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The Evolution of Everything

How New Ideas Emerge

Written by Matt Ridley

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The Evolution of Everything

How New Ideas Emerge

MATT RIDLEY

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PROLOGUE
The General Theory of Evolution

The word 'evolution' originally means 'unfolding'. Evolution is a story, a narrative of how things change. It is a word freighted with many other meanings, of particular kinds of change. It implies the emergence of something from something else. It has come to carry a connotation of incremental and gradual change, the opposite of sudden revolution. It is both spontaneous and inexorable. It suggests cumulative change from simple beginnings. It brings the implication of change that comes from within, rather than being directed from without. It also usually implies change that has no goal, but is open-minded about where it ends up. And it has of course acquired the very specific meaning of genetic descent with modification over the generations in biological creatures through the mechanism of natural selection.

This book argues that evolution is happening all around us. It is the best way of understanding how the human world changes, as well as the natural world. Change in human institutions, artefacts and habits is incremental, inexorable and inevitable. It follows a narrative, going from one stage to the next; it creeps rather than jumps; it has its own spontaneous momentum, rather than being driven from outside; it has no goal or end in mind; and it largely happens by trial and error – a version of natural selection. Take, for example, electric light. When an obscure engineer named Thomas Newcomen in 1712 hit upon

the first practical method of turning heat into work, he could have had no notion that the basic principle behind his invention – the expansion of water when boiled to make steam – would eventually result, via innumerable small steps, in machines that generate electricity to provide artificial light: heat to work to light. The change from incandescent to fluorescent and next to LED light is still unfolding. The sequence of events was and is evolutionary.

My argument will be that in all these senses, evolution is far more common, and far more influential, than most people recognise. It is not confined to genetic systems, but explains the way that virtually all of human culture changes: from morality to technology, from money to religion. The way in which these streams of human culture flow is gradual, incremental, undirected, emergent and driven by natural selection among competing ideas. People are the victims, more often than the perpetrators, of unintended change. And though it has no goal in mind, cultural evolution none the less produces functional and ingenious solutions to problems – what biologists call adaptation. In the case of the forms and behaviours of animals and plants, we find this apparent purposefulness hard to explain without imputing deliberate design. How can it not be that the eye was designed for seeing? In the same way, we assume that when we find human culture being well adapted to solve human problems, we tend to assume that this is because some clever person designed it with that end in mind. So we tend to give too much credit to whichever clever person is standing nearby at the right moment.

The way that human history is taught can therefore mislead, because it places far too much emphasis on design, direction and planning, and far too little on evolution. Thus, it seems that generals win battles; politicians run countries; scientists discover truths; artists create genres; inventors make breakthroughs; teachers shape minds; philosophers change minds; priests teach morality; businessmen lead businesses; conspirators cause crises;

gods make morality. Not just individuals, but institutions too: Goldman Sachs, the Communist Party, the Catholic Church, Al Qaeda – these are said to shape the world.

That's the way I was taught. I now think it is more often wrong than right. Individuals can make a difference, of course, and so can political parties or big companies. Leadership still matters. But if there is one dominant myth about the world, one huge mistake we all make, one blind spot, it is that we all go around assuming the world is much more of a planned place than it is. As a result, again and again we mistake cause for effect; we blame the sailing boat for the wind, or credit the bystander with causing the event. A battle is won, so a general must have won it (not the malaria epidemic that debilitated the enemy army); a child learns, so a teacher must have taught her (not the books, peers and curiosity that the teacher helped her find); a species is saved, so a conservationist must have saved it (not the invention of fertiliser which cut the amount of land needed to feed the population); an invention is made, so an inventor must have invented it (not the inexorable, inevitable ripeness of the next technological step); a crisis occurs, so we see a conspiracy (and not a cock-up). We describe the world as if people and institutions were always in charge, when often they are not. As Nassim Taleb remarks in his book *Antifragile*, in a complex world the very notion of 'cause' is suspect: 'another reason to ignore newspapers with their constant supply of causes for things'.

Taleb is brutally dismissive of what he mockingly calls the Soviet-Harvard illusion, which he defines as lecturing birds on flight and thinking that the lecture caused their skill at flying. Adam Smith was no less rude about what he called the man of system, who imagines 'that he can arrange the different members of a great society with as much ease as the hand arranges the different pieces upon a chess-board', without considering that on the great chessboard of human society, the pieces have a motion of their own.

To use a word coined by Abraham Lincoln, I hope gradually to 'disenthrall' you over the course of this book, from the obsession with human intentionality, design and planning. I want to do for every aspect of the human world a little bit of what Charles Darwin did for biology, and get you to see past the illusion of design, to see the emergent, unplanned, inexorable and beautiful process of change that lies underneath.

I have often noticed that human beings are surprisingly bad at explaining their own world. If an anthropologist from Alpha Centauri were to arrive here and ask some penetrating questions, he would get no good answers. Why is the homicide rate falling all around the world? Criminologists cannot agree. Why is global average income more than ten times what it was in the nineteenth century? Economic historians are divided. Why did some Africans start to invent cumulative technology and civilisation around 200,000 years ago? Anthropologists do not know. How does the world economy work? Economists pretend to explain, but they cannot really do so in any detail.

These phenomena belong in a strange category, first defined in 1767 by a Scottish army chaplain by the name of Adam Ferguson: they are the result of human action, but not of human design. They are *evolutionary* phenomena, in the original meaning of the word – they unfold. And evolutionary phenomena such as these are everywhere and in everything. Yet we fail to recognise this category. Our language and our thought divide the world into two kinds of things – those designed and made by people, and natural phenomena with no order or function. The economist Russ Roberts once pointed out that we have no word to encompass such phenomena. The umbrella that keeps you dry in a shower of rain is the result of both human action and human design, whereas the rainstorm that soaks you when you forget it is neither. But what about the system that enables a local shop to sell you an umbrella, or the word umbrella itself, or the etiquette that demands that you tilt your umbrella to one side to let another pedestrian pass? These – markets, language,

customs – are man-made things. But none of them is designed by a human being. They all emerged unplanned.

We transfer this thinking back into our understanding of the natural world too. We see purposeful design in nature, rather than emergent evolution. We look for hierarchy in the genome, for a 'self' in the brain, and for free will in the mind. We latch on to any excuse to blame an extreme weather event on human agency – whether witchdoctoring or man-made global warming.

Far more than we like to admit, the world is to a remarkable extent a self-organising, self-changing place. Patterns emerge, trends evolve. Skeins of geese form Vs in the sky without meaning to, termites build cathedrals without architects, bees make hexagonal honeycombs without instruction, brains take shape without brain-makers, learning can happen without teaching, political events are shaped by history rather than vice versa. The genome has no master gene, the brain has no command centre, the English language has no director, the economy has no chief executive, society has no president, the common law has no chief justice, the climate has no control knob, history has no five-star general.

In society, people are the victims and even the immediate agents of change, but more often than not the causes are elsewhere – they are emergent, collective, inexorable forces. The most powerful of these inexorable forces is biological evolution by natural selection itself, but there are other, simpler forms of evolutionary, unplanned change. Indeed, to borrow a phrase from a theorist of innovation, Richard Webb, Darwinism is the 'special theory of evolution'; there's a general theory of evolution too, and it applies to much more than biology. It applies to society, money, technology, language, law, culture, music, violence, history, education, politics, God, morality. The general theory says that things do not stay the same; they change gradually but inexorably; they show 'path dependence'; they show descent with modification; they show trial and error; they show selective persistence. And human beings none the less take credit

for this process of endogenous change as if it was directed from above.

This truth continues to elude most intellectuals on the left as well as the right, who remain in effect 'creationists'. The obsession with which those on the right resist Charles Darwin's insight – that the complexity of nature does not imply a designer – matches the obsession with which those on the left resist Adam Smith's insight – that the complexity of society does not imply a planner. In the pages that follow, I shall take on this creationism in all its forms.

1

The Evolution of the Universe

> If you possess a firm grasp of these tenets, you will see
> That Nature, rid of harsh taskmasters, all at once is free
> And everything she does, does on her own, so that gods play
> No part . . .
>
> Lucretius, *De Rerum Natura*, Book 2, lines 1090–3

A 'skyhook' is an imaginary device for hanging an object from the sky. The word originated in a sarcastic remark by a frustrated pilot of a reconnaissance plane in the First World War, when told to stay in the same place for an hour: 'This machine is not fitted with skyhooks,' he replied. The philosopher Daniel Dennett used the skyhook as a metaphor for the argument that life shows evidence of an intelligent designer. He contrasted skyhooks with cranes – the first impose a solution, explanation or plan on the world from on high; the second allow solutions, explanations or patterns to emerge from the ground up, as natural selection does.

The history of Western thought is dominated by skyhooks, by devices for explaining the world as the outcome of design and planning. Plato said that society worked by imitating a designed cosmic order, a belief in which should be coercively enforced.

Aristotle said that you should look for inherent principles of intentionality and development – souls – within matter. Homer said gods decided the outcome of battles. St Paul said that you should behave morally because Jesus told you so. Mohamed said you should obey God's word as transmitted through the Koran. Luther said that your fate was in God's hands. Hobbes said that social order came from a monarch, or what he called 'Leviathan' – the state. Kant said morality transcended human experience. Nietzsche said that strong leaders made for good societies. Marx said that the state was the means of delivering economic and social progress. Again and again, we have told ourselves that there is a top–down description of the world, and a top–down prescription by which we should live.

But there is another stream of thought that has tried and usually failed to break through. Perhaps its earliest exponent was Epicurus, a Greek philosopher about whom we know very little. From what later writers said about his writings, we know that he was born in 341 BC and thought (as far as we can tell) that the physical world, the living world, human society and the morality by which we live all emerged as spontaneous phenomena, requiring no divine intervention nor a benign monarch or nanny state to explain them. As interpreted by his followers, Epicurus believed, following another Greek philosopher, Democritus, that the world consisted not of lots of special substances including spirits and humours, but simply of two kinds of thing: voids and atoms. Everything, said Epicurus, is made of invisibly small and indestructible atoms, separated by voids; the atoms obey the laws of nature and every phenomenon is the result of natural causes. This was a startlingly prescient conclusion for the fourth century BC.

Unfortunately Epicurus's writings did not survive. But three hundred years later, his ideas were revived and explored in a lengthy, eloquent and unfinished poem, *De Rerum Natura* (*Of the Nature of Things*), by the Roman poet Titus Lucretius

Carus, who probably died in mid-stanza around 49 BC, just as dictatorship was looming in Rome. Around this time, in Gustave Flaubert's words, 'when the gods had ceased to be, and Christ had not yet come, there was a unique moment in history, between Cicero and Marcus Aurelius when man stood alone'. Exaggerated maybe, but free thinking was at least more possible then than before or after. Lucretius was more subversive, open-minded and far-seeing than either of those politicians (Cicero admired, but disagreed with, him). His poem rejects all magic, mysticism, superstition, religion and myth. It sticks to an unalloyed empiricism.

As the Harvard historian Stephen Greenblatt has documented, a bald list of the propositions Lucretius advances in the unfinished 7,400 hexameters of *De Rerum Natura* could serve as an agenda for modernity. He anticipated modern physics by arguing that everything is made of different combinations of a limited set of invisible particles, moving in a void. He grasped the current idea that the universe has no creator, Providence is a fantasy and there is no end or purpose to existence, only ceaseless creation and destruction, governed entirely by chance. He foreshadowed Darwin in suggesting that nature ceaselessly experiments, and those creatures that can adapt and reproduce will thrive. He was with modern philosophers and historians in suggesting that the universe was not created for or about human beings, that we are not special, and there was no Golden Age of tranquillity and plenty in the distant past, but only a primitive battle for survival. He was like modern atheists in arguing that the soul dies, there is no afterlife, all organised religions are superstitious delusions and invariably cruel, and angels, demons or ghosts do not exist. In his ethics he thought the highest goal of human life is the enhancement of pleasure and the reduction of pain.

Thanks largely to Greenblatt's marvellous book *The Swerve*, I have only recently come to know Lucretius, and to appreciate the extent to which I am, and always have been without

knowing it, a Lucretian/Epicurean. Reading his poem in A.E. Stallings's beautiful translation in my sixth decade is to be left fuming at my educators. How could they have made me waste all those years at school plodding through the tedious platitudes and pedestrian prose of Jesus Christ or Julius Caesar, when they could have been telling me about Lucretius instead, or as well? Even Virgil was writing partly in reaction to Lucretius, keen to re-establish respect for gods, rulers and top–down ideas in general. Lucretius's notion of the ceaseless mutation of forms composed of indestructible substances – which the Spanish-born philosopher George Santayana called the greatest thought that mankind has ever hit upon – has been one of the persistent themes of my own writing. It is the central idea behind not just physics and chemistry, but evolution, ecology and economics too. Had the Christians not suppressed Lucretius, we would surely have discovered Darwinism centuries before we did.

The Lucretian heresy

It is by the thinnest of threads that we even know the poem *De Rerum Natura*. Although it was mentioned and celebrated by contemporaries, and charred fragments of it have been found in the Villa of the Papyri at Herculaneum (a library belonging probably to Julius Caesar's father-in-law), it sank into obscurity for much of history. Passing quotations from it in the ninth century AD show that it was very occasionally being read by monks, but by 1417 no copy had been in wide circulation among scholars for more than a millennium. As a text it was effectively extinct. Why?

It is not hard to answer that question. Lucretius's special contempt for all forms of superstition, and indeed his atomism, which contradicted the doctrine of transubstantiation, condemned him to obscurity once the Christians took charge. His elevation of the pleasure principle – that the pursuit of pleasure could lead to goodness and that there was nothing nice about

pain – was incompatible with the recurring Christian obsession that pleasure is sinful and suffering virtuous.*

Whereas Plato and Aristotle could be accommodated within Christianity, because of their belief in the immortality of the soul and the evidence for design, the Epicurean heresy was so threatening to the Christian Church that Lucretius had to be suppressed. His atheism is explicit, even Dawkinsian, in its directness. The historian of philosophy Anthony Gottlieb compares a passage from Lucretius with one from Richard Dawkins's *The Selfish Gene*. The first talks of 'the generation of living creatures' by 'every sort of combination and motion'; the second of how 'unordered atoms could group themselves into ever more complex patterns until they ended up manufacturing people'. Lucretius was, carped John Dryden, at times 'so much an atheist, he forgot to be a poet'. He talks about people 'crushed beneath the weight of superstition', claims that 'it is religion breeds wickedness' and aims to give us 'the power to fight against the superstitions and the threats of priests'. Little wonder they tried to stamp him out.

They almost succeeded. St Jerome – keen to illustrate the wages of sin – dismissed Lucretius as a lunatic, driven mad by a love potion, who then committed suicide. No evidence to support these calumnies exists; saints do not show their sources. The charge that all Epicureans were scandalous hedonists was trumped up and spread abroad, and it persists to this day. Copies of the poem were rooted out of libraries and destroyed, as were

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* Greenblatt's book has been severely criticised, as successful books often are, by other academics, mainly on the grounds that he stands accused of exaggerating the illiteracy and ignorance of the medieval clerisy, that he misses the fact that the poem was at least sporadically mentioned in the ninth century, and that he is too harsh towards religious thinking. But in his main argument that *De Rerum Natura* was suppressed and attacked by Christianity – even after its rediscovery – and had an influence on the Renaissance and the Enlightenment, once it was widely circulated after 1417, there is no doubt that Greenblatt is right.

any other Epicurean and sceptical works. Almost all traces of such materialist and humanist thought had apparently long since vanished from Europe when in 1417 a Florentine scholar and recently unemployed papal secretary named Gian Francesco Poggio Bracciolini, stumbled upon a copy of the whole poem. Poggio was hunting for rare manuscripts in libraries in central Germany when he came across a copy of *De Rerum Natura* in a monastic library (probably at Fulda). He sent a hastily-made copy to his wealthy bibliophile friend Niccolò Niccoli, whose transcription was then copied more than fifty times. In 1473 the book was printed and the Lucretian heresy began to infect minds all across Europe.

Newton's nudge

In his passionate attachment to rationalism, materialism, naturalism, humanism and liberty, Lucretius deserves a special place in the history of Western thought, even above the beauty of his poetry. The Renaissance, the scientific revolution, the Enlightenment and the American Revolution were all inspired by people who had to some degree imbibed Lucretius. Botticelli's *Venus* effectively depicts the opening scene of Lucretius's poem. Giordano Bruno went to the stake, with his mouth pinned shut to silence his heresies, for quoting Lucretius on the recombination of atoms and the awe with which we should embrace the idea that human beings are not the purpose of the universe. Galileo's Lucretian atomism, as well as his Copernican heliocentrism, was used against him at his trial. Indeed, the historian of science Catherine Wilson has argued that the whole of seventeenth-century empiricism, started by Pierre Gassendi in opposition to Descartes, and taken up by the most influential thinkers of the age, including Thomas Hobbes, Robert Boyle, John Locke, Gottfried Leibniz and Bishop Berkeley, was fuelled to a remarkable extent by the sudden popularity of Lucretius.

As Lucretian ideas percolated, the physicists were the first

to see where they led. Isaac Newton became acquainted with Epicurean atomism as a student at Cambridge, when he read a book by Walter Charleton expounding Gassendi's interpretation of Lucretius. Later he acquired a Latin edition of *De Rerum Natura* itself, which survives from his library and shows signs of heavy use. He echoed Lucretian ideas about voids between atoms throughout his books, especially the *Opticks*.

Newton was by no means the first modern thinker to banish a skyhook, but he was one of the best. He explained the orbits of the planets and the falling of apples by gravity, not God. In doing so, he did away with the need for perpetual divine interference and supervision by an overworked creator. Gravity kept the earth orbiting the sun without having to be told. Jehovah might have kicked the ball, but it rolled down the hill of its own accord.

Yet Newton's disenthralment was distinctly limited. He was furious with anybody who read into this that God might not be in ultimate charge, let alone not exist. He asserted firmly that: 'This most elegant system of the sun, planets, and comets could not have arisen without the design and dominion of an intelligent and powerful being.' His reasoning was that, according to his calculations, the solar system would eventually spin off into chaos. Since it apparently did not, God must be intervening periodically to nudge the planets back into their orbits. Jehovah has a job after all, just a part-time one.

The swerve

That's that then. A skyhook still exists, just out of sight. Again and again this was the pattern of the Enlightenment: gain a yard of ground from God, but then insist he still holds the field beyond and always will. It did not matter how many skyhooks were found to be illusory, the next one was always going to prove real. Indeed, so common is the habit of suddenly seeing design, after all the hard work has been done to show that emergence

is more plausible, that I shall borrow a name for it – the swerve. Lucretius himself was the first to swerve. In a world composed of atoms whose motions were predictable, Lucretius (channelling Democritus and Epicurus) could not explain the apparent human capacity for free will. In order to do so, he suggested, arbitrarily, that atoms must occasionally swerve unpredictably, because the gods make them do so. This failure of nerve on the part of the poet has been known since as the Lucretian swerve, but I intend to use the same phrase more generally for each occasion on which I catch a philosopher swerving to explain something he struggles to understand, and positing an arbitrary skyhook. Watch out, in the pages that follow, for many Lucretian swerves.

Newton's rival, Gottfried Leibniz, in his 1710 treatise on theodicy, attempted a sort of mathematical proof that God existed. Evil stalked the world, he concluded, the better to bring out the best in people. God was always calculating carefully how to minimise evil, if necessary by allowing disasters to occur that killed more bad people than good. Voltaire mocked Leibniz's 'optimism', a word that then meant almost the opposite of what it means today: that the world was perfect and unimprovable ('optimal'), because God had made it. After 60,000 people died in the Lisbon earthquake of 1755, on the morning of All Saints' Day when the churches were full, theologians followed Leibniz in explaining helpfully that Lisbon had earned its punishment by sinning. This was too much for Voltaire, who asked sardonically in a poem: 'Was then more vice in fallen Lisbon found/Than Paris, where voluptuous joys abound?'

Newton's French follower Pierre-Louis Maupertuis went to Swedish Lapland to prove that the earth was flattened towards the poles, as Newtonian mechanics predicted. He then moved on from Newton by rejecting other arguments for the existence of God founded on the wonders of nature, or the regularity of the solar system. But having gone thus far, he suddenly stopped (his Lucretian swerve), concluding that his own 'least action' principle to explain motion displayed such wisdom on the part

of nature that it must be the product of a wise creator. Or, to paraphrase Maupertuis, if God's as clever as me, he must exist. A blazing non sequitur.

Voltaire, perhaps irritated by the fact that his mathematically gifted mistress Emilie, Marquise du Châtelet had slept with Maupertuis and had written in defence of Leibniz, then based his character Dr Pangloss in his novel *Candide* on an amalgam of Leibniz and Maupertuis. Pangloss remains blissfully persuaded – and convinces the naïve Candide – that this is the best of all possible worlds, even as they both experience syphilis, shipwreck, earthquake, fire, slavery and being hanged. Voltaire's contempt for theodicy derived directly and explicitly from Lucretius, whose arguments he borrowed throughout life, styling himself at one point the 'latter-day Lucretius'.

Pasta or worms?

Voltaire was by no means the first poet or prose stylist to draw upon Lucretius, nor would he be the last. Thomas More tried to reconcile Lucretian pleasure with faith in *Utopia*. Montaigne quoted Lucretius frequently, and echoed him in saying 'the world is but a perennial movement . . . all things in it are in constant motion'; he recommended that we 'fall back into Epicurus' infinity of atoms'. Britain's Elizabethan and Jacobean poets, including Edmund Spenser, William Shakespeare, John Donne and Francis Bacon, all play with themes of explicit materialism and atomism that came either directly or indirectly from Lucretius. Ben Jonson heavily annotated his Dutch edition of Lucretius. Machiavelli copied out *De Rerum Natura* in his youth. Molière, Dryden and John Evelyn translated it; John Milton and Alexander Pope emulated, echoed and attempted to rebut it.

Thomas Jefferson, who collected five Latin versions of *De Rerum Natura* along with translations into three languages, declared himself an Epicurean, and perhaps deliberately echoed Lucretius in his phrase 'the pursuit of happiness'. The poet and

physician Erasmus Darwin, who helped inspire not just his evolutionary grandson but many of the Romantic poets too, wrote his epic, erotic, evolutionary, philosophical poems in conscious imitation of Lucretius. His last poem, *The Temple of Nature*, was intended as his version of *De Rerum Natura*.

The influence of this great Roman materialist culminates rather neatly in the moment when Mary Shelley had the idea for *Frankenstein*. She had her epiphany after listening to her husband Percy discuss with George, Lord Byron, the coming alive of 'vermicelli' that had been left to ferment, in experiments of 'Dr Darwin'. Given that Shelley, Byron and Erasmus Darwin were all enthusiastic Lucretians, perhaps she misheard and, rather than debating the resurrection of pasta, they were actually quoting the passage in *De Rerum Natura* (and Darwin's experimental imitation of it) where Lucretius discusses spontaneous generation of little worms in rotting vegetable matter – 'vermiculos'. Here is the history of Western thought in a single incident: a Classical writer, rediscovered in the Renaissance, who inspired the Enlightenment and influenced the Romantic movement, then sparks the most famous Gothic novel, whose villain becomes a recurring star of modern cinema.

Lucretius haunted philosophers of the Enlightenment, daring free thinkers further down the path that leads away from creationist thinking. Pierre Bayle, in his *Thoughts on the Comet of 1680*, closely followed Lucretius's Book 5 in suggesting that the power of religion derived from fear. Montesquieu channelled Lucretius in the very first sentence of *The Spirit of the Laws* (1748): 'Laws in their most general signification, are the necessary relations arising from the *nature of things*' (my emphasis). Denis Diderot in his *Philosophical Thoughts* echoed Lucretius to the effect that nature was devoid of purpose, the motto for his book being a line from *De Rerum Natura*: 'Now we see out of the dark what is in the light'. Later, in *The Letter on the Blind and the Deaf*, Diderot suggested that God himself was a mere product of the senses, and went to jail for the heresy. The atheist philosopher Paul-

Henri, baron d'Holbach, took Lucretian ideas to their ultimate extreme in his *Le Système de la Nature* of 1770. D'Holbach saw nothing but cause and effect, and matter in motion: 'no necessity to have recourse to supernatural powers to account for the formation of things'.

One place where such scepticism began to take hold was in geology. James Hutton, a farmer from southern Scotland, in 1785 laid out a theory that the rocks beneath our feet were made by processes of erosion and uplift that are still at work today, and that no great Noachian flood was needed to explain seashells on mountaintops: 'Hence we are led to conclude, that the greater part of our land, if not the whole, had been produced by operations natural to this globe.' He glimpsed the vast depths of geological time, saying famously, 'We find no vestige of a beginning – no prospect of an end.' For this he was vilified as a blasphemer and an atheist. The leading Irish scientist Richard Kirwan even went as far as to hint that ideas like Hutton's contributed to dangerous events like the French Revolution, remarking on how they had 'proved too favourable to the structure of various systems of atheism or infidelity, as these have been in their turn to turbulence and immorality'.

No need of that hypothesis

The physicists, who had set the pace in tearing down skyhooks, continued to surprise the world. It fell to Pierre-Simon Laplace (using Emilie du Châtelet's improvements to cumbersome Newtonian geometry) to take Newtonism to its logical conclusion. Laplace argued that the present state of the universe was 'the effect of its past and the cause of its future'. If an intellect were powerful enough to calculate every effect of every cause, then 'nothing would be uncertain and the future just like the past would be present before its eyes'. By mathematically showing that there was no need in the astronomical world even for Newton's Nudge God to intervene to keep the solar system

stable, Laplace took away that skyhook. 'I had no need of that hypothesis,' he told Napoleon.

The certainty of Laplace's determinism eventually crumbled in the twentieth century under assault from two directions – quantum mechanics and chaos theory. At the subatomic level, the world turned out to be very far from Newtonian, with uncertainty built into the very fabric of matter. Even at the astronomical scale, Henri Poincaré discovered that some arrangements of heavenly bodies resulted in perpetual instability. And as the meteorologist Edward Lorenz realised, exquisite sensitivity to initial conditions meant that weather systems were inherently unpredictable, asking, famously, in the title of a lecture in 1972: 'Does the flap of a butterfly's wings in Brazil set off a tornado in Texas?'

But here's the thing. These assaults on determinism came from below, not above; from within, not without. If anything they made the world a still more Lucretian place. The impossibility of forecasting the position of an electron, or the weather a year ahead, made the world proof against the confidence of prognosticators and experts and planners.

The puddle that fits its pothole

Briefly in the late twentieth century, some astronomers bought into a new skyhook called the 'anthropic principle'. In various forms, this argued that the conditions of the universe, and the particular values of certain parameters, seemed ideally suited to the emergence of life. In other words, if things had been just a little bit different, then stable suns, watery worlds and polymerised carbon would not be possible, so life could never get started. This stroke of cosmic luck implied that we lived in some kind of privileged universe uncannily suitable for us, and this was somehow spooky and cool.

Certainly, there do seem to be some remarkably fortuitous features of our own universe without which life would be impossible. If the cosmological constant were any larger, the pres-

sure of antigravity would be greater and the universe would have blown itself to smithereens long before galaxies, stars and planets could have evolved. Electrical and nuclear forces are just the right strength for carbon to be one of the most common elements, and carbon is vital to life because of its capacity to form multiple bonds. Molecular bonds are just the right strength to be stable but breakable at the sort of temperatures found at the typical distance of a planet from a star: any weaker and the universe would be too hot for chemistry, any stronger and it would be too cold.

True, but to anybody outside a small clique of cosmologists who had spent too long with their telescopes, the idea of the anthropic principle was either banal or barmy, depending on how seriously you take it. It so obviously confuses cause and effect. Life adapted to the laws of physics, not vice versa. In a world where water is liquid, carbon can polymerise and solar systems last for billions of years, then life emerged as a carbon-based system with water-soluble proteins in fluid-filled cells. In a different world, a different kind of life might emerge, if it could. As David Waltham puts it in his book *Lucky Planet*, 'It is all but inevitable that we occupy a favoured location, one of the rare neighbourhoods where by-laws allow the emergence of intelligent life.' No anthropic principle needed.

Waltham himself goes on to make the argument that the earth may be rare or even unique because of the string of ridiculous coincidences required to produce a planet with a stable temperature with liquid water on it for four billion years. The moon was a particular stroke of luck, having been formed by an interplanetary collision and having then withdrawn slowly into space as a result of the earth's tides (it is now ten times as far away as when it first formed). Had the moon been a tiny bit bigger or smaller, and the earth's day a tiny bit longer or shorter after the collision, then we would have had an unstable axis and a tendency to periodic life-destroying climate catastrophes that would have precluded the emergence of intelligent life. God might claim

credit for this lunar coincidence, but Gaia – James Lovelock's theory that life itself controls the climate – cannot. So we may be extraordinarily lucky and vanishingly rare. But that does not make us special: we would not be here if it had not worked out so far.

Leave the last word on the anthropic principle to Douglas Adams: 'Imagine a puddle waking up one morning and thinking, "This is an interesting world I find myself in – an interesting hole I find myself in – fits me rather neatly, doesn't it? In fact it fits me staggeringly well, may have been made to have me in it!" '

Thinking for ourselves

It is no accident that political and economic enlightenment came in the wake of Newton and his followers. As David Bodanis argues in his biography of Voltaire and his mistress, *Passionate Minds*, people would be inspired by Newton's example to question traditions around them that had apparently been accepted since time immemorial. 'Authority no longer had to come from what you were told by a priest or a royal official, and the whole establishment of the established church or the state behind them. It could come, dangerously, from small, portable books – and even from ideas you came to yourself.'

Gradually, by reading Lucretius and by experiment and thought, the Enlightenment embraced the idea that you could explain astronomy, biology and society without recourse to intelligent design. Nikolaus Copernicus, Galileo Galilei, Baruch Spinoza and Isaac Newton made their tentative steps away from top–down thinking and into the bottom–up world. Then, with gathering excitement, Locke and Montesquieu, Voltaire and Diderot, Hume and Smith, Franklin and Jefferson, Darwin and Wallace, would commit similar heresies against design. Natural explanations displaced supernatural ones. The emergent world emerged.