How Can Complex Structures Evolve by Natural Selection?

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WRITER'S COMMENT: This essay, written for Professor Aliki Dragona's UWP 101 class (Advanced Composition), addressed a rather broad prompt: explain some technical subject in your own field of study, in a format appropriate to a publication of your choice. As I am an Evolution and Ecology student, it seemed natural to write about an evolutionary topic, such as preadaptation. I decided to aim the essay towards the generally educated and curious readership of Scientific American. *This gave me the flexibility to treat a somewhat complicated subject with a level of detail that would not be appropriate for a more general audience, but still allowed me to write an informative essay for an audience of nonexperts. My ultimate goal was to produce a piece that informed the reader of the depth and richness of evolutionary theory and, at the same time, addressed what some critics of evolution believe is a fatal flaw in the theory: the presence of complex structures.*

—Michael May

INSTRUCTOR'S COMMENT: For their third assignment I asked my UWP 101 students to explain a complex concept in their field in the form of an article that would be submitted to their favorite general audience publication; this assignment also had to function as preparation for their 2,500-word term project. I advised the students to choose a concept that we would not recognize immediately, but that, after reading their article, we would feel comfortable with. Michael told me he liked reading Scientific American *and asked if I knew anything about "preadaption." I did not, but after reading Michael's engaging and eloquent explanation, I knew that he had succeeded in his mission. What makes Michael's article particularly attractive is his ability to interweave complex current academic research and wonderful quotes from Darwin, explain a complex concept lucidly, and maintain a lively and fluid style. I was hooked from his first paragraph on giraffes; Michael's essay shows us what good writing is.*

—Aliki Dragona, University Writing Program

On some dry savannah in Africa, a giraffe stretches its neck up to pick the leaves off the tallest part of an acacia tree. This giraffe's neck is, by some fluke of genetics, slightly longer than the necks of its compatriots, and because of that it is able to reach slightly higher and eat slightly more in these times of drought and famine. Because of this advantage, this giraffe lives longer and bears more young than others are able to; those young resemble their parent and have slightly longer necks than their competitors, and thus the cycle repeats. It is plain to see that, over vast amounts of time, the length of the average giraffe neck will increase. We might imagine that the ancient giraffe had a shorter neck, perhaps much like a horse. The transformation from short- to long-necked represents no real intellectual challenge, since it is easy to imagine intermediate neck lengths that would put their owners at an advantage. Unfortunately, not everything in this world is so simple.

A bird's flight feather is a remarkable structure. A stiff central rachis supports branching barbs and barbules which interlink so they can act as a single surface, preventing moving air from perforating the feather and rendering it useless for flight. Asymmetry between the leading and trailing edges of the feather provide the aerodynamic properties necessary to maintain lift. Clearly, the feather is a complex machine, with many vital pieces that must work together to make it useful for flight. It is difficult to see how this structure could have evolved gradually, because there are no beginning or intermediate stages we might imagine that could serve the purpose of flight: reduce the feather to a simple rachis, and the creature that bears it is as flightless as a creature that does not. The simple process of adaptation appears unable to account for the production of the feather.

So how could feathers possibly have evolved? How do evolutionary scientists account for the obvious and nearly ubiquitous presence of complex structures in nature? As defined by prominent American evolutionary biologist and author of the popular textbook *Evolution,* Dr. Douglas Futuyma, an *adaptation* is "a feature that has become prevalent in a population because of a selective advantage conveyed by that feature in the improvement of some function" (2009). The process of adaptation, then, is the gradual change of some feature over evolutionary time, whereby that feature becomes better able to perform its function. How this applies to simple examples, such as that of the giraffe's neck, is clear: even a short neck is capable of reaching some vegetation, but any slight increase in neck length allows the animal to reach higher leaves, which confers an advantage. But how this process might apply to a complex feature like a feather is not immediately obvious: while the flight feather of a modern bird is marvelously suited to perform the function of flight, a simpler, intermediate feather would likely be totally incapable of helping a bird to fly.

The concept of *preadaptation* is invoked to explain complex cases which seem unlikely to have evolved by the gradual refinement of a preexisting structure. According to Futuyma, a *preadaptation* is "a feature that fortuitously serves a new function" (2009). A preadapted feature has likely evolved to fulfill some other function, but, perhaps by sheer coincidence, it is also capable of performing an entirely different function. In this light, complex structures like the bird's feather become explicable, even expected.

We can understand the case of a bird's feather when we consider the possibility of preadaptation. To do so, we must examine the fossil record to determine what the earlier feathers looked like and what they may have been used for. Today, paleontologists believe that birds evolved from a group of light, predatory dinosaurs called maniraptorans (to which the famous *Velociraptor* belongs). For many reasons, not the least of which is the need to support a fast-paced predatory lifestyle, such maniraptorans are believed to have been warm-blooded. Maintaining a high constant body temperature is energetically costly, so adaptations to retaining heat are extremely beneficial. Because of this, scientists believe that feathers may have evolved first as elongated scales in these dinosaurs (or their ancestors) as an adaptation for retaining body heat, in much the same way that hair does in modern mammals (Xu and Guo 2009). This prediction is supported by recent discoveries of remarkably well-preserved fossils of maniraptoran dinosaurs bearing what appear to be light, filamentous body coverings. As dinosaurs became more and more bird-like, their feathers became more complex, evolving simple branching structures to increase the surface area of their feathers, thus increasing their ability to insulate. Feathers were also likely important in mating displays, as they are in modern birds, and it is believed that this, too, would have driven the evolution of ever more complex feathers.

Eventually, as feathers became more complex and attained greater and greater surface area, they reached a point where they became important aerodynamically, which marked a change in their function and allowed them to be adapted for flight. Scientists suspect one of two scenarios is true: 1) primitive feathers allowed arboreal dinosaurs to parachute safely to the ground from trees, a behavior that could be adapted to passive gliding and eventually powered flight, or 2) primitive feathers provided downward force to speedy dinosaurs to improve traction and maneuverability (in much the same way a spoiler functions on a racecar), and this drove the evolution of the improved aerodynamic properties that would eventually enable flight. In this way, feathers advanced from protective structures (scales), to simple filaments, to complex branched structures, and eventually to the wonderfully adapted structures we see today.

Many have urged that the presence of complex structures is damning evidence against evolutionary theory, that structures with purportedly nonfunctional intermediates are evidence of some other force at work (Behe 1996); if these structures could not have arisen gradually, then they could not have been produced by natural selection, and evolution must therefore be false, or at best inadequate. Darwin foresaw these challenges, and in *On the Origin of the Species* he wrote,

> We should be extremely cautious in concluding that an organ could not have been formed by transitional gradations of some kind. Numerous cases could be given amongst the lower animals of the same organ performing at the same time wholly distinct function. (175)

Clearly, preadaptation provides us with a framework to understand the presence of otherwise unexplainable structures, both visible and microscopic, which is vital to understanding the rich complexity of the natural world.

References

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