The Greatest Show on Earth

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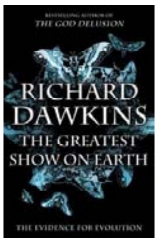

The Greatest Show on Earth: The Evidence for Evolution,
Richard Dawkins
Paperback; Bantam Press, London, pp.ix+470, 2010. Price: ₹399/-

The year 2009 was celebrated all over the world as the Darwin bicentennial – and the 150th anniversary of the publication of the epoch-making book *The Origin of Species*. The general public learnt from it about a discovery made independently by Charles Darwin and Alfred Russel Wallace: life on earth had evolved from simple beginnings, and a process known as natural selection could explain how. The Darwin bicentennial was marked by conferences, talks, exhibitions and writings. *The Greatest Show On Earth* was one of the many publications brought out to mark the event.

This book tries to convey two messages. The first is implicit and is present as a backdrop. Life is a property of matter; and it is possible to account for the properties of living matter on a rational basis. The second message is reiterated over and over again with fascinating examples. It concerns the fact that for all their extraordinary diversity, living forms exhibit basic similarities. Why? The reason is that at a deep level they are related to one another. They appear very different because life on earth has evolved. The organisms that we see are descended from common ancestors that went through a series of modifications to give rise to the different lineages that inhabit the earth today. Even though it is not his main theme, Dawkins makes some comments on *how* evolution takes place.

The story goes back to the dawn of life some 4000 million years ago. As everything else, living matter had to function within the constraints laid down by the laws of physics and chemistry. It coped with the problems of growth, survival and reproduction by organising itself into ever-changing forms. Each new form led to an incremental improvement in the chance of leaving behind successors. A more efficient metabolism, larger size, sharper senses, stronger muscles, faster speed, better means of defence and offence…, all contributed. When averaged over long epochs, the pace of change was infinitesimal. But the net change was such that ancestors and descendants appeared very different. Simultaneously, separate lineages formed and changes accumulated independently in them; life on earth diversified.

Evolution shows no signs of purpose or foresight. Individuals happen to differ slightly, and because of those differences, some individuals leave behind more descendants than others. Small differences accumulate and, over the course of thousands of generations, give rise to large differences. During the process, organisms evolve a variety of strategies for survival and reproduction. That means getting on with other living creatures, whether they are sources of food, predators, mates or communicators. During evolution gains and losses need to be traded off against each other: for instance, an advantage of increased size may have to be considered along with (perhaps) the disadvantage of a consequent loss in speed.

Why do we say that evolution is a fact? Popular thought to the contrary, the fossil record is not the main reason. Fossils are informative of course, and provide vivid case studies of evolution. But the indirect evidence is just as powerful. Patterns in the distribution of plants and animal forms (biogeography) tell us a great deal. So also do similarities in their structure and shape (anatomy and morphology), the way they develop (embryology), their behaviour (ethology) and, not least, their genes (DNA sequences). When all the evidence is considered together, it becomes impossible to doubt that all living creatures are related by a common history of descent with modification.

For obvious reasons, the evidences for how evolution has occurred are not that easy to come by. Also, the routes have been many. The predominant mode of evolution in the large is natural selection (known popularly, though misleadingly, as 'survival of the fittest'). Natural selection depends on experimentally verifiable properties of plants, animals and microbes. And in contrast to other evolutionary hypotheses, it explains adaptation, namely the astonishing fact that living beings give the impression of being products of design – as if a skilled engineer was behind them.

Thanks to the work of the Japanese theoretician Motoo Kimura and others, we have learnt that evolution can also take place without natural selection. The truth of this fact can be inferred by comparing variant sequences of the same protein that are found in different organisms. Even better, one can compare DNA sequences – the molecular signatures of organisms. For any change in the form of a plant or animal dependably to be passed on to its progeny, it has to be driven by an alteration in its DNA. Natural selection depends on the likelihood of an accidental change (mutation) in the DNA turning out to be advantageous. But a change in DNA need not always cause a change in form or any other trait. The change may be 'neither good nor bad'; one says that it has a neutral effect.

Curiously, in spite of being neutral, the change can spread within a population. It can do so via a succession of chance events that, mathematically, can be described in a manner similar to Brownian movement or diffusion. Now, as far as we can tell, among all the possible ways in which a protein-coding DNA sequence can mutate, the majority are harmful and are weeded out by natural selection. Of the remaining portion, a majority are neutral. Only a minority of a minority of mutations is advantageous. The consequences for evolution are profound, because this implies that evolution operates at two levels. If one looks at the level of DNA, most evolutionary change is neutral. It is only a relatively tiny fraction of change in DNA that gets exposed to natural selection and acts as the basis of adaptive evolution.

This book is about evolution – about the fact that the forms of life on earth have changed, and that the change has come about via a process of descent with modification. However, it is impossible to describe the enormous variety of ways in which evolutionary change can take place without asking, how could it have happened? Dawkins asks the question and answers it in the way most evolutionary biologists did until very recently, and probably do today too. Most biologists believe that the explanation for evolution in the large, at the level of whole organisms and their traits, is natural selection. And as mentioned more than once, natural selection explains why plants and animals exhibit *adaptation* – namely, why their parts so often give the impression of being custom-built for the various uses to which they are put.

Adaptation depends on cumulative modifications based on small changes that take place by chance and, individually, happen to improve the organism's chances of survival and reproduction. The point is that natural selection cannot operate unless each change is tiny and (given the rarity of mutations) the pace of change is gradual. This is easy to understand: in an intricately organised system that is functioning reasonably well, any big change that occurs accidentally will almost certainly make it impossible for the system to function any longer.

Dawkins draws our attention to two important features of adaptations. First, as we have seen, they involve trade-offs. A change that looks like an improvement in respect of one trait may make the situation worse than before in respect of another. Still, the change can spread by natural selection if the net gain is positive. For example, bright colouration may be good (because it helps in attracting potential mates) but may also be bad (because it also attracts predators). It all depends on which way the balance works in a specific context. There is a second, little-appreciated, characteristic of adaptations. To my knowledge this is the first time it has been explained in non-technical language. Namely, the costs and benefits that have to be traded off against each other resemble what economists call *marginal* utilities. This means that a cost (or benefit) does not have an absolute value independent of the context. Rather, it must be estimated with reference to the situation that exists and how it is affected. Here is an example. We pay money to see a film if we think that *that* film is going to be sufficiently good to excuse the cost. We do not maintain a running account of the accumulated joy from seeing films, or of how much we have spent on them over our entire life, in order to make sure that the overall pleasure-minus-expenditure balance is positive.

This way of calculating costs and benefits can lead to counter-intuitive evolutionary out-comes. Initially, it can happen that more than one possible modification is advantageous to an organism, and there is nothing to choose between them. But taking one of the many seemingly equivalent alternatives may foreclose future options. It may compel subsequent changes to follow a course that, in the long run, looks like a horrible mistake. The final result would make even a lay person, let alone a good designer, laugh. The textbook example of such an evolutionary mistake is the blind spot in our eyes. We have a blind spot because our retinal layers are, in a sense, inside-out. Instead of being in the front, which is where the light comes from, the photoreceptor cells are at the very back of the eye. And instead of being at the back, the nerve cells that carry visual signals to the brain are towards the front. In order to reach the brain, the optic nerve has to punch a hole through the retina. Any light that falls on the portion where the optic nerve goes in, remains invisible. The hole is, literally, our blind spot. The fact that 'mistakes' like the blind spot are possible, shows that evolution does not involve intelligent design. Dawkins mentions cases that may not be as familiar to the general reader: the bizarre routes taken by the male vas deferens in humans and the recurrent laryngeal nerve in giraffes. One cannot help wondering whether the perils of dealing in marginal utilities are also taught to economists.

Natural selection has been through a curious history of its own and has gone through phases of rejection followed by acceptance. Today its position is that of an orthodox theory that is accepted by the biological mainstream, though with modifications made since the time of Darwin and Wallace. One such modification involves a principle that is slowly gaining acceptance, known as niche construction. It refers to the tendency, similar to a river digging its own channel, of living organisms to modify their environment in a way that improves their efficiency. Whenever it operates, niche construction makes it impossible to think of an organism and its environment as independent entities; instead the two have to be regarded in concert as a single strongly interacting system. The reasoning is all the more valid if the environment in question is made up of living creatures too, whether belonging to the same or other types.

Going beyond such modifications, people have begun once again to question the basic usefulness of natural selection for explaining changes in which adaptation may not be involved – at least not obviously. In particular, doubts have been raised about how well natural selection can account for major transitions in evolution such as the appearance of new species and, more so, of the qualitatively different forms of life ranging from sponges to animals with backbones, that are catalogued by biologists under the names of different phyla.

The most spectacular of all transitions was what is called the Cambrian explosion. It involved the appearance of complex living forms from unicellular ancestors about 530 million years ago. As the doubters see it, the Cambrian explosion throws up a major problem. The problem is that within a comparatively short period of geological time – a matter of many million years – not only did multicellularity itself evolve, but so did all the major groups of multicellular life, the phyla that we identify today. They assert that the suddenness of the change makes it difficult to imagine that it was made up of a long and gradual series of cumulative modifications. Therefore, they go on, principles other than natural selection must have had a hand.

Here, a much suggested alternative to natural selection goes by the name of self-organisation. In the context of evolution, models for self-organisation depend on the unquestioned fact that cells move, adhere and communicate with each other. Next, it can be shown that if a few plausible assumptions about the biochemistry of communication are true – for example, the existence of positive feedbacks and mutual inhibition – it is possible for large groups of cells spontaneously to give rise to intricate spatial patterns. This can happen once a threshold (in the intensity of feedback or adhesion, say) is crossed; the transition can appear to be sudden. Further, the number of possible patterns can be few. Supporters of self-organisation point to the small number of phyla – there are some 30 or so – as additional evidence in favour of the hypothesis. Others deny that a problem exists at all. They say that a few million years during the pre-Cambrian was long enough for qualitative environmental challenges – a rapid build-up of oxygen in the atmosphere and the seas is a popular candidate – followed by intense natural selection to lead to major changes with diversification.

The difficulty with assessing the merits of the rival sides is that in both cases the bulk of the argument rests on plausibility. Reasonable assumptions require to be made regarding the state of affairs at a stage in our ancestry that remains mysterious with regard to important details; people differ fundamentally on what assumptions are reasonable. An added problem is that our knowledge of the way in which the (all highly evolved) microbes, plants and animals of today function, acts as a constraint. We find it difficult to decide what features of present-day life must be retained when thinking about the past and what features discarded as later evolutionary accretions. Hope may be at hand from an area of evolutionary biology that is in its infancy. This is the attempt to reconstruct, as it were, ancient genomes on the computer. Irrespective of how the self-organisation debate turns out, it needs a firmer underpinning. Contemporary findings from molecular, cell and developmental biology remain to be assimilated into evolutionary theory; our understanding of biochemical evolution is barely beginning. In all these cases a common facet of our ignorance is that we need to find out how best to combine the knowledge of single units (single genes, cells or pathways), and the ways in which they work as coordinated groups, into one picture. These issues are touched on here only tangentially.

Dawkins has produced yet another marvellous piece of science popularisation. The contents are not new, but his ability to package subtle concepts in easily readable prose makes this book special. He disposes of many myths along the way. One of them is that evolution has stopped (no, it goes on); a second is that humans are descended from chimpanzees (actually we had a common ancestor who lived roughly 7 million years ago); then there is the belief that humans are on the top of the evolutionary tree (if there is a top, every organism that is alive today sits there: all lineages have evolved over the same length of time). Intelligent designers are shown where they go wrong – most tellingly, by pointing out that natural selection can also lead to mistakes.

As 'mistakes' go, the uniquely human propensity for behaving irrationally provides a rich area for analysis. Unfortunately there is not much here about the evolution of behaviour. It would have been interesting to get Dawkins's thoughts on a fascinating point: with the spectacular exception of one species, behaviour is always rational (it must be). Human beings are the exception of course. A refusal to accept the fact of evolution, especially in the United States, is provided as an example. Other examples are nearer at hand. Not long ago there was a black magic ritual in the state legislature and secretariat complex in Bangalore. Apparently the aim was to bring down the government. The Indian Space Research Organisation has provided us similar entertainment over the years. As a precaution against unsuccessful launches, ISRO carries scale models of its satellites to be worshipped in advance at the temple at Tirupati. Among living creatures, only humans throw rationality to the winds – and get away with it. Anyone who wants to speculate why should read this book.

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