Part VI

Evolution

Catching evolution in action

A hundred years ago Charles Darwin's theory of evolution by natural selection was taught as the foundation of biology in public schools throughout the United States. Then something happened. In the 1920s, conservative religious groups began to argue against the teaching of evolution in our nation's schools. Darwinism, they said, contradicted the revealed word of God in the Bible and thus was a direct attack on their religious beliefs. Many of you will have read about the 1925 Scopes "monkey trial" or seen the move about it, *Inherit the Wind*. In the backwash of this controversy, evolution for the first time in this century disappeared from the schools. Textbook publishers and local school boards, in a wish to avoid the dispute, simply chose not to teach evolution. By 1959, 100 years after Darwin's book, a famous American geneticist cried in anguish, "A hundred years without Darwin is enough!" What he meant was that the theory of evolution by natural selection has become the central operating concept of the science of biology, organic evolution being one of the most solidly validated facts of science. How could we continue to hide this truth from our children, crippling their understanding of science?

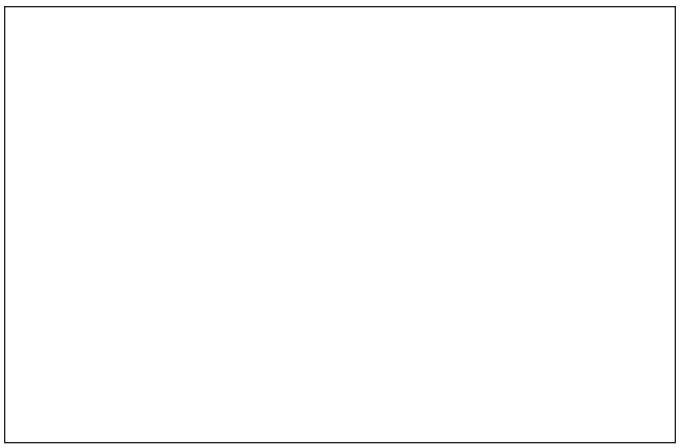
In the 1970s, Darwin reappeared in our nation's schools, part of the wave of concern about science that followed *Sputnik*. Not for long, however. Cries from creationists for equal time in the classroom soon had evolution out of our classrooms again. Only in recent years, amid considerable uproar, have states like California succeeded in reforming their school curriculums, focusing on evolution as the central principle of biology. In other states, teaching Darwin remains controversial.

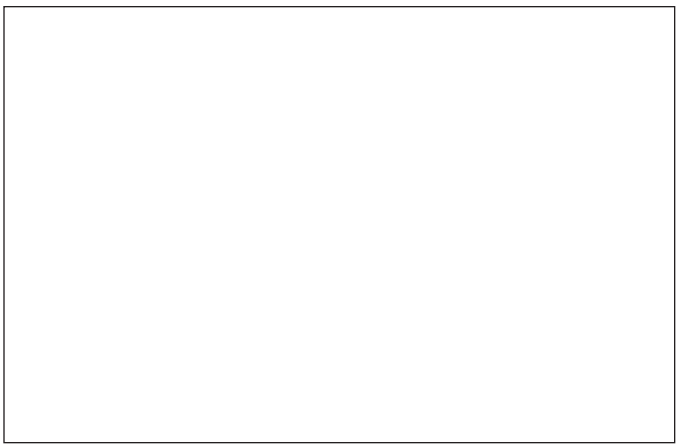
While Darwin's proposal that evolution occurs as the result of natural selection remains controversial in many local school boards, it is accepted by practically every biologist who has examined it seriously. In this section, we will review the evidence supporting Darwin's theory. Evolutionary biology is unlike most other fields of biology in which hypotheses are tested directly with experimental methods. To study evolution, we need to investigate what happened in the past, sometimes many millions of years ago. In this way, evolutionary biology is similar to astronomy and history, relying on observation and deduction rather than experiment and induction to examine ideas about past events.

The evolution of protective coloration in guppies. In pools below waterfalls where predation is high, guppies are drab colored. In the absence of the highly predatory pike cichlid, guppies in pools above waterfalls are much more colorful and attractive to females. The evolution of these differences can be experimentally tested.

Nonetheless, evolutionary biology is not entirely an observational science. Darwin was right about many things, but one area in which he was mistaken concerns the pace at which evolution occurs. Darwin thought that evolution occurred at a very slow, almost imperceptible, pace. However, in recent years many case studies of natural populations have demonstrated that in some circumstances evolutionary change can occur rapidly. In these instances, it is possible to establish experimental studies to directly test evolutionary hypotheses. Although laboratory studies on fruit flies and other organisms have been common for more than 50 years, it has only been in recent years that scientists have started conducting experimental studies of evolution in nature.

To conduct experimental tests of evolution, it is first necessary to identify a population in nature upon which strong selection might be operating (see above). Then, by manipulating the strength of the selection, an investigator can predict what outcome selection might produce, then look and see the actual effect on the population.





Evolutionary change in spot number. Populations transported to the low-predation environment quickly increased in number of spots, whereas selection in more dangerous environments, like the predator-filled pool *above right*, led to less conspicuous fish.

The Experiment

Guppies offer an excellent experimental opportunity. The guppy, *Poecilia reticulata*, is found in small streams in northeastern South America and the nearby island of Trinidad. In Trinidad, guppies are found in many mountain streams. One interesting feature of several streams is that they have waterfalls. Amazingly, guppies are capable of colonizing portions of the stream above the waterfall. During flood seasons, rivers sometimes overflow their banks, creating secondary channels that move through the forest. During these occasions, guppies may be able to move upstream and invade pools above waterfalls. By contrast, not all species are capable of such dispersal and thus are only found in these streams below the first waterfall. One species whose distribution is restricted by waterfalls is the pike cichlid, *Crenicichla alta*, a voracious predator that feeds on other fish, including guppies.

Because of these barriers to dispersal, guppies can be found in two very different environments. In pools just below the waterfalls, predation is a substantial risk and rates of survival are relatively low. By contrast, in similar pools just above the waterfall, few predators prey on guppies. As a result, guppy populations above and below waterfalls have evolved many differences. In the high-predation pools, guppies exhibit drab coloration. Moreover, they tend to reproduce at a younger age.

The differences suggest the action of natural selection. Perhaps as a result of shunting energy to reproduction rather than growth, the fish in high-predation pools attain relatively smaller adult sizes. By contrast, male fish above the waterfall display gaudy colors that they use to court females. Adults there mature later and grow to larger sizes.

Although the differences between guppies living above and below the waterfalls are consistent with the hypothesis that they represent evolutionary responses to differences in the strength of predation, alternative explanations are possible. Perhaps, for example, only very large fish are capable of moving past the waterfall to colonize pools. If this were the case, then a founder effect would occur in which the new population was established solely by individuals with genes for large size.

The only way to rule out such alternative possibilities is to conduct a controlled experiment. The first experiments were conducted in large pools in laboratory greenhouses. At the start of the experiment, a group of 2000 guppies were divided equally among 10 large pools. Six months later, pike cichlids were added to four of the pools and killifish (which rarely prey on guppies) to another four, with the remaining pools left as "no predator" controls.

The Results

Fourteen months later (which corresponds to 10 guppy generations), the scientists compared the populations. The guppies in the killifish and control pools were indistinguishable, brightly colored and large. In contrast, the guppies in the pike cichlid pools were smaller and drab in coloration. These results established that predation can lead to rapid evolutionary change, but does this laboratory experiments reflect what occurs in nature?

To find out, scientists located two streams that had guppies in pools below a waterfall, but not above it. As in other Trinidadian streams, the pike cichlid was present in the lower pools, but only the killifish was found above the waterfalls. The scientists then transplanted guppies to the upper pools and returned at several-year intervals to monitor the populations. Despite originating from populations in which predation levels were high, the transplanted populations rapidly evolved the traits characteristic of low-predation guppies: they matured late, attained greater size and brighter colors. Control populations in the lower pools, by contrast, continued to mature early and at smaller size. These results demonstrate that substantial evolutionary change can occur in less than 12 years.

To explore this concept further go to our interactive lab at www.mhhe.com/raven6e