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Adaptations: Product of Evolution

Pierrick Bourrat
Department of Philosophy, Macquarie University, North Ryde, NSW, Australia
Department of Philosophy & Charles Perkins Centre, The University of Sydney, Camperdown, NSW, Australia

Definition

Structure or behavior of an individual that is the long-term outcome of the process of natural selection.

Introduction

The word adaptation has a vernacular and two technical senses. In a vernacular sense, an individual's adaptation is simply the adjustment of this individual to new conditions. For instance, when the temperature at the place you are located increases sufficiently, you start sweating. Your temperature adjusts or adapts to this new temperature. This is an adaptation in the vernacular sense, which is different from what evolutionary biologists and psychologists are referring to when they use the word "adaptation," although a link between the vernacular and the technical senses exists. An adaptation, for an evolutionary scientist, is both a structure (for instance, an organ) or a behavior which is the outcome of the process of natural selection, and the evolutionary process by which such a structure was produced. Thus, one technical meaning of the term "adaptation" in evolutionary sciences refers to the product of natural selection, while the other refers to the process by which such a product is obtained.

The Process of Adaptation

One of the greatest achievements of Darwin's (1859) theory is that it can explain how complex structures to which we attribute functions are the products of an unguided process. William Paley, a famous theologian, is well known for having formulated a version of the "watchmaker analogy" in his influential book *Natural Theology* written in 1802, one version of which is the following. If you stumble upon a rock on the beach, it is unlikely you will ask who designed the rock and whether the rock has a purpose. But if you now stumble upon a watch, you will want to know who produced the watch, as well as the purpose of this complex object. Design calls for a designer, in this case a watchmaker, according to Paley. Natural selection can explain complex "watch-like" structures, ones which appear to bear the hallmarks of intentional design, without recourse to any sort of intentional designer. This type of reasoning led Richard Dawkins (1986, p. 21) to claim that: "[n]atural selection is the blind watchmaker,

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blind because it does not see ahead, does not plan consequences, has no purpose in view. Yet the living results of natural selection overwhelmingly impress us with the appearance of design as if by a master watchmaker, impress us with the illusion of design and planning."

How can natural selection achieve this result without invoking a designer? Suppose you have a population of individuals that all differ in their characteristics. For instance, some individuals are able to detect light, while others are not. Suppose also that being able to detect light produces an advantage in terms of survival or reproduction, so that on average light-sensitive individuals have a larger number of offspring than light-insensitive individuals. The reason for this advantage could be because seeing light permits an individual to detect some movements and consequently escape predators more often than light-insensitive individuals. Finally, suppose that individuals transmit their ability to detect light to their offspring with some fidelity. On average, light-sensitive individuals produce light-sensitive offspring more often than light-insensitive individuals do. At the next generation, we expect the population to have a higher proportion of light sensitive individuals than it had in the previous generation. This recipe for evolution by natural selection, which at its cores invokes variation, difference in fitness (reproductive output), and heredity has been proposed a number of times ever since Darwin presented his own version in the *Origin* (for a review of them see Godfrey-Smith 2009; for a famous version see Lewontin 1970). It embodies the principles by which a population can adapt to its environment. Yet, all one gets after one generation is a population in which individuals are slightly better able to escape predators than they were in the previous generation, nothing like complex structures such as an eye.

But suppose now you repeat this process over and over again for thousands of generations, with some individuals exhibiting new variation (acquired by random or blind mutations) at each generation. For instance, one mutation could increase or decrease the number of cells able to detect the light, change their position, etc. With such a process of blind variation (i.e., random from the point of view of the individual bearing this difference in terms of the advantage or disadvantage it will produce), the population will start exhibiting increasingly complex structures. And, in fact, this is precisely what Nilsson and Pelger (1994) demonstrated. Using a computer simulation, they showed that by random mutations increasing or decreasing in different ways the optical quality of a patch of light-sensitive cells, a structure similar to that of the mammalian eye or eye of an octopus can evolve in less than 2000 steps (1829 to be precise), where each step can modify one element of the structure of the patch by one percent. Given the fidelity with which traits are typically transmitted from generation to the other, they estimated that it would take less than 400,000 generations to evolve an eye. This is, according to them, a pessimistic estimate since natural selection would typically work on several elements of the structure of the eye at once, while their simulation only tweaked one element at a time.

Nilsson and Pelger's simulations represent a proof of concept: With a simple process producing blind or random variation, differential success, and transmission of characteristics over time, complex structures or behaviors can emerge. These structures are adaptations.

Adaptive, Maladaptive, and Adaptation

How many steps does it require for a structure to become an adaptation? In the case of the eye presented above, this is equivalent to asking for the threshold point at which the structure is sufficiently different from the patch of light-sensitive cells so that we can call it an adaptation to detect and escape from predators (assuming the bearer of the structure is prey). There is no definitive answer to this question. But recognizing that it has no definitive answer leads to some interesting distinctions, especially in the context of human cognition in its modern environment. An adaptation, as we characterized it, is the product of natural selection. Yet, we also saw that after one generation natural selection already produces a difference: the proportion of the most successful variants will increase (of course this assumes that genetic drift can be neglected). Should we call the difference an adaptation?

Strictly speaking one might want to do so and accordingly call this a *simple* adaptation (or one-step adaptation). In some contexts, this is exactly what is done. For instance, being a heterozygote with the sickle-cell variant of hemoglobin, which results from a single mutation from normal hemoglobin, is regarded as a classical adaptation against malaria (Kwiatkowski 2005). Unfortunately, being a homozygote with the sickle-cell variant leads to a disease known as "sickle-cell anemia." That said, when the structure or function is more complex, such as an eye, a small difference improving the success of individuals when compared to others is called "adaptive" rather than an adaptation. This distinguishes cases in which a structure has been selected for millions of years in an ancestral environment and yet has a negative effect on fitness in the modern environment – think about the adaptive role of liking sugar in an ancestral environment and its current role on obesity and cardiovascular diseases – from cases in which the adaptation still has an advantageous role in the modern environment. In the latter case the adaptation is also adaptive, while in the former it is not; the adaptation is now maladaptive.

Furthermore, the adaptive/adaptation distinction permits us to account for structures that had no previous function (something known as an evolutionary by-product) and suddenly become advantageous. In such a case, the structure is adaptive without being an adaptation. For instance, some scholars have argued that the beliefs in supernatural agents encountered in many religions started originally as a by-product of an adaptation to detect agency in the environment (Boyer 2001). Since it is costlier not to detect an agent when there is one than to detect an agent when there is none (think about the consequence of not detecting a predator or opponents when there is one), the thesis that beliefs in supernatural agency are a by-product of our evolved cognition is a plausible hypothesis. From this by-product, some people have argued that specific beliefs about supernatural agents, for instance that they are interested in human morality, have an adaptive value without necessarily being an adaptation: it might currently increase the fitness of people more prone to have such beliefs without having been selected for in the past (for a review of these different hypotheses see Bourrat 2015). If an adaptive process goes on for many generations, an adaptive structure will become an adaptation.

Conclusion

Adaptation is a fundamental concept of Darwinian apparatus. Without this concept, it would be extremely difficult to make sense of the biological complexity around us. In particular, it plays an important role in evolutionary psychology since many complex behaviors, despite their lack adaptiveness in the current environment (or even their deleterious effects, a phenomenon known as evolutionary mismatch), are often regarded as adaptations for an ancestral human environment, known as the environment of evolutionary adaptedness (EAA). Despite the perils of having an adaptationist story for every trait (known as "just so stories"), as forcefully argued by Gould and Lewontin (1979), by and large, the success of evolutionary sciences rests upon generating such stories and then rigorously assessing whether they withstand diverse empirical tests.

Cross-References

- ▶ Adaptive Benefits
- ▶ Byproduct of Adaptations
- ▶ Maladaptations
- ▶ Mismatch Between Evolved Morality and Modern World
- ▶ Strong Adaptationism
- ▶ The Adaptationist Program
- ▶ Weak Adaptationism

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