screams from the depths of my prescientific brain centres, and almost compels me to say, 'It must be a miracle. There is no scientific explanation. It's got to be supernatural.' But the still small voice of scientific education speaks a different message. Penn and Teller are world-class illusionists. There is a perfectly good explanation. It is just that I am too naive, or too unobservant, or too unimaginative, to think of it. That is the proper response to a conjuring trick. It is also the proper response to a biological phenomenon that appears to be irreducibly complex. Those people who leap from personal bafflement at a natural phenomenon straight to a hasty invocation of the supernatural are no better than the fools who see a conjuror bending a spoon and leap to the conclusion that it is 'paranormal'.

In his book *Seven Clues to the Origin of Life*, the Scottish chemist A. G. Cairns-Smith makes an additional point, using the analogy of an arch. A free-standing arch of rough-hewn stones and no mortar can be a stable structure, but it is irreducibly complex: it collapses if any one stone is removed. How, then, was it built in the first place? One way is to pile a solid heap of stones, then carefully remove stones one by one. More generally, there are many structures that are irreducible in the sense that they cannot survive the subtraction of any part, but which were built with the aid of scaffolding that was subsequently subtracted and is no longer visible. Once the structure is completed, the scaffolding can be removed safely and the structure remains standing. In evolution, too, the organ or structure you are looking at may have had scaffolding in an ancestor which has since been removed.

'Irreducible complexity' is not a new idea, but the phrase itself was invented by the creationist Michael Behe in 1996.[62] He is

credited (if credited is the word) with moving creationism into a new area of biology: biochemistry and cell biology, which he saw as perhaps a happier hunting ground for gaps than eyes or wings. His best approach to a good example (still a bad one) was the bacterial flagellar motor.

The flagellar motor of bacteria is a prodigy of nature. It drives the only known example, outside human technology, of a freely rotating axle. Wheels for big animals would, I suspect, be genuine examples of irreducible complexity, and this is probably why they don't exist. How would the nerves and blood vessels get across the bearing?* The flagellum is a thread-like propeller, with which the bacterium burrows its way through the water. I say 'burrows' rather than 'swims' because, on the bacterial scale of existence, a liquid such as water would not feel as a liquid feels to us. It would feel more like treacle, or jelly, or even sand, and the bacterium would seem to burrow or screw its way through the water rather than swim. Unlike the so-called flagellum of larger organisms like protozoans, the bacterial flagellum doesn't just wave about like a whip, or row like an oar. It has a true, freely rotating axle which turns continuously inside a bearing, driven by a remarkable little molecular motor. At the molecular level, the motor uses essentially the same principle as muscle, but in free rotation rather than in intermittent contraction.! It has been happily described as a tiny outboard motor (although by engineering standards - and

* There is an example in fiction. The children's writer Philip Pullman, in *His Dark Materials*, imagines a species of animals, the 'mulefa', that co-exist with trees that produce perfectly round seedpods with a hole in the centre. These pods the mulefa adopt as wheels. The wheels, not being part of the body, have no nerves or blood vessels to get twisted around the 'axle' (a strong claw of horn or bone). Pullman perceptively notes an additional point: the system works only because the planet is paved with natural basalt ribbons, which serve as 'roads'. Wheels are no good over rough country.

f Fascinatingly, the muscle principle is deployed in yet a third mode in some insects such as flies, bees and bugs, in which the flight muscle is intrinsically oscillatory, like a reciprocating engine. Whereas other insects such as locusts send nervous instructions for each wing stroke (as a bird does), bees send an instruction to switch on (or switch off) the oscillatory motor. Bacteria have a mechanism which is neither a simple contractor (like a bird's flight muscle) nor a reciprocator (like a bee's flight muscle), but a true rotator: in that respect it is like an electric motor or a Wankel engine.

unusually for a biological mechanism - it is a spectacularly inefficient one).

Without a word of justification, explanation or amplification, Behe simply *proclaims* the bacterial flagellar motor to be irreducibly complex. Since he offers no argument in favour of his assertion, we may begin by suspecting a failure of his imagination. He further alleges that specialist biological literature has ignored the problem. The falsehood of this allegation was massively and (to Behe) embarrassingly documented in the court of Judge John E. Jones in Pennsylvania in 2005, where Behe was testifying as an expert witness on behalf of a group of creationists who had tried to impose 'intelligent design' creationism on the science curriculum of a local public school - a move of 'breathtaking inanity', to quote Judge Jones (phrase and man surely destined for lasting fame). This wasn't the only embarrassment Behe suffered at the hearing, as we shall see.

The key to demonstrating irreducible complexity is to show that none of the parts could have been useful on its own. They all needed to be in place before any of them could do any good (Behe's favourite analogy is a mousetrap). In fact, molecular biologists have no difficulty in finding parts functioning outside the whole, both for the flagellar motor and for Behe's other alleged examples of irreducible complexity. The point is well put by Kenneth Miller of Brown University, for my money the most persuasive nemesis of 'intelligent design', not least because he is a devout Christian. I frequently recommend Miller's book, *Finding Darwin's God,* to religious people who write to me having been bamboozled by Behe.

In the case of the bacterial rotary engine, Miller calls our attention to a mechanism called the Type Three Secretory System or TTSS.[63] The TTSS is not used for rotatory movement. It is one of several systems used by parasitic bacteria for pumping toxic substances through their cell walls to poison their host organism. On our human scale, we might think of pouring or squirting a liquid through a hole; but, once again, on the bacterial scale things look different. Each molecule of secreted substance is a large protein with a definite, three-dimensional structure on the same scale as the TTSS's own: more like a solid sculpture than a liquid. Each molecule is individually propelled through a carefully shaped mechanism, like an automated slot machine dispensing, say, toys or

bottles, rather than a simple hole through which a substance might 'flow'. The goods-dispenser itself is made of a rather small number of protein molecules, each one comparable in size and complexity to the molecules being dispensed through it. Interestingly, these bacterial slot machines are often similar across bacteria that are not closely related. The genes for making them have probably been 'copied and pasted' from other bacteria: something that bacteria are remarkably adept at doing, and a fascinating topic in its own right, but I must press on.

The protein molecules that form the structure of the TTSS are very similar to components of the flagellar motor. To the evolutionist it is clear that TTSS components were commandeered for a new, but not wholly unrelated, function when the flagellar motor evolved. Given that the TTSS is tugging molecules through itself, it is not surprising that it uses a rudimentary version of the principle used by the flagellar motor, which tugs the molecules of the axle round and round. Evidently, crucial components of the flagellar motor were already in place and working before the flagellar motor evolved. Commandeering existing mechanisms is an obvious way in which an apparently irreducibly complex piece of apparatus could climb Mount Improbable.

A lot more work needs to be done, of course, and I'm sure it will be. Such work would never be done if scientists were satisfied with a lazy default such as 'intelligent design theory' would encourage. Here is the message that an imaginary 'intelligent design theorist' might broadcast to scientists: 'If you don't understand how something works, never mind: just give up and say God did it. You don't know how the nerve impulse works? Good! You don't understand how memories are laid down in the brain? Excellent! Is photosynthesis a bafflingly complex process? Wonderful! Please don't go to work on the problem, just give up, and appeal to God. Dear scientist, don't *work* on your mysteries. Bring us your mysteries, for we can use them. Don't squander precious ignorance by researching it away. We need those glorious gaps as a last refuge for God.' St Augustine said it quite openly: 'There is another form of temptation, even more fraught with danger. This is the disease of curiosity. It is this which drives us to try and discover the secrets of nature, those secrets which are beyond our understanding, which

can avail us nothing and which man should not wish to learn' (quoted in Freeman 2002).

Another of Behe's favourite alleged examples of 'irreducible complexity' is the immune system. Let Judge Jones himself take up the story:

> In fact, on cross-examination, Professor Behe was questioned concerning his 1996 claim that science would never find an evolutionary explanation for the immune system. He was presented with fifty-eight peer-reviewed publications, nine books, and several immunology textbook chapters about the evolution of the immune system; however, he simply insisted that this was still not sufficient evidence of evolution, and that it was not 'good enough.'

Behe, under cross-examination by Eric Rothschild, chief counsel for the plaintiffs, was forced to admit that he hadn't read most of those fifty-eight peer-reviewed papers. Hardly surprising, for immunology is hard work. Less forgivable is that Behe dismissed such research as 'unfruitful'. It certainly is unfruitful if your aim is to make propaganda among gullible laypeople and politicians, rather than to discover important truths about the real world. After listening to Behe, Rothschild eloquently summed up what every honest person in that courtroom must have felt:

> Thankfully, there are scientists who do search for answers to the question of the origin of the immune system . . . It's our defense against debilitating and fatal diseases. The scientists who wrote those books and articles toil in obscurity, without book royalties or speaking engagements. Their efforts help us combat and cure serious medical conditions. By contrast, Professor Behe and the entire intelligent design movement are doing nothing to advance scientific or medical knowledge and are telling future generations of scientists, don't bother.[64]

As the American geneticist Jerry Coyne put it in his review of Behe's book: 'If the history of science shows us anything, it is that

we get nowhere by labelling our ignorance "God".' Or, in the words of an eloquent blogger, commenting on an article on intelligent design in the *Guardian* by Coyne and me,

> Why is God considered an explanation for anything? It's not - it's a failure to explain, a shrug of the shoulders, an 'I dunno' dressed up in spirituality and ritual. If someone credits something to God, generally what it means is that they haven't a clue, so they're attributing it to an unreachable, unknowable sky-fairy. Ask for an explanation of where that bloke came from, and odds are you'll get a vague, pseudo-philosophical reply about having always existed, or being outside nature. Which, of course, explains nothing.[65]

Darwinism raises our consciousness in other ways. Evolved organs, elegant and efficient as they often are, also demonstrate revealing flaws - exactly as you'd expect if they have an evolutionary history, and exactly as you would not expect if they were designed. I have discussed examples in other books: the recurrent laryngeal nerve, for one, which betrays its evolutionary history in a massive and wasteful detour on its way to its destination. Many of our human ailments, from lower back pain to hernias, prolapsed uteruses and our susceptibility to sinus infections, result directly from the fact that we now walk upright with a body that was shaped over hundreds of millions of years to walk on all fours. Our consciousness is also raised by the cruelty and wastefulness of natural selection. Predators seem beautifully 'designed' to catch prey animals, while the prey animals seem equally beautifully 'designed' to escape them. Whose side is God on?[66]

THE ANTHROPIC PRINCIPLE: PLANETARY VERSION

Gap theologians who may have given up on eyes and wings, flagellar motors and immune systems, often pin their remaining

hopes on the origin of life. The root of evolution in non-biological chemistry somehow seems to present a bigger gap than any particular transition during subsequent evolution. And in one sense it is a bigger gap. That one sense is quite specific, and it offers no comfort to the religious apologist. The origin of life only had to happen once. We therefore can allow it to have been an extremely improbable event, many orders of magnitude more improbable than most people realize, as I shall show. Subsequent evolutionary steps are duplicated, in more or less similar ways, throughout millions and millions of species independently, and continually and repeatedly throughout geological time. Therefore, to explain the evolution of complex life, we cannot resort to the same kind of statistical reasoning as we are able to apply to the origin of life. The events that constitute run-of-the-mill evolution, as distinct from its singular origin (and perhaps a few special cases), cannot have been very improbable.

This distinction may seem puzzling, and I must explain it further, using the so-called anthropic principle. The anthropic principle was named by the British mathematician Brandon Carter in 1974 and expanded by the physicists John Barrow and Frank Tipler in their book on the subject.[67] The anthropic argument is usually applied to the cosmos, and I'll come to that. But I'll introduce the idea on a smaller, planetary scale. We exist here on Earth. Therefore Earth must be the kind of planet that is capable of generating and supporting us, however unusual, even unique, that kind of planet might be. For example, our kind of life cannot survive without liquid water. Indeed, exobiologists searching for evidence of extra-terrestrial life are scanning the heavens, in practice, for signs of water. Around a typical star like our sun, there is a so-called Goldilocks zone - not too hot and not too cold, but just right - for planets with liquid water. A thin band of orbits lies between those that are too far from the star, where water freezes, and too close, where it boils.

Presumably, too, a life-friendly orbit has to be nearly circular. A fiercely elliptical orbit, like that of the newly discovered tenth planet informally known as Xena, would at best allow the planet to whizz briefly through the Goldilocks zone once every few (Earth) decades or centuries. Xena itself doesn't get into the Goldilocks

zone at all, even at its closest approach to the sun, which it reaches once every 560 Earth years. The temperature of Halley's Comet varies between about 47°C at perihelion and minus 270°C at aphelion. Earth's orbit, like those of all the planets, is technically an ellipse (it is closest to the sun in January and furthest away in July*); but a circle is a special case of an ellipse, and Earth's orbit is so close to circular that it never strays out of the Goldilocks zone. Earth's situation in the solar system is propitious in other ways that singled it out for the evolution of life. The massive gravitational vacuum cleaner of Jupiter is well placed to intercept asteroids that might otherwise threaten us with lethal collision. Earth's single relatively large moon serves to stabilize our axis of rotation,[68] and helps to foster life in various other ways. Our sun is unusual in not being a binary, locked in mutual orbit with a companion star. It is possible for binary stars to have planets, but their orbits are likely to be too chaotically variable to encourage the evolution of life.

Two main explanations have been offered for our planet's peculiar friendliness to life. The design theory says that God made the world, placed it in the Goldilocks zone, and deliberately set up all the details for our benefit. The anthropic approach is very different, and it has a faintly Darwinian feel. The great majority of planets in the universe are not in the Goldilocks zones of their respective stars, and not suitable for life. None of that majority has life. However small the minority of planets with just the right conditions for life may be, we necessarily have to be on one of that minority, because here we are thinking about it.

It is a strange fact, incidentally, that religious apologists love the anthropic principle. For some reason that makes no sense at all, they think it supports their case. Precisely the opposite is true. The anthropic principle, like natural selection, is an *alternative* to the design hypothesis. It provides a rational, design-free explanation for the fact that we find ourselves in a situation propitious to our existence. I think the confusion arises in the religious mind because the anthropic principle is only ever mentioned in the context of the problem that it solves, namely the fact that we live in a life-friendly place. What the religious mind then fails to grasp is that two candidate solutions are offered to the problem. God is one. The anthropic principle is the other. They are *alternatives*.

* If you find that surprising, you may be suffering from northern hemisphere chauvinism, as described on page 115.

Liquid water is a necessary condition for life as we know it, but it is far from sufficient. Life still has to originate in the water, and the origin of life may have been a highly improbable occurrence. Darwinian evolution proceeds merrily once life has originated. But how does life get started? The origin of life was the chemical event, or series of events, whereby the vital conditions for natural selection first came about. The major ingredient was heredity, either DNA or (more probably) something that copies like DNA but less accurately, perhaps the related molecule RNA. Once the vital ingredient - some kind of genetic molecule - is in place, true Darwinian natural selection can follow, and complex life emerges as the eventual consequence. But the spontaneous arising by chance of the first hereditary molecule strikes many as improbable. Maybe it is - very very improbable, and I shall dwell on this, for it is central to this section of the book.

The origin of life is a flourishing, if speculative, subject for research. The expertise required for it is chemistry and it is not mine. I watch from the sidelines with engaged curiosity, and I shall not be surprised if, within the next few years, chemists report that they have successfully midwifed a new origin of life in the laboratory. Nevertheless it hasn't happened yet, and it is still possible to maintain that the probability of its happening is, and always was, exceedingly low - although it did happen once!

Just as we did with the Goldilocks orbits, we can make the point that, however improbable the origin of life might be, we know it happened on Earth because we are here. Again as with temperature, there are two hypotheses to explain what happened - the design hypothesis and the scientific or 'anthropic' hypothesis. The design approach postulates a God who wrought a deliberate miracle, struck the prebiotic soup with divine fire and launched DNA, or something equivalent, on its momentous career.

Again, as with Goldilocks, the anthropic alternative to the design hypothesis is statistical. Scientists invoke the magic of large numbers. It has been estimated that there are between 1 billion and 30 billion planets in our galaxy, and about 100 billion galaxies in the universe. Knocking a few noughts off for reasons of ordinary prudence, a billion billion is a conservative estimate of the number of available planets in the universe. Now, suppose the origin of life,

the spontaneous arising of something equivalent to DNA, really was a quite staggeringly improbable event. Suppose it was so improbable as to occur on only one in a billion planets. A grant-giving body would laugh at any chemist who admitted that the chance of his proposed research succeeding was only one in a hundred. But here we are talking about odds of one in a billion. And yet . . . even with such absurdly long odds, life will still have arisen on a billion planets - of which Earth, of course, is one.[69]

This conclusion is so surprising, I'll say it again. If the odds of life originating spontaneously on a planet were a billion to one against, nevertheless that stupefyingly improbable event would still happen on a billion planets. The chance of finding any one of those billion life-bearing planets recalls the proverbial needle in a haystack. But we don't have to go out of our way to find a needle because (back to the anthropic principle) any beings capable of looking must necessarily be sitting on one of those prodigiously rare needles before they even start the search.

Any probability statement is made in the context of a certain level of ignorance. If we know nothing about a planet, we may postulate the odds of life's arising on it as, say, one in a billion. But if we now import some new assumptions into our estimate, things change. A particular planet may have some peculiar properties, perhaps a special profile of element abundances in its rocks, which shift the odds in favour of life's emerging. Some planets, in other words, are more 'Earth-like' than others. Earth itself, of course, is especially Earth-like! This should give encouragement to our chemists trying to recreate the event in the lab, for it could shorten the odds against their success. But my earlier calculation demonstrated that even a chemical model with odds of success as low as one in a billion would *still* predict that life would arise on a billion planets in the universe. And the beauty of the anthropic principle is that it tells us, against all intuition, that a chemical model need only predict that life will arise on *one* planet in a billion billion to give us a good and entirely satisfying explanation for the presence of life here. I do not for a moment believe the origin of life was anywhere near so improbable in practice. I think it is definitely worth spending money on trying to duplicate the event in the lab and - by the same token, on SETI, because I think it is likely that there is intelligent life elsewhere.

Even accepting the most pessimistic estimate of the probability that life might spontaneously originate, this statistical argument completely demolishes any suggestion that we should postulate design to fill the gap. Of all the apparent gaps in the evolutionary story, the origin of life gap can seem unbridgeable to brains calibrated to assess likelihood and risk on an everyday scale: the scale on which grant-giving bodies assess research proposals submitted by chemists. Yet even so big a gap as this is easily filled by statistically informed science, while the very same statistical science rules out a divine creator on the 'Ultimate 747' grounds we met earlier.

But now, to return to the interesting point that launched this section. Suppose somebody tried to explain the general phenomenon of biological adaptation along the same lines as we have just applied to the origin of life: appealing to an immense number of available planets. The observed fact is that every species, and every organ that has ever been looked at within every species, is good at what it does. The wings of birds, bees and bats are good at flying. Eyes are good at seeing. Leaves are good at photosynthesizing. We live on a planet where we are surrounded by perhaps ten million species, each one of which independently displays a powerful illusion of apparent design. Each species is well fitted to its particular way of life. Could we get away with the 'huge numbers of planets' argument to explain all these separate illusions of design? No, we could not, repeat *not.* Don't even think about it. This is important, for it goes to the heart of the most serious misunderstanding of Darwinism.

It doesn't matter how many planets we have to play with, lucky chance could never be enough to explain the lush diversity of living complexity on Earth in the same way as we used it to explain the existence of life here in the first place. The evolution of life is a completely different case from the origin of life because, to repeat, the origin of life was (or could have been) a unique event which had to happen only once. The adaptive fit of species to their separate environments, on the other hand, is millionfold, and ongoing.

It is clear that here on Earth we are dealing with a generalized *process* for optimizing biological species, a process that works all

over the planet, on all continents and islands, and at all times. We can safely predict that, if we wait another ten million years, a whole new set of species will be as well adapted to their ways of life as today's species are to theirs. This is a recurrent, predictable, multiple phenomenon, not a piece of statistical luck recognized with hindsight. And, thanks to Darwin, we know how it is brought about: by natural selection.

The anthropic principle is impotent to explain the multifarious details of living creatures. We really need Darwin's powerful crane to account for the diversity of life on Earth, and especially the persuasive illusion of design. The origin of life, by contrast, lies outside the reach of that crane, because natural selection cannot proceed without it. Here the anthropic principle comes into its own. We can deal with the unique origin of life by postulating a very large number of planetary opportunities. Once that initial stroke of luck has been granted - and the anthropic principle most decisively grants it to us - natural selection takes over: and natural selection is emphatically not a matter of luck.

Nevertheless, it may be that the origin of life is not the only major gap in the evolutionary story that is bridged by sheer luck, anthropically justified. For example, my colleague Mark Ridley in *Mendel's Demon* (gratuitously and confusingly retitled *The Cooperative Gene* by his American publishers) has suggested that the origin of the eucaryotic cell (our kind of cell, with a nucleus and various other complicated features such as mitochondria, which are not present in bacteria) was an even more momentous, difficult and statistically improbable step than the origin of life. The origin of consciousness might be another major gap whose bridging was of the same order of improbability. One-off events like this might be explained by the anthropic principle, along the following lines. There are billions of planets that have developed life at the level of bacteria, but only a fraction of these life forms ever made it across the gap to something like the eucaryotic cell. And of these, a yet smaller fraction managed to cross the later Rubicon to consciousness. If both of these are one-off events, we are not dealing with a ubiquitous and all-pervading *process,* as we are with ordinary, run-of-the-mill biological adaptation. The anthropic principle states that, since we are alive, eucaryotic and conscious, our planet has to be

one of the intensely rare planets that has bridged all three gaps.

Natural selection works because it is a cumulative one-way street to improvement. It needs some luck to get started, and the 'billions of planets' anthropic principle grants it that luck. Maybe a few later gaps in the evolutionary story also need major infusions of luck, with anthropic justification. But whatever else we may say, *design* certainly does not work as an explanation for life, because design is ultimately not cumulative and it therefore raises bigger questions than it answers - it takes us straight back along the Ultimate 747 infinite regress.

We live on a planet that is friendly to our kind of life, and we have seen two reasons why this is so. One is that life has evolved to flourish in the conditions provided by the planet. This is because of natural selection. The other reason is the anthropic one. There are billions of planets in the universe, and, however small the minority of evolution-friendly planets may be, our planet necessarily has to be one of them. Now it is time to take the anthropic principle back to an earlier stage, from biology back to cosmology.

THE ANTHROPIC PRINCIPLE: COSMOLOGICAL VERSION

We live not only on a friendly planet but also in a friendly universe. It follows from the fact of our existence that the laws of physics must be friendly enough to allow life to arise. It is no accident that when we look at the night sky we see stars, for stars are a necessary prerequisite for the existence of most of the chemical elements, and without chemistry there could be no life. Physicists have calculated that, if the laws and constants of physics had been even slightly different, the universe would have developed in such a way that life would have been impossible. Different physicists put it in different ways, but the conclusion is always much the same. Martin Rees, in *Just Six Numbers*, lists six fundamental constants, which are believed to hold all around the universe. Each of these six numbers is finely tuned in the sense that, if it were slightly different, the

universe would be comprehensively different and presumably unfriendly to life.*

An example of Rees's six numbers is the magnitude of the so-called 'strong' force, the force that binds the components of an atomic nucleus: the nuclear force that has to be overcome when one 'splits' the atom. It is measured as E, the proportion of the mass of a hydrogen nucleus that is converted to energy when hydrogen fuses to form helium. The value of this number in our universe is 0.00"7, and it looks as though it had to be very close to this value in order for any chemistry (which is a prerequisite for life) to exist. Chemistry as we know it consists of the combination and re-combination of the ninety or so naturally occurring elements of the periodic table. Hydrogen is the simplest and commonest of the elements. All the other elements in the universe are made ultimately from hydrogen by nuclear fusion. Nuclear fusion is a difficult process which occurs in the intensely hot conditions of the interiors of stars (and in hydrogen bombs). Relatively small stars, such as our sun, can make only light elements such as helium, the second lightest in the periodic table after hydrogen. It takes larger and hotter stars to develop the high temperatures needed to forge most of the heavier elements, in a cascade of nuclear fusion processes whose details were worked out by Fred Hoyle and two colleagues (an achievement for which, mysteriously, Hoyle was not given a share of the Nobel Prize received by the others). These big stars may explode as supernovas, scattering their materials, including the elements of the periodic table, in dust clouds. These dust clouds eventually condense to form new stars and planets, including our own. This is why Earth is rich in elements over and above the ubiquitous hydrogen: elements without which chemistry, and life, would be impossible.

The relevant point here is that the value of the strong force crucially determines how far up the periodic table the nuclear fusion cascade goes. If the strong force were too small, say 0.006

* 1 say 'presumably', partly because we don't know how different alien forms of life might be, and partly because it is possible that we make a mistake if we consider only the consequences of changing one constant at a time. Could there be other *combinations* of values of the six numbers which would turn out to be friendly to life, in ways that we do not discover if we consider them only one at a time? Nevertheless, I shall proceed, for simplicity, as though we really do have a big problem to explain in the apparent fine-tuning of the fundamental constants.

instead of 0.007, the universe would contain nothing but hydrogen, and no interesting chemistry could result. If it were too large, say 0.008, all the hydrogen would have fused to make heavier elements. A chemistry without hydrogen could not generate life as we know it. For one thing, there would be no water. The Goldilocks value - 0.007 - is just right for yielding the richness of elements that we need for an interesting and life-supporting chemistry.

I won't go through the rest of Rees's six numbers. The bottom line for each of them is the same. The actual number sits in a Goldilocks band of values outside which life would not have been possible. How should we respond to this? Yet again, we have the theist's answer on the one hand, and the anthropic answer on the other. The theist says that God, when setting up the universe, tuned the fundamental constants of the universe so that each one lay in its Goldilocks zone for the production of life. It is as though God had six knobs that he could twiddle, and he carefully tuned each knob to its Goldilocks value. As ever, the theist's answer is deeply unsatisfying, because it leaves the existence of God unexplained. A God capable of calculating the Goldilocks values for the six numbers would have to be at least as improbable as the finely tuned combination of numbers itself, and that's very improbable indeed - which is indeed the premise of the whole discussion we are having. It follows that the theist's answer has utterly failed to make any headway towards solving the problem at hand. I see no alternative but to dismiss it, while at the same time marvelling at the number of people who can't see the problem and seem genuinely satisfied by the 'Divine Knob-Twiddler' argument.

Maybe the psychological reason for this amazing blindness has something to do with the fact that many people have not had their consciousness raised, as biologists have, by natural selection and its power to tame improbability. J. Anderson Thomson, from his perspective as an evolutionary psychiatrist, points me to an additional reason, the psychological bias that we all have towards personifying inanimate objects as agents. As Thomson says, we are more inclined to mistake a shadow for a burglar than a burglar for a shadow. A false positive might be a waste of time. A false negative could be fatal. In a letter to me, he suggested that, in our ancestral past, our greatest challenge in our environment came from each

other. 'The legacy of that is the default assumption, often fear, of human intention. We have a great deal of difficulty seeing anything other than *human* causation.' We naturally generalized that to divine intention. I shall return to the seductiveness of 'agents' in Chapter 5.

Biologists, with their raised consciousness of the power of natural selection to explain the rise of improbable things, are unlikely to be satisfied with any theory that evades the problem of improbability altogether. And the theistic response to the riddle of improbability is an evasion of stupendous proportions. It is more than a restatement of the problem, it is a grotesque amplification of it. Let's turn, then, to the anthropic alternative. The anthropic answer, in its most general form, is that we could only be discussing the question in the kind of universe that was capable of producing us. Our existence therefore determines that the fundamental constants of physics had to be in their respective Goldilocks zones. Different physicists espouse different kinds of anthropic solutions to the riddle of our existence.

Hard-nosed physicists say that the six knobs were never free to vary in the first place. When we finally reach the long-hoped-for Theory of Everything, we shall see that the six key numbers depend upon each other, or on something else as yet unknown, in ways that we today cannot imagine. The six numbers may turn out to be no freer to vary than is the ratio of a circle's circumference to its diameter. It will turn out that there is only one way for a universe to be. Far from God being needed to twiddle six knobs, there are no knobs to twiddle.

Other physicists (Martin Rees himself would be an example) find this unsatisfying, and I think I agree with them. It is indeed perfectly plausible that there is only one way for a universe to be. But why did that one way have to be such a set-up for our eventual evolution? Why did it have to be the kind of universe which seems almost as if, in the words of the theoretical physicist Freeman Dyson, it 'must have known we were coming'? The philosopher John Leslie uses the analogy of a man sentenced to death by firing squad. It is just possible that all ten men of the firing squad will miss their victim. With hindsight, the survivor who finds himself in a position to reflect upon his luck can cheerfully say, 'Well,

obviously they all missed, or I wouldn't be here thinking about it.' But he could still, forgivably, wonder why they all missed, and toy with the hypothesis that they were bribed, or drunk.

This objection can be answered by the suggestion, which Martin Rees himself supports, that there are many universes, co-existing like bubbles of foam, in a 'multiverse' (or 'megaverse', as Leonard Susskind prefers to call it).* The laws and constants of any one universe, such as our observable universe, are by-laws. The multiverse as a whole has a plethora of alternative sets of by-laws. The anthropic principle kicks in to explain that we have to be in one of those universes (presumably a minority) whose by-laws happened to be propitious to our eventual evolution and hence contemplation of the problem.

An intriguing version of the multiverse theory arises out of considerations of the ultimate fate of our universe. Depending upon the values of numbers such as Martin Rees's six constants, our universe may be destined to expand indefinitely, or it may stabilize at an equilibrium, or the expansion may reverse itself and go into contraction, culminating in the so-called 'big crunch'. Some big crunch models have the universe then bouncing back into expansion, and so on indefinitely with, say, a 20-billion-year cycle time. The standard model of our universe says that time itself began in the big bang, along with space, some 13 billion years ago. The serial big crunch model would amend that statement: our time and space did indeed begin in our big bang, but this was just the latest in a long series of big bangs, each one initiated by the big crunch that terminated the previous universe in the series. Nobody understands what goes on in singularities such as the big bang, so it is conceivable that the laws and constants are reset to new values, each time. If bang-expansion-contraction-crunch cycles have been going on for ever like a cosmic accordion, we have a serial, rather than a parallel, version of the multiverse. Once again, the anthropic principle does its explanatory duty. Of all the universes in the series, only a minority have their 'dials' tuned to biogenic conditions. And, of course, the present universe has to be one of that minority, because we are in it. As it turns out, this serial version of the multiverse must now be judged less likely than it once was, because

* Susskind (2006) gives a splendid advocacy of the anthropic principle in the megaverse. He says the idea is hated by most physicists. I can't understand why. I think it is beautiful - perhaps because my consciousness has been raised by Darwin.

recent evidence is starting to steer us away from the big crunch model. It now looks as though our own universe is destined to expand for ever.

Another theoretical physicist, Lee Smolin, has developed a tantalizingly Darwinian variant on the multiverse theory, including both serial and parallel elements. Smolin's idea, expounded in *The Life of the Cosmos,* hinges on the theory that daughter universes are born of parent universes, not in a fully fledged big crunch but more locally in black holes. Smolin adds a form of heredity: the fundamental constants of a daughter universe are slightly 'mutated' versions of the constants of its parent. Heredity is the essential ingredient of Darwinian natural selection, and the rest of Smolin's theory follows naturally. Those universes that have what it takes to 'survive' and 'reproduce' come to predominate in the multiverse. 'What it takes' includes lasting long enough to 'reproduce'. Because the act of reproduction takes place in black holes, successful universes must have what it takes to make black holes. This ability entails various other properties. For example, the tendency for matter to condense into clouds and then stars is a prerequisite to making black holes. Stars also, as we have seen, are the precursors to the development of interesting chemistry, and hence life. So, Smolin suggests, there has been a Darwinian natural selection of universes in the multiverse, directly favouring the evolution of black hole fecundity and indirectly favouring the production of life. Not all physicists are enthusiastic about Smolin's idea, although the Nobel Prize-winning physicist Murray Gell-Mann is quoted as saying: 'Smolin? Is he that young guy with those crazy ideas? He may not be wrong.'[70] A mischievous biologist might wonder whether some other physicists are in need of Darwinian consciousness-raising.

It is tempting to think (and many have succumbed) that to postulate a plethora of universes is a profligate luxury which should not be allowed. If we are going to permit the extravagance of a multiverse, so the argument runs, we might as well be hung for a sheep as a lamb and allow a God. Aren't they both equally unparsimonious ad hoc hypotheses, and equally unsatisfactory? People who think that have not had their consciousness raised by natural selection. The key difference between the genuinely

extravagant God hypothesis and the apparently extravagant multiverse hypothesis is one of statistical improbability. The multiverse, for all that it is extravagant, is simple. God, or any intelligent, decision-taking, calculating agent, would have to be highly improbable in the very same statistical sense as the entities he is supposed to explain. The multiverse may seem extravagant in sheer *number* of universes. But if each one of those universes is simple in its fundamental laws, we are still not postulating anything highly improbable. The very opposite has to be said of any kind of intelligence.

Some physicists are known to be religious (Russell Stannard and the Reverend John Polkinghorne are the two British examples 1 have mentioned). Predictably, they seize upon the improbability of the physical constants all being tuned in their more or less narrow Goldilocks zones, and suggest that there must be a cosmic intelligence who deliberately did the tuning. I have already dismissed all such suggestions as raising bigger problems than they solve. But what attempts have theists made to reply? How do they cope with the argument that any God capable of designing a universe, carefully and foresightfully tuned to lead to our evolution, must be a supremely complex and improbable entity who needs an even bigger explanation than the one he is supposed to provide?

The theologian Richard Swinburne, as we have learned to expect, thinks he has an answer to this problem, and he expounds it in his book *Is There a God?*. He begins by showing that his heart is in the right place by convincingly demonstrating why we should always prefer the simplest hypothesis that fits the facts. Science explains complex things in terms of the interactions of simpler things, ultimately the interactions of fundamental particles. I (and I dare say you) think it a beautifully simple idea that all things are made of fundamental particles which, although exceedingly numerous, are drawn from a small, finite set of *types* of particle. If we are sceptical, it is likely to be because we think the idea too simple. But for Swinburne it is not simple at all, quite the reverse.

Given that the number of particles of any one type, say electrons, is large, Swinburne thinks it too much of a coincidence that so many should have the same properties. One electron, he could stomach. But billions and billions of electrons, *all with the same*

properties, that is what really excites his incredulity. For him it would be simpler, more natural, less demanding of explanation, if all electrons were different from each other. Worse, no one electron should naturally retain its properties for more than an instant at a time; each should change capriciously, haphazardly and fleetingly from moment to moment. That is Swinburne's view of the simple, native state of affairs. Anything more uniform (what you or I would call more simple) requires a special explanation. 'It is only because electrons and bits of copper and all other material objects have the same powers in the twentieth century as they did in the nineteenth century that things are as they are now.'

Enter God. God comes to the rescue by deliberately and continuously sustaining the properties of all those billions of electrons and bits of copper, and neutralizing their otherwise ingrained inclination to wild and erratic fluctuation. That is why when you've seen one electron you've seen them all; that is why bits of copper all behave like bits of copper, and that is why each electron and each bit of copper stays the same as itself from microsecond to microsecond and from century to century. It is because God constantly keeps a finger on each and every particle, curbing its reckless excesses and whipping it into line with its colleagues to keep them all the same.

But how can Swinburne possibly maintain that this hypothesis of God simultaneously keeping a gazillion fingers on wayward electrons is a *simple* hypothesis? It is, of course, precisely the opposite of simple. Swinburne pulls off the trick to his own satisfaction by a breathtaking piece of intellectual *chutzpah.* He asserts, without justification, that God is only a *single* substance. What brilliant economy of explanatory causes, compared with all those gigazillions of independent electrons all just happening to be the same!

> Theism claims that every other object which exists is caused to exist and kept in existence by just one substance, God. And it claims that every property which every substance has is due to God causing or permitting it to exist. It is a hallmark of a simple explanation to postulate few causes. There could in this respect be no

> simpler explanation than one which postulated only one cause. Theism is simpler than polytheism. And theism postulates for its one cause, a person [with] infinite power (God can do anything logically possible), infinite knowledge (God knows everything logically possible to know), and infinite freedom.

Swinburne generously concedes that God cannot accomplish feats that are *logically* impossible, and one feels grateful for this forbearance. Having said that, there is no limit to the explanatory purposes to which God's infinite power is put. Is science having a little difficulty explaining X? No problem. Don't give X another glance. God's infinite power is effortlessly wheeled in to explain X (along with everything else), and it is always a supremely *simple* explanation because, after all, there is only one God. What could be simpler than that?

Well, actually, almost everything. A God capable of continuously monitoring and controlling the individual status of every particle in the universe *cannot* be simple. His existence is going to need a mammoth explanation in its own right. Worse (from the point of view of simplicity), other corners of God's giant consciousness are simultaneously preoccupied with the doings and emotions and prayers of every single human being - and whatever intelligent aliens there might be on other planets in this and 100 billion other galaxies. He even, according to Swinburne, has to decide continuously *not* to intervene miraculously to save us when we get cancer. That would never do, for, 'If God answered most prayers for a relative to recover from cancer, then cancer would no longer be a problem for humans to solve.' And *then* what would we find to do with our time?

Not all theologians go as far as Swinburne. Nevertheless, the remarkable suggestion that the God Hypothesis is *simple* can be found in other modern theological writings. Keith Ward, then Regius Professor of Divinity at Oxford, was very clear on the matter in his 1996 book *God, Chance and Necessity:*

> As a matter of fact, the theist would claim that God is a very elegant, economical and fruitful explanation for the

> existence of the universe. It is economical because it attributes the existence and nature of absolutely everything in the universe to just one being, an ultimate cause which assigns a reason for the existence of everything, including itself. It is elegant because from one key idea - the idea of the most perfect possible being - the whole nature of God and the existence of the universe can be intelligibly explicated.

Like Swinburne, Ward mistakes what it means to explain something, and he also seems not to understand what it means to say of something that it is simple. I am not clear whether Ward really thinks God is simple, or whether the above passage represented a temporary 'for the sake of argument' exercise. Sir John Polkinghorne, in *Science and Christian Belief,* quotes Ward's earlier criticism of the thought of Thomas Aquinas: 'Its basic error is in supposing that God is logically simple - simple not just in the sense that his being is indivisible, but in the much stronger sense that what is true of any part of God is true of the whole. It is quite coherent, however, to suppose that God, while indivisible, is internally complex.' Ward gets it right here. Indeed, the biologist Julian Huxley, in 1912, defined complexity in terms of 'heterogeneity of parts', by which he meant a particular kind of functional indivisibility.[71]

Elsewhere, Ward gives evidence of the difficulty the theological mind has in grasping where the complexity of life comes from. He quotes another theologian-scientist, the biochemist Arthur Peacocke (the third member of my trio of British religious scientists), as postulating the existence in living matter of a 'propensity for increased complexity'. Ward characterizes this as 'some inherent weighting of evolutionary change which favours complexity'. He goes on to suggest that such a bias 'might be some weighting of the mutational process, to ensure that more complex mutations occurred'. Ward is sceptical of this, as well he should be. The evolutionary drive towards complexity comes, in those lineages where it comes at all, not from any inherent propensity for increased complexity, and not from biased mutation. It comes from natural selection: the process which, as far as we know, is the only

process ultimately capable of generating complexity out of simplicity. The theory of natural selection is genuinely simple. So is the origin from which it starts. That which it explains, on the other hand, is complex almost beyond telling: more complex than anything we can imagine, save a God capable of designing it.

AN INTERLUDE AT CAMBRIDGE

At a recent Cambridge conference on science and religion, where I put forward the argument I am here calling the Ultimate 747 argument, I encountered what, to say the least, was a cordial failure to achieve a meeting of minds on the question of God's simplicity. The experience was a revealing one, and I'd like to share it.

First I should confess (that is probably the right word) that the conference was sponsored by the Templeton Foundation. The audience was a small number of hand-picked science journalists from Britain and America. I was the token atheist among the eighteen invited speakers. One of the journalists, John Horgan, reported that they had each been paid the handsome sum of $15,000 to attend the conference, on top of all expenses. This surprised me. My long experience of academic conferences included no instances where the audience (as opposed to the speakers) was paid to attend. If I had known, my suspicions would immediately have been aroused. Was Templeton using his money to suborn science journalists and subvert their scientific integrity? John Horgan later wondered the same thing and wrote an article about his whole experience.[72] In it he revealed, to my chagrin, that my advertised involvement as a speaker had helped him and others to overcome their doubts:

> The British biologist Richard Dawkins, whose participation in the meeting helped convince me and other fellows of its legitimacy, was the only speaker who denounced religious beliefs as incompatible with science, irrational, and harmful. The other speakers - three

> agnostics, one Jew, a deist, and 12 Christians (a Muslim philosopher canceled at the last minute) - offered a perspective clearly skewed in favor of religion and Christianity.

Horgan's article is itself endearingly ambivalent. Despite his misgivings, there were aspects of the experience that he clearly valued (and so did I, as will become apparent below). Horgan wrote:

> My conversations with the faithful deepened my appreciation of why some intelligent, well-educated people embrace religion. One reporter discussed the experience of speaking in tongues, and another described having an intimate relationship with Jesus. My convictions did not change, but others' did. At least one fellow said that his faith was wavering as a result of Dawkins's dissection of religion. And if the Templeton Foundation can help bring about even such a tiny step toward my vision of a world without religion, how bad can it be?

Horgan's article was given a second airing by the literary agent John Brockman on his 'Edge' website (often described as an on-line scientific *salon)* where it elicited varying responses, including one from the theoretical physicist Freeman Dyson. I responded to Dyson, quoting from his acceptance speech when he won the Templeton Prize. Whether he liked it or not, by accepting the Templeton Prize Dyson had sent a powerful signal to the world. It would be taken as an endorsement of religion by one of the world's most distinguished physicists.

> 'I am content to be one of the multitude of Christians who do not care much about the doctrine of the Trinity or the historical truth of the gospels.'

But isn't that exactly what any atheistic scientist *would* say, if he wanted to sound Christian? I gave further quotations from Dyson's acceptance speech, satirically interspersing them with imagined questions (in italics) to a Templeton official:

Oh, you want something a bit more profound, as well? How about. . .

'I do not make any clear distinction between mind and God. God is what mind becomes when it has passed beyond the scale of our comprehension.'

Have I said enough yet, and can I get back to doing physics now? Oh, not enough yet? OK then, how about this:

'Even in the gruesome history of the twentieth century, I see some evidence of progress in religion. The two individuals who epitomized the evils of our century, Adolf Hitler and Joseph Stalin, were both avowed atheists.'*

Can I go now?

Dyson could easily refute the implication of these quotations from his Templeton acceptance speech, if only he would explain clearly what evidence he finds to believe in God, in something more than just the Einsteinian sense which, as I explained in Chapter 1, we can all trivially subscribe to. If I understand Horgan's point, it is that Templeton's money corrupts science. I am sure Freeman Dyson is way above being corrupted. But his acceptance speech is still unfortunate if it seems to set an example to others. The Templeton Prize is two orders of magnitude larger than the inducements offered to the journalists at Cambridge, having been explicitly set up to be larger than the Nobel Prize. In Faustian vein, my friend the philosopher Daniel Dennett once joked to me, 'Richard, if ever you fall on hard times . . .'

For better or worse, I attended two days at the Cambridge conference, giving a talk of my own and taking part in the discussion of several other talks. I challenged the theologians to answer the point that a God capable of designing a universe, or anything else, would have to be complex and statistically improbable. The strongest response I heard was that I was brutally foisting a scientific epistemology upon an unwilling theology, f Theologians had always defined God as simple. Who was I, a scientist, to dictate

* This calumny is dealt with in Chapter 7.
f This accusation is reminiscent of 'NOMA', whose overblown claims I dealt with in Chapter 2.

to theologians that their God had to be complex? Scientific arguments, such as those I was accustomed to deploying in my own field, were inappropriate since theologians had always maintained that God lay outside science.

I did not gain the impression that the theologians who mounted this evasive defence were being wilfully dishonest. I think they were sincere. Nevertheless, I was irresistibly reminded of Peter Medawar's comment on Father Teilhard de Chardin's *The Phenomenon of Man,* in the course of what is possibly the greatest negative book review of all time: 'its author can be excused of dishonesty only on the grounds that before deceiving others he has taken great pains to deceive himself'.[73] The theologians of my Cambridge encounter were *defining* themselves into an epistemological Safe Zone where rational argument could not reach them because they had *declared by fiat* that it could not. Who was I to say that rational argument was the only admissible kind of argument? There are other ways of knowing besides the scientific, and it is one of these other ways of knowing that must be deployed to know God.

The most important of these other ways of knowing turned out to be personal, subjective experience of God. Several discussants at Cambridge claimed that God spoke to them, inside their heads, just as vividly and as personally as another human might. I have dealt with illusion and hallucination in Chapter 3 ('The argument from personal experience'), but at the Cambridge conference I added two points. First, that if God really did communicate with humans that fact would emphatically not lie outside science. God comes bursting through from whatever other-worldly domain is his natural abode, crashing through into our world where his messages can be intercepted by human brains - and that phenomenon has nothing to do with science? Second, a God who is capable of sending intelligible signals to millions of people simultaneously, and of receiving messages from all of them simultaneously, cannot be, whatever else he might be, simple. Such bandwidth! God may not have a brain made of neurones, or a CPU made of silicon, but if he has the powers attributed to him he must have something far more elaborately and non-randomly constructed than the largest brain or the largest computer we know.

Time and again, my theologian friends returned to the point that there had to be a reason why there is something rather than nothing. There must have been a first cause of everything, and we might as well give it the name God. Yes, I said, but it must have been simple and therefore, whatever else we call it, God is not an appropriate name (unless we very explicitly divest it of all the baggage that the word 'God' carries in the minds of most religious believers). The first cause that we seek must have been the simple basis for a self-bootstrapping crane which eventually raised the world as we know it into its present complex existence. To suggest that the original prime mover was complicated enough to indulge in intelligent design, to say nothing of mindreading millions of humans simultaneously, is tantamount to dealing yourself a perfect hand at bridge. Look around at the world of life, at the Amazon rainforest with its rich interlacement of lianas, bromeliads, roots and flying buttresses; its army ants and its jaguars, its tapirs and peccaries, treefrogs and parrots. What you are looking at is the statistical equivalent of a perfect hand of cards (think of all the other ways you could permute the parts, none of which would work) - except that we know how it came about: by the gradualistic crane of natural selection. It is not just scientists who revolt at mute acceptance of such improbability arising spontaneously; common sense balks too. To suggest that the first cause, the great unknown which is responsible for something existing rather than nothing, is a being capable of designing the universe and of talking to a million people simultaneously, is a total abdication of the responsibility to find an explanation. It is a dreadful exhibition of self-indulgent, thought-denying skyhookery.

I am not advocating some sort of narrowly scientistic way of thinking. But the very least that any honest quest for truth must have in setting out to explain such monstrosities of improbability as a rainforest, a coral reef, or a universe is a crane and not a skyhook. The crane doesn't have to be natural selection. Admittedly, nobody has ever thought of a better one. But there could be others yet to be discovered. Maybe the 'inflation' that physicists postulate as occupying some fraction of the first yoctosecond of the universe's existence will turn out, when it is better understood, to be a cosmological crane to stand alongside Darwin's biological one. Or

3 The temptation is a false one, because the designer hypothesis immediately raises the larger problem of who designed the designer. The whole problem we started out with was the problem of explaining statistical improbability. It is obviously no solution to postulate something even more improbable. We need a 'crane', not a 'skyhook', for only a crane can do the business of working up gradually and plausibly from simplicity to otherwise improbable complexity.

4 The most ingenious and powerful crane so far discovered is Darwinian evolution by natural selection. Darwin and his successors have shown how living creatures, with their spectacular statistical improbability and appearance of design, have evolved by slow, gradual degrees from simple beginnings. We can now safely say that the illusion of design in living creatures is just that - an illusion.

5 We don't yet have an equivalent crane for physics. Some kind of multiverse theory could in principle do for physics the same explanatory work as Darwinism does for biology. This kind of explanation is superficially less satisfying than the biological version of Darwinism, because it makes heavier demands on luck. But the anthropic principle entitles us to postulate far more luck than our limited human intuition is comfortable with.

6 We should not give up hope of a better crane arising in physics, something as powerful as Darwinism is for biology. But even in the absence of a strongly satisfying crane to match the biological one, the relatively weak cranes we have at present are, when abetted by the anthropic principle, self-evidently better than the self-defeating skyhook hypothesis of an intelligent designer.

If the argument of this chapter is accepted, the factual premise of religion - the God Hypothesis - is untenable. God almost certainly does not exist. This is the main conclusion of the book so far. Various questions now follow. Even if we accept that God doesn't exist, doesn't religion still have a lot going for it? Isn't it consoling?

Doesn't it motivate people to do good? If it weren't for religion, how would we know what is good? Why, in any case, be so hostile? Why, if it is false, does every culture in the world have religion? True or false, religion is ubiquitous, so where does it come from? It is to this last question that we turn next.