

*I. The Science of Religion*  
*II. The Religion of Science*

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## I. THE SCIENCE OF RELIGION

It is with trepidation and humility that I come, from the oldest university in the English-speaking world to what must surely be the greatest. My trepidation is not lessened by the titles that, perhaps unwisely, I gave the organizers all those months ago. Anybody who publicly belittles religion, however gently, can expect hate mail of a uniquely unforgiving species. But the very fact that religion arouses such passions catches a scientist's attention.

As a Darwinian, the aspect of religion that catches *my* attention is its profligate wastefulness, its extravagant display of baroque uselessness. Nature is a miserly accountant, grudging the pennies, watching the clock, punishing the smallest waste.<sup>1</sup> If a wild animal habitually performs some useless activity, natural selection will favour rival individuals who devote the time, instead, to surviving and reproducing. Nature cannot afford frivolous *jeux d'esprits*. Ruthless utilitarianism trumps, even if it doesn't always seem that way.

I am a Darwinian student of animal behaviour—an ethologist and follower of Niko Tinbergen. You won't be surprised, therefore, if I talk about animals (nonhuman animals, I should add, for there is no sensible definition of an animal that excludes ourselves). The tail of a male bird of paradise, extravagant though it seems, would be penalised by females if it were less so. The same for the time and labour that a male bower bird puts into making his bower. Anting is the odd habit of birds, such as jays, of "bathing" in an ant's nest and apparently inciting the ants to invade the feathers. Nobody knows for sure what the benefit of anting is: perhaps some kind of hygiene, cleansing the feathers of parasites. My point is that uncertainty as to detail doesn't—nor should it—stop Darwinians from believing, with great confidence, that anting must be for something.

Such a confident stance is controversial—at Harvard if nowhere else—and you may be aware of the wholly unwarranted slur that functional

1. Natural selection, as Charles Darwin said, "is daily and hourly scrutinizing, throughout the world, every variation, even the slightest; rejecting that which is bad, preserving and adding up all that is good; silently and insensibly working, whenever and wherever opportunity offers, at the improvement of each organic being..." (*On the Origin of Species* [London: John Murray, 1859]).

hypotheses are untestable “Just So Stories.” This is such a ridiculous claim that the only reason it has come to be widely accepted is a certain style of bullying advocacy originating, I reluctantly have to say, at Harvard. All you have to do to test a functional hypothesis of a piece of behaviour is to engineer an experimental situation in which the behaviour doesn’t happen, or in which its consequences are negated. Let me give a simple example of how to test a functional hypothesis.

Next time a housefly lands on your hand, don’t immediately brush it off; watch what it does. You won’t wait long before it brings its hands together as if in prayer, then wrings them in what seems like ritual fastidiousness. This is one of the ways in which a fly grooms itself. Another is to wipe a hind leg over the same side wing. They also rub middle and hind feet together, or middle and front. Flies spend so much time self-grooming that any Darwinian would immediately guess that it is vital for survival.<sup>2</sup> And this is a testable hypothesis.

An appropriate experimental design is the “Yoked Control.” Put a matched pair of flies in a small arena and watch them. Every time Fly A starts to groom itself, scare both into flight. After two hours of this regime, Fly A will have done no grooming at all. Fly B will have groomed itself a lot. It will have been scared off the ground as many times as A, but at random with respect to its grooming. Now put A and B through a battery of comparison tests. Is A’s flying performance impaired by dirty wings? Measure it and compare it with B’s. Flies taste with their feet, and it is a reasonable hypothesis that “foot washing” unclogs their sense organs. Well-tried methods for measuring the taste threshold of flies have been published. Compare the threshold sugar concentration that A and B can taste. Compare their tendency to disease. As a final test, compare the two flies’ vulnerability to a chameleon.

Repeat the trial with lots of pairs of flies and do a statistical analysis comparing each A with its corresponding B. I would put my shirt on the A flies’ being significantly impaired in at least one faculty vitally affecting survival. The reason for my confidence is purely the Darwinian conviction that natural selection would not have allowed them to spend so

2. The more so because—this is less paradoxical than it sounds—grooming is often instantly fatal. When a chameleon, for example, is around, grooming is very likely to be the last thing the fly does. Predatory eyes often lock onto movement. A motionless target goes unnoticed. A flying target is difficult to hit. A grooming fly’s shuttling limbs stimulate the predator’s movement-detectors, but the fly as a whole is a sitting target. The fact that flies spend so much time grooming, in spite of its being so dangerous, argues for a very strong survival value.

much time on an activity if it were not useful. This is not a “Just So Story”; the reasoning is thoroughly scientific, and it is fully testable.

Religious behaviour in bipedal apes occupies large quantities of time. It devours huge resources. A medieval cathedral would consume hundreds of man-centuries in the building. Sacred music and devotional paintings largely monopolised medieval and renaissance talent. Thousands, perhaps millions, of people have died, often accepting torture first, for loyalty to one religion rather than a scarcely distinguishable alternative. Devout people have died for their gods, killed for them, fasted for them, whipped blood from their backs, undertaken a lifetime of celibacy, sworn themselves to lonely silence for the sake of religion. Nobody does this kind of list better than Steven Pinker, and I’m going to quote *How the Mind Works* on the peculiar problems you face in the United States—whether in spite of or because of the constitutional separation of church and state I do not know:

According to polls, more than a quarter of today’s Americans believe in witches, almost half believe in ghosts, half believe in the devil, half believe that the book of Genesis is literally true, sixty-nine percent believe in angels, eighty-seven percent believe that Jesus was raised from the dead, and ninety-six percent believe in a God or universal spirit.

More generally, Pinker remarks,

In culture after culture, people believe that the soul lives on after death, that rituals can change the physical world and divine the truth, and that illness and misfortune are caused and alleviated by spirits, ghosts, saints, fairies, angels, demons, cherubim, djinns, devils and gods.<sup>3</sup>

Though the details differ across cultures, no known culture lacks some version of the time-consuming, wealth-consuming, hostility-provoking, fecundity-forfeiting rituals of religion. All this presents a major puzzle to anyone who thinks in a Darwinian way. We guessed why jays ant; my old maestro Niko Tinbergen did an experimental test of why seagulls remove empty eggshells from the nest (eggshells are conspicuous and attract predators). Isn’t religion a challenge, an *a priori* affront to Darwinism, demanding similar explanation? Why do we pray and

3. Steven Pinker, *How the Mind Works* (New York: Norton, 1997).

indulge in costly practices that, in many individual cases, more or less totally consume our lives?

Of course the caveats must now come tumbling in. Religious behaviour is Darwinian business only if it is widespread, not some weird anomaly. Apparently it *is* universal, and the problem won't go away just because the details differ across cultures. As with language, the underlying phenomenon is universal, though it plays out differently in different regions. Not all individuals are religious, as most of this educated audience will testify. But religion is a human universal: every culture, everywhere in the world, has a style of religion that even nonpractitioners recognize as the norm for that society, just as it has a style of clothing, a style of courting, and a style of meal-serving.

Could it be a recent phenomenon, sprung up since our genes underwent most of their natural selection? Its ubiquity argues against any simple version of this idea. Nevertheless there is a version of it that it will be my main purpose to advocate today. The propensity that was naturally selected in our ancestors was not religion per se. It had some other benefit, and it only incidentally manifests itself as religious behaviour. We'll understand religious behaviour only after we have renamed it. Once again, it is natural for an ethologist to use an example from non-human animals.

The "dominance hierarchy" was first discovered as the "pecking order" in hens. Each hen learns which individuals she can beat in a fight, and which beat her. In a well-established dominance hierarchy, little overt fighting is seen. Stable groupings of hens, who have time to sort themselves into a pecking order, lay more eggs than hens in coops whose membership is continually changed. This might suggest an "advantage" to the phenomenon of the dominance hierarchy. But that's not good Darwinism, because the dominance hierarchy is a group-level phenomenon. Farmers may care about group productivity, but natural selection doesn't.

For a Darwinian, the question "What is the survival value of the dominance hierarchy?" is an illegitimate question. The proper question is "What is the individual survival value of deferring to stronger hens? And of punishing lack of deference from weaker ones?" Darwinian questions have to direct attention toward the level at which genetic variations might exist. Tendencies to aggression or deference in individual hens are a proper target because they either do or easily might vary genetically. Group phenomena like dominance hierarchies don't in themselves vary genetically, because groups don't have genes. Or at least

you'll have your work cut out arguing some peculiar sense in which a group phenomenon could be subject to genetic variation. You might contrive it via some version of what I have called the *Extended Phenotype*, but I am too sceptical to accompany you on that theoretical journey.

My point, of course, is that religion may be like the dominance hierarchy. "What is the survival value of religion?" may be the wrong question. The right question may have the form, "What is the survival value of some as yet unspecified individual behaviour, or psychological characteristic, which manifests itself, under appropriate circumstances, as religion?" We have to rewrite the question before we can sensibly answer it.

I must first acknowledge that other Darwinians have gone straight for the unrewritten question and proposed direct Darwinian advantages of religion itself—as opposed to psychological predispositions that accidentally manifest themselves as religion. There is a little evidence that religious belief protects people from stress-related diseases. The evidence is not good, but it would not be surprising. A non-negligible part of what a doctor can provide for a patient is consolation and reassurance. My doctor doesn't literally practise the laying on of hands. But many's the time I have been instantly cured of some minor ailment by a reassuringly calm voice from an intelligent face surmounting a stethoscope. The placebo effect is well documented. Dummy pills, with no pharmacological activity at all, demonstrably improve health. That is why drug trials have to use placebos as controls. It's why homeopathic remedies appear to work, even though they're so dilute that they have the same amount of the active ingredients as the placebo control—zero molecules.

Is religion a medical placebo, which prolongs life by reducing stress? Perhaps, although the theory is going to have to run the gauntlet of sceptics who point out the many circumstances in which religion increases stress rather than decreases it. In any case, I find the placebo theory too meagre to account for the massive and all-pervasive worldwide phenomenon of religion. I do not think we have religion because our religious ancestors reduced their stress levels and hence survived longer. I don't think that's a big enough theory for the job.

Other theories miss the point of Darwinian explanations altogether. I mean suggestions such as "Religion satisfies our curiosity about the universe and our place in it." Or "Religion is consoling. People fear death and are drawn to religions that promise we'll survive it." There may be some psychological truth here, but it's not in itself a Darwinian explanation. As Steven Pinker has said,

...it only raises the question of *why* a mind would evolve to find comfort in beliefs it can plainly see are false. A freezing person finds no comfort in believing he is warm; a person face-to-face with a lion is not put at ease by the conviction that it is a rabbit.<sup>4</sup>

A Darwinian version of the fear-of-death theory would have to be of the form, "Belief in survival after death tends to postpone the moment when it is put to the test." This could be true or it could be false—maybe it's another version of the stress and placebo theory—but I shall not pursue the matter. My only point is that this is the *kind* of way in which a Darwinian must rewrite the question. Psychological statements—that people find some belief agreeable or disagreeable—are proximate, not ultimate explanations.

Darwinians make much of this distinction between proximate and ultimate. Proximate questions lead us into physiology and neuroanatomy. There is nothing wrong with proximate explanations. They are important, and they are scientific. But my preoccupation today is with Darwinian ultimate explanations. If neuroscientists, such as the Canadian Michael Persinger, find a "god centre" in the brain, Darwinian scientists like me want to know why the god centre evolved. Why did those of our ancestors who had a genetic tendency to grow a god centre survive better than rivals who did not? The ultimate Darwinian question is not a better question, not a more profound question, not a more scientific question than the proximate neurological question. But it is the one I am talking about today.

Some alleged ultimate explanations turn out to be—or in some cases avowedly are—group selection theories. Group selection is the controversial idea that Darwinian selection chooses among groups of individuals, in the same kind of way as it chooses among individuals within groups. The Cambridge anthropologist Colin Renfrew, for example, suggests that Christianity survived by a form of group selection because it fostered the idea of in-group loyalty and brotherly love. The American evolutionist D. S. Wilson has made a similar suggestion in *Darwin's Cathedral*.

Here's a made-up example, to show what a group-selection theory of religion might look like. A tribe with a stirringly belligerent "god of battles" wins wars against a tribe whose god urges peace and harmony, or a tribe with no god at all. Warriors who believe that a martyr's death will send them straight to paradise fight bravely and willingly give up their

4. Pinker, *How the Mind Works*, p. 555.



lives. So tribes with certain kinds of religion are more likely to survive in intertribal selection, steal the conquered tribe's cattle, and seize their women as concubines. Such successful tribes spawn daughter tribes who go off and propagate more daughter tribes, all worshipping the same tribal god. Notice that this is different from saying that the *idea* of the warlike religion survives. Of course it will, but in this case the point is that the group of people who hold the idea survive.

There are formidable objections to group selection theories. A partisan in the controversy, I must beware of riding off on a hobby horse far from today's subject. There is also much confusion in the literature between true group selection, as in my hypothetical example of the God of Battles, and something else that is *called* group selection but turns out to be either kin selection or reciprocal altruism. Or there may be a confusion of "selection between groups" and "selection between individuals in the particular circumstances furnished by group living."<sup>5</sup>

Those of us who object to group selection have always admitted that in principle it can happen. The problem is that, when it is pitted against individual-level selection—as when group selection is advanced as an explanation for individual self-sacrifice—individual-level selection is likely to be stronger. In our hypothetical tribe of martyrs, a single self-interested warrior, who leaves martyrdom to his colleagues, will end up on the winning side because of their gallantry. Unlike them, however, he ends up alive, outnumbered by women and in a conspicuously better position to pass on his genes than his fallen comrades.

This is an oversimplified toy example, but it illustrates the perennial tension between group selection and individual selection. Group-selection theories of individual self-sacrifice are always vulnerable to subversion from within. If it comes to a tussle between the two levels of selection, individual selection will tend to win because it has a faster turnover. Mathematical models arguably come up with special conditions under which group selection might work. Arguably, religions in human tribes set up just such special conditions. This is an interesting line of theory to pursue, but I shall not do so here.

Instead, I shall return to the idea of rewriting the question. I previously cited the pecking order in hens, and the point is so central to my thesis that I hope you will forgive another animal example to ram it home. Moths fly into the candle flame, and it doesn't look like an

5. All these confusions are exemplified by D. S. Wilson's lifelong crusade in favour of what he calls group selection.

accident. They go out of their way to make a burnt offering of themselves. We could label it “self-immolation behaviour” and wonder how Darwinian natural selection could possibly favour it. My point, again, is that we need to rewrite the question before we can even attempt an intelligent answer. It isn’t suicide. Apparent suicide emerges as an inadvertent side-effect.

Artificial light is a recent arrival on the night scene. Until recently, the only night lights were the moon and the stars. Because they are at optical infinity, their rays are parallel, which makes them ideal compasses. Insects are known to use celestial objects to steer accurately in a straight line. They can use the same compass, with reversed sign, for returning home after a foray. The insect nervous system is adept at setting up a temporary rule of thumb such as “Steer a course such that the light rays hit your eye at an angle of  $30^\circ$ .” Since insects have compound eyes, this will amount to favouring a particular ommatidium.

But the light compass relies critically on the celestial object being at optical infinity. If it isn’t, the rays are not parallel but diverge like the spokes of a wheel. A nervous system using a  $30^\circ$  rule of thumb to a candle, as though it were the moon, will steer its moth, in a neat logarithmic spiral, into the flame.

It is still, on average, a good rule of thumb. We don’t notice the hundreds of moths who are silently and effectively steering by the moon or a bright star, or even the lights of a distant city. We see only moths hurling themselves at our lights, and we ask the wrong question. Why are all these moths committing suicide? Instead, we should ask why they have nervous systems that steer by maintaining an automatic fixed angle to light rays, a tactic that we notice only on the occasions when it goes wrong. When the question is rephrased, the mystery evaporates. It never was right to call it suicide.

Once again, apply the lesson to religious behaviour in humans. We observe large numbers of people—in many local areas it amounts to 100 percent—who hold beliefs that flatly contradict demonstrable scientific facts as well as rival religions. They not only *hold* these beliefs but devote time and resources to costly activities that flow from holding them. They die for them, or kill for them. We marvel at all this, just as we marvelled at the “self-immolation behaviour” of the moths. Baffled, we ask why. Yet again, the point I am making is that we may be asking the wrong question. The religious behaviour may be a misfiring, an unfortunate manifestation of an underlying psychological propensity that in other circumstances was once useful.

What might that psychological propensity have been? What is the equivalent of the parallel rays from the moon as a useful compass? I shall offer a suggestion, but I must stress that it is only an example of the kind of thing I am talking about. I am much more wedded to the general idea that the question should be properly put than I am to any particular answer.

My specific hypothesis is about children. More than any other species, we survive by the accumulated experience of previous generations. Theoretically, children might learn from experience not to swim in crocodile-infested waters. But, to say the least, there will be a selective advantage to child brains with a rule of thumb: Believe whatever your grown-ups tell you. Obey your parents, obey the tribal elders, especially when they adopt a solemn, minatory tone. Obey without question.

I have never forgotten a horrifying sermon, preached in my school chapel when I was little. Horrifying in retrospect: at the time, my child brain accepted it as intended by the preacher. He told the story of a squad of soldiers, drilling beside a railway line. At a critical moment the drill sergeant's attention was distracted, and he failed to give the order to halt. The soldiers were so well schooled to obey orders without question that they carried on marching, right into the path of an oncoming train. Now, of course, I don't believe the story, but I did when I was nine. The point is that the preacher wished us children to regard as a *virtue* the soldiers' slavish and unquestioning obedience to an order, however preposterous. And, speaking for myself, I think we *did* regard it as a virtue. I wondered whether I would have had the courage to do my duty by marching into the train.

To be fair, I don't think the preacher thought he was delivering a religious message. It was more military than religious, from what I remember: in the spirit of Tennyson's "Charge of the Light Brigade," which he may well have quoted:

"Forward the Light Brigade!"  
Was there a man dismayed?  
Not though the soldier knew  
Some one had blundered:  
Theirs not to make reply,  
Theirs not to reason why,  
Theirs but to do and die:  
Into the valley of Death  
Rode the six hundred.

From the high command's point of view it would be madness to allow every individual soldier discretion over whether or not to obey orders. Soldiers are drilled to become as much like computers as possible.

Computers do what they are told. They slavishly obey whatever instructions are properly delivered in their own programming language. This is how they do useful things like word-processing and spreadsheet calculations. But, as an inevitable by-product, they are equally automatic in obeying bad instructions. They have no way of telling whether an instruction will have a good effect or a bad. They simply obey, as soldiers are supposed to.

It is their unquestioning obedience that makes computers vulnerable to infection by viruses and worms. A maliciously designed program that says: "Copy me to every name in any address list that you find on this hard disk" will simply be obeyed, and then obeyed again by the other computers to which it is sent, in exponential expansion. It is impossible to design a computer that is usefully obedient and at the same time immune to infection.

If I have done my softening-up work well, you will already have completed the argument about child brains and religion. Natural selection builds child brains with a tendency to believe whatever their parents and tribal elders tell them. And this very quality automatically makes them vulnerable to infection by mind viruses. For excellent survival reasons, child brains need to trust parents, and trust elders whom their parents tell them to trust. An automatic consequence is that the truster has no way of distinguishing good advice from bad. The child cannot tell that "If you swim in the river you'll be eaten by crocodiles" is good advice but "If you don't sacrifice a goat at the time of the full moon, the crops will fail" is bad advice. They both sound equally trustworthy. They are both advice from a trusted source, both delivered with a solemn earnestness that commands respect and demands obedience.

The same goes for propositions about the world, about the cosmos, about morality, and about human nature. And, of course, when the child grows up and has children of her own, she will naturally pass the whole lot on to her own children—nonsense as well as sense—using the same impressive gravitas of manner.

On this model, we should expect that, in different geographical regions, different arbitrary beliefs having no factual basis will be handed down, to be believed with the same conviction as useful pieces of traditional wisdom, such as the belief that manure is good for the crops. We should also expect that these nonfactual beliefs will evolve over genera-

tions, either by random drift or by following some sort of analogue of Darwinian selection, eventually showing a pattern of significant divergence from common ancestry. Languages drift apart from a common parent, given sufficient time in geographical separation. The same is true of traditional beliefs and injunctions, handed down the generations, initially because of the programmability of the child brain. I shall mention this again in my second lecture.

And now, here's a charming story from my newspaper, the *Independent*, at Christmas one year. In a school Nativity Play, the Three Wise Men were played by Shadbreet Bains (a Sikh), Musharaff Khallil (a Muslim), and Adele Marlowe (a Christian), all aged four.

No, it is *not* charming, it is grotesque. How could any decent person think it right to label four-year-old children with the cosmic and theological opinions of their parents? To see this, imagine an identical photograph, with the caption *changed* as follows: "Shadbreet Bains (a Keynesian), Musharaff Khallil (a Monetarist), and Adele Marlowe (a Marxist), all aged four." Wouldn't this be a candidate for prosecution as child abuse? Yet, because of the weird privileged status of religion, not a squeak of protest was heard—nor is it ever heard on any similar occasion. In the *Independent*, the only complaint in the subsequent Letters to the Editor was from "The Campaign for Real Education," whose spokesman said multifaith religious education was extremely dangerous because: "Children these days are taught that all religions are of equal worth, which means that their own has no special value."



FIGURE 1. Shadbreet Bains (a Sikh), Musharaff Khallil (a Muslim), and Adele Marlowe (a Christian), all aged four.



FIGURE 2. Shadbreet Bains (a Keynesian), Musharaff Khallil (a Monetarist), and Adele Marlowe (a Marxist), all aged four.

Just imagine the outcry if the caption had read, “Shadbreet Bains (an Atheist), Musharaff Khallil (an Agnostic), and Adele Marlowe (a Secular Humanist), all aged four.” In Britain, where we lack a constitutional separation between church and state, atheist parents usually go with the flow and let schools teach their children whatever religion prevails in the culture. The-Brights.net is scrupulous in setting out the rules for children to sign up: “The decision to be a Bright must be the child’s. Any youngster who is told he or she must, or should, be a Bright can NOT be a Bright.” Can you even begin to imagine the Roman Catholic church issuing such a self-denying ordinance?

Our society, including the nonreligious sector, has accepted the preposterous idea that it is normal and right to slap religious labels on tiny children, although no other comparable labels. Please, please raise your consciousness about this, and raise the roof whenever you hear it happening. A child is not a Christian child, not a Muslim child, not a Jewish child, but a child of Christian parents, a child of Muslim parents, or a child of Jewish parents. That terminology, by the way, would be an excellent piece of consciousness-raising for the children themselves. It would sow the seed of the idea that religion is something for them to choose—or not—when they become old enough to do so.

I must again stress that the hypothesis of the programmability of the child brain is only one example. The message of the moths and the can-

dle flame is more general. As a Darwinian, I am proposing a family of hypotheses, all of which have in common that they do not ask what is the survival value of religion. Instead they ask, "What was the survival value, in the wild past, of having the kind of brain which, in the cultural present, manifests itself as religion?" And I should add that child brains are not the only ones that are vulnerable to infection of this kind. Adult brains are too, especially if primed in childhood. Charismatic preachers can spread the word far and wide among adults, as if they were diseased persons spreading an epidemic.

So far, the hypothesis suggests only that brains (especially child brains) are *vulnerable* to infection. It says nothing about which viruses will infect. In one sense it doesn't matter. Anything the child believes with sufficient conviction will get passed on to its children, and hence to future generations. This is a nongenetic analogue of heredity. Some people will say it is memes rather than genes. I don't want to sell memetic terminology to you today, but it is important to stress that we are not talking about genetic inheritance. What is genetically inherited, according to the theory, is the tendency of the child brain to believe what it is told. This is what makes the child brain a suitable vehicle for nongenetic heredity.

If there is nongenetic heredity, could there also be nongenetic Darwinism? Is it arbitrary which mind viruses end up exploiting the vulnerability of child brains? Or do some viruses survive better than others? This is where those theories that I earlier dismissed as proximate, not ultimate, come in. If fear of death is common, the idea of immortality might survive as a mind virus better than the competing idea that death snuffs us out like a light. Conversely, the idea of posthumous punishment for sins might survive, not because children like the idea but because adults find it a useful way to control them. One could devote a whole lecture to listing religious ideas and examining the possible "survival value" of each. I did a bit of this in my essay "Viruses of the Mind" (originally written for Dan Dennett and now reprinted in *A Devil's Chaplain*), but I have no time for that here. The important point is that survival value does not have its normal Darwinian meaning of genetic survival value. This is not the normal Darwinian conversation about why a gene survives in preference to its alleles in the gene pool. This is about why one idea survives in the pool of ideas in preference to rival ideas. It is this notion of rival ideas surviving, or failing to survive, in a pool of ideas that the word "meme" was intended to capture.

Let's go back to first principles and remind ourselves of exactly what is going on in natural selection. The necessary condition is that accurately self-replicating information exists in alternative, competing versions. Following George C. Williams in his *Natural Selection*, I shall call them "codices" (singular "codex"). The archetypal codex is a gene: not the physical molecule of DNA but the information it carries.

Biological codices, or genes, are carried around inside bodies whose qualities—phenotypes—they helped to influence. The death of the body entails the destruction of any codices that it contains, unless they have previously been passed on to another body, in reproduction. Automatically, therefore, those genes that positively affect the survival and reproduction of bodies in which they sit will come to predominate in the world, at the expense of rival genes.

A familiar example of a *nongenetic* codex is the so-called chain letter, although "chain" is not a good word. It is too linear, doesn't capture the idea of explosive, exponential spread. Equally ill-named, and for the same reason, is the so-called chain reaction in an atomic bomb. Let's change "chain letter" to "postal virus" and look at the phenomenon through Darwinian eyes.

Suppose you received through the mail a letter that simply said, "Make six copies of this letter and send them to six friends." If you slavishly obeyed the instruction, and if your friends and their friends did too, the letter would spread exponentially and we'd soon be wading knee deep in letters. Of course most people would not obey such a bald, unadorned instruction. But now, suppose the letter said, "If you do not copy this letter to six friends, you will be jinxed, a voodoo will be placed on you, and you will die young, in agony." Most people still wouldn't send it on, but a significant number probably would. Even quite a low percentage would be enough for it to take off.

The promise of reward may be more effective than the threat of punishment. We have probably all received examples of the slightly more sophisticated style of letter, which invites you to send money to people already on the list, with the promise that you will eventually receive millions of dollars when the exponential explosion has advanced further. Whatever our personal guesses as to who might fall for these things, the fact is that many do. It is an empirical fact that chain letters circulate.

Oliver Goodenough and I published in *Nature* a short article about a famous postal virus, the inane but widely travelled St. Jude Letter. In any gathering of people the likelihood is high that some will have received the St. Jude Letter; maybe more than once. The St. Jude doesn't



ask you for money, so there isn't even a whiff of a plausible rationale to justify its bald assertion that if you send the letter on you will accrue fabulous riches, and if you do not you will perish in misery. Nevertheless, the U.S. Post Office reports that the St. Jude letter has been right round the world in great waves (at least nine times at the time of our paper).

Postal viruses also appeal to human sentiment. The most famous example is the Craig Shergold Letter, which gained a new lease of life when the Internet came along. In 1989, a nine-year-old British boy called Craig Shergold was diagnosed with a brain tumour. Somebody circulated a letter saying that Craig's ambition before he died was to get into the *Guinness Books of Records* for receiving the most "get well cards." It asked people to send the boy a card and forward the requesting letter on to others. It was this last clause that turned the letter into a virus. Within a year, Craig had broken the record; as a result of the publicity, his case came to the attention of a good surgeon, who operated on him, and he is still alive. But the cards kept on coming. The Internet kicked in, and, by 1999, a quarter of a billion cards had arrived. Craig, who was by then nineteen, asked that they should stop. King Canute had as much success with the tide. Cards continued to flood in at a rate of about 300,000 per week.

Various mutant versions of the letter are now in existence. At some point "get well card" mutated to "business card" or, in another strain of the virus, to "birthday card." Craig's age mutated to seven (perhaps more appealing than nine) and (perhaps via seven) to seventeen, but in any case he is now twenty-three. His name mutated many times. A partial list of *variants* now in circulation includes Craig Shergold (original wild type), Craig Sheford, Craig Shirgold, Craig Shelford, Craig Sherford, Craig Sheppard, Greg Sherold, and Greg Sherwood. The cards are still coming, in spite of repeated efforts by him and his family to stop them.

The point of the story is that no genes are involved, yet postal viruses display an entirely authentic epidemiology, including the successive waves of infection rolling around the world and including the evolution of new mutant strains of the original virus.

And the lesson for understanding religion, to repeat, is that when we ask the Darwinian question "What is the survival value of religion?" we don't have to mean genetic survival value. The conventional Darwinian question translates into "How does religion contribute to the survival and reproduction of individual religious people and hence the propagation of genetic propensities to religion?" But my point is that we don't need to bring genes into the calculation at all. There is at least something

Darwinian going on here, something epidemiological going on, which has nothing to do with genes. It is the religious ideas themselves that survive, or fail to survive, in direct competition with rival religious ideas.

It is at this point that I have an argument with some of my Darwinian colleagues. Purist evolutionary psychologists will come back at me and say something like this. Cultural epidemiology is possible only because human brains have certain evolved tendencies, and by evolved we mean genetically evolved. You may document a worldwide epidemic of reverse baseball hats, or an epidemic of copycat martyrdoms, or an epidemic of total-immersion baptisms. But these nongenetic epidemics depend upon the human tendency to imitate. And we ultimately need a Darwinian—by which they mean genetic—explanation for the human tendency to imitate.

And this, of course, is where I return to my theory of childhood gullibility. I stressed that it was only an example of the kind of theory I want to propose. Ordinary genetic selection sets up childhood brains with a tendency to believe their elders. Ordinary, straight-down-the-line Darwinian selection of genes sets up brains with a tendency to imitate, hence indirectly to spread rumours, spread urban legends, and believe cock-and-bull stories in chain letters. But *given* that genetic selection has set up brains of this kind, they then provide the equivalent of a new kind of nongenetic heredity, which might form the basis for a new kind of epidemiology, and perhaps even a new kind of nongenetic Darwinian selection. I believe that religion, along with chain letters and urban legends, is one of a group of phenomena explained by this kind of nongenetic epidemiology, with the possible admixture of nongenetic Darwinian selection. If I am right, religion has no survival value for individual human beings, nor for the benefit of their genes. The benefit, if there is any, is to religion itself.

## II. THE RELIGION OF SCIENCE

Carl Sagan, in his inspiring book *Pale Blue Dot*, wrote the following:

How is it that hardly any major religion has looked at science and concluded, "This is better than we thought! The Universe is much bigger than our prophets said, grander, more subtle, more elegant"? Instead they say, "No, no, no! My god is a little god, and I want him to stay that way." A religion, old or new, that stressed the magnificence of the Universe as revealed by modern science might be able to

draw forth reserves of reverence and awe hardly tapped by the conventional faiths. Sooner or later, such a religion will emerge.<sup>1</sup>

Sagan was often accused of scientism, defined by the *Oxford Dictionary* as “a term applied (freq. in a derogatory manner) to a belief in the omnipotence of scientific knowledge and techniques. . . .” Here are three of the usage specimens given by the dictionary:

Scientism, as a belief that science can furnish answers to all human problems, makes science a substitute for philosophy, religion, manners, and morals.

It really appeared to many educated people that at last all the secrets of the universe would be discovered and all the problems of human life solved. This superstition . . . we may call “Scientism.”

. . . scientism represents the same superstitious attitude which, in previous times, ascribed such power to a supernatural agency.

“Scientism” is one of those words, like “reductionism,” which is only ever uttered with a sneer. I am frequently accused of scientism myself; sometimes explicitly accused of elevating science to a religion—usually by the kind of person who thinks “elevate” is an appropriate verb to use.

In this lecture I shall vigorously forswear any suggestion that science is, or should be, a religion. But I’ll recognize at least enough commonality between them to feed a worthwhile debate. Science is *not* a religion, but it does some of the things over which religion once felt a certain *droit de seigneur*. Not morality, I must add. I shall not talk about morality at all today, mostly for lack of time.

Religions used to feed on the sense of rapt wonder that we associate with scientific writers such as Loren Eiseley, Lewis Thomas, and Carl Sagan himself. An Anglican clergyman, one of my teachers of whom I was fond, told me of the never-forgotten instant that triggered his own calling. As a boy, he was lying prone in a field, his face buried in the grass. He suddenly became preternaturally aware of the tangled stems and roots, as a whole new world—the world of ants and beetles and, though he may not have been aware of them, soil bacteria and other micro-organisms by the billions. At that moment, the micro-world of the soil seemed to swell and become one with the universe, and with the

1. Carl Sagan, *Pale Blue Dot* (London: Headline, 1995), p. 52.

soul of the boy contemplating them. He interpreted the experience in religious terms, and it eventually led him to the priesthood. But much the same mystic feeling is common among scientists. I am only one of many who have experienced it.

In his boyhood at least, my clergyman was unlikely to have known the closing lines of *On the Origin of Species*, the famous “entangled bank” passage, “with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth.” Had he read the passage, he would certainly have empathized with it and, instead of the priesthood, might have been led to Darwin’s view that all was “produced by laws acting around us.”<sup>2</sup>

Thus, from the war of nature, from famine and death, the most exalted object which we are capable of conceiving, namely, the production of the higher animals, directly follows. There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved.<sup>3</sup>

All Carl Sagan’s books and, I would like to hope, my own touch those nerve-endings of transcendent awe that religion, in past times, monopolised. For this reason, I often hear myself described as a deeply religious person. An American correspondent asked her professor whether he had a view about me. “Sure,” he replied. “He’s positive science is incompatible with religion, but he waxes ecstatic about nature and the universe. To me, that *is* religion!” But is “religion” the right word to use? I think not. Words are our servants, not our masters, but that’s no excuse for actively misleading people.

Much unfortunate misunderstanding is caused by failure to distinguish what might be called Einsteinian religion from supernatural religion. The last words of Stephen Hawking’s *A Brief History of Time*, “For then we should know the mind of God,” have notoriously misled people toward the misconception that Hawking is religious.<sup>4</sup> Ursula Goodenough’s *The Sacred Depths of Nature* clearly shows that she is a complete atheist. Yet she goes to church regularly, and there are numerous pas-

2. Charles Darwin, *On the Origin of Species* (London: John Murray, 1859), p. 489.

3. *Ibid.*, p. 490.

4. Stephen Hawking, *A Brief History of Time* (New York: Bantam Books, 1988).

sages in her book, and especially in the publisher's blurbs, that seem to be almost begging to be taken out of context and used as ammunition for supernaturalist religion. She calls herself a "religious naturalist."

The present astronomer royal, Sir Martin Rees, goes to church as an "unbelieving Anglican," out of "loyalty to the tribe." He has no supernatural beliefs but shares exactly the sense of wonder that the universe provokes in many of us. Plenty of intellectual atheists proudly call themselves Jews, and observe Jewish rites, mostly out of loyalty to an ancient tradition but also because of a muddled (in my view) willingness to label as "religion" the Einsteinian sense of wonder that many of us share. A large number of scientists who give the impression they are religious turn out to be religious only in the Einsteinian sense. What, then, was Einstein's religion?

One of Einstein's most quoted remarks is: "Science without religion is lame, religion without science is blind." But listen to the context in which that most eagerly repeated sentence appears. He characterises "religion" as

the faith in the possibility that the regulations valid for the world of existence are rational, that is, comprehensible to reason. I cannot conceive of a genuine scientist without that profound faith. The situation may be expressed by an image: science without religion is lame, religion without science is blind. . . . I must nevertheless qualify this assertion. . . .<sup>5</sup>

And Einstein goes on to make it very clear that he is using the word "religion" in a special sense that leaves no room at all for a personal God.

Einstein was obviously quite annoyed at the way religious apologists continually misused his name in their support. He wrote in a letter:

It was, of course, a lie what you read about my religious convictions, a lie which is being systematically repeated. I do not believe in a personal God and I have never denied this but have expressed it clearly. If something is in me which can be called religious then it is the unbounded admiration for the structure of the world so far as our science can reveal it.

5. Conference on Science, Philosophy and Religion in Their Relation to the Democratic Way of Life, *Science, Philosophy, and Religion: A Symposium* (New York, 1941).

Einstein said that his God was Spinoza's, and Spinoza believed that "neither intellect nor will appertain to God's nature."<sup>6</sup> "God's will" simply means the laws of nature. Here are some more quotations from Einstein, to give a flavour of Einsteinian religion.

I am a deeply religious nonbeliever. This is a somewhat new kind of religion.

I have never imputed to Nature a purpose or a goal, or anything that could be understood as anthropomorphic. What I see in Nature is a magnificent structure that we can comprehend only very imperfectly, and that must fill a thinking person with a feeling of humility. This is a genuinely religious feeling that has nothing to do with mysticism.

The idea of a personal God is quite alien to me and seems even naive.

Einstein, then, was certainly not a theist. He was repeatedly indignant at the suggestion. Was he a deist? Or a pantheist?

Let's remind ourselves of the terminology. A theist believes in a supernatural intelligence who does some combination of the following: answers prayers; forgives (or punishes) sins; frets about right and wrong, and knows when we do them (or even *think* them); intervenes in the world by performing miracles. A deist is one who believes in a supernatural intelligence whose activities are confined to setting up the laws that govern the universe in the first place. The deist God never intervenes thereafter. A pantheist uses the word "God" as a nonsupernatural synonym for Nature, or for the Universe, or for the lawfulness that governs the workings of the universe.

Deists differ from theists in that their God does not answer prayers, is not interested in sins or confessions, does not read our thoughts, and above all does not intervene with capricious miracles. Deists differ from pantheists in that the deist God is some kind of cosmic intelligence who set up the laws of the universe, rather than the pantheist's metaphoric or poetic *synonym* for the laws of the universe. Pantheism is sexed-up atheism. Deism is watered-down theism. The evidence agrees that Einstein was not a deist but a pantheist, and this is what I mean by Einsteinian religion. It is summarised in yet another quotation:

6. Max Jammer, *Einstein and Religion* (Princeton University Press, 1999), p. 44.

To sense that behind anything that can be experienced there is a something that our mind cannot grasp and whose beauty and sublimity reaches us only indirectly and as a feeble reflection, this is religiousness. In this sense I am religious.

In this sense, I too am religious.

There is every reason to think that famous Einsteinisms like “God is subtle but he is not malicious” and “He does not play dice” and “Did God have a choice in creating the Universe?” are not deistic, and certainly not theistic. “God does not play dice” should be translated as “Randomness does not lie at the heart of all things.” “Did God have a choice in creating the Universe?” means “Could the universe have begun in any other way than the way in which it did begin?” Einstein was using “God” here in a purely metaphorical, poetic sense. So is Stephen Hawking, and so are most of those physicists who occasionally slip into the language of religious metaphor. Paul Davies’s *The Mind of God* seems to hover somewhere between Einsteinian pantheism and an obscure form of deism—for which he was rewarded with the million-dollar Templeton Prize. And talking of the Templeton Prize, Dan Dennett said to me, “Richard, if ever you fall on hard times . . .”

Dennett, as you know, coined the useful distinction between cranes and skyhooks. Cranes are explanatory devices that actually do some explanatory work. Natural selection is the champion crane of all time. It has lifted life from primeval simplicity to the dizzy heights of complexity, beauty, and apparent design that we marvel at today. Skyhooks do no explanatory work and usually demand more explanation than they provide. This is why I don’t go along with those who find only a trivial difference between deism, which postulates a creative intelligence at the beginning of the universe, and pantheism, which doesn’t.

Creative intelligence is something that needs explaining in its own right. Darwinian evolution provides an explanation—the only workable explanation so far suggested—for the existence of intelligence. Creative intelligence comes into the world *late*, as the derived product of a long process of gradual change: the slow evolution of nervous systems, or some other kind of computational machinery (which may be secondarily designed by evolved nervous systems). In this respect, deism is as bad as theism: creative intelligence had some sort of prior existence and is responsible for designing the universe, with the laws and constants that eventually, through evolution, brought into being our kind of creative intelligence. This wasteful and unparsimonious view is radically different

from the Einsteinian use of God as a poetic synonym for the laws of the universe. A universe that begins with creative intelligence is a very different kind of universe from a universe in which creative intelligence is *explained* as emerging after millions of years of evolution.

In the Einsteinian sense I am religious. But I prefer not to call myself religious because I think it is misleading. It is misleading because, for the vast majority of people, “religion” implies supernaturalism. For the same reason, I would have preferred it if physicists such as Einstein, Hawking, and others would refrain from using the word “God” in their special physicists’ metaphorical sense. The metaphorical God of the physicists is light-years away from the interventionist, miracle-wreaking, thought-reading, sin-punishing, prayer-answering God of the theists and of ordinary language. Deliberately to confuse the two is, in my opinion, an act of intellectual high treason.

From now on, unless otherwise stated, when I speak of religion in this lecture it will be theistic, supernaturalist religion, as understood and practised by the vast majority of people who call themselves religious.

Theistic religions have traditionally offered answers to questions that today we hand over to science: questions of cosmology and biology, which are nowadays answered by, for example, the Big Bang theory and the theory of evolution. What has happened today is that sophisticated theologians wisely abandon *explanation*—which religion does badly—to science, which does it well. Instead, theology concentrates on topics like morality and guidance for life. Science doesn’t pretend to do morality, and it doesn’t do it well. It is by no means clear that religion does it well either. Indeed, I think a powerful case for the opposite can be made, but that is not my topic here.

Today’s theological sophists insist that religion and science do not compete because they are not directly comparable. They occupy non-communicating realms, nonoverlapping magisteria. Science explores the way the universe is, and how things work. Religion has nothing to say on this, but it has its own equally important domain: morals, values, and “ultimate” questions.

Others try to sum it up as: “Science is concerned with ‘how questions,’ religion with ‘why questions.’” There is something maddening about the complacent silliness of assuming, without further discussion, that “why” questions have some sort of universal, ultimate legitimacy.

To begin with a relatively trivial point, there are unequivocally scientific questions in which everyone happily uses the word “why”: Why is the sky blue? Why does hot air rise? Why are predators rarer than their



prey? Even in the sense of “what is the purpose of...?” “why” can be translated into scientific terms. In my previous lecture I asked why birds ant and offered the answer: “To delouse their feathers.” The respectable Darwinian translation is implicit: “Ancestral birds with a genetic tendency to ant had more offspring because they were less likely to suffer from louse-borne diseases.”

“What is the purpose of a boomerang?” invites a very different kind of answer, in terms of the deliberate intentions of the designer or of the user. It is because deliberate purpose sits so prominently at the forefront of human consciousness that some find creationist explanations of the natural world appealing. I suspect that this may also supply the explanation for our having to wait till the nineteenth century for a Darwin to solve a problem that, with hindsight, seems easier than the hard problems solved two centuries earlier by Newton and Galileo, and two millennia earlier by Archimedes and Pythagoras.

“What is the purpose of a light bulb?”; “What is the purpose of a firefly’s luminescent organ?”; and “What is the purpose of the sun?” sound superficially similar. They are utterly different. The first invites an answer in terms of human intention, the second in terms of Darwinian natural selection. The third deserves no answer at all in my opinion, but, within the framework of a religion, it can be treated as a special case of the light-bulb question, where the deliberate intention is that of a divine rather than a mortal person. In this case the answer might be: “The purpose of the sun is to give us warmth, to enable us to see, and to sustain plant life so we can eat.”

Science would not so much deny the answer as deny the legitimacy of ever asking the question in the first place. The mere fact that it is possible to frame a question in the English language doesn’t make it legitimate. “What is the purpose of the sun?” is no more legitimate than “What is the colour of jealousy?” In poetic vein, we might say green is the colour of jealousy and red the colour of anger, but poetry moves us into a different realm, the realm of neither religion nor science.

Setting aside questions that science ignores or rejects, like the colour of jealousy or the purpose of the sun, are there any deep and important questions that science cannot answer? Of course there are many that science cannot *yet* answer. But are there any that science in principle can never answer? Very possibly. We don’t know. An example might be: “Where did the laws and fundamental constants of physics come from?” But if science cannot answer such questions, that emphatically doesn’t mean that any other discipline—for example, religion—can.

I have previously quoted a conversation I had with the professor (i.e., chairman) of astrophysics at Oxford. I asked him to explain the Big Bang to me and he did so, rather well. I went on: "Then where did the fundamental laws and constants of physics come from in the first place?" "Ah," he said with a smile, "Now we move beyond the realm of science. This is where I have to hand over to our good friend the chaplain." But, I was tempted to reply, why the chaplain?... Why not the gardener or the chef?

There are some profoundly difficult questions about the origin of the universe, about the origin of physical law and fundamental constants, about the curvature of space-time, about the paradoxical behaviour of quanta, and about the nature of consciousness. It may be that humanity will never reach the quietus of complete understanding. But *if* we do, I venture the confident prediction that it will be science, not religion, that brings us there. And if that sounds like scientism, so much the better for scientism.

I am anxious not to be misunderstood, so let me stress again that I am *not* expressing confidence that humanity *will* succeed in answering the deep questions of existence. But in the (possibly unlikely) event that we *do* succeed, I am very confident that it is more likely to be through scientific than religious ways of thinking. However unlikely it may be that science will one day understand everything about the cosmos and the nature of life, it is even less likely that religion will.

The flip side of "two separate magisteria" is the claim that religion "keeps off science's patch." Religion is supposed to confine itself to its proper domain—whatever that might be—leaving to science questions of how the world works. That way, science and religion can coexist in a respectful, even "loving," to quote Steve Gould, concordat. In practice, however, religion seldom respects science's patch and is normally to be found trampling—if nowadays rather sheepishly—all over it.

Pope John Paul II recently gained kudos in the scientific community by coming down, firmly and unequivocally, in favour of evolution. This seems a clear case of respecting science's patch. Yet at the same time the pope's church, with his encouragement, promotes a whole range of doctrines that simply are scientific claims. Jesus lacked a human father. He walked three days after his death. God intervenes at crucial moments in evolution. God intervenes in human affairs to save particular individuals from disease. Mary's body went physically to heaven, with no trace of it remaining on earth. This last one is especially notable since it implies

that heaven is a physical place, a scientific claim if ever there was one. It was promulgated by Pope Pius XII as recently as 1950.

All miracle stories are about alleged facts that fall clearly in the domain of science. Miracles are the subject of a double standard that is certainly patronising and arguably duplicitous. Sophisticated theologians dismiss miracles as of no importance, quaint stories, perhaps with symbolic or allegorical significance. To ask whether they are literally true is naïve, simplistic, missing the point. Who would be so insensitive, so reductionist, so *scientific* even, as to ask whether the Miracle of Lourdes, or the Apparition of Fatima, or the stigmata of Padre Pio really happened?

That's what theologians say when they are talking to scientists, or to the sort of educated audience that would attend a Tanner Lecture. You would think there is no conflict with science, no wayward straying from magisterium to magisterium! But seek out the pilgrims who flock to Lourdes or St. Peter's Square, Fatima or Medjugorje, and ask them whether they believe miracles really happen, literally. We all know what their answer will be. *Of course* they believe it, not as some watered-down symbolic allegory—by which they'd feel short-changed—but as literal truth. And they are encouraged to do so by bishops and archbishops, whatever those prelates may say when talking to scientists or other educated audiences.

Far from religion keeping off science's turf, it is precisely the apparent scientific content of miracles that attracts people into churches and mosques. It is only when these stories are challenged on scientific grounds that apologists scuttle for cover behind the wall of "separate magisteria." But you cannot have it both ways. Priests should either come out fighting for their miracles, admitting the corollary that they are trampling on science's territory—and good luck to them—or they should take "separate magisteria" seriously and honestly admit that miracles don't literally happen—in which case, just watch those congregations melt away.

This is one reason—there aren't many—for respecting fundamentalist creationists. At least they are honest and consistent about what they believe: unlike sophisticated theologians who say one thing for the academy and something very different for the congregation.

Before leaving miracles, I need to make an important qualification. An alleged event that violates the expectations of *existing* science should not be treated as a miracle. Never forget (Arthur C.) Clarke's Third

Law: “Any sufficiently advanced technology is indistinguishable from magic.”<sup>7</sup> Radio is not a miracle, but it would certainly have seemed so in the Middle Ages. Religious miracles, however, are not sold to congregations as exploiting as-yet-undiscovered scientific principles. Nobody is suggesting that Mother Teresa’s medallion (the healing power of which was the “miracle” needed to justify her beatification) generated a force field hitherto unknown to physics, a field that, one day, science will make available to everybody. No, the church’s claim is precisely that a miracle is a one-off violation of the laws of physics, which God, because he made those laws, can break when he chooses, for example, to signal that Mother Teresa should be a saint. Miracles are capricious, singular departures from normality. This is emphatically not keeping off science’s turf; *not separate magisteria*.

Scientific journals like the *Quarterly Review of Biology* occasionally devote a whole issue to one particular question. One could imagine a symposium issue devoted to why the dinosaurs went extinct, with papers devoted to different theories or lines of evidence. Scientists often disagree, and they can even become acrimonious. But, though disagreements might figure in our symposium issue of the journal, the authors will at least agree on what it would take to make them change their minds: evidence. If they disagree today, it is because the evidence is so far incomplete.

But imagine that science worked in a very different way. Suppose the contents list of our Symposium Issue of the *Quarterly Review of Biology* looked like the one in Figure 3:

The first item on the list is a typical scientific paper. I don’t think any reasonable person could deny that the rest of the list constitutes a fair satire on how religions typically support their beliefs.

How do we know what to *believe*? My *Quarterly Review* satire signals five partially overlapping types of answer to the question. Four of them come from religion, only one from science.

1. Evidence. The facts support X.
2. Tradition. Our people have always believed X.
3. Authority. My Holy Book (or priest) says X.
4. Faith. I just *know* X in my bones.
5. Revelation. An inner voice tells me X.

7. “Hazards of Prophecy: The Failure of Imagination,” in *Profiles of the Future: An Inquiry into the Limits of the Possible* (New York: Harper and Row, 1973).

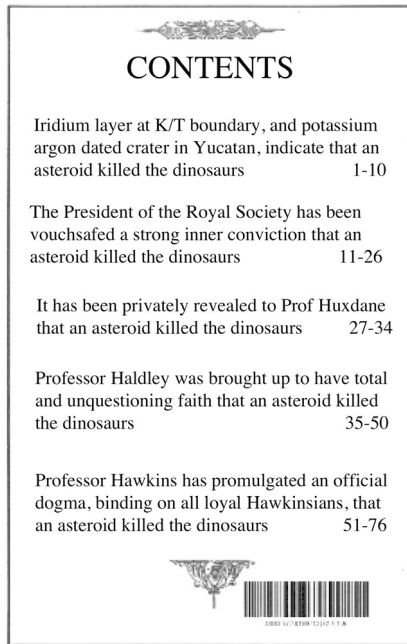


FIGURE 3.

First, evidence. Scientists believe X because we have seen evidence for it. Philosophers may turn this around: the X hypothesis has withstood strenuous attempts to falsify it. But I am not concerned with such refinements. It still counts as evidence, even if technically all our beliefs are on probation. Nor shall I lose any time on fashionable claims that science is just the white, Western, patriarchal view of truth. Science works. That is why when you go to an international conference on cultural relativism you go by Boeing 747 rather than by magic carpet.

Let me list just a tiny sample of what we know, or have very strong reason to believe, through evidence-based science. Our universe began at a particular time, more than ten billion and less than twenty billion years ago, and has been expanding ever since. Much of the mass in the universe is agglomerated in stars, spherical nuclear furnaces in which the ninety-two naturally occurring elements are being formed. Earth is between four and five billion years old. Its surface is not static but composed of movable plates on which the visible continents sit. We know approximately the shape of the map of the world at any given date in the past, and it looks increasingly unfamiliar the farther back we go. Life has been a major feature of earth's surface layers for at least the last half of the

planet's existence, probably more. All known life is descended from a common ancestor, which shared the same highly specific digital genetic code. We know the code precisely, know how it is translated word for word, and have an approximate idea of how bodily form emerges as a result. Ancestral forms change gradually and divergently into descendant life forms over millions of years, the process being guided in functional directions by the nonrandom survival of random variations in genetically coded information. We now have the means to know, if only we had the time and the money to grind it out, the entire family tree relating every living species to every other living species. And we have the means to estimate the date of each branch point in millions, or tens of millions, of years. The list of things we know as a result of scientific evidence is formidably large.

As for what we know as a result of religious evidence, the less said the better. Miracles, as we have seen, are a source of embarrassment to educated theologians, although they are helpful in recruiting congregations. The other kind of evidence adduced by religious apologists is that presented by "scientific creationists," nowadays euphemistically disguised as "intelligent design theorists." Obviously at Harvard there is no need to waste time on them, and I shall pass straight on to the second of my list of five grounds for belief: tradition.

One of the most striking features of religion is that it runs in families. This country, like my own, has many Christians and Jews. If we lived in Pakistan or India we'd be worshipping Allah or the Hindu pantheon of hundreds of gods. If we'd been brought up in ancient Greece, we'd be worshipping Zeus and Apollo. If Vikings, Wotan and Thor. Out of hundreds of possible religions, the vast majority of people just happen to end up in the same religion as their parents. And isn't it a remarkable coincidence: whichever religion you are brought up in, it always turns out to be the right religion.

We are all familiar with those maps of the world, colour-shaded to denote predominant language. Atlases use the same kind of colour-coding to designate predominant religion. Since religions hold contradictory beliefs about important truths, it is as if those truths depended upon the geographical location of the believer. We have become so accustomed to this that it doesn't seem strange. It is exactly what you would expect from the theory of religion that I tried to outline yesterday. To get an idea of how preposterous it is, imagine that the colours on the map are coded for areas where the local population favours different theories of how the dinosaurs went extinct. Imagine that science worked in such

a way. But science, on the contrary, is international. Scientists in different countries look at the same evidence and, if the evidence is strong enough, will all eventually come to the same conclusion. It may not always quite work out like that, but that is the ideal to which all scientists aspire.<sup>8</sup>

Tradition is almost wholly absent from science. To a small extent, dynasties of scientists can be discerned: scientists occasionally appear to inherit the opinions, or the approach to science, of their professor, or even their grand-professor or great-grand-professor. But it is only a minor effect, given far less weight than evidence, which is available to all. Similarly, there is some slight tendency for scientists from different parts of the world to follow different national approaches. But such regionalism is again negligible compared to the universalism of science. And all scientists subscribe to the *ideal* of universal cross-culturalism of science. Confronted with the same strong evidence, an Indian scientist, an American scientist, and a Japanese scientist will come to the same conclusion.

I shall leave tradition there and switch to the next item on the list of reasons for believing things: authority. Authority in religion is of two kinds, scriptural and priestly authority, and both are only too familiar. But just imagine if science worked in the same way: "*On the Origin of Species* is the inspired word of the Prophet Darwin. No word of it can possibly be mistaken. All Darwinian children must learn to recite it by heart, nodding their little heads backward and forward as they do so." Just imagine if biologists, instead of going out into the field and doing research on seagulls or antelopes or dandelions, spent their time locked in argument about exactly what Darwin meant in chapter 6, line 32. Or, worse, exactly what some learned exegete meant in his *interpretation* of Darwin's inspired words. There is no need to continue. The point is made.

The doctrine of papal infallibility and the fatwa on Salman Rushdie are only extreme examples of the power of priestly authority. There is no doubt that Salman Rushdie was, and perhaps still is, in real physical

8. I cannot resist an anecdote at the expense of certain schools of social science. An undergraduate student close to me is studying at a British university (not my own). Her degree subject is Human Science, which is a mixture of science and social science. She loves the science but hates the social science because its teachers are avowedly antiscientific and anti-Darwinian. She told me that one lecturer in anthropology even went so far as to say that the beauty of anthropology, as opposed to science, is that when two anthropologists look at the same evidence they come to opposite conclusions. I hasten to add that this was his personal opinion, not necessarily typical of all anthropologists. But you can imagine how discouraging such nihilistic nonsense is to a young aspiring scholar.

danger because of priestly authority. In Iran, on July 21, 1998, Ruhollah Rowhani, a 52-year-old man with four children, was hanged for allegedly converting a Muslim woman to the Bahai faith. On August 18, 2001, Dr. Younus Shaikh, a Pakistani medical doctor, was sentenced to death for speculating, in front of students who subsequently reported him to the religious authorities, that the Prophet Muhammad might not have been a Muslim before he invented the religion at the age of forty.<sup>9</sup> Just imagine if science worked like *that*.

To be fair, scientists, too, sometimes argue by authority, but it is not something we are proud of. It happens in spite of scientific principles, not in pursuit of them. William Thomson, Lord Kelvin, was one of the fathers of thermodynamics and among the leading physicists of the nineteenth century. His authoritative thermodynamic calculation that the age of the earth did not allow enough time for evolution was a thorn in the side of Darwin, who, sadly, didn't live long enough to see his own vindication by the discovery of radioactivity. Kelvin wielded his authority not only as one of the most eminent physicists of the age but also on behalf of physics itself, which was, and still is, respected as senior to biology or geology. Kelvin, in effect, said that physics didn't allow enough time for evolution, so Darwin's biology must be wrong. Darwin could have retorted—but didn't—that biology demonstrates that evolution is a fact, so Kelvin's physics must be wrong. The following authoritative opinions are also attributed to Lord Kelvin. Radio has no future. Heavier-than-air flying machines are impossible. X-rays will prove to be a hoax.

There is a defensible version of the argument from authority. It is like betting on a horse on the recommendation of a reliable tipster: "John Maynard Smith has an excellent track record. He has been right so many times in the past that, if he supports a theory, you would be wise to take it seriously." There is nothing wrong with this kind of argument, so long as it is used only as a guide to which hypotheses are likely to be worth testing. Argument from authority is *never* used by scientists as evidence that something in the world of nature must be the case. It routinely is used in exactly this way in religion.

Let me move on from authority to faith. Faith means believing something in spite of lack of evidence. In religion, faith is a virtue. Religious people gain special kudos if they steadfastly believe, in the teeth of evi-

9. Happily, after an international outcry and strong representations to the Pakistan government, Dr. Shaikh has now been released.



dence to the contrary. Doubting Thomas, the patron saint of scientists, who wanted evidence of the resurrection of Jesus, is held up to us as less virtuous than the other disciples whose faith was strong enough to need none.

Tertullian said *Certum est quia impossibile est* (it is certain because it is impossible). In the seventeenth century, when dying for one's faith was as common in Christian circles as it is in Islam today, Sir Thomas Browne said: "I *desire* to exercise my faith in the difficultest point; for to credit ordinary and visible objects is not faith, but perswasion." And he lamented: "Methinks there be not impossibilities enough in religion for an active faith."<sup>10</sup> Faith in the teeth of evidence was satirised in Douglas Adams's Electric Monk, a labour-saving device that you could buy to do your believing for you. It was advertised as "capable of believing things they wouldn't believe in Salt Lake City."<sup>11</sup> When we first encounter the Electric Monk, on a horse, it believes, in the teeth of all the evidence, that the whole world is bright pink.

What about faith in science? Again, it happens. And again, it is treated with suspicion. The astronomer Sir Arthur Eddington used the solar eclipse of 1919 to test General Relativity's prediction that light from the stars would be bent as it passed close to the sun. Eddington's measurements brilliantly vindicated the prediction and turned Einstein into a worldwide celebrity. But Einstein himself was insouciant. Any other result and... "I would have felt sorry for the dear Lord. The theory is correct."<sup>12</sup> Scientific ears hear that with a *frisson* of naughtiness. Such faith, presumably based on aesthetic elegance, does smack of religion. Luckily, Einstein was right. The evidence did support him, and it continues to do so.

There are indeed physicists whose faith in the aesthetic beauty of their equations would lead them to mistrust contrary evidence from experiment. But if repeated experiments persistently told the same story they would, however reluctantly, climb down. Experimental evidence ultimately trumps mathematical beauty, in what T. H. Huxley lamented as: "The great tragedy of science—the slaying of a beautiful hypothesis by an ugly fact."<sup>13</sup> Einstein also, as we have seen, wrote of "faith in the

10. *Religio Medici*, section 9.

11. *Dirk Gently's Holistic Detective Agency* (New York: Simon and Schuster, 1987).

12. Max Jammer, *Einstein and Religion* (Princeton: Princeton University Press, 2002), p. 53.

13. *Oxford Dictionary of Quotations*, 4th ed., ed. Angela Partington (Oxford: Oxford University Press, 1992), p. 358.

possibility that the regulations valid for the world of existence are rational, that is, comprehensible to reason,"<sup>14</sup> and he added that he could not conceive of a genuine scientist without that profound faith. I can't either.

The same Sir Arthur Eddington sounded superficially as though he was expressing blind faith in the Second Law of Thermodynamics when he said:

If someone points out to you that your pet theory of the universe is in disagreement with Maxwell's equations—then so much the worse for Maxwell's equations. If it is found to be contradicted by observation—well, these experimentalists do bungle things sometimes. But if your theory is found to be against the second law of thermodynamics I can give you no hope; there is nothing for it but to collapse in deepest humiliation.<sup>15</sup>

Eddington's advice could, in effect, be reworded in the form of an instruction to a patent inspector (such as, now that I think about it, Einstein himself). If an inventor tries to patent a perpetual motion machine, Eddington was in effect saying, don't even bother to look at his drawings. Don't waste your time working through his calculations. You know, without even looking, that his idea cannot work.

A more commonplace type of faith in science arises because no one individual has the time or the ability to check the evidence. I believe what physicists tell me about the speed of light, and I believe what geology textbooks tell me about plate tectonics, even though I haven't examined the evidence myself. I believe it because I know how the system of peer review works. I know that a result that is sufficiently earth-shaking (metaphorically or literally) will have been repeated by other groups of scientists, checked and rechecked by sceptical experts who could, if I sought them out, explain the details to me.

I know that bad science is sometimes done, and even fraudulent science. A scientist who is detected in fraud is drummed out of the profession. Unfortunately, because fiddling data is such a heinous offence in scientific eyes, scientists are extremely averse to suspecting it in colleagues, whistle-blowers are given a hard time, and the result is that some fraud gets through. But the procedure of science is such that it will

14. Conference on Science, Philosophy and Religion in Their Relation to the Democratic Way of Life, *Science, Philosophy, and Religion: A Symposium*.

15. *The Nature of the Physical World* (New York: Macmillan, 1948), p. 74.

eventually be detected, at least if the fraudulent finding is important enough to arouse attention. And if it is not important, well, perhaps we can regretfully live with it. The point is that a scientist caught falsifying data would be disgraced for life. The same cannot be said even of the *aspirations* of certain other professions, let alone the practice.<sup>16</sup>

To repeat, scientists have faith in secondhand evidence because nobody has the time or the ability to check it all personally. The culture of science relies heavily upon honesty. The honesty is proximally policed by the peer review system, and ultimately by the universally accepted knowledge that the entire enterprise of science would be pointless if scientists fiddled their data.

Scientists often use faith to guide them in deciding what theories are likely to be worth testing. But finally, those theories have to be tested. Scientists have faith of a kind, but it is not blind faith, it is faith shored up by evidence, and by a culture of scepticism and honesty.

Finally, revelation. In religion, private, internal revelation is treated as a reason for belief in something. I have already mentioned the doctrine of the Assumption of the body of Mary into heaven. A Dark-Age legend grew into a mediaeval tradition, but it was finally made into a doctrine of the Roman Catholic Church only when, as late as 1950, its truth was revealed to Pope Pius XII. “We pronounce, declare and define it to be a divinely revealed dogma: that the Immaculate Mother of God, the ever Virgin Mary having completed the course of her earthly life, was assumed body and soul to heavenly glory.”<sup>17</sup>

This kind of revelation really doesn’t happen in science. The nearest approach is the kind of aesthetic, poetic affirmations that scientists, especially physicists as we have seen, sometimes make. A lovely example is from the great American physicist John Archibald Wheeler: “. . .we will grasp the central idea of it all as so simple, so beautiful, so compelling

16. Scientists are not like trial lawyers, paid to advocate a particular point of view as strongly as possible, whether they believe it or not, confident in the knowledge that somebody else is paid to advocate the opposite. Here too, individual scientists sometimes lapse, but, yet again, this is reprehended by the scientific community. It is foreign to the culture of science, even if it sometimes happens. With lawyers, it is positively admired. John Mortimer, famous English lawyer and raconteur, tells humorous stories of adversarial tactics. One respected old advocate used to blow up an inflatable cushion to distract the jury, just when his opponent was reaching the climax of his eloquence. Even if this didn’t happen in fact, it is close enough to legal culture to be regarded as funny. Lawyers laugh at Mortimer’s old lawyer with affection, not horror at the possible injustice meted out by the distracted jury. Advocacy is foreign to the culture of science, and is reproved when it surfaces.

17. *Munificentissimus Deus: Apostolic Constitution of Pope Pius XII Defining Dogma of the Assumption*, November 1, 1950.

that we will say to each other, ‘Oh, how could it have been otherwise! How could we all have been so blind for so long!’”<sup>18</sup>

Or listen to the great Indian astrophysicist Subrahmanyan Chandrasekhar (1910–95):

This “shuddering before the beautiful,” this incredible fact that a discovery motivated by a search after the beautiful in mathematics should find its exact replica in Nature, persuades me to say that beauty is that to which the human mind responds at its deepest and most profound.<sup>19</sup>

The relationship of beauty to truth constantly recurs in physics. Isaac Newton himself, in one of his occasional moments of modesty, referred to it:

I don’t know what I may seem to the world, but as to myself, I seem to have been only like a boy playing on the sea-shore and diverting myself in now and then finding a smoother pebble or a prettier shell, whilst the great ocean of truth lay all undiscovered before me.<sup>20</sup>

And of course we again can’t leave out the greatest physicist since Newton: “The most beautiful thing we can experience is the mysterious. It is the source of all true art and science.”<sup>21</sup> This brings us full circle.

And to my conclusion. Science is not a religion. It is much more than a religion. It has all the virtues that religion once had, with none of the vices that religion still has. And all this with no mention of its usefulness. Great as it undoubtedly is, the usefulness of science is trivial compared with its power to inspire and uplift the spirit.

18. “How Come the Quantum?” *Annals of the New York Academy of Sciences* 480 (1986): 304.

19. *Truth and Beauty: Aesthetics and Motivations in Science* (Chicago: University of Chicago Press, 1987), p. 54.

20. David Brewster, *Memoirs of the Life, Writings, and Discoveries of Sir Isaac Newton* (Johnson Reprint Corp., June 1955).

21. “The World As I See It,” *Forum and Century* 84 (1929): 193–94.