CHAPTER 11

NATURAL SELECTION: THE SECOND HALF OF DARWIN'S HYPOTHESIS

NATURAL SELECTION

Darwin had read Malthus. He understood Malthus' basic argument and realized that a simple observation of nature demonstrated that Malthus' thesis could be directly applied to the survival of individual plants and animals, and ultimately to species. Malthus, a minister in the Anglican Church, had observed the growing wretchedness of cities and, beginning in 1798, published the following thesis: populations tend to increase exponentially (2, 4, 8, 16, 32) while the food supply increases linearly (1, 2, 3, 4, 5, 6). The observation was simple: if each couple has four children, then for two people in generation 1 there will be four people in generation 2; and if these four (two couples) each have four children, then in generation 3 there will be eight. What this leads to, as Malthus demonstrated by estimates of population size, is that the society will soon run out of food and some will die, by starvation, war, or disease. Thus some will die, and the population will not expand at its full potential. As Darwin saw, this logic obviously applies to the rest of the biological world. If a pair of spawning fish lays 50,000 eggs, but next year the fish population is more-or-less the same, then on average 49,998 of the eggs have died before returning to spawn. This is also true for plants with their thousands of seeds, and even for mammals or birds that have one infant per year but go through several breeding cycles in their lives. Thus nature includes huge levels of mortality for all creatures.

Darwin's extension of this idea to the natural world was just the first part of his great insight. The second part of the insight was that who would live and who would die would not necessarily be completely random. For instance, suppose there was a variation in color of caterpillars, such that some matched the leaves on which they lived and fed better than others. Suppose also the likely scenario that the largest number of the caterpillar deaths was the result of bird predation (birds eating them). The birds would most likely find and eat the caterpillars that looked least like the leaves, ignoring those that most resembled the leaves. This would be selection rather than random loss. Darwin further supposed that the variation itself was not random but was inherited—that is, that the moths deriving from bright green caterpillars produced bright green caterpillars, and those deriving from dull green caterpillars produced dull green caterpillars. If the variation was inherited and some variants survived better than others, then the next generation would consist of a higher proportion of the more favored variant. In each succeeding generation the proportion of the more favored variant would increase, until finally virtually the entire population would consist of the most favored variant. If at an earlier time that variant had been very rare, over time the species would have changed from the less favored to the more favored variant. Wallace proposed essentially the same hypothesis, with the exception that he focused on the existence of populations of varieties, in which one population would survive at the expense of another. He did not question the origin of the varieties. Darwin argued that the variations were individual, leading to the survival of individuals of specific characteristics. Neither had, at the time, a mechanism for inheritance of traits.

This is what natural selection, or "descent with modification" means. All species produce far more young than two per couple, and yet the population sizes remain roughly constant. Individuals vary in many characteristics. If one variant of a characteristic favors survival of an individual, and this characteristic is inherited, then the species will gradually over time evolve to resemble the favored variant—descent with modification.

There is one modest correction that we need to add: We used the term "survival," but all we really need is that the individual achieve reproduction of the next generation. Thus salmon die shortly after laying their eggs, and female black widows and praying mantises eat their mates shortly after they have mated. There are even insects whose young are born by chewing their way through, and killing, the mother. Survival is not the issue; leaving young to the next generation is. Thus the theory of natural selection more specifically says that there is inherited variation in the ability of individuals to leave progeny (young) to the next generation. Those individuals that leave more progeny will in successive generations increase their proportion in the population, until the species would change. Given sufficient time, this natural selection would be able to create new species and even major new types of animals or plants.

SURVIVAL OF THE FITTEST—NOT WHAT YOU THINK IT MEANS!

Two terms cause considerable confusion (and anger) whenever evolution is discussed. The source of the problem is that scientific terminology is by necessity precise, while ordinary speech is not. As we have discussed previously (page 10), words such as "significant" have different meanings to working scientists than they do in casual conversation. In a somewhat similar manner, "natural selection" and "survival of the fittest" are often used in public in a sense broader than, or even in conflict with, the scientific meaning.

"Natural selection" refers to a series of inferences based on some relatively straight-forward observations. Although the observations seem fairly obvious, their implications did not take hold until the social observations typified by Malthus began to be accepted. It had been clear for centuries that humans could change the appearance of species by controlling breeding. Whether one considered the races or varieties of dogs, cats, goldfish, wheat, corn, oranges, apples, or peaches, it was evident that human selection could adapt species in many ways. Dogs could be selected to be hunters, work-dogs such as huskies, burrow-entering badger hounds such as dachshunds, lap dogs such as Shi-tzus or chihuahuas, racing dogs, etc. The new idea proposed by Darwin was that this type of selection could take place by natural forces, and that species could be changed by these forces. (Wallace did not make the connection between human-controlled breeding and natural selection. See page 92.)

The first set of observations was simply Malthusian, noted for the animal and plant world. They were that all species have great potential fertility; population can increase exponentially; but that populations tend to remain stable in size; and that environmental resources are limited. Let's look briefly at these before moving to the inference. Whether we talk about fish, which can lay 10,000 eggs; trees, which can shed hundreds of thousands of seeds; or mosquitoes, which can lay a few hundred eggs and go through a generation in two weeks, it is obvious that most species can easily reproduce enough young to fill any location on earth. Even humans can do this. When humans reach a new, uninhabited but fertile land, as when they first settled the Falkland (Malvinas) Islands, families can average eight children. Allowing for a generation time of twenty years, one couple can produce 64 descendants in forty years, and 512 descendants in sixty years. But it is also obvious that such a population explosion rarely happens. Fish may lay 10,000 eggs, but by-and-large there will be the same number of trout in a stream from one year to the next. Even though a pair of mosquitoes, starting to breed for instance on April 15 could produce 100 quadrillion quadrillion (100 followed by thirty zeros) mosquitoes by October 15, the mosquito population varies only moderately from one year to the next. We understand today that there is not enough food for these astronomical numbers. Other factors may also be limiting. For instance, there might not be very many places to hide in a stream, so that many baby fish would be very visible to predators. These observations: that any species has a potential to reproduce that is greater than the standing population; that population sizes tend to remain stable; and that resources can be limiting, lead to the first important inference:

> Inference: There must be a struggle for existence and only a fraction of offspring survive.

This much is relatively obvious, but the next jump requires some observation and thought. The first observation is that individuals vary extensively in characteristics. This is obvious in humans and dogs, but it is also true of all other creatures. Even penguins can identify their mates and their offspring without confusion and, if you cared to make the study, you could find differences among individual ants. The second observation is also somewhat obvious, but must be coupled to the first to build a hypothesis. The second observation is that much of the variation is heritable. We understand this today. Children generally bear substantial resemblance to one or both parents. If we wish to have a Dalmatian puppy that will mature with few spots, we have a better chance if we breed two lightly-spotted dogs than if we breed two dogs with heavy black patches. Although one peach tree might produce better peaches because it is in better soil, overall we will get better peaches by growing trees from peach seeds gathered from the best trees rather than from the worst trees. The inferences, however, are more profound, and consider that nature enforces the same choices that we might make. If we discard the peaches from a rather sickly tree and instead plant the seeds only from the healthiest tree, we have guaranteed the survival of the progeny (young) of the latter tree (plus the tree that pollinated it) and have condemned the former tree to extinction. The proposition is that nature does the same thing.

> Inference: Survival is not random. Those individuals with the traits that fit them best to the environment will leave more offspring.

In the same sense that we chose which peach tree would leave young to the next generation, nature can do by virtue of the fact that a large percentage of the new generation will die. Much will be random: Perfectly healthy seeds will land on rocky or otherwise inhospitable soil, will be eaten by birds or other animals, or will succumb to other uncontrollable events. But for some of the seeds, their survival will not be random. Perhaps one seed can resist a late or early frost a bit better than another. Perhaps its shell is just a bit harder, so that a squirrel cannot bite through it. Perhaps its shape allows it to be carried, by wind, water, or animal, to a more distant location, where there are more sites in which it can grow. Perhaps one of the fish fry (baby fish) is colored just a little darker and is less visible against the sides of the stream, or its markings make it much harder to see against the plants in the stream. It will survive infancy and grow to eventually reproduce, while others will not.

We use the examples of baby fish and seeds because most mortality is in infancy, but the same rules could apply to the adults. One bird's preference for a nesting site might lead it to choose a site that turns out to be far more secure in high winds than the choice of another bird. A male fish might have brighter, more colorful markings that appeal to a female. A bird has a larger beak and can eat larger seeds than other members of its species.

The continuation of this hypothesis states that, for example, in a time of famine only the birds with the larger beaks can eat a different type of seed and therefore survive, the next generation will be the children of the large-beaked birds and will, on average, have larger beaks. This process can continue, with each generation having larger beaks than the previous generation, gradually changing the species.

This latter phenomenon has been seen to occur in time observable to humans. Evolutionists seeking to test the hypothesis have observed that climate conditions during the growing season strongly affect the size and availability of seeds. In several instances, a drought resulting in smaller seeds has led to greater survival of birds with smaller beaks, and the subsequent downward shift in mean size of beaks in the population. Other studies, identifying other quantifiable sources of selection, have established equivalent changes in other characteristics. Such immediate evidences of evolution have been most clearly observed in islands or other isolated populations, where migration to and from other locations or huge variation in resources does not confuse the issue.

> Inference: This unequal ability of individuals to survive and reproduce (SELECTION) will lead to a gradual change in population, accumulating favorable characteristics.

This, then is what natural selection means. In the same fashion that humans can produce German shepherds, Shi-tzus, and greyhounds by selecting characteristics of dogs over several generations, nature could alter species over many generations by selecting for characteristics that give one individual a survival advantage over another. This is what is meant by "survival of the fittest".

There is one other term that we need to define. Most people use the expression "survival of the fittest" to mean the strongest, biggest, or most capable of making money. In the context of evolution, "fittest" does not carry this connotation at all. "Fittest" means ONLY "better capable of leaving offspring to the next generation". This is the only currency in which natural selection works. Any variation that makes it more likely that one individual will leave offspring to the next generation than another individual makes the first more fit. A smaller cockroach, one that can squeeze into a crevice and thus avoid being stomped on; greater tolerance for living in a terrible climate, such as a desert or the arctic; greater timidity, as opposed to a more curious individual, who sticks his nose out while a predator is still in the area; acceptance of a food shunned by other animals—all of these might be examples of greater "fitness". The rule is that, whatever works, works. Any adaptation that improves the possibility of leaving progeny can be selected for. It has nothing to do with beauty, strength, or size. This is why we have many bizarre shapes and lifestyles of creatures—spindly, fragile creatures, creatures that live in very hostile environments, creatures that eat poisonous plants and animals, species in which the male is a puny parasite attached to the female, species such as the black widow and the praying mantis in which the female eats the male after mating, species in which the female is an immobile bag of eggs, and species in which the young hatch by devouring the mother's body and destroying her. LIMITING reproduction may even be a selective advantage, if overbreeding threatens to use up resources. Consider two populations of, for instance, grasshoppers. One population produces 300 eggs per couple, which unfortunately leads to consumption of all available leaves by early August. Two hundred ninety-five nymphs die of starvation before reproducing. The second population lays only 100 eggs per couple, but this population does not use up the entire food supply, and more survive to reproduce. Depending on other circumstances, lower reproduction may be a selective advantage.

Figures 11.1 and 11.2 illustrate some of the truly bizarre creatures—a very small sampling of the many that could be shown—that can be found in this world. The theory of natural selection proposes that for one reason or another each of these


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species appeared because its ancestors were better able to survive and reproduce than were ancestors that might have been a bit more "normal".

SPECIES THAT DO NOT "EVOLVE"

A final question that one can raise is the following; if this process of selection operates continuously, how is it that some species do not change? After all, we have many types of animals and plants on earth that we often call "primitive". We consider fish and frogs to be less evolved than mammals and birds, or ferns and mosses to be less evolved than flowering plants. Many individual types of animals and plants have been on this planet for a very long time. We can identify 300 million to 400 million year old fossils that are clearly dragonflies, cockroaches, and ferns, very similar to species seen today (though not actually the same species). Did these creatures simply opt out of natural selection? Is it possible for a species to reach perfection and not continue to evolve?

Most likely the answer to the first question is "no" and to the second question, "sort of" or "in a sense"? We do not really think that creatures achieve "perfection". As we will discuss in Chapter 26, the forces of evolution include interactions with other species, so that, for instance, predators could evolve to get better, forcing the prey to evolve, and in any case, as discussed above, perfection could lead to overbreeding and, ultimately, starvation. The issue seems to be more that, if the environment does not change, then creatures adapted to that environment will not change very much. Sequoia trees would fit this definition. Their ancestors first appeared with the dinosaurs, 180 million years ago, and they were quite common in the temperate, mist-filled climates of the time. Since then, the changing earth (see Chapters 22 and 23, pages 303 and 319) has reduced the area on the earth with that type of climate. Thus most of the sequoia trees have left us. A few remain, very similar to their ancestors, in the few areas on earth that maintain a climate similar to the period in which they thrived.

The same might be said of creatures such as the horseshoe crab (which is more closely related to spiders than to crabs). Although in fact it is different

Figure 11.1. A handful of the bizarre creatures found on earth. A. Anteater, South America. B. Spider shrimp, Australia. C. Leaf insect, Malaysia. D. Pelican, USA. E. "Pacman" frog, Argentina. F. The orange creature is a coral, a community of sea anemone-type creatur/es. The red, white, and blue creature is a sea cucumber, related to starfish. The magenta (violet) animal is a type of marine mollusk. Two fish are also visible. Australian Great Barrier Reef. G. An antlion. This insect larva uses its spade-like head to dig a pit in sandy soil. When an ant slips on the edge, the antlion by jerking its head showers its victim with sand so that it loses its grip. When the ant falls to the bottom, the antlion grabs it with its piercing and sucking mouthparts. You can see these common creatures around houses in the United States. H. A duck-billed platypus. It has a duck-like nose (left) and a beaver-like tail. It spends most of its life in water, lays eggs, and nurses its young, and feeds them with milk secreted from sweat-like glands—not true nipples—on its chest. First descriptions of this animal were assumed to be a hoax in Europe. Credits: Ridiculous animals - Antlion: From Swain, Ralph B, 1948, The Insect Guide, Doubleday & Co., Inc., Garden City, NY, illustrated by SuZan N. Swain

Figure 11.2. A. Manta ray, Atlantic Ocean. B. Pacific octopus, Pacific Ocean. C. Baobab trees, Africa. This list can be continually expanded. Credits: Manta - "© Photographer: Harald Bolten | Agency: Dreamstime.com", Octopus - "© Photographer: John Abramo | Agency: Dreamstime.com", Baobab - "© Photographer: Muriel Lasure | Agency: Dreamstime.com"

in many respects from its ancestors, its resemblance to trilobites is striking, particularly considering that the trilobites lived 300 to 400 million years ago (Fig. 3.5).

Horseshoe crabs live near rocky ocean shores, and the physical characteristics of such shores have not changed much since the oceans were formed. The earth has grown warmer and colder, but there was always a range of temperatures such that some seas were warmer than others. As we described above, the criterion for natural selections is "Whatever works, works". A perfectly reasonable corollary would be, "If it ain't broke, don't fix it." A horseshoe crab, primitive though it may be, is a very efficient creature. I once watched a dog try to attack one. Its shell is a dome that very few creatures can get their mouths around, it can flail its tail and do some damage to an attacker, and it can scuttle into the sand quite rapidly. There are few creatures in the sea, sharks included, that can find a way to take a bite out of it. Besides, there is very little meat under all that shell. Whatever works, works. It worked for this group of trilobites, and it works today. If it ain't broke, don't fix it.

You can reasonably challenge this line of argument by asking, "If the trilobites were so good, where are they now?" The first answer is that they were a very large and diverse group of animals, found in many locations on the globe including China, Morocco, Rochester, New York, and Oklahoma. As a group they did very well, surviving for almost 300 million years, three times as long as the dinosaurs. The second part of the answer is that there have been many massive changes in the history of the earth (see Chapter 23, page 319). These changes have led to great shifts in the predominant creatures on the earth, from the amphibian and ferns to the dinosaurs and pine tree-like trees (gymnosperms or conifers) to the mammals and flowering plants. During these periods the trilobites finally disappeared, leaving their descendants, including the horseshoe crab. One species is quite common along the Atlantic Coast of North America, and others are found in Asia, but this group of animals is no longer predominant in the world. The few that have survived, though well adapted to their environment and that environment is not changing rapidly, are different from their ancestors and their descendants will differ from them.

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STUDY QUESTIONS

1. Argue for or against the position that Malthus' hypothesis was correct (Malthus' full argument is available online) and that it is also correct for the biological world.
2. Argue for or against the position that Malthus is the true father of the theory of evolution.
3. Are there true evolutionary relics in the modern world? In what way are they true evolutionary relics? In what way are they not?

4. For those creatures alleged to be evolutionary relics, under what conditions do they currently live? Do these conditions differ from conditions in nearby environments?
5. Describe, in your own words, the primary inferences of Darwin's hypothesis. Be prepared to defend each one with appropriate evidence. Is there any evidence to the contrary?
6. Define, in your own words, "survival of the fittest".
7. Identify the strangest plant or animal that you have ever encountered. Can you identify any reason why such a shape, habit, or behavior should enhance the potential of the species to reproduce?