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From albatrosses to us, the interaction of 'neighbourly' gene networks drives evolution.

GENETICS

The neighbourly nature of evolution

Mark Pagel relishes an analysis of how natural selection riffles through life's immense genetic library.

You inhabit something of a miracle, in engineering terms. Your body consists of trillions of cells, woven together into something whose complexity far outstrips that of the most sophisticated objects our best engineers can produce, from computers and skyscrapers to space shuttles. A relatively simple outer form belies a teeming society of chemical reactions and protein engineering. This must maintain itself within strict temperature and physiological limits while enduring a complex and frequently unpredictable external environment. And, to achieve its long lifespan, it must avoid the sort of catastrophic breakdown that plagues human-engineered objects.

All the breathtaking innovation required to produce this complexity rests on two pillars of evolution that are, for the most part, either ignored or unappreciated. These are robustness and evolvability, which together grant what evolutionary biologist Andreas Wagner calls "innovability" in his engaging and intelligent *Arrival of the Fittest*. Wagner's message is that these two foundation stones of evolution exist because of an unexpected and remarkable degree of neighbourliness (not his term) that seems to characterize life — a neighbourliness that allows species to innovate more rapidly and successfully than previously imagined.

Arrival of the Fittest: Solving Evolution's Greatest Puzzle
ANDREAS WAGNER
Current/Oneworld: 2014.

Think of a rigid, riveted steel girder. It is, in many respects, a robust object, able to bear weight and resist high temperatures. But it is not evolvable — there is nothing it can be but a girder. Now think of the most evanescent thing you can, perhaps a wisp of smoke in a breeze. It is highly evolvable — it can change — but it is not at all robust. The wonder of you and me and albatrosses is that we are not only robust, but also evolvable. Equally wonderful is that life as we know it would not be possible any other way.

Here is why. To get from simple replicating molecules through to single-celled organisms such as bacteria and eventually on to complex and ungainly multicellular organisms like giant squid, natural selection has had to search through a vast library of varieties and combinations of genes. Now, imagine you are in the squid section of the library and you want to make an albatross. Every step along the way has to be something that works: it has to be a competitive organism.

Wagner has discovered what makes this search possible. It is good neighbours, and lots of them. The genes that make our bodies typically do not act alone. Instead, they form large and complex networks that interact to produce metabolisms, tissues and organs. Wagner has built computer models of these networks in which he randomly alters some feature, mimicking *in silico* the sort of random mutation that natural selection relies on. He then asks whether the mutated network as a whole can still perform the job it was designed to do.

Overwhelmingly, the answer is yes, and it is this insensitivity to random change that makes biology robust to mutations and mishaps, and evolvable. Even better, Wagner finds that he does not have to travel very far along these mutational pathways before he encounters new neighbourhoods, where the networks produce different products. For instance, a network that can consume glucose might lie near one that can consume other fuels, such as acetate. Wagner thinks that these features of gene networks are repeated in proteins, metabolisms and the basic chemistry of cells. *In vivo* studies back him up.

This offers an answer to one of the most fundamental questions of evolution: how has natural selection had time to search the almost limitless library of life? The answer, posits Wagner, is that it does not usually have to search very far: squid and albatrosses are closer neighbours than we might have expected. *Arrival of the Fittest* will give you a new appreciation of the sheer improbability, but also the plausibility, of the diversity of life. ■

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