Life Ascending

The Ten Great Inventions of Evolution

Chapter 6: Movement

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About

Dr Nick Lane is a British biochemist and writer. He was awarded the first Provost's Venture Research Prize in the Department of Genetics, Evolution and Environment at **University College London**, where he is now a Reader in Evolutionary Biochemistry. Dr Lane's research deals with evolutionary biochemistry and bioenergetics, focusing on the origin of life and the evolution of complex cells. Dr Lane was a founding member of the UCL Consortium for Mitochondrial Research, and is leading the UCL Research Frontiers Origins of Life programme. He was awarded the 2011 BMC Research Award for Genetics, Genomics, Bioinformatics and Evolution, and the 2015 Biochemical Society Award for his sustained and diverse contribution to the molecular life sciences and the public understanding of science.

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'Nature, red in tooth and claw' must be one of the most over-quotedreferences to Darwin in the English language. Even so, the phrase captures the essence, if not of natural selection itself, then at least the popular perception of it. The line is taken from the brooding poem In Memoriam by Tennyson, which was finished in 1850, nine years before the publication of Darwin's Origin of Species. The poem is a response to the death of Tennyson's friend, the poet Arthur Hallam, and the immediate context of the line is a shockingly bleak contrast between the love of God and the utter indifference of Nature. Not only do individuals perish, Tennyson has Nature say, but so too do species: 'A thousand types are gone: I care for nothing, all shall go!' In our own case 'all' implicitly means all that we hold dear – purpose, love, truth, justice, God. Although never quite losing his faith, Tennyson at times seems to be wracked with doubts.

This stark view of nature, later attributed to the grinding wheels of natural selection, has been attacked from many quarters. Taken literally, the idea at best ignores herbivores, plants, algae, fungi, bacteria, and so on, reducing all life to the vivid struggle between predator and prey. And taken metaphorically, as the more general struggle for existence favoured by Darwin, it tends to play down the importance of cooperation between individuals and species, even of genes within the individual: the importance of symbiosis in nature. I don't want to dwell on cooperation here, but rather to take the line literallyand to consider the importance of predation, and specifically the way in which powered movement, or motility, transformed the world in which we live long ago.

'Red in tooth and claw' already implies movement. First catch your prey: not usually a passive quest. But then to clamp your jaws requires opening and closing a mouth with some force: muscles are needed. Claws, too, can hardly tear unless wielded with ferocity, powered by muscles. I suppose if we try to imagine a passive form of predation we might come up with something like a fungus; but even then some form of movement is involved, if only slow strangulation by sucking hyphae. But my real point is that, without motility, predation as a way of life is barely imaginable. Motility, then, is the deeper, the more profound, invention. To capture prey and eat it, you must first learn to move, whether like a tiny amoeba, creeping and engulfing, or with the power, speed and grace of a cheetah.

Motility has indeed transformed life on earth in ways that are not immediately apparent, from the complexity of ecosystems to the pace and direction of evolution among plants. This story is betrayed by the fossil record, which gives an insight, however imperfect, into the webs of interactions between species, and the way in which these change over time. Intriguingly, the fossil record points to a rather abrupt change in complexity following the greatest mass extinction in the history of our planet, that at the end of the Permian period, 250 million years ago, when 95 per cent of all species are thought to have vanished. After this great extinction wiped the slate clean, nothing was ever the same again.

The world was complex enough before the Permian, of course. On land there were giant trees, ferns, scorpions, dragonflies, amphibians, reptiles. The seas were full of trilobites, fish, sharks, ammonites, lampshells, sea lilies (stalked crinoids, almost totally wiped out in the Permian extinction) and corals. A cursory inspection might suggest that some of these 'types' have changed, but that the ecosystems were not so very different; yet a detailed inventory says otherwise.

The complexity of an ecosystem can be estimated by the relative number of species: if a handful of species dominate, and the rest carve out a marginal existence, then the ecosystem is said to be simple. But if large numbers ofspecies coexist together in similar numbers, then the ecosystem is far more complex, with a much wider web of interactions between species. By totting up the number of species living together at any one time in the fossil record, it's possible to come up with an 'index' of complexity, and the results are somewhat surprising. Rather than a gradual accrual of complexity over time, it seems there was a sudden gearshift after the great Permian extinction. Before the extinction, for some 300 million years, marine ecosystems had been split roughly fifty-fifty between the simple and complex; afterwards, complex systems outweighed simple ones by three to one, a stable and persistent change that has lasted another 250 million years to this day. So rather than gradual change there was a sudden switch. Why?

According to palaeontologist Peter Wagner, at the Field Museum of Natural History in Chicago, the answer is the spread of motile organisms. The shift took the oceans from a world that was largely anchored to the spot – lampshells, sea lilies, and so on, filtering food for a meagre low-energy living – to a new, more active world, dominated by animals that move around, even if as inchingly as snails, urchins and crabs. Plenty of animals moved around before the extinction, of course, but only afterwards did they become dominant. Why this gearshift took place after the Permian mass extinction is unknown, but might perhaps relate to the greater 'buffering' against the world that comes with a motile lifestyle. If you move around, you often encounter rapidly changing environments, and so you need greater physical resilience. So it could be that the more motile animals had an edge in surviving the drastic environmental changes that accompanied the apocalypse (more on this in Chapter 8). The doomed filter feeders had nothing to cushion them against the blow.

Whatever the reasons, the rise and rise of the motile after the Permian extinction transfigured life. Moving around meant that animals bumped into each other far more often, both literally and figuratively, which in turn enabled a greater web of potential interactions between species: not just more predation, but also more grazing, scavenging and burrowing. There were always good reasons to move, but the new lifestyles that came with motility gave animals a particular reason to be in a particular place at a particular time, and indeed a different place at a different time. That is to say, it gave them purpose deliberate, goal-directed behaviour.

But the rewards of motility go beyond lifestyle, for motility also dictates the pace of evolution, the rate at which genes, and species, change over evolutionary time. While the fastest evolvers of all are parasites and pathogenic bacteria, which must deal with the endlessly inventive and sadistic persecution of the immune system, animals press them hard. In contrast, filter feeders, and plants in general, fixed as they are to the spot, don't evolve as quickly. The idea of the Red Queen, who must run to stay in the same place, at least in relation to her competitors, is almost alien to a world of fixed filter feeders that remain essentially unchanged for aeons before being wiped out at a stroke. But there is an exception to this rule of thumb, which again emphasises the importance of motility: the flowering plants.

Before the Permian extinction, there weren't any flowering plants to be seen. The plant world was a monotonous green, like a coniferous forest today. The explosion of colour in flowers and fruit was purely a response to the animal world. Flowers, of course, attract pollinators, motile animals, which transport the pollen from one plant to another, spreading wide the benefits of sex for the sessile plants. Fruit, too, calls upon the motility, and guts, of the animal world to disperse seeds. And so the flowering plants have coevolved with the animals, each side in hock to the other – the plants fulfilling the deepest cravings of the pollinators and fruit-eaters, the animals blindly executing the silent stratagems of the plants, at least until we humans started producing seedless fruit. Such interweaving of destinies sped the pace of evolution among the flowering plants to match that of their animal partners.

So motility brings with it a need to deal with rapidly changing environments, more interactions between plants and other animals, new lifestyles like predation, and more complex ecosystems. All these factors encouraged the development of better senses (better ways of 'sampling' the surrounding world) and a faster pace of evolution, simply to keep up, not just among animals, but among many plants too. At the heart of all this innovation is a single invention, which made it all possible: muscle. While not perhaps engendering the same sense of perfection as organs like the eye, when viewed down the microscope muscles are an awesomely purposeful-looking array of fibres acting in concert to exert force. They are machines that convert chemical energy into mechanical force, an invention as fantastical as those ofLeonardo. But how did such a purposeful machine come to be? In this chapter we ’ll look into the origin and evolution of the molecular machinery that drives the contraction of muscle, which enabled animals to alter the world so utterly…

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