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THE PAST IS A FOREIGN COUNTRY

In which we argue that, while the historical reductionist approach to science has had its triumphs, it has been shown to be inadequate in exploring complex issues.

Before Darwin and the great synthesis that was *On the Origin of Species,* it had been common to reduce any significant problem to its individual strands for separate study. In this chapter we explore the rationale behind this reductionist response to evolution as it was played out in the nineteenth century, before the return to a wholistic understanding.

In the 1950s, approaches to knowledge were at a watershed, the point at which a reductionist past began to separate from a wholistic future. In no spirit of criticism, for it was a creature of its time, this event is nowhere better illustrated than by the Honours course in zoology at King's College London from 1955 to 1958. The structure of DNA – the ultimate reductionist triumph – had been published only two years earlier in *Nature* but academic courses had not even begun to come to terms with the implications of this astounding discovery.

So, undergraduate zoologists in those years still assiduously took animals to bits and examined the bits. They carried out simple physiological experiments on some of the bits, such as frog muscle, or tortured amoebae in Petri dishes. Student botanists were doing the same sorts of things on the floor above with plants. It was very enjoyable, and quite Victorian, as some of the apparatus had been in constant use for 100 years.

There were, of course, occasional 'enrichment' lectures from savants from other universities, and students were taken out into the field to complement their laboratory studies with a bit of natural history. Fieldwork consisted of traipsing around the English countryside armed with tape measures, quadrats, pond nets, collecting bottles and pooters (also called aspirators; these last were simple glass devices with which you could suck up by mouth, without swallowing, anything for later study that was too small or too venomous to handle). It was good fun, but there was not much theoretical basis, beyond elementary statistics; it was strictly a matter of seeing what was there and counting it. Systematic zoology, slotting things into their separate taxonomic boxes, was the major objective. The leading metaphors that applied to evolution tended to be those of mathematical genetics and palaeontology and Kipling's *Just So Stories*. However, the sun was setting on this predominating method of inquiry.

At the end of their three years, students were rewarded with graded degrees. This put them in *their* boxes, where they were expected to stay for the rest of their lives. The 1955–58 group only remained in their boxes until the 1960s, when the desperate need for the multidisciplinary approach was becoming clear.

At the time there was some excuse for continuing with reductionism. The science of modern genetics – now called genomics – had made its first steps as the functions of the nucleic acids were worked out and the first cautious identifications were made of the 'letters' in the DNA code. Elsewhere, the *Fundamentals of Ecology* by Eugene Odum and *Distribution and Abundance of Animals* by Andrewartha and Birch had just been published in 1953 and 1954, respectively. Rapidly developing postwar technology was beginning to make possible the elementary steps of a wholistic science that permitted the study of complex systems. The wholism–reductionism dichotomy was still often evident in conflicting interpretations of experimental findings and in the setting of competing priorities for future research.

It is essential to understand that there is nothing intrinsically evil about reductionism. In fact, humans are probably born both reductionist and wholist. It is perfectly natural for a child to break something to see what it is made of or take something to pieces to see how it works. At the same time, they see the world as a whole, centred on themselves. Most people move on from that position as they acquire the dominant knowledge of their own era. It is therefore impossible to assign the philosophy of reductionism to a particular place or time of origin. A useful historical starting point

for discussion is with a fourteenth-century monk, William of Occam (or Ockham) and his Law of Parsimony (Occam's Razor). It states that, in reasoned argument you must not increase the unknowns. In other words, work only with what is known. Two centuries later, René Descartes, one of the key figures in the science revolution of the Renaissance, used this rule to promulgate a very mechanistic view of biology. For example, he believed that animals were merely automatons made of meat and rejected any view that posited purpose in their existence.

Reductionism has proved to be a useful tool in science, which progresses by accretion of knowledge, so that arguments improve as more of the unknowns become known. The contrasting view to reductionism is wholism: the idea that things can have properties as a whole (emergent properties) that cannot be understood from a simple knowledge of their individual parts. Even a quick look at evolutionary history suggests that the evolutionary process is a series of emergent phenomena.

Emergent properties are generally the properties of complex systems, whose complexity is the consequence of many simple, reiterated, recursive interactions. Every major evolutionary event has led to consequences that a contemporary observer, from Mars, say, could not have predicted. The fables in Chapter 3 emphasise this point. The whole of the biosphere, including human social systems, is an emergent consequence of the appearance of the first cell.

To do them justice, many reductionists understood this phenomenon, but chose to ignore it in the process of studying what was possible, given the state of science at the time. Up to the middle of the twentieth century, the study of biological and human systems as a 'whole' was difficult, unreliable and time-consuming. It created an unfortunate but pragmatic situation, where things were studied more because they *could* be studied, rather than because they necessarily *should* be.

The reductionist approach to humans is epitomised by the study of anatomy. There, the process of dissection, of separation into parts, made studying the whole living organism impossible. The physiologists followed suit and not until the end of the nineteenth century did scientists shake off the pseudosciences such as phrenology (determining character from the shape of the skull) and phlebotomy (treatment of disease by bleeding) and begin the attempt to study *Homo sapiens* as an integrated whole. Ironically, the medical profession has achieved great success by developing

blood tests for known disorders, a process arguably wholist (identifying the disease) and reductionist (creating the blood test and prescribing a remedy) at the same time.

The advent of genomics, the study of the highly variable genetic kit owned by all organisms (see, for example, Lesk 2017), brought about another wave of scientific reductionism. Readily available 'cookbooks' gave the simple and detailed instructions for gene sequencing and manipulation. Graduate students were exploited as intelligent workhorses to do the menial task of gene and protein sequencing. The cynical slogans 'one polypeptide chain, one PhD' and later, as techniques evolved, 'one gene, one PhD' were current around the turn of the twentieth century!

The past is indeed a foreign country and, as LP Hartley remarked, they certainly did things differently there. The sense of the connectedness of things was lost during the Enlightenment when the scientific method of destructive analysis became de rigeur. Philosophers believed that understanding came from dissection, and much understanding did come. By unweaving the network of knowledge into its component threads, the philosophers of the time were so intoxicated by their so-called objective discoveries that they lost sight of the whole. Once the metaphor of individual creation by a higher being was recognised as untenable, it was replaced by another dangerous metaphor, evolution. Darwin's plea for his tangled bank was forgotten and life on Earth came to be seen as a battlefield of relentless competition among all forms of life and the story one of a struggle for existence.

This pessimistic view of life gave rise to the popular evolutionary catchphrase, 'the survival of the fittest'. It was not of Darwin's invention although he did use it from time to time. It was a convenient dictum, erroneously interpreted and applied by many to the human condition. Poor people were considered, *because* of their poverty, to be less fit – but less fit for what? In Victorian times, competition had been held as the way to social and financial success. It had been invoked in empire-building, business, sport, in the establishment of class structure and in people's identity. It had thus been easy to distort Darwin's message further and portray competition as the natural and most desirable condition towards which human beings can aspire.

The authorship of this unfortunate phrase, 'the survival of the fittest', is ascribed to Herbert Spencer, a great if somewhat misguided supporter of Darwin. The most pernicious use of this catchy war cry occurred when

Francis Galton adopted it as a justification for his sociological theories. Out of these came eugenics, and while Galton took a positive view by encouraging 'above average individuals' to marry and have children, it left open the question of who decided who were these 'above average' people who were to be the parents of the brave new world – and left unanswered what to do with the 'less than average'. The answer to the question of who were above average usually proved to be 'us', the Establishment. Claiming that this was 'scientific' implied, erroneously, that it was objective and the decision could be made without sympathetic or ethical considerations.

The unstated corollary, that the below average – which came to mean 'not human like us' – should be prevented from breeding, led to it being used to justify the horrific excesses of the Second World War and to subsequent cases of wholesale murder euphemised as 'ethnic cleansing'. So, at the end of the nineteenth century, the new biologically based hypothesis of the primacy of social competition in evolution became very much the vogue. It was followed in the early twentieth century by the belief in 'the perfectibility of man' based on an optimistic enthusiasm for human social engineering, eugenics. In Nazi Germany, this heady brew was laced with a large dollop of Wagnerian mysticism. The quest for the true Aryan – blond, blue-eyed, muscular and fit – led those not conforming to this ideal straight to the concentration camps. The Russian cartoonist Boris Efimov lampooned this vile creed in 1941 with a picture of the fascist big three and the caption 'A true Aryan should be tall like Goebbels, muscular and slim like Goering and blond like Hitler'. Now, in the twenty-first century, social Darwinism can be recognised for what it is, a distortion of Darwin's theory into a justification for 'unnatural' selection.

The nineteenth century was a time of great change. As noted above, natural philosophers had been flirting with the idea of evolution for some time but no-one had been able to suggest a satisfactory mechanism for it. The Christian Establishment was still more or less intact, although Thomas Robert Malthus, himself a churchman, had, in 1798, set the bomb under it that would eventually undermine the fundamental base and bring the edifice down. In his *Essay on the Principle of Population*, Malthus had grasped the importance of exponential growth, in which the size of the population progressively doubles, until all resources are used up (Figure 14). He wrote that 'the power of population is indefinitely greater than the power in the earth to produce subsistence for man'. This proposition remains especially relevant today.

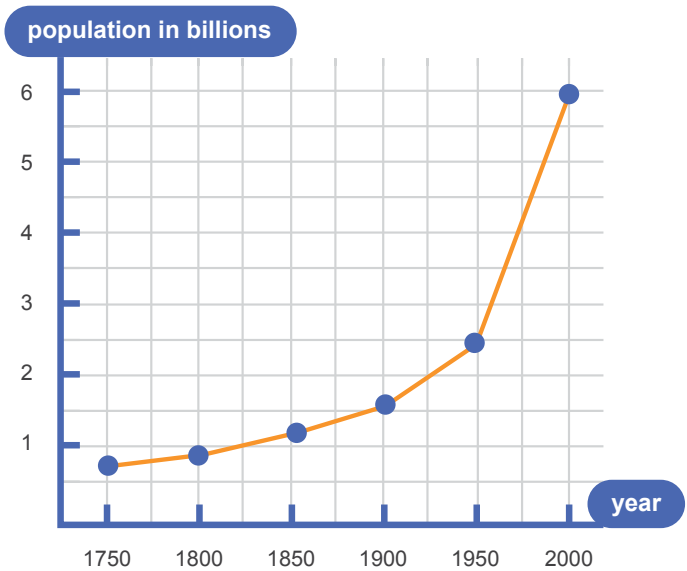

Figure 14. Human population growth since 1750.

Malthus's seminal paper inspired Darwin's search for a mechanism of evolution, although it is focused on the selective pressure created by the growth of every population of organisms, a 'single-factor' explanation of a complex system of relationships. It suited the thinking in Victorian times and still resonates. The proliferation of the poor was used to justify the belief in a hierarchy of rank and privilege underwritten by wealth, by God's will.

There is a common view of life that is unnecessarily pessimistic. Consider the following words from *Last of the Summer Wine,* a low-key but highly successful BBC TV comedy program. Three ageing Yorkshiremen are leaning on a five-barred gate, overlooking a beautiful Yorkshire dale in early summer and musing on the meaning of life. The character of Norman Clegg, a self-made philosopher of penetrating observation, having commented on the beauty goes on remark that 'faintly on the breeze, you begin to sense the million munching teeth of tiny things scoffing even tinier things'.

In this line, spoken with delicate nuance by that fine actor, Peter Sallis, Clegg is expressing a commonly held view, that 'ecology is a terrible book in a beautiful cover', that 'red in tooth and claw' is a foundation for the beauty of nature. And, indeed, it would be depressing, if it were

true. In fact, it is a very animal-based view and takes no account of the overwhelming biomass of green plants and fungi, and the myriad instances of cooperation between organisms – including humans. Even if cooperation between members of the same species is ruled out (which it cannot be), there are so many other examples of inter-species cooperation to give the lie to this pessimistic view. Even at the turn of the century, Kropotkin (1902) could write 'don't compete! – competition is always injurious to the species, and you have plenty of resources to avoid it!'

In the middle of the Victorian century, it was unfortunate for the popular conception of evolution that one of the great Victorian writers, Alfred, later Lord, Tennyson, was also grappling with these ideas and got in first, before Darwin. It is a pity, because his imagery, given all the impact of the art of a great poet, stays with us. Tennyson was, in the current vernacular, in a bad place when he wrote a threnody for his close friend, Arthur Henry Hallam, who had died unexpectedly. *In Memoriam A.H.H*, completed and published a decade before *On the Origin of Species,* expresses Tennyson's failure to reconcile an uncaring Nature with the Christian God of Love. In the following verses, she, Nature, is a metaphor for the extinction of previous life forms:

> 'So careful of the type?' but no.
> From scarped cliff and quarried stone
> She cries, 'A thousand types are gone:
> I care for nothing, all shall go.

Those who, like Hallam, clung to a belief that nature was love, were conflicted by the thinking of the time:

> Who trusted God was love indeed
> And love Creation's final law –
> Tho' Nature, red in tooth and claw
> With ravine, shriek'd against his creed –

Hugh Miller, the greatest palaeontologist of the time, shared Tennyson's internal torment. Miller was the stonemason author of *Old Red Sandstone.* His was the seminal and encyclopaedic work, first published in 1851 (*Everyman* edition 1919), on the Devonian fossils from 'scarped cliff and quarried stone', which he compiled to illustrate the glory of God. Already depressed, it is said that when he learned that his own work was one of the main planks in the evolutionary theory being developed by Darwin, he shot himself.

Like social Darwinism, Tennyson's trope, 'nature, red in tooth and claw', outlived its context and reverberated down through the twentieth century. It is a strongly zoocentric and negative point of view and ignores the great bulk of evolutionary creation in which life forms interact to mutual advantage. In the plant kingdom, for example, death is not the necessary end product of the depredations of a nibbling caterpillar. In the animal kingdom, large carnivores live at peace with one another and often share the same territory by occupying different ecological niches; lions and leopards coexist because they hunt at different times of the day for different prey.

Darwinism has always been cursed with people who try to encapsulate in a few words the important concept of evolution. Misunderstanding the evolutionary relationship of humans to apes, Bishop Wilberforce poked fun at Thomas Huxley by asking him whether it was through his grandfather or grandmother that he claimed his descent from a monkey. Huxley's response, probably apocryphal, has also echoed down the years: 'I would rather have a monkey as an uncle than a man who uses his intellect to obfuscate an argument'. As we shall find in later chapters, the idea that humans are descended from monkeys is so nearly right, while being hopelessly wrong, that it survives today.

Herbert Spencer's 'survival of the fittest' also became a catchcry – probably every English-speaking secondary school child can trot it out if asked about evolution – but in itself, it is meaningless and adds nothing to the debate as it is self-referential and circular. (Who are the fittest? The ones that survive. Who are the survivors? The ones that are the fittest. And so on.)

The search for the 'missing link' between monkey and man had become so imbued with evolutionary politics by the turn of the century that someone went out of his way in 1908 to provide one in the shape of the artfully constructed fossils that comprise 'Piltdown Man'. Although the comparative anatomists had their suspicions, Piltdown Man was not finally exploded until new methods of dating were available in the 1950s. The skull was found to be only 500 years old, that of an evolutionary modern man, the lower jaw came from an orangutan and the filed down teeth from a chimpanzee.

A better term is the 'struggle for existence', but even that is not very good. Struggle can be interpreted in many ways and too often is assumed to mean the struggle between members of the same species for resources. But more often the struggle is against the environment: against wind, rain, drought, poor soils, fire, frost, heatwave, earthquake, tsunami, asteroid strikes, disease and random events. A random event is anything we have not thought of in this list, such as falling out of a tree! This was already, in 1905, apparent to Peter Kropotkin in his travels across Northern Europe. The attention of the Russian zoologist was caught by the numerous cooperative interactions he encountered among the birds and mammals in the harsh environments of the north. This so impressed him that he recorded his observations in a major essay entitled *Mutual Aid: A Factor of Evolution*. Unfortunately, this too was seized on to support political objectives, this time of anarchism, guaranteed to startle the horses of the Establishment.

As a general principle, natural selection as a foundation for the evolutionary story has stood the test of time. Evolutionary change through natural selection has been accepted as shaping our everyday physical and social reality, very much as proposed by Charles Darwin a century and a half ago. On the other hand, the story it told continued to generate highly imaginative ideas, built on incomplete evidence, and interpreted through the historical and cultural lenses of the day. For instance, in the nineteenth century, when the idea of a struggle for survival leapt to prominence (although not initiated by Darwin), it was immediately used to justify the power hierarchy and to impress on impoverished people the feeling that their condition was divinely ordained and all they could expect. It was a convenient reminder for the poor to invite them to sing, during their devotions in church, the verse of Mrs Cecil Alexander's 1848 hymn 'All Things Bright and Beautiful':

> The rich man in his castle,
> The poor man at his gate,
> God made them high and lowly
> And ordered their estate.

The authors remember singing this verse with gusto and enjoyment in their primary schools; happily it is rarely sung today. The hymn was the subject of a sardonic and satirical parody, 'All Things Dull and Ugly', by Monty Python.

The Victorians, presiding over a vast empire held in check by military power, were prone to see everything in terms of the metaphor of conflict, a vision reflected in their hymns – 'Fight the Good Fight', 'Onward Christian Soldiers', 'Soldiers of Christ Arise and Put your Armour on', to name a few. Charles Darwin himself had a much softer view of nature than most, but he could still write at the end of *On the Origin of Species* that:

> from the war of nature, from famine and death, the most exalted object which we are capable of conceiving, namely, the production of the higher animals, directly follows. There is grandeur in this view of life …

Note that this too is animal-centred, approaching the world from the perspective of the animal kingdom, without acknowledging the contribution of plants, or the social constructions of *Homo sapiens*. It does, however, acknowledge and warn that any approach to the concept of evolution by natural selection is necessarily anthropocentric, that is, human-centred, being a product of human thought. And, as we have seen, its interpretation is always through the social understanding of the times. In the tradition of reductionist science trying to eradicate subjectivity, it has meant that evolution has been interpreted as a given biophysical condition, thus ignoring the contribution of humans, both as a major influence on, and interpreter of, the evolutionary process.

In 1900, the rediscovery of Mendel's important study of inheritance in peas at last provided a mechanism by which natural selection could operate. In sexual reproduction, there is a re-sorting of each individual's genetic program at each generation. Three independent scientists rediscovered and republished Mendel's findings in their own countries within a few months. In England, Hugo de Vries was given the credit for the disinterment. Mendel's contribution was the discovery of 'particulate' inheritance, of the gene. Characteristics specified by these particles were passed to the next generation intact, not in bits to be blended, as had previously been supposed. A good account of the impact of Mendel on biological thought is to be found in Edelson (1999).

Another 'heresy' put to the sword in this period was so-called Lamarckism. Summarised as the inheritance of characteristics acquired in a lifetime, Darwin viewed it quite kindly. With, however, the important discovery by Mendel of the inheritable effects of genes, scientists lined up in their traditional adversarial positions. It had to be either one or the other: Darwin and Mendel in one corner, Lamarck in the other. In a *cause celebre*

after the Great War, in 1926 the biologist Paul Kammerer was accused of falsifying evidence to support the Lamarckist position on environmental influences on inheritance. Kammerer was probably correct in what he observed, but his Lamarckian interpretation at that time was considered to be heretical (Koestler 1971).

Today, a rather different version of the Lamarckian view is widely accepted and made respectable as 'epigenesis', from the Latin meaning on or around the genes. Epigenesis is the idea that environmental changes experienced during the lifetime of a plant or an animal may also affect its offspring (Francis 2011). As a concept it is not terribly controversial today. But in 1926, the battle lines were drawn. Few thought in terms of this *and* that.

'Darwinism *and* Lamarckism' is a phrase that was rarely encountered in a positive way in a single sentence in the last century. The more common 'Darwinism *or* Lamarckism' embodied the confrontational nature of science in those days – two sides, drawn up and ready to do battle, a battle that the Darwin supporters turned into a rout. It was a very asymmetric war. A great deal of the evidence for Darwinism was already available while Lamarckists were readily dismissed as cranks.

Not until the end of the twentieth century did modern scientific techniques precipitate a serious resurrection of interest in Lamarckism. Then, with a nod to the Frenchman, it was rechristened 'epigenesis' in *Lamarck's Signature* by Steele et al. (1998), who described a way by which information from non-reproductive cells can be inherited. The authors, self-proclaimed Darwinists, were not trying to replace Darwinism with Lamarckism – their aim was to modify modern evolutionary theory to include some Lamarckian phenomena. Such collaboration had not been permitted before.

We know today that no DNA comes into the world naked. In the case of bacteria, the two daughter cells resulting from a cell division partake evenly of all the pre-existing cellular paraphernalia. In the case of reproduction by gametes – human reproduction, say – the maternal egg possesses all the machinery for cell growth and division, needing only the stimulus and the DNA provided by the sperm cell, which inserts only its nucleus into the egg to begin development. All cellular membranes thus come from pre-existing membranes provided by the egg, needing only their capacity for self-assembly to equip the new organism.

With discovery of the genetic code in DNA by Watson and Crick in 1953, the reductionist approach was given another lease of life. Immense effort was put into deciphering the code, determining which triplet of bases coded for what amino acid, learning how coding took place, how the code was translated into a polypeptide chain and the roles played by the various RNAs. This phase of research was well underway by 1970, and molecular biologists began to manipulate genes to find out how they were regulated and then went on to sequence complete genomes. The first organism to have its genome 'read' was a free-living (as opposed to parasitic) nematode worm, *Caenorhabditis elegans*, in 1998, an achievement that won Sydney Brenner a Nobel Prize, reported by Check (2002).

The past reductionism that considered plant and animal inheritance solely as the consequence of sexual recombination supported by mutation and genetic drift is long gone. Evolution by natural selection can now be considered chemical (the expression of genes in the dance of RNA and associated protein molecules around the DNA), environmental (selection pressures generated by changes in the real world), social (the influence of interaction with organisms of our own and other species) and historic (epigenetic – changes to the genome brought about by life experiences) and more. The introduction of the three-letter word 'and' between items on that list creates an entirely different evolutionary landscape. The concept of evolutionary change as the wholistic outcome of multiple interacting factors is now widely accepted, and is providing the justification for rethinking Darwinian evolution in the twenty-first century.

As an example of reductionism as a success, consider biochemistry and cell physiology in the middle of last century. The reductionist approach was to try to take cells and tissues apart to isolate the subcellular components and make tissue extracts in an effort to determine their function. A common technique was to take the tissue of interest, such as rat liver, add a concentrated sugar solution and blend them together in a kitchen blender. Having broken down nearly all the structures in the cells of the liver, the result was placed in a tube in a centrifuge and spun at about 1,000 times the force of gravity. The pellet formed at the bottom of the tube was discarded and liquid was transferred to another tube and centrifuged once more, this time at much higher g-forces. A beige-coloured pellet was obtained that proved to be composed of millions of energy-producing organelles, called mitochondria, from the liver cells. Mitochondria thus prepared were very stable and, under the electron microscope, looked much the same as they had done when in the liver.

In the reaction flask, under relatively simple experimental conditions, they could be made to carry out their normal cellular function of energy production that previously they had performed within the cell.

Much earlier, in 1890, Altmann, using a light microscope, had noticed granules within the cytoplasm of cells that he thought might be bacteria. With the advent of electron microscopy, the bacteria-like granules turned out to be mitochondria. Altmann's observation was an inspired anticipation of Margulis's symbiotic theory of the origin of eukaryotic (modern) cells 80 years later. Her work, a return to the study of the whole, led to the recognition of the cooperative events that underpinned multicellular life throughout the living systems of the planet, of which more in the next chapter.

There is one discipline, that of human palaeontology, where, in its beginnings, the thread of evolution was invisible. The scarcity of human fossils at the time of *On the Origin of Species* led to much interest in the so-called 'missing link' between the anthropoid apes and humans. There are now many other examples of 'missing links' that are not, in fact, missing, in different evolutionary lines such as the living ginkgo tree that takes us back nearly 300 million years to the era of the cycads, or the fossil *Tiktaalik*, a so-called 'fishapod' that bridges the gap between fish and amphibians, or the fossil *Archaeopteryx* that relates dinosaurs to birds. The human 'missing link' was seized on by the religiously inclined. The fact that it was missing reinforced their entrenched view of the uniqueness and divine origin of humans, even though there are, in fact, many living species that might be considered to be intermediary between non-human primates and humans.

Today, Darwin's work stands as a bridge between the biophysical understanding of evolutionary change and the recognition of the role of human social evolution. In his book on the *Expression of Emotions* (1872), he accepts the human dimension as a major contribution to evolutionary change in its own right.

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