What drives the emergence and perfection of species?

Evolution: Harmonizing Chaos

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The complexity and refinement of biological phenomena lead many to see them as the work of forces we do not know or understand. Nevertheless, one does not have to resort to any "intelligent design" concept, for instance, to explain the diversity of live on Earth - it suffices to be familiar with the theory of evolution by natural selection and the molecular foundations of biological processes. Our understanding of evolution may be built on a set of relatively simple and verifiable tenets

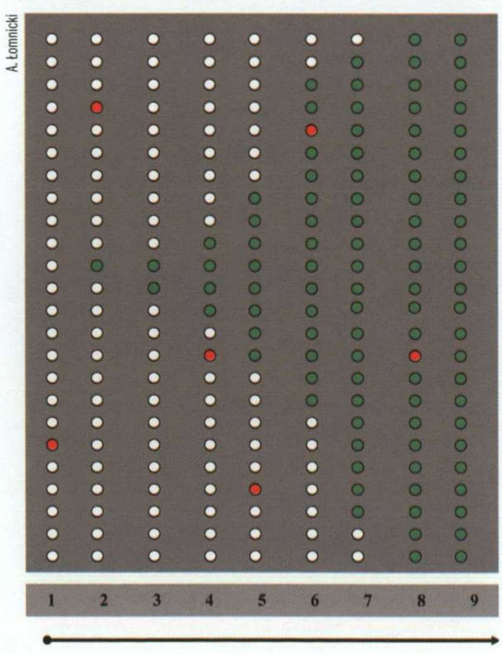
While setting aside the origin of life on Earth, the details of which remain an open issue, let us turn our attention to the minimal conditions necessary for the process of evolution via natural selection. Firstly, matter has to exist in discrete units, meaning fragments physically separate from other fragments (these might be the individual molecules of chemical compounds, for example). Secondly, this matter must be capable of *autocatalysis*, which means drawing in other matter from its environs and changing it into itself - a well-known phenomenon in nature. The upshot of these two characteristics is that the resulting growth of such units will give them a tendency to divide into smaller units. The process of evolution only requires two more conditions: the first is a long period of time, the latter is chance (or chaos), ensuring that differences appear from time to time between parent fragments and their offspring fragments.

Obviously, the plants, animals, and microorganisms filling the world around us are not very reminiscent of such "fragments of autocatalyzing matter," and are significantly more complex than molecules that are capable of such autocatalysis, such as RNA. Nonetheless, there are no solid arguments to assert that the processes described here *cannot* result in the emergence and development of life forms like the ones we are familiar with.

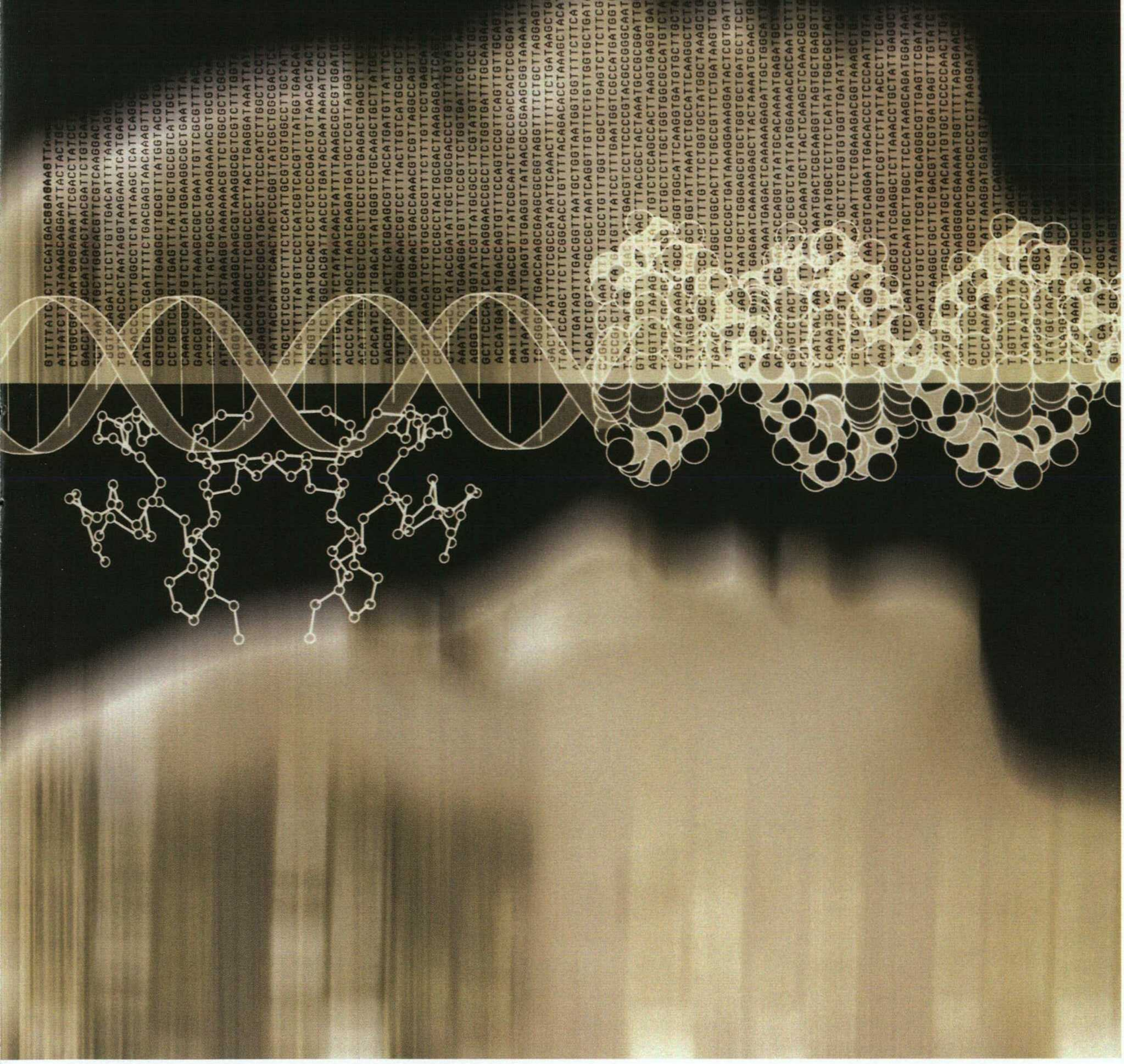
Deliberate change?

Of all the questions that arise here, two seem to be particularly pertinent: whether chaos really is the prime mover for the process of evolution (in other words, whether mutations occur independently of the changing requirements the environment poses for organisms), and whether complex biological systems (the eye being a classical example) can emerge without the existence of an intelligent design that sets forth the path of evolution.

The notion that mutations represent an appropriate response to changes in the environment, rather than being the work of random errors in the replication



How the selection mechanism operates for a single gene, in a population with a fixed number of individuals? In the first generation, almost all the individuals carry a single version of the gene (white), aside from individual harmful mutations (red), whose carriers die without offspring.
The appearance of the green mutation gives its carriers a competitive edge over carriers of the white version, leading to a genetic shift in the entire population within a relatively short time



The mutations that appear in the DNA of all living species represent evolution's "raw material." In fact, we are nothing more than the result of numerous mistakes in gene replication, verified by natural selection

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of nucleic acids, is so attractive to many researchers that it continues to resurface in the biological literature. One of the most well-known cases was the debate about "directed mutations," which were thought to occur in starved bacteria so as to facilitate growth by harnessing newly-available food substances.

Subsequent research has shown that such allegedly deliberate mutations were in essence random, and that only in confrontation with the environment was it possible to assess their value and to choose those that were favorable.

This story demonstrates yet again that the concept of random mutagenesis is something that follows not from the dogmatic stubbornness of neo-Darwinists, but from empirical reality. Biologists likewise routinely confirm that mutations prove to be harmful significantly more often than beneficial – exactly what we should expect to result from random changes being introduced into complex systems. An experiment carried out to identify how frequently random mutations turn out to be harmful, and how frequently they are potentially beneficial, showed that the former are two orders of magnitude more frequent. Moreover, their phenotype impact (on the form and function of the organism) is much stronger, and so the composite negative impact of random mutations is indeed more than a thousand times greater than their positive impact!

The process whereby organs and entire organisms emerge via natural selection does not have analogies in man-made mechanisms. This would entail, for example, the task of transforming a helicopter

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The random process of evolution supported by natural selection sometimes leads to very unexpected results. The eye organs of the octopus or squid resemble those of mammals, yet evolved in a very different way

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craft into a jet plane by proceeding one small element at a time, with the craft functioning better with each successive modification. Mankind would be inclined to simply design the jet plane from scratch. In nature, however, small random changes can lead to the emergence of complex adaptive structures because favorable systems are built up gradually, with further evolution representing a modification of what has already been achieved.

Drifting evolution

The influence of chaos also manifests itself in another aspect of evolutionary biology, called "genetic drift."

Within each population, there are more gametes that are carriers of various genes, than gametes which survive into the next generation in the form of zygotes. In the absence of selection, the choice of which gametes survive is random - similar to when a limited number of balls are drawn from a bag holding many balls of various colors. If a small number of balls are drawn from the bag, the color proportions in the resulting sample will most likely differ from those in the original set, and the shift is entirely unpredictable, or chaotic. A series of such drawings can be seen as modeling a small population as it proceeds through several generations. The theory of genetic drift, based on the laws of probability, shows that such drifting leads to the fixation of only a single version of each gene. Selection, too, can lead to the fixation of a single version of a gene - yet the mechanism of selection is completely different.

How can we distinguish changes consolidated via random processes from those that result from selection? That is difficult to ascertain, yet on the DNA sequence level it often can be. When discovering sequences that have been "preserved" in the genetic material of distantly related species, we can surmise that selection has acted to halt the accumulation of random changes to certain important structures. On the other hand, if we know that certain nucleotide changes are more frequent than the laws of probability might anticipate, we should suspect that they are being supported by selection. This paints a general picture of evolution where random mutations and the outcome of drift play a vast role in generating and consolidating variability on the molecular level. Yet on the phenotype level, chaotic changes are incomparably less common because under the influence of selection, changes in certain DNA sequences and proteins (the ones that

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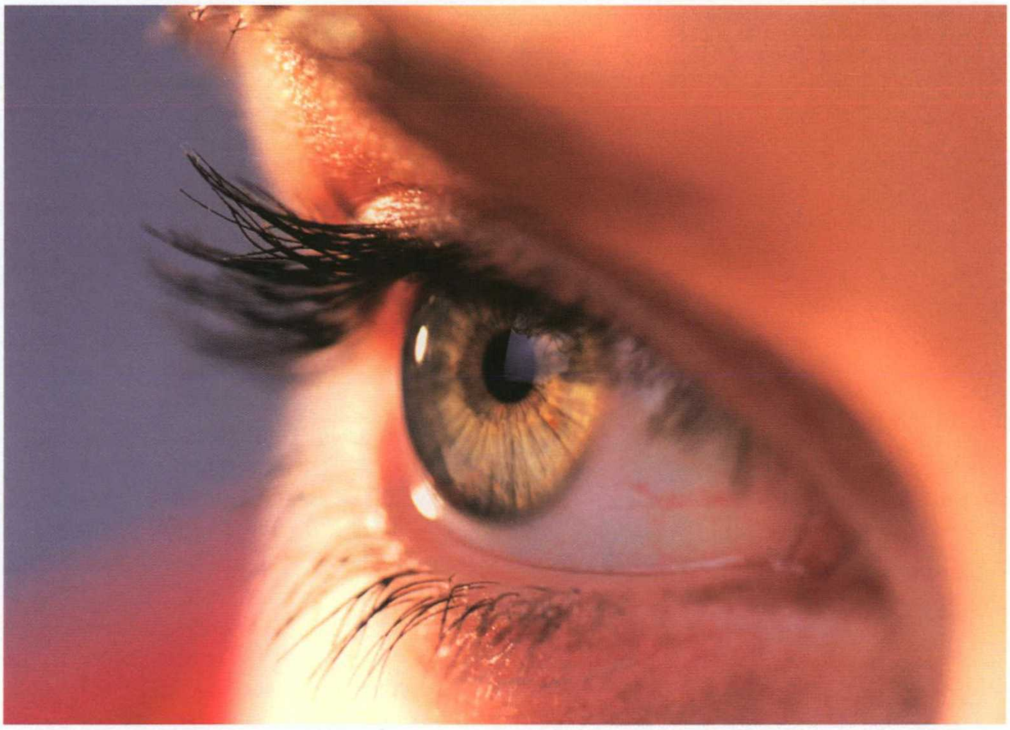

Convergence is a process whereby separate-yet--parallel evolutionary pathways lead to very similar structures or functions. Human and octopus eyes offer a perfect example of convergence; other examples include the similiar body shape of fish and whales

have the strongest impact on the phenotype) are either halted or guided.

Mindless selection

Natural selection copes very well with explaining the emergence and preservation of complex and ideal adaptations. This raises the question of whether all the traits seen in plants, animals, and microorganisms might represent adaptations that arise via selection, ones which always increase the chances of surviving and producing offspring. The existence of such ideal organisms would be more indicative of an ideal design, than of historically conditioned development via natural selection. By adopting the selection hypothesis, we assume that it constitutes a reaction to what an organism experiences at any given moment. Selection chooses from among those traits which are available, out of chaotic variability. Selection cannot anticipate anything - and so if an organism already possesses a certain solution, it may take steps to perfect this solution but it cannot reject it outright and replace it with something completely different. The classic example that confirms this logic is the crossing of the alimentary and respiratory tracts in land-based vertebrates. There is no justification for why these tracts should cross, aside from historical grounds. Moreover, the fact that they *do* cross might easily lead an given organism to choke on liquid or even die, thus obviously a harmful trait. Something similar holds true for the *vas deferens* in human males, which run inside the abdominal cavity above the ureter merely because the testes were not lowered outside the bodily cavity at one time in the past. Here it is hard to speak of any sort of intelligent design; such phenomena can only be explained in terms of the mindless, yet frequently successful influence of selection. ■

Further reading:

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