2

ALL KNOWLEDGE IS METAPHOR

In which we argue that we can know nothing 'for certain'. The best thinkers generate the best metaphors. Evolution is a particularly powerful one.

As they begin their careers, budding biologists are, quite rightly, cautioned against the mortal sin of *teleology*. This word is derived from the Greek *telos* meaning 'end' and *logos* 'reason'. Its extreme form can be expressed by an example, thus: 'the purpose of evolution is to create humans'. Few will deny that the process of evolution has produced humans, but the process itself is not concerned with producing humans. There is no reason to suppose that if the whole of evolution were reset at the beginning and rerun, we would get exactly the same outcomes. We might see similarities, because convergent evolution is a well-studied phenomenon, but not the same.

Yet evolution *appears* to be purposive. If you study it, you get a feeling of direction and organisation increasing with time. These are called trends – trends towards multicellular organisms, towards increasing size, towards increasing intelligence and so on. The trends illustrate ways of succeeding in the universal objective of staying alive as long as possible, to improve chances of producing viable offspring that will continue the process.

Consider this sentence:

> The view through the window shows the leaves that are scattering as the wind blows them across the road and the small clouds that are racing across the sky.

But wait a minute. Notwithstanding the conventional images of mythical winged beings in the corners of ancient maps, winds do not 'blow'. Only humans do that. Neither do clouds 'race'. Racing has implications of competition against others, or against time. Oh, and time does not race either, the clock 'tells' you that it ticks along at steady rate. But a clock 'tells' you nothing … And so on. Human language is full of conventional metaphors that are clearly understood by those who speak the same language.

From its beginnings in the seventeenth century, scientists have worried about the meanings of words and their ambiguity, particularly when naming plants or animals. The 'father of taxonomy', Carl Linnaeus, did the scientific world a great service by introducing the system of binomial classification. For example, before Linnaeus, English people might talk about the blackbird (or, in the next county, the ouzel) and the song thrush (or mavis, across the border in Scotland), without being sure that they were referring to the same bird. After Linnaeus gave them the rather unfortunate generic name of *Turdus* coupled with different specific names, they became, respectively, *T. merula* and *T. philomelos*. No more ambiguity and, thanks to Linnaeus's system of classification, we can be sure we are all singing from the same song sheet when we praise the calls of these two common songbirds.

Scientists like their own 'language' to be unambiguous. For example, 'acid' is a class of molecule with very specific properties and they do not really like it if people 'drop acid' or make 'acid' remarks or write with a pen 'dipped in vitriol'. Vitriol is the old name for sulphuric acid. Perhaps ambiguity might be removed by writing its formula instead: 'She writes with a pen dipped in H_2SO_4'.

It doesn't work – chemistry kills prose!

The ideal of science is to be objective, to describe the world as it 'really' is. This is impossible when writing in any natural language. The everyday words that we use carry too much baggage for objectivity. What is a rose? Gertrude Stein wrote that 'a rose is a rose is a rose'. But is it? Because it is also a member of the family Rosaceae, a perfume, a beautiful young woman, a symbol of true love, a device attached to a watering can, a compass and the badge of the medieval House of Lancaster. Change its colour from red to white and it is the badge of the medieval House of York. *The Name of the Rose* is a book written by Umberto Eco. We determine what is meant by 'rose' by its context.

Language is therefore an imperfect method of communication. In fact, Darwin used it to his advantage when discussing his ideas with non-scientists. In *On the Origin of Species* he refers to 'a Creator', rather than 'God', at the end of the famous last 'tangled bank' paragraph. In his letters, he subsequently regretted even this.

We have already, in this chapter, discussed the 'biological sin' of claiming that the end point of a process of biological adaptation is the cause of it taking place. Two other biological sins can be joined with this one: they are anthropocentrism and anthropomorphism. Anthropocentrism is the conviction, held by many religious groups, that humans are the focal point of the universe. The universe was constructed for us, and our planetary system is designed for our convenience. Genesis (1:26) even tells us that humans have:

> dominion over the fish of the sea, and over the fowl of the air, and over the cattle, and over all the earth, and over every creeping thing that creepeth upon the earth.

One has only to look through a microscope or a large telescope to doubt this proposition.

Anthropomorphism is imagining that inanimate objects around us are alive and that animals are really little (or large) human beings. Our ancestors saw faces in the fire, animals in the clouds, gods in the trees and stones, and were fearful. Our children are particularly prone to anthropomorphism and live vicarious lives through their teddy bears and dolls, honing their developing empathic skills. The familiar concept of 'Mother Nature' herself is an anthropomorphism. She is a fictional demigoddess who is somehow loving, nurturing and compassionate. This is a view of life far from the true state of affairs.

We were told, as students, that if we felt an urge coming on to attribute purpose to evolution, or if we felt that our ancient inclination to anthropocentrism and anthropomorphism was emerging, we should, for our own biological respectability, preface it with the words *it is as if…*

There are a lot of places in this book where purists would have us write *It is as if …* If we did so, however, it would be repetitive and tedious for the readers. Instead, we crave indulgence and ask them to take the qualification for granted where we have omitted it. Evolution does not have 'purpose' in the human sense but it is convenient to write as if it did. Living organisms do not have human purposes and human intelligences, but it is convenient to write as if they did. Later on in this chapter we refer to James Lovelock's metaphor of Gaia, only four letters, but used to describe 'the self-organising, self-maintaining, cooperative, global biosphere that interacts with the physical and chemical world'. Four letters doing the work of 110 that are themselves shorthand for the greatest overarching entity on Earth. How convenient is that?

All science is metaphor. Charles Darwin's metaphor of natural selection as the origin of species was a globally momentous one. Those two words encapsulate the essence of the evolutionary process, meaning 'it is as if Nature were selecting from among the offspring of each organism'. From which it follows that 'it is as if Nature were capable of choosing' and 'it is as if Nature were an individual, the sum total of biological activity'. Or, to quote again from the 'tangled bank' paragraph in the *Origin*:

> these elaborately constructed forms, so different from each other, and dependent upon each other in so complex a manner, have all been produced by laws acting around us.

'Dependent upon each other in so complex a manner' paves the way for two further great metaphors, this time of the twentieth century, one of which has great relevance for us in the twenty-first. One explains the evolutionary origin of the modern, non-bacterial cell, the other the evolutionary origin of the planet itself. We will revisit them in Chapter 3.

We have already discussed the role of metaphor in language. Now we go further: all reality is metaphor. The metaphor of natural selection facilitates our description of the properties of evolution. Two important ones are that it self-organises and encourages cooperation among the life forms it shapes. Given these characteristics, we conclude that it is as if the golden thread of Darwin's cooperative evolution has woven the biosphere into a network that enfolds the planet to create James Lovelock's Gaia, another metaphor that commands our respect.

If you doubt the power of reality as metaphor, consider particle physics. The concept of the atom itself is a metaphor, one that has been refined over millennia. No-one has ever seen a single atom. Democritus (c. 460–370 BC) is first recorded as having imagined some of its properties; obviously never having seen one he could only say 'it is as if' the atom were the smallest indivisible bit of matter. Pure metaphor. Others refined it and, at the beginning of the nineteenth century, Dalton distilled the idea of an atom into a set of axioms that still hold true today.

Subsequent atomic models ('model' is another name for a metaphor) have represented the atom as a plum pudding with the electrons as the plums or, by analogy with the Solar System, a 'planetary' system in which electrons orbit a nucleus made up of protons and neutrons. That last sentence is dripping with metaphor. The 'planetary system' appears, much modified, in most of today's textbooks. We can continue this metaphor hunt, as physicists do, into particle physics with 'quantum', 'string' and 'knot' hypotheses, or argue that subatomic particles have the qualities of 'charm' and 'spin' and 'up' and 'down'. All metaphors. So is the idea of any other organisational unit from a cell to a city. Indeed, the city is often used as a metaphor to explain the functions of a living cell. It works well both ways.

Metaphors of evolutionary change are many and varied. The 'missing link' in the 'great chain of being', the 'survival of the fittest', 'adaptive radiation', 'the apple does not fall far from the tree' and even DNA: these are metaphors, all of which apply to evolutionary change, that have entered our language until we have forgotten that they are indeed metaphors.

Take, for example, an enzyme. An enzyme is a component of the cell that cannot be detected *unless it is doing its job* of enabling a chemical reaction. Enzymes are many and have been an essential part of life from the beginning – and also a part of whatever went before fully living systems. Indeed, it is enzymes that enable life to control one of the essential resources of life, energy flow, discussed in Chapter 7.

All life depends on cells. This includes viruses that may be precursors to or derived from cells but need to enter a cell to multiply. Unlike viruses, cells are self-contained entities that are capable of carrying out all the functions of life. As we will see, there are fundamentally two types of cell. There are ancient cells – bacteria and blue-green algae – and there are modern cells, the ones that are found in all other living things.

In the nineteenth century, German physiologist Wilhelm Kühne (1837–1900) discovered that non-living extracts of cells could carry out chemical reactions. He called the unknown agents 'enzymes' and so began the science of biochemistry. Thousands of enzymes are now listed by the International Union of Biochemistry and Molecular Biology's Enzyme Commission.

An enzyme is a molecule that promotes a chemical reaction while remaining itself unchanged. They have many practical applications. You may have encountered them in detergents for removing 'stubborn stains'. They are also used in textile and paper manufacture and in foods and beverages. Rennet is an enzyme from calves' stomachs. It was used traditionally for making milk junkets and can still be bought at the supermarket.

Victorian biochemists thought that enzymes were the very stuff of life and, indeed, they were not far wrong. All cellular activities are accomplished by means of enzymes. In the twenty-first century we know that the complex protein molecules that form the majority of biological enzymes have themselves evolved from simpler molecules. But has anybody ever *seen* an enzyme? They have seen solutions that contain them. They may have seen their shadows in electron micrographs. They may have seen crystals of protein enzymes, but sadly, such crystals have no enzymatic properties – these do not appear until the crystals are dissolved in water with an appropriate mixture of other molecules. The concept 'enzyme' is a *quality* displayed by a molecule only under the right circumstances; and is an extremely useful metaphor.

An elaborate set of metaphors links the ideas associated with a modern cell with the way that the first cities came about. This is because the biological imperatives for both cell and city are the same: the control and coordination of the basic necessities of life. The city, of course, as a human construction, has social imperatives as well.

Historian of ideas Lewis Mumford developed a series of criteria that helped explain the complexity of a modern city. First, a city needs a granary, to hold the community's corn safe and dry so as provide seed and food for the following year. At its earliest, the seed store was just a deep hole in dry ground. Then, because of the danger of flooding, communities began to make large clay pots in which to store the seed above ground. Later still came barns and silos. When money came into use (a metaphor for seed corn and future prosperity) the 'granary' became a savings bank.

Second, there was the need for a holy place to provide a community focus and to encourage social cohesion. There, rituals were performed to appease a pantheon of gods who were considered responsible for environmental change, life and death. The holy places began to acquire structure, wood and stone circles. Today, there are great churches, sacred spaces designed to preserve the valued objects of the people. Associated with them were, first, the great libraries and, later, museums.

Third was the control centre of the budding city, a chieftain's hall, a queen's royal palace or a war lord's citadel, where the decisions were made about the obligations of citizens and means of defence for the community. It was a place where the rulers and the community could meet and agree on future plans: a centre of government, a parliament. The power of the community was vested in the priests of the temple and the guardians of the citadel, those who controlled the food supply and other resources. Strong people were required to wrestle with gods, to defend the city and husband resources. Communities began to organise themselves into a class system, with serfs at the bottom layer and the priests and royalty at the top.

As we now know, the nucleus of the modern cell coordinates cellular activities so that they are responsive to environmental change (appeasing the gods!) and defence. These are analogous to the roles of the church, the citadel and the library. There are membranous structures, the mitochondria, that are the 'powerhouses' of the modern cell. The cell membrane (the city wall) is continually taking in, through its gates, nutrient molecules to be broken down by metabolic enzymes (serfs, who do all the hard work). A transport system delivers the molecules to the powerhouse, to act as fuel from which to derive the energy that is used to drive all cellular functions.

The other major type of modern cell, the plant cell, taps into the primary power source, the sun, by means of chloroplasts. These are collectors of solar energy. Plant cells do not need a continual source of proteins and carbohydrates from outside. They can make their own as long as they have access to carbon dioxide and a source of inorganic nitrogen (this is why ammonium nitrate is such a good fertiliser – it is 35 per cent by weight nitrogen).

Thus, cells and cities can be made to fall within the same set of metaphors. For modern cells, the best comparison is with a medieval city at the beginning of the Industrial Revolution rather than the giant conurbations of today. It is better to think of those as clusters of cities, or 'multi-urban' by analogy with 'multi-cellular'. Almost all the functions of a pre-industrial city are represented in the cells that make up an individual life form. Or is it the other way around? Are the functions of the cell represented in the city?

The city and the cell at maturity are steady state systems, with the imports ideally balancing the exports, and for the city, immigration balancing emigration. When the balance is lost, then cities become disorganised and cells grow old and die. One can go on making these comparisons. And the reason for this is that all forms of life organise themselves around their need for resources. At the most basic level, the needs of people are the needs of cells.

Now here are two metaphors, of a type more generally known as fables. Stay with them, for they are part of the argument! They demonstrate that biological and social phenomena, when viewed at vastly different levels of magnification, can show remarkable similarities.

Fable 1. Ken and the Grex

At Harvard University, a young man, Ken, was trying to define a research question about the behaviour of a type of single-celled amoeba. He picked up a Petri dish filled with nutrient agar gel, suitable nourishment for the little organisms. He then reached for a culture tube containing amoebae that he'd collected and added a drop to the agar plate. It spread out over the surface and he settled down with a microscope to take observations over the next two or three days. Under the microscope, the cells of the amoebae appeared as small silvery blobs moving slowly around on the gel. He noted that the blobs were widely distributed, sometimes as individuals, sometimes in small clumps.

All at once, he realised that all the individual amoebae in his field of view had been slowly moving – except that one had stopped and now appeared to be attracting or signalling, somehow, to the others. After a while he noted that more and more blobs seemed to be forming small associations or clumps. Gradually, all the amoebae coalesced into streams and headed towards the amoeba that had first started signalling. Just like, the young man thought whimsically, a huge crowd of people, viewed from the air, heading into a major baseball game. What was the attraction? A series of clever experiments showed him that the one stationary amoeba was emitting a powerful chemical attractant. After a while, a large clump formed. Eventually the clump became an independent slug-like creature. It started moving in a coordinated way in one direction and he recognised it as a slime mould. The student wrote an important thesis on the self-organising capacities of the 'grex' as he named the strange slug-like accumulation of amoebae.

Fable 2. The Alien and the Earthlings

A young Alien from a not too distant planet, having taken a self-teaching unit called Earth studies, was trying to learn more about the planet Earth and to define a research question. Her space vehicle was parked in stationary orbit over a large collection of buildings that the Earthlings called a city. In the centre was a huge circular enclosure that was, at that moment, empty of Earthlings. The Alien settled down with her electron telescope to take observations of the round space that she had mentally called an arena. Over the next two or three hours, the Earthlings appeared as small coloured blobs moving all over the city. The Alien noted that the blobs were widely distributed, sometimes as individuals, sometimes in small clumps.

Then she noticed that there was a general movement towards the arena. Obviously, there was some kind of attractant to bring the blobs together. At first, only a few Earthlings were slowly moving around the enclosure. After a while she noted more and more Earthlings appearing. Suddenly she realised that *all* the Earthlings in her field of view were slowly moving to what appeared to be gaps in the enclosure. They then became the focus of attention of all the others. They appeared to be signalling, calling to each other. Gradually, all the Earthlings coalesced into streams heading through the gaps.

What was the attraction? She noted that, after a while, the large gathering had appeared to coalesce into a single clump-like group of individuals around the rim of the arena. Later still, the rim had turned into a single creature, responding as a whole with coordinated sounds, and wave-like motions. The waves seemed to correspond with the actions of a small group within the centre of the enclosure or arena.

The Alien went home and wrote interesting stories about the self-organising capacities of the Earthlings.

At the end of the twenty-first century, the Earthlings discovered a tiny, inert satellite, about 5 metres in diameter, in stationary orbit around Earth. When its recordings were deciphered, it was found that the ant-sized Aliens' interstellar achievements derived from their ability to form a conscious collective intelligence.

The Alien and the Earthlings is an imagined story, so it is strictly science fiction. *Ken and the Grex,* though, is science 'faction', almost true. There *was* such a PhD student in 1933; his name was Kenneth Raper, and he discovered the interesting little slime mould, *Dictyostelium discoideum* (Raper 1935). He died 54 years later, a Fellow of the American Academy of Sciences, replete with scientific honours. His slime mould has become a model organism (a metaphor) for studies of the evolution of self-organisation, multicellularity and embryonic development.

And the moral of our two fables, as the duchess might have said to Alice when wandering through Wonderland, is that *Dictyostelium* and *Homo sapiens* both start off as individuals and organise themselves into complex structures. Cells and people respond in similar ways – but a person has another layer of history because, right at the beginning, they start off as a single cell, a fertilised egg, and self-organise into a human being and later, as a human being, become part of a self-organising social system.

Further, cooperative evolution has a habit of repeating itself. What worked once can work again – at different levels of magnification and complexity. The modern cell is a cooperative construct of three or four ancient, bacteria-like cells working in partnership (see Chapter 3). It was a great evolutionary success. If it worked with ancient cells, why not try modern cells? And it worked again. We find modern cells cooperating to make all the plants, the fungi and the animals. Take another step, and we have organisms of one species – bees or humans – working together in colonies and developing social systems. If that works, why not try collaboration between organisms of different species? This is cooperative evolution, an intrinsic property of life on Earth and the subject of this book.

To return to the fables, the view through the microscope is like the view the imaginary alien had of the Earth through her telescope. Eventually all the earthlings, like amoebae, coalesce to form a 'grex' or crowd, which grows and grows as more join in. Now they can enjoy a much higher level of connectivity – that is to say, information transfer – and go to sporting events, interacting with each other and their environment to produce a Mexican wave.

Dictyostelium slugs and towns have this in common. In the beginning, there is no central slug-organising cell or group of cells. The slug grows until it reaches an optimum size and it starts to move. Arriving at a suitable place, the slug stops and differentiates further as cells assume different functions. And it also appears that *Dictyostelium* performs a sort of bacterial farming, because it transpires that these cells have brought bacterial spores with them to seed their new 'pastures'. Its amoebic citizens in spore form undergo a diaspora (!) and with their precious cargo of bacterial spores blow away to found new communities.

The city starts as a settlement of a few people, then becomes a village and self-organises itself around some basic human needs, grows into a town and then a city that persists for a time until it reaches the end of its cycle and disperses.

To carry biological analogy even further, individual humans, during social development, pass from a single-celled stage, through a multi-celled stage that is analogous to a village, represented by the very early embryo. The 'village' rapidly becomes a small 'town' as it passes through stages of tissue and organ formation, and finally becomes a human being.

The evolution of human societies begins with the cellular family, which enlarges with simple cooperation between family members followed by recruitment of outsiders, to the point of permanent differentiation, where individuals began to specialise in specific tasks.

Towns, when they grow naturally, rather than being laid out by surveyors, develop similar characteristics to one another and are usually sited to take advantage of some important local resource, such as water and minerals. In early human communities, gold was not so important but flint, copper, tin and iron soon became so. The flint mines of Grimes Graves, in Norfolk, England, are evidence that flint had a considerable pulling power. The flint mines were worked for about 300 years, more than 4,000 years ago. Grimes Graves became an industrial centre that exported worked flints to Europe. Still in England, copper and tin mining in the early Bronze Age also created important centres.

When the smelting of bronze started, what we might call the 'tissue' stage arrived as, within their communities, people of like purpose began to associate. Populations stratified into classes, some charged with defence of the commons, who worked closely with a priestly class that interceded on behalf of the people for the favour of the gods. Others plied the various trades that made up a Bronze Age community, and, in Homer's words, 'By mutual confidence and mutual aid great deeds are done, and great discoveries made'.

Communities continued to increase in size and became tribes and city-states. Still clinging to the biological analogy, this is the time of organ formation. As a biological organ is made up of cooperating tissues (made up, in turn, of cooperating cells) so different trades took on different roles. The leather industry, say, diversified into tanners, cordwainers and cobblers, harness makers, jerkin makers and so on. Groups of artisans working in a common endeavour formed into societies and organisations to protect their knowledge and livelihood. Out of this came the medieval guilds.

Figure 1 summarises some of the unintended consequences of being human. As connectivity between individuals increases, so do their institutions increase in complexity. Thus, guilds grew out of the fraternity of, say, stoneworkers, and exemplify the way that barriers were gradually being erected between classes of people.

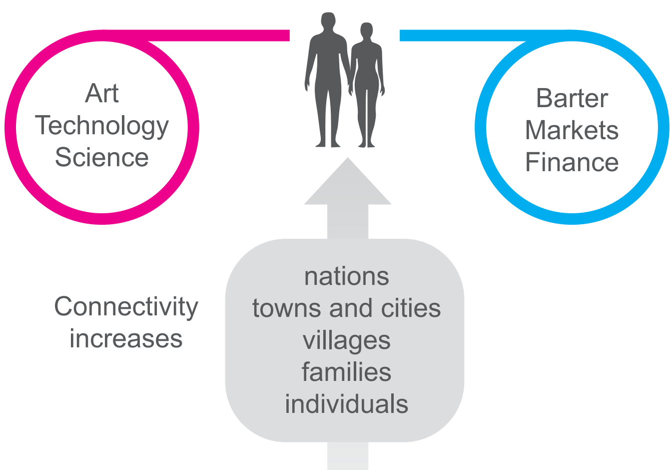

Figure 1. The unintended consequences of being human.

They became formalised and the barriers were strongly enforced by the guilds who protected their knowledge obsessively and even secretly. They erected professional hurdles that acolytes had to climb over before they could be admitted to membership. In the modern world they still exist under different names – a university is such a one, although not secret – and are essential to the smooth running of nations.

Returning to the two fables, they show that views of life at different levels of magnification offer the same general picture. Like that classical example of a fractal, the coastline that offers the same general characteristics at every magnification, biological systems also offer the same general view wherever you look. Rainforests on different continents are created from different components, but a rainforest is recognisably a rainforest, whether you are in Australia, Africa, the Americas, Asia or Europe. Rainforests have the same general aspect: they smell the same, they feel the same and a tree is recognisably a tree, wherever you are. Rainforests all 'work' in the same way. The differences lie in plants and animals that each occupy similar ecological niches. In your mind's eye, follow this thread of biological cooperation and travel back through layers of time, stopping every so often to look around. What you see at every stop may be a dramatically different stage of forest development.

It is no accident that human behaviour maps onto biological systems. First, people are made of the stuff of life and this chapter is intended to illustrate and emphasise the repetitiveness of living systems. What worked once can work again. It also emphasises the layers of evolution. In the beginning, the world was solely inhabited by ancient types of cells that were similar in form to modern bacteria. Three or four of them got together to make the modern cell, the sort of cell of which we are made. Modern cells got together and made animals and plants. The whole of organic evolution was implicit in that first cooperative assemblage of ancient cells. Third, it illustrates the important phenomenon of self-organisation. Cities and slime moulds are self-organised; so are ant, wasp, bee and termite societies, so are towns and cities, so are ecological systems.

All of the animal phyla that we recognise today existed half a billion years ago, in the Cambrian period. At that time, the only photosynthetic plants were the blue-green algae, and seaweeds. All other plant groups were dependent on land colonisation, for which there is evidence, 450 million years old, in the form of fossilised plant spores. Every organism since that time has been brought about by evolution playing with what has gone before – mixing, stretching, squeezing, twisting, duplicating, aggregating, slowing or speeding development, or sculpting with programmed cell death. Living things are like 'the Colonel's Lady and Judy O'Grady', sisters under the skin, as Rudyard Kipling remarked in another context. But they are far more than that. They are all obeying the imperatives of life set down with the birth of the first cell.

In this chapter, we have briefly explored the power of metaphor in science and in human affairs and have introduced the stories that will emerge as we follow evolution from Charles Darwin's earliest ideas to Lovelock's formulation of the Gaia hypothesis. Earth's history is a series of tales of increasing connection and collaboration. These concepts, of course, are metaphors themselves but are the best that philosophers can do, given the state of knowledge. Reality itself is a metaphor and we have to explore it through the eyes of scientists, historians and sociologists.

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