Devolution (biology)

Devolution, **de-evolution**, or **backward evolution** is the notion that species can change into more "primitive" forms over time. In modern biology the term is redundant: evolutionary science deals with selection or adaptation that results in populations of organisms genetically different from their ancestral forms. The discipline makes no general distinction between changes leading to populations of forms less complex or more complex than their ancestors, and in such terms the concept of a primitive species cannot be defined consistently. Consequently, within the discipline such a word is rarely useful.

Current non-technical application of the concept of “devolution” is based largely on the fallacies that:

- in biology there is a preferred hierarchy of structure and function, and that
- evolution must mean "progress" to “more advanced” organisms with more complex structure and function.

Those errors in turn are related to two misconceptions: that:

- evolution is supposed to make species more “advanced”, as opposed to “primitive"; and that
- modern species that have lost some of the functions or complexity of their ancestors must accordingly be degenerate forms. (Note however that degeneracy in this context has little to do with the current technical use of the term degeneracy in biology).

1 Concepts underlying ideas of devolution

The idea of de-evolution is based at least partly on the presumption that “evolution” requires some sort of purposeful direction towards “increasing complexity”. Modern evolutionary theory, beginning with Darwin at least, poses no such presumption and the concept of evolutionary change is independent of either any increase in complexity of organisms sharing a gene pool, or any decrease, such as in vestigiality or in loss of genes.[1] Earlier views that species are subject to “cultural decay”, “drives to perfection”, or “devolution” are practically meaningless in terms of current (neo-)Darwinian theory.[2] Early scientific theories of transmutation of species such as Lamarckism and orthogenesis perceived species diversity as a result of a purposeful internal drive or tendency to form improved adaptations to the environment. In contrast, Darwinian evolution and its elaboration in the light of subsequent advances in biological research, have shown that adaptation through natural selection comes about when particular heritable attributes in a population happen to give a better chance of successful reproduction in the reigning environment than rival attributes do. By the same process less advantageous attributes are less “successful"; they decrease in frequency or are lost completely. Since Darwin’s time it has been shown how these changes in the frequencies of attributes occur according to the mechanisms of genetics and the laws of inheritance originally investigated by Gregor Mendel. Combined with Darwin’s original insights, genetic advances led to what has variously been called the modern evolutionary synthesis[3] or neo-Darwinism. In these terms evolutionary adaptation may occur most obviously through the natural selection of particular alleles. Such alleles may be long established, or they may be new mutations. Selection also might arise from more complex epigenetic or other chromosomal changes, but the fundamental requirement is that any adaptive effect must be heritable.[4]

The concept of devolution on the other hand, requires that there be a preferred hierarchy of structure and function, and that evolution must mean “progress” to “more advanced” organisms. For example, it could be said that “feet are better than hooves" or "lungs are better than gills", so their development is “evolutionary” whereas change to an inferior or “less advanced” structure would be called “devolution”. In reality an evolutionary biologist defines all heritable changes to relative frequencies of the genes or indeed to epigenetic states in the gene pool as evolution.[5] All gene pool changes that lead to increased fitness in terms of appropriate aspects of reproduction are seen as (neo-)Darwinian adaptation because, for the organisms possessing the changed structures, each is a useful adaptation to their circumstances. For example, hooves have advantages for running quickly on plains, which benefits horses, and feet offer advantages in climbing trees, which some ancestors of humans did.[1]

The concept of devolution as regress from progress relates to the ancient ideas that either life came into being through special creation or that humans are the ultimate product or goal of evolution. The latter belief is related to anthropocentrism, the idea that human existence is the point of all universal existence. Such thinking can lead on to the idea that species evolve because they

"need to" in order to adapt to environmental changes. Biologists refer to this misconception as teleology, the idea of intrinsic finality that things are "supposed" to be and behave a certain way, and naturally tend to act that way to pursue their own good. From a biological viewpoint, in contrast, if species evolve it is not a reaction to necessity, but rather that the population contains variations with traits that favour their natural selection. This view is supported by the fossil record which demonstrates that roughly ninety-nine percent of all species that ever lived are now extinct.[1]

People thinking in terms of devolution commonly assume that progress is shown by increasing complexity, but biologists studying the evolution of complexity find evidence of many examples of decreasing complexity in the record of evolution. The lower jaw in fish, reptiles and mammals has seen a decrease in complexity, if measured by the number of bones. Ancestors of modern horses had several toes on each foot; modern horses have a single hooved toe. Modern humans may be evolving towards never having wisdom teeth, and already have lost most of the tail found in many other mammals - not to mention other vestigial structures, such as the vermiform appendix or the nictitating membrane.[1] In some cases, the level of organization of living creatures can also "shift" downwards (e.g., the loss of multicellularity in some groups of protists, animals and fungi).[6]

A more rational version of the concept of devolution, a version that does not involve concepts of "primitive" or "advanced" organisms, is based on the observation that if certain genetic changes in a particular combination (sometimes in a particular sequence as well) are precisely reversed, one should get precise reversal of the evolutionary process, yielding an atavism or "throwback", whether more or less complex than the ancestors where the process began.[7] At a trivial level, where just one or a few mutations are involved, selection pressure in one direction can have one effect, which can be reversed by new patterns of selection when conditions change. That could be seen as reversed evolution, though the concept is of not much interest because it does not differ in any functional or effective way from any other adaptation to selection pressures.[8] As the number of genetic changes rises however, one combinatorial effect is that it becomes vanishingly unlikely that the full course of adaptation can be reversed precisely. Also, if one of the original adaptations involved complete loss of a gene, one can neglect any probability of reversal. Accordingly, one might well expect reversal of peppered moth colour changes, but not reversal of the loss of limbs in snakes.

2 History of devolution

The concept of *devolution* or degenerative evolution was used by scientists in the 19th century, at this time it was believed by most biologists that evolution had some kind of direction.

In 1857 the physician Bénédict Morel influenced by Lamarckism claimed that environmental factors such as taking drugs or alcohol would produce degeneration in the offspring of those individuals, and would revert those offspring to a primitive state.[9] Morel, a devout Catholic, had believed that mankind had started in perfection, contrasting modern humanity to the past, Morel claimed there had been "Morbid deviation from an original type".[10] The theory of devolution, was later advocated by some biologists.

According to (Luckhurst, 2005):

> Darwin soothed readers that evolution was progressive, and directed towards human perfectibility. The next generation of biologists were less confident or consoling. Using Darwin's theory, and many rival biological accounts of development then in circulation, scientists suspected that it was just as possible to *devolve*, to slip back down the evolutionary scale to prior states of development.[11]

One of the first biologists to suggest devolution was Ray Lankester, he explored the possibility that evolution by natural selection may in some cases lead to devolution, an example he studied was the regressions in the life cycle of sea squirts. Lankester discussed the idea of devolution in his book *Degeneration: A Chapter in Darwinism* (1880). He was a critic of progressive evolution, pointing out that higher forms existed in the past which have since degenerated into simpler forms. Lankester argued that "if it was possible to evolve, it was also possible to devolve, and that complex organisms could devolve into simpler forms or animals".[12][13]

Anton Dohrn also developed a theory of degenerative evolution based on his studies of vertebrates. According to Dohrn many chordates are degenerated because of their environmental conditions. Dohrn claimed cyclostomes such as lampreys are degenerate fish as there is no evidence their jawless state is an ancestral feature but is the product of environmental adaptation due to parasitism. According to Dohrn if cyclotomes would devolve further then they would resemble something like an Amphioxus.[14]

Peter J. Bowler has written that devolution was taken seriously by proponents of orthogenesis and others in the late 19th century who at this period of time firmly believed that there was a direction in evolution. Orthogenesis was the belief that evolution travels in internally directed trends and levels. The paleontologist Alpheus Hyatt discussed the concept of devolution in his work, Hyatt used the concept of *racial senility* as the mechanism of devolution. Bowler defines *racial senility* as "an evolutionary retreat back to a state resembling that from which it began."[15]

Hyatt who studied the fossils of invertebrates believed that up to a point ammonoids developed by regular stages up until a specific level but would later due to unfavourable conditions descend back to a previous level, this according to Hyatt was a form of lamarckism as the degeneration was a direct response to external factors. To Hyatt after the level of degeneration the species would then become extinct, according to Hyatt there was a "phase of youth, a phase of maturity, a phase of senility or degeneration foreshadowing the extinction of a type".[16][17] To Hyatt the devolution was predetermined by internal factors which organisms can neither control or reverse. This idea of all evolutionary branches eventually running out of energy and degenerating into extinction was a pessimistic view of evolution and was unpopular amongst many scientists of the time.[18]

Carl H. Eigenmann an ichthyologist wrote *Cave vertebrates of America: a study in degenerative evolution* (1909) in which he concluded that cave evolution was essentially degenerative.[19] The entomologist William Morton Wheeler[20] and the Lamarckian Ernest MacBride (1866-1940) also advocated degenerative evolution. According to Macbride invertebrates were actually degenerate vertebrates, his argument was based on the idea that "crawling on the seabed was inherently less stimulating than swimming in open waters."[21]

3 Dollo's law

Main article: Dollo's law

Complex organs evolve in a lineage over many generations, and once lost they are unlikely to re-evolve. This observation is sometimes generalized to a hypothesis known as *Dollo's law*, which states that evolution is not reversible. This does not mean that similar engineering solutions cannot be found by natural selection. For instance the tail of the cetacea—whales, dolphins and porpoises which are evolved from formerly land-dwelling mammals—is an adaptation of the spinal column for propulsion in water. Unlike the tail of the mammal's marine ancestor, the Sarcopterygii, and the other teleosts, which move from side to side, the cetacean's tail moves up and down as it flexes its mammalian spine, but the function of the tail in providing propulsion is remarkably similar.

4 Streamlining evolution

"Devolution", the verb "devolve" and the past participle "devolved" are all common terms in science fiction for changes over time in populations of living things that make them less complex and remove some of their former adaptations. The terminology used herein is non-technical, but the phenomenon is a real but counter-intuitive one, more accurately known as streamlining evolution. Since the development and maintenance of a feature such as an organ or a metabolite has an opportunity cost, changes in the environment that reduce the utility of an adaptation may mean that a higher evolutionary fitness is achieved by no longer using the adaptation, thus better using resources. This requires a mutation that inactivates one or more genes, perhaps by a change to DNA methylation or a methionine codon. Streamlining evolution allows evolution to remove features no longer of much/any use, like scaffolding on a completed bridge.

However, "devolution" in practice typically refers to changes that occur from a problem no longer existing rather than superior solutions existing. For instance, of the several hundred known species of animal that live their entire lives in total darkness, most have non-functional eyes rather than no eyes. This is due, for instance, to deterioration of the optic nerve. It occurs because mutations that prevent eye formation have low probability. However, several eyeless animal species, such as the Kauai cave wolf spider, who live in total darkness, and whose ancestry mostly had eyes, do exist. Together with gene duplication, streamlining evolution makes evolution surprisingly able to produce radical changes, despite being limited to successive, slight modifications.

5 See also

- Degeneration
- Devo, a band whose name is a contraction of the term
- Dysgenics
- Evolution of complexity
- Galápagos, a novel by Kurt Vonnegut, set (mostly) 1 million years in the future where humans have "devolved" to have much smaller brains
- Great chain of being
- HeLa
- International Society for Krishna Consciousness views on evolution
- Ray Lankester, in particular the section *Invertebrates and degeneration*.
- Ulas family
- Yeridat ha-dorot

6 References

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