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Ian Stewart and Jack Cohen
Excerpt
More information

Prologue

Fifteen thousand million years ago the universe was no bigger than the dot at the end of this sentence.

A tiny, tiny, *tiny* fraction of a second before that – but there was no fraction of a second before that. There was no time before the universe began, and without time, there can be no 'before'. (As well to ask what lies north of the North Pole.♪) There was no space, no time, and no matter. But when the space that was coextensive with the universe had grown to the size of a dot, time had already begun to tick. The temperature within the dot was far too high for matter to exist, but there was plenty of what was required to create matter: radiation. The primal dot seethed with radiant energy.

During time's first duodecillionth (10^{-39}) of a second of existence, the universe was a 'false vacuum', a state of negative pressure in which every fragment of space repelled every other fragment. Space exploded exponentially, and in that near-infinitesimal instant the universe inflated from a tiny dot to a ball many light-years across as its negative pressure literally blew it apart. As the temperature dropped the false vacuum gave way to a true vacuum, a state of zero pressure, and the era of inflation ceased. The universe, now large enough to be interesting, continued to expand under its own momentum – but more sedately, at a rate of a few thousand kilometres per second.

When time was one ten thousandth of a second old, the temperature of the universe dropped to a trillion degrees. Pairs of particles, one of matter, one of antimatter, were winking into existence and out again, born in and dying as fluctuations of radiant energy. Matter and radiation were in perfect balance. However, the balance between matter and antimatter was imperfect. For every 999,999,999 antiprotons there were 1,000,000,000 protons. From that imbalance came everything that we know.

When time attained the grand old age of one second, the temperature of the nascent universe had fallen to a mere ten billion degrees. Electrons and antielectrons, colliding in pairs, filled the universe with bursts of neutrinos and antineutrinos. Neutrons, no longer stable, decayed into protons and electrons.

Two minutes after time began (some say one and a half minutes, others three) the universe had cooled to one billion degrees, and matter as we know it began to assemble. Neutrons paired incestuously with their proton offspring to form creation's first atoms – heavy hydrogen, otherwise known as deuterium. Deuterium fused into helium and matter began to diversify.

After half an hour the universe changed: now it was three quarters hydrogen, one quarter helium. The pace of change slowed. It took seven hundred thousand years before the universe cooled enough to become transparent to light. By then, matter had formed itself into almost a hundred different elements. It took a hundred million years for that matter to clump itself into galaxies, and for the first stars to shine.

Ripples in the early fabric of spacetime, amplified by the inexorable tug of gravity, folded in on themselves, collapsing under their own mass, leaving huge voids hundreds of millions of light-years across, bubbles of emptiness filling the universe like foam. On the surfaces of the bubbles, matter condensed into vast sheets and filaments. One such structure – let us call it the Distant Superattractor – made itself felt a billion light-years away, as its gravitational attraction sucked matter inwards towards its centre. There was nothing that greatly distinguished it from trillions of equally enormous clusters of matter.

Smaller – but still many thousands of light-years across – was a clump of matter known as the Great Attractor. Like all of the matter in a region of space billions of light-years across, it streamed towards the Distant Superattractor. Within and around the Great Attractor, matter arrayed itself into a hierarchy of ever-smaller clumps, which were sucked towards the Great Attractor even as it made its way towards the Distant Superattractor. One such was the Local Supercluster, a group of tens of thousands of galaxies that surged collectively towards the constellation Virgo at 700 kilometres per hour. The Local Supercluster was composed of more than a hundred galactic clusters, none differing significantly from the rest – the M101 cluster, the M81 cluster, the Virgo cluster, the Local Group ... A typical cluster is several million light-years across, and is composed of hundreds of galaxies; an individual galaxy is some hundred thousand light-years in diameter, a vast swirl of matter that rotates once every quarter of a billion years.

In the Local Group were two dozen galaxies: Andromeda, M33, and one – not greatly different from any other – known simply as 'The Galaxy'. Like most galaxies it was spiral in form, although unusually it had two smaller close companions known as the Greater and Lesser Magellanic Clouds. Its spiral arms – like those of most other galaxies – were density waves, places where its component atoms piled up against each other. Along the crests of those waves the pressure became so intense that it sparked nuclear reactions, and stars came into being.

In this one galaxy there were more than a hundred billion stars.

One such star – not especially different from its companions – had spectral class G2, meaning that its surface temperature was about average (six thousand degrees) and the light that it emitted (at a level of brightness that was also close to the average) showed a prominent trace of calcium. Like many stars, it was enclosed in a cloud of cosmic debris – stardust blown across the intergalactic space in shockwaves generated by explosions in the galactic core. All of the different chemical elements born in stars' nuclear furnaces were present – some in abundance, others the merest traces. Among them, fused into existence by a coincidental resonance of nuclear vibrations, was the element carbon.

As the universe grew older, and colder, and larger, this particular cloud of stardust – like many others – began to condense, the grains sticking to each other, to form irregular lumps of methane ice, dense clouds of gas, fragments of rock. As it condensed, it also collapsed into a flattish disc, spinning on its axis, a swirl of cooling matter that collided, bounced, broke, stuck, aggregated. As time passed, a mere instant on cosmic scales, the clumps became fewer, but bigger. Crushed under their own gravity, they formed flattened spheres – planets. The G2 star acquired a solar system.

None of this was especially unusual.

Each planet, forming in its own particular place, found itself in possession of the features that its mode of formation would naturally create – a rocky core, a methane–hydrogen atmosphere, a surface flowing with molten metal or dotted with lakes of acid, encircling companions ... Each planet acquired its own identity. This in particular was true of the third planet, counting outwards from the central star. Much of its surface was covered by a thin layer of water. It had an atmosphere, mostly nitrogen. And its surface temperature was within the range at which water remained liquid. Although no other planet in this particular solar system resembled the third in these respects, it was probably much the same as many other planets around many other stars in many other galaxies.

Everywhere, even in the depths of intergalactic space, atoms bumped against each other and stuck to form molecules. On the third planet this happened more often than in the vacuum between the stars, because there were more atoms to bump into. The individual features of the third planet constrained the kind of molecule that occurred, producing structures that would not have occurred on a methane world or an ice giant. One day there arose a collection of molecules that could make copies of itself – a replicating system. Perhaps it came together accidentally in the primal soup of the oceans, perhaps it was given a helping hand by the receptive surfaces of rocks or clays. However it happened, the replicator did what replicators do – it replicated. Over and over again. After a fairly short time the planet became distinctly unusual, its chemistry subverted and reorganised by the voracious replicator. The replicator made the occasional mistake, but some mistakes could also replicate, and soon a kind of long-term War of the Replicators was under way, as ever more sophisticated molecular collectives did battle for the right to continue replicating.

It all got rather complicated.

For instance: one group of replicators acquired the knack of converting starlight into food.

For instance: an early success, the bacterium, attained such numbers that one of its metabolic by-products, the corrosive gas oxygen, came to occupy a substantial portion of the planet's atmosphere.

For instance: other groups of replicators evolved the ability to leave the solid ground and soar upon the gases of the atmosphere.

For instance: sixty-five million years ago an especially successful type of replicator was exterminated, planetwide, by the impact of a large rock. Other tiny hairy warm-blooded replicators suddenly found that their main competition had vanished from the face of the third planet, and their rapidly diversifying successors exploded across continents and oceans.

For instance: today, two of the descendants of those tiny creatures are busy delineating their own limited version of the entire story in strange, angular geometric symbols, impressed in contrasting pigment upon sheets of compressed white vegetable matter, in the hope that other creatures of similar kind will scan the sheets with their light-detecting sensors – and in some inexplicable manner imbibe meaning and significance and make them part of themselves. Typically for these replicators we find a tiny portion of the ungraspable universe making a glorious, hopeless attempt to encapsulate that awe-inspiring whole inside its own tiny form, improbably employing weak electrical impulses that scuttle along a network of a trillion tiny fibres – vibrant, alive, and even more ungraspable than the universe that it is attempting to grasp.

A circle closes.

A mystery opens.

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1 The Origins of Life

A woman scientist♪ had been working for some time with a chimpanzee, teaching it to carry out various tasks such as opening a box and rewarding it with fruit. One day, after a session with the chimpanzee, she came into the coffee room half laughing and half crying, obviously very emotional. Her colleagues, a little alarmed, finally managed to get out of her what had happened. She had decided to leave the laboratory area temporarily, and had undone the bolt on the door – whereupon the chimpanzee had solemnly handed her a stick of celery.

Our prologue is one way to tell the story of who we are and how we got here. Such a story has several virtues: it demonstrates how utterly incomprehensible the universe in its entirety is, and how difficult it is for a newly intelligent upright ape to close the conceptual circle by encapsulating the sheer vastness of that universe inside its tiny brain case. It encourages humility. It is the cosmological story as we currently conceive it, the best guess that today's science can make about a past that we cannot revisit and distances too enormous for us to cross. It is a story so strange that we may be tempted to dismiss it as wild speculation, but that will not make the strangeness go away, because if that story is false then the true story must be even stranger.

Assuming there is such a thing as *the* true story of the origins of the universe, which is debatable.

From our own point of view, however – we mean the human race, not JC & IS – this story is impersonal and back to front. It starts with nothing, and ends with each one of us as some kind of accidental by-product of forces beyond our wildest imagination. It describes a universe that is largely alien to the one that we inhabit, which is a private universe filled with very different, human-scale things – friends, spouses, children, pets, plants, bricks and mortar. Each of us inhabits a personal universe; in a sense each of us *is* a personal universe – for if we are destroyed then our personal universe vanishes with us. The universe of cosmology is made of fundamental particles, such as electrons, and radiation, such as light; but our personal universes are made of very different kinds of things. We don't mean that our own universes aren't made from ordinary matter – we mean that this matter is organised in a different manner. Most of the interesting features of our personal universes are people and their activities – friends and lovers, enemies and acquaintances from our work or our play. Because most of us live in cities the typical personal universe is urban, composed of buildings, rooms, out-of-town shopping centres … What occupies most of our daily thoughts is *people* – their influence upon us, and ours upon them. There are babysitters to arrange, theatre tickets to book, bosses to placate, bank managers to be persuaded that a loan would be a sound business proposition …

Sometimes the external 'non-people' world intrudes, but even then it normally does so by way of a human-made artefact: the car needs new tyres, the lawn needs mowing, a sudden attack of 'flu needs medication. Changes arising outside our own small circle affect our lives in ways we do not anticipate and of which we may not approve – new machinery makes our job unnecessary, anti-pollution laws add to the cost of doing business, a new disease infests our food supply, vandals cut our telephone wires, or people from a country thousands of miles away, which we have never visited, start dropping bombs on us. When the outside world intrudes upon our personal universe we become conscious that the outside exists, but most of the time we still interpret the intrusion in personal terms. We look for a new job that suits our abilities, we hire a lawyer to help us avoid our expensive new legal obligations, we temporarily stop eating burgers, we call the telephone repair man, we build bomb shelters and sit in them cursing the enemy while the bombs fall.

But we do more than that. Many other creatures look up into the night-time sky and see the stars, but we stare at them, wonder how many there are, wonder how far away they are, wonder how they got there, wonder what they are made of, wonder – indeed – why they are there at all. We link them into simple patterns and weave stories around them to help us to rationalise their existence and to remember which pattern is which – the Hunter, the Hero, the Princess, the Bear, the Swan. Although we cannot get inside other animals' heads, we see no evidence that any other creature looks outside its personal universe in this manner. Maybe chimpanzees and dolphins do; maybe the whale's enigmatic and interminable song is an exercise in submarine philosophy – but maybe it's just the whale's way of saying 'Hi, anybody out there? This is me.' Chimps and dolphins and whales don't build astronomical observatories, they don't make calendars to predict the seasons, they don't carve symbolic versions of their thoughts on rocks. Maybe they're wiser than we are, having fun instead of agonising about their place in the vast uncaring universe; but wiser or not, even the bright ones behave differently from us.

When we look outside our personal universe, we find that the external world is organised in its own characteristic way. It has gravity, ecology, dinosaurs, $E = mc^2$, angles of a triangle adding up to 180°, and so on. It is impersonal: while it is perfectly reasonable to argue with your bank manager that she should increase your overdraft above £180, it is fruitless to argue with a triangle in the hope of increasing the sum of its angles above 180°. On the other hand, the external universe links into our personal world in many ways: calories in food, digital music on CDs, passenger jets, television. All these technologies depend on science, and science is our most successful way to dig into the structure of that external, impersonal universe. Television strengthens the connection between the personal and impersonal worlds by providing science programmes on how the world began or how it will end, and natural history programmes – like our pets and aquariums, house plants and gardens – provide tenuous links with the rest of living nature. All this notwithstanding, we are much more concerned about how we fit into our personal circle of friends than about how we all fit into the complex ecology of our own planet.

Those of us who are scientists behave in exactly the same way, but we tend to be more bothered by it, because we have real trouble understanding why we're doing it. Our scientific instincts tell us that the real universe out there is actually far more important, on any serious scale of events, than whether Mary told her mother she was dieting … but somehow questions on the level of Mary's diet take up much more of the scientist's time than the whys and wherefores of galactic superclusters – even when the scientist is a cosmologist.

We lead a dual existence – *in* nature but not *of* it, perpetually reacting to our estimate of what the world will be rather than what it is right now. We mirror the world outside us with another in our heads: our perceptions of that world. It's a distorting mirror, an imperfect representation, but to us it seems *real*. In a funny self-centred way we see ourselves as existing slightly to one side of the rest of the universe. We are in control of our world, we can make choices, we have *minds* that we can make up or change. Everything else is just following the inexorable impulses of nature. When we think of an amoeba, a fox, an oak tree, or a dinosaur, we think of them as a part of nature. The amoeba fiddles about putting out pseudopods and ingesting food particles, and that's about it. The fox runs through the bushes chasing a rabbit for dinner, and when it encounters the occasional bunch of subhumans on horseback it's too busy running from the dogs to debate the morality of blood sports. The oak tree is just sitting there synthesising, drawing in water from its roots and carbon dioxide from the air, and if it's worrying about anything it's about the impending winter and dropping its leaves – not whether the neighbouring oak tree thinks it's a cad for fertilising too many of its acorns. We see dinosaurs as eating, breathing, multiplying, and dying out against the great backdrop of natural forces, like the K/T meteorite that hit the Earth 65 million years ago and caused mayhem all over the planet. Gary Larson's 'Far Side' cartoons often work by imputing human-type motivation to animals, and they are funny because we know that most animals *don't* worry about their circle of friends.

All very well. But how much of our belief that we are special is grounded in fact, and how much is just a comfortable illusion of superiority? The belief that we are superior to other animals is a human value judgement, and as such is likely to be biased in our own favour, but there can be little doubt that we are *different* – in important ways – from the other animals on our planet. These differences must be explained. Their explanation is made more difficult, but also much more interesting, by the fact that human beings have not always been as they are now. Few of us doubt that we evolved from creatures that, like most animals, related directly to the natural world and thereby avoided all of the social problems that occupy our every waking minute and even assail us in our dreams.

How did that happen?

This question is the central issue that will shape our narrative. What was it about this particular lump of rock, in this particular spiral arm of this not terribly special galaxy, that made us the way we are? How is it *possible* for inanimate matter to turn into complex creatures like us with their own inner worlds of mind and imagination? Given that it is possible, why did it happen? Why us?

Some will ascribe it to God and be satisfied: we have nothing to say to them.

Some will ascribe it to inexorable consequences of the fundamental laws of physics, and be satisfied: we have nothing to say to them either.

We *do* have something to say, however, to those who find either answer incomplete, people who think that our presence on this planet and our curious mental abilities deserve to be explained rather than explained away. In *Figments of Reality* (henceforth abbreviated to *Figments*) we attempt to explain the evolution of human beings from a new point of view – one that differs considerably from the usual scientific story, although it retains many points of contact with it. More accurately, we shall look at the questions of mind and culture from *two* disparate viewpoints, which complement rather than contradict each other. One is the conventional scientific viewpoint: take the system to bits – in a conceptual sense – and see how those bits fit together. The other, less conventional but in our opinion equally important, is to look at *context*, and see how the system is shaped by what lies around it.

Along the way we shall be forced to reassess the orthodox scientific stories about how things work, many of which are little better than myths. We don't think that such reassessment makes the orthodox stories any less 'true' (we'll air some of our prejudices about truth later), and we certainly don't think that it makes them any less 'scientific'. The point is that if you approach the questions from different directions you may find yourself wanting different kinds of answer, just as 'God' may satisfy a priest in search of virtuous living but not a programmer in search of virtual reality. We think that such changes of perspective help to make many problems of human evolution and cultural development seem less puzzling. In particular they will help us to tell the story of human mind and culture in a more accessible way – one that explains, rather than just asserts, the scientific bases of our world and of ourselves.

We'll give you the bare bones of the story now, to act as a 'road map' for the rest of the book. First, we look at the origins of life and its evolution – both on Earth, the story of how we came into being, and elsewhere, the story of what might have happened instead and what might be happening right now on a planet of some distant sun. We describe the evolution of senses – in particular sight, hearing, and smell – showing how they have influenced the evolution of networks of nerve cells, leading to that most flexible and enigmatic of all organs, the brain. We demonstrate that, far from being mere passive observers of reality, our senses are fine-tuned during development to emphasise those features in which our brains have an especial interest. By manipulating these mental features we construct 'conceptual maps' of the reality around us, which enable us to make up our minds (take decisions) and change our minds (modify our choices in response to the consequences of those decisions). We do not so much *observe* reality as put together our personal representation of it and drape that back on to our perceptions of the external world. This facility is moderated by intelligence – the ability to reason, to solve problems – which is not merely a structural feature of large brains with intricate networks of nerves. Intelligence arose in intimate association with a marvellous non-genetic trick used by parents to provide their offspring with a head start in life, a trick that we call 'privilege'. Privilege begins with yolk and nests, and culminates – so far – in culture. We further claim that it is not intelligence alone, or culture alone, that leads to mind, but both – interacting 'complicitly'.

A feature of our minds that is often singled out as *the* thing that makes us uniquely human is language. Some scientists think that language is a necessary prerequisite for intelligence, and others that intelligence is a necessary prerequisite for language. We think that both are right – and so both are wrong, for each thinks the other mistaken and both are mistaken about 'prerequisite'. Language and intelligence evolved *together*, both being inextricably linked to culture.

Finally, we tell of the rise of human culture, the techniques that cultures employ to survive in a changing world, and the effect of cultural differences on displaced ethnic groups, leading to multicultural societies in which individuals grapple with changes in their cultural identity. We tell of the growth of global communications that lock the multiculture in place, so that we cannot go back even if we wish to. We take a brief look at the future of human multiculture. And we wrap the entire package up and tie it with a neat bow, by means of a unifying concept – extelligence – that is the contextual and cultural analogue of internal, personal intelligence.

To kick the whole story off, we now ask a 'warm-up' question: how did inanimate matter give rise to life? In the Prologue we described the current view of the origins of the universe, the 'Big Bang' theory as it is called. Space, time, and matter arose from nothing; then the simple kinds of primal matter that existed at the prevailing high temperatures began to combine to make all of the different chemical elements – hydrogen, helium, lithium, beryllium, boron, carbon, nitrogen, oxygen ... These different atoms then combined to form chemical molecules – two hydrogens plus an oxygen to make water, one carbon and two oxygens to make carbon dioxide. The bodies of living creatures are made from millions of different molecules, all of which trace back to the nuclear reactions in the cores of stars. Literally, 'we are stardust', as Joni Mitchell sang about Woodstock.♪

Particles building into atoms, and atoms into molecules – these we can comprehend, they're just like bricks building into a house. But houses don't develop a will of their own, get up, and walk away. Living creatures did, and that's a real puzzle. How did inanimate, inorganic chemistry somehow generate the rich flexibility of life? Not all at once, that's for sure. There was no wondrous, special moment, pregnant with significance, at which life suddenly appeared on the planet. Instead, life emerged gradually from non-life. In this respect the origins of life are a bit like the origins of a person's life. There was a time when Maureen didn't exist. At what time did the egg, embryo, fetus, child, become Maureen? At what time did it become human? Surely there was not a specific *moment* of becoming Maureen – though people who don't know about it do talk of 'the moment of fertilisation' – except in a legal sense, at her naming cere-