Have any of Earth’s creatures stopped evolving?

The goblin shark, duck-billed platypus, lungfish, tadpole shrimp, cockroach, *coelacanths* and the horseshoe crab — these creatures are famous in the world of biology, because they look as though they stopped evolving long ago. To use a term introduced by Charles Darwin in 1859, they are “living fossils”. And to their ranks, some have added humans, based on the idea that technology and modern medicine has, for all intents and purposes, eliminated natural selection by allowing most infants to live to reproductive age and pass on their genes.

It may be tempting to conclude from the sharks, horseshoe crabs and other creatures that evolution does often stop, and that Darwin’s “living fossil” term makes sense. But such a conclusion would be wrong.

Some argue that Darwin never intended the phrase to be used seriously. “The term is over-simplifying and leads to people believing that some things haven’t evolved, which is so wrong,” noted Africa Gómez, a biologist at Hull University in the United Kingdom who led a genetic analysis of the tadpole shrimp that in 2013 demonstrated that this “living fossil” is no fossil at all. “They have been evolving non-stop and speciating and radiating, so why on earth are they called living fossils?”

The same is true if one looks closely at the other “living fossils. They are all evolving, humans included. This is partially because there is more to biology than meets the eye, with things changing constantly at the cellular and biochemical level. But it’s also because Darwin’s watershed discovery, natural selection, known in popular language as ‘survival of the fittest’ is not the only evolutionary force.

Goblin shark

Death prior to reaching reproductive age and lack of reproductive capability are not the only factors controlling biological change. Mathematics also plays a role here. Keep the environmental conditions the same around a biological group, remove selective pressures, but mess with the numbers of individuals in a population, and evolution still happens. Living things evolve, whether you see it on the surface or not.

There is more to evolution than meets the eye

Natural selection is the best-known evolutionary force and there are numerous examples of it operating quickly in recent times. To illustrate how natural selection works to biology students, teachers and textbook writers typically use examples of creatures with physically obvious changes. Among the more popular is the peppered moth of England. Early in the Industrial Revolution, peppered moths were light-colored. This camouflaged them against the white bark of birch trees around industrializing cities. Over a half-century, as the soot from burning coal in factories darkened the bark of the trees, the moths darkened their coloring too. It happened through natural selection. If you're black moth on a white tree, you're likely to get eaten by a bird, but when the trees darkened, now the dark moths had the advantage.

Another textbook example of natural selection is the high incidence of sickle cell disease in humans in places where malaria is endemic. Malaria and sickle cell disease are both deadly without modern medicine, but to have sickle cell disease one must carry two copies of a gene for defective hemoglobin, one from each parent. Having one defective copy, and one normal copy of the relevant gene however protects an individual from the parasite that causes malaria. But it causes no sickle cell crises, unless the individual engages in extreme exercise, or travels to high altitudes.

The lesson from these examples is that natural selection, due to environmental factors, leads to overt changes, but that a biological status quo should persist as long as everything in the environment remains copacetic.

Doing the math

In the mid to late 19th century, Darwin enjoyed a fair amount of publicity in England, and throughout the world. That publicity was well deserved, but Darwin's contemporary, Gregor Mendel, was effectively invisible. Working from a monastery in a region that is now part of the Czech Republic, Mendel made fundamental discoveries about inheritance that eventually would put him in chapter one of every genetics text book. Darwin thought that children were a blend of their parents. But using plant models, Mendel figured out that this was not the case. Rather, he found that traits often disappeared from parents to offspring, only to reappear in future generations.


Lungfish

Early in the 20th century, a British researcher named Reginald Punnett was asking a lot of questions about inheritance to himself and also to his colleagues. Together with biologist William Bateson, Punnett would end up co-founding the Journal of Genetics in 1910. But Punnett also had a mathematician friend named Godfrey Hardy. Together, Punnett and Hardy used to play a lot of cricket, and one day on the cricket field Punnett mentioned that the problem of inheritance might be understood best in light of mathematics.

This led Hardy to publish what was called Hardy's Law in June of 1908. It was an algebraic expression showing how the numbers and ratios of genes and traits should stay the same, or shift over time. It would have made Hardy the sole founder of population biology, if not for the fact that somebody else had already discovered it six months earlier. That man was Wilhelm Weinberg, a German physician who had derived a similar equation of population genetics in January, 1908. When this was realized, geneticists began referring to what we now call the Hardy-Weinberg Principle, and an equation by the same name.

The Hardy Weinberg Principle illustrates that there is an equilibrium that is maintained –the ratio's alleles, alternate forms of each gene– remain the same, so there is no evolution — if selective pressure is removed, but there are a couple of other requirements. The population must be reproductively isolated (separated from other organisms that can produce offspring with it), and the population must be infinitely large.

If the number of individuals in an isolated, successful population is not infinity, then a force called genetic drift comes into play. Like the increasing chances of getting more heads or more tails as the number of random coin tosses is decreased, genetic drift increases as the size of a population decreases. Other things that happen in nature are founder effects and bottlenecks, both of which you can equate to drawing a handful of gumballs from a jar and ending up holding gumballs with a ratio of colors that differs from the color ratio in the jar, due to the randomness of sampling.


Horseshoe crab

With a founder effect, a small group of individual's gets isolated, and due to chance the ratio of alleles for various genes is different from the mother population. The same is true in a bottleneck effect, which happens when the bulk of a population gets killed off, and due to to chance, the ratio of different alleles in the surviving gene pool is different from what it was in the mother population.

Whereas founder effects and bottlenecks remove diversity from the gene pool of a population, the opposite can happen when migration and other factors bring populations together. Thus, while in the case of humanity, modern medicine and other technologies may indeed be reducing the impact of natural selection, migration and founder effects has been playing a major roles as transportation and other technologies have developed. And these phenomena may play a still more influential role if human colonization of the Moon, Mars, or free space becomes reality. In nature all phenomena that change the gene pool operate in concert, affecting the course of evolution, whether in tadpole shrimp, lungfish, or humans.

David Warmflash is an astrobiologist, physician and science writer. BIO. Follow him on Twitter @CosmicEvolution

This article was originally published at the GLP on November 27, 2017.