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ARTIFICIAL SELECTION AND NATURAL SELECTION

Darwin returned to England in 1836 and became an accepted member of the scientific community. His journal, *Voyage of the Beagle,* became a best-seller, and he set about reviewing his collected data, thinking about what process could produce the changes in species he was by this time convinced had occurred. He read a now famous essay by Thomas Malthus, which warned (back in 1798) of the explosive growth of human population, and he realized that every species reproduces in such numbers that it will grow explosively until it reaches the carrying capacity of its environment.

Darwin suddenly had the insight that new species developed in nature by exactly the same process that humans had been using since time immemorial to develop more useful varieties of domestic animals and plants. This plate shows the two processes side by side for comparison.

Color the heading Artificial Selection, titles A and B, and the associated structures in the upper left portion of the plate.

In many parts of the world, farmers have problems with badgers stealing their chickens, so hunting badgers is very popular. Centuries ago, farmers in Germany decided that since selective breeding had been useful in improving other kinds of domestic animals and plants, it ought to be able to develop a dog with short enough legs to chase the badger down into its burrow, strong enough paws and claws to dig after the badger, and large enough jaws and teeth to be a match for the badger when it was caught.

Of course, no dog existed with all these characteristics, but of the dogs available, some had shorter legs than the others, some had stronger paws, and so on, so dogs that came closest to the ideal were separated from the other dogs and mated.

Color arrow C and the center left portion of the plate.

Naturally, the ideal dog was not produced immediately, but with the recombination that is a built-in part of the genetic process, a few of the offspring came closer to the ideal and were selected to produce the next generations.

Color the remainder of the left side of the plate.

The farmers continued this process of selection generation after generation. With the passage of *time,* the constant recombination of genes, an occasional mutation, and the constant "selective pressure" of the *breeders* always separating out as breeding stock the dogs with the best badger-hunting traits, the ideal breed for the job eventually developed. It was half a dog high and two dogs long, with short legs, stout paws and claws, and strong jaws: the breed known today as the dachshund (German: *Dachs,* "badger"; *Hund,* "dog").

Color the heading Natural Selection and titles A^1 and B^1 and the associated illustration at the upper right.

Giraffes had always fascinated biologists as outstanding examples of adaptation. Their extremely long necks and long legs, with the front legs longer than the hind ones, adapt them so well to reaching the leaves and tender twigs of the trees on which they feed that they have no serious competitors for that food source. The question was, What made them grow that way?

The answer proposed in 1809 by Jean Baptiste de Lamarck was that as ancestral giraffes reached higher and higher to eat, their bodies responded to an "inner need" and their necks grew longer. These longer necks were then passed on to their offspring, who kept reaching higher, so their necks grew still longer, and so on. Unfortunately, our present-day knowledge of heredity shows this otherwise beautiful theory to be false.

Darwin correctly recognized that variation occurs naturally in all species and that some factor in the environment could perform the same role as a selective breeder, selecting individuals with certain variations to reproduce and preventing, or at least reducing, the reproduction of others. In the case of the giraffe, the *selective factor* would have been the trees, which provided food only for giraffes that could reach high enough.

It seems likely that whenever ancestors of giraffes first found themselves in their present environment, they probably had short necks too, and as long as some leaves and twigs were close enough to the ground, a short neck was no disadvantage. But when the giraffe population reached the carrying capacity of its environment and a food shortage developed—as it always will, sooner or later—giraffes with slightly longer than average necks had a *survival* advantage. If they weren't the only ones to survive, they at least survived in larger numbers.

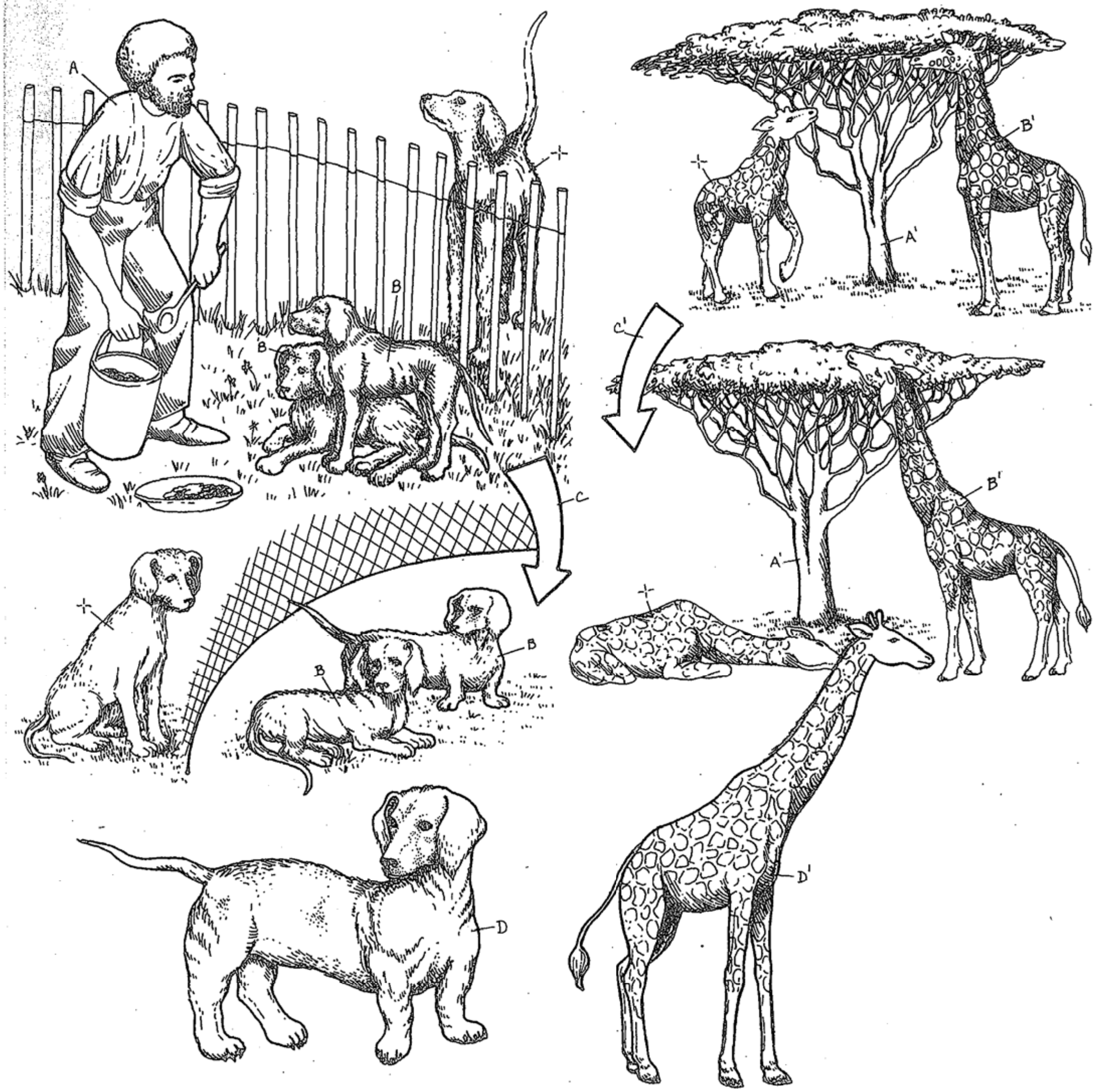
Color title and arrow C^1 and the remainder of the plate.

With the passage of thousands of years in an environment where any mutation or recombination of existing genes would confer a survival advantage if they made it possible to reach higher on the tree, the giraffes that survived had to be the sort of strange creatures we see today.

ARTIFICIAL SELECTION AND NATURAL SELECTION

ARTIFICIAL SELECTION*
BREEDER A
DESIRED PARENTS B
TIME C
RESULT D

NATURAL SELECTION*
SELECTIVE FACTOR A'
SURVIVOR B'
TIME C'
RESULT D'



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NATURAL SELECTION WE CAN SEE

Since Darwin's exposition of the principles of natural selection, biologists have found numerous examples of natural selection occurring in periods of time much shorter than the many thousands of years usually required. One outstanding example of this is what is known as industrial melanism (Greek: *melas,* "black"), the turning black of certain species in areas that were blackened with the soot of the coal-burning factories that sprang up in great numbers during the Industrial Revolution.

Color titles A, A¹, and B and the associated structures in the upper illustration. Use light gray or gray-green for A and A¹. Use black for B.

One of the best-studied cases of industrial melanism is the change in color of the peppered moths in the vicinity of Manchester, England. Nature study has been popular for centuries in England, so there are records of observations and insect collections going back several hundred years. In the vicinity of Manchester, a certain rather large moth *(Biston betularia)* was well known. It was called the *peppered moth* because it resembled a white moth on which pepper had been sprinkled. It was nocturnal in its habits and spent all the daylight hours resting on the trunks of trees, where it blended in almost perfectly with the *lichens* covering the tree trunks, since the lichens had the same "peppered" coloration. Only occasionally was a rare *black* member of this species spotted.

Color title B¹ and structures A, B, and B¹ in the lower illustration. Use black for B¹.

In the second half of the nineteenth century, however, more and more black moths began to show up. That change in the moths corresponded exactly with the progress of the Industrial Revolution. In that coal-burning part of England, the amount of *soot* put into the air by factories was so great that it *covered the tree trunks* in industrial areas, killing the lichens and turning the tree trunks black. Under those conditions, of course, the black moths were as well camouflaged as the peppered ones had been on the lichen-covered trunks. Eventually 98 percent of the moths of this species in industrial areas were black. This same change was observed in many dozens of other species of moths in similar industrial areas in England and the United States, wherever forests became polluted with soot. In unpolluted forests, the moths retained their light coloration.

The question then arose of just how this change was occurring. One hypothesis was that it must just be the results of natural selection, due to birds or other predators eating moths that didn't blend in with the background. But that left unanswered the question of how the first black moths appeared originally. Another hypothesis was that the moths ate or absorbed something in the soot that turned them black. Yet another hypothesis was that the moths had some sort of built-in reflex that caused them to turn themselves black whenever they sensed that their principal background had turned black. The English biologist H.B.D. Kettlewell decided to go out into the forests to investigate this problem thoroughly.

Color the remainder of the plate.

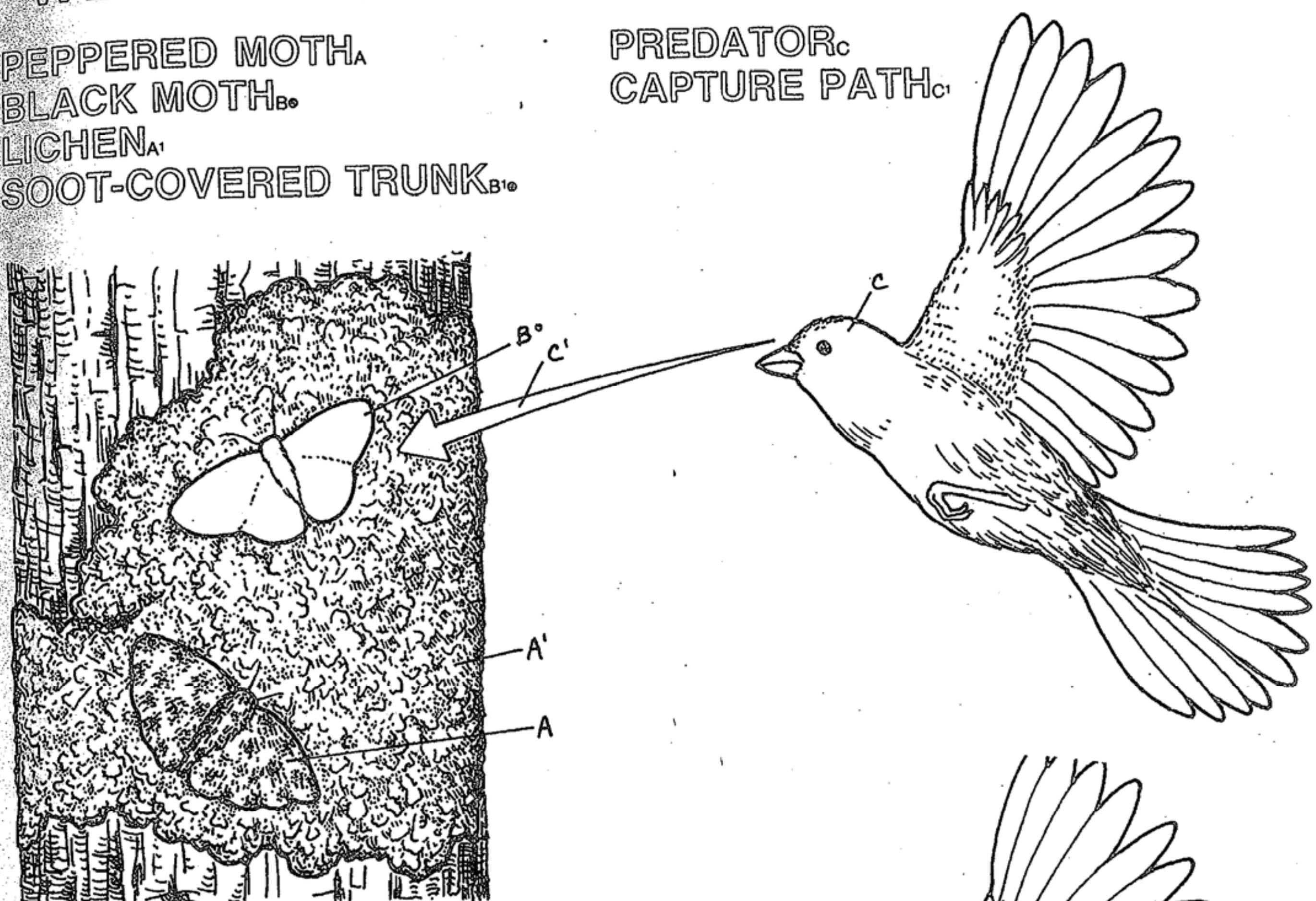
Kettlewell captured equal numbers of black and peppered moths, put identifying paint marks on their undersides where the marks wouldn't show when the moths were resting on a trunk, and released one set in an area with blackened tree trunks and another in an unpolluted area with trunks still covered with lichens. When he came back to recapture the moths, he recovered only half as many of the peppered moths as he did black moths in the soot-blackened forest, and in the light-colored forest he recovered only half as many black moths as he did peppered moths. He also examined the stomach contents of birds known to feed on the moths and found that in blackened forests they ate a disproportionately large number of light-colored moths and in light-colored forests the reverse was true. He also set up movie cameras and captured on film what is summarized in the illustrations of this plate. When a bird is zooming in toward a tree trunk looking for lunch, it is much more likely to see and therefore capture a black moth on a lichen-covered tree trunk or a peppered moth on a blackened tree trunk.

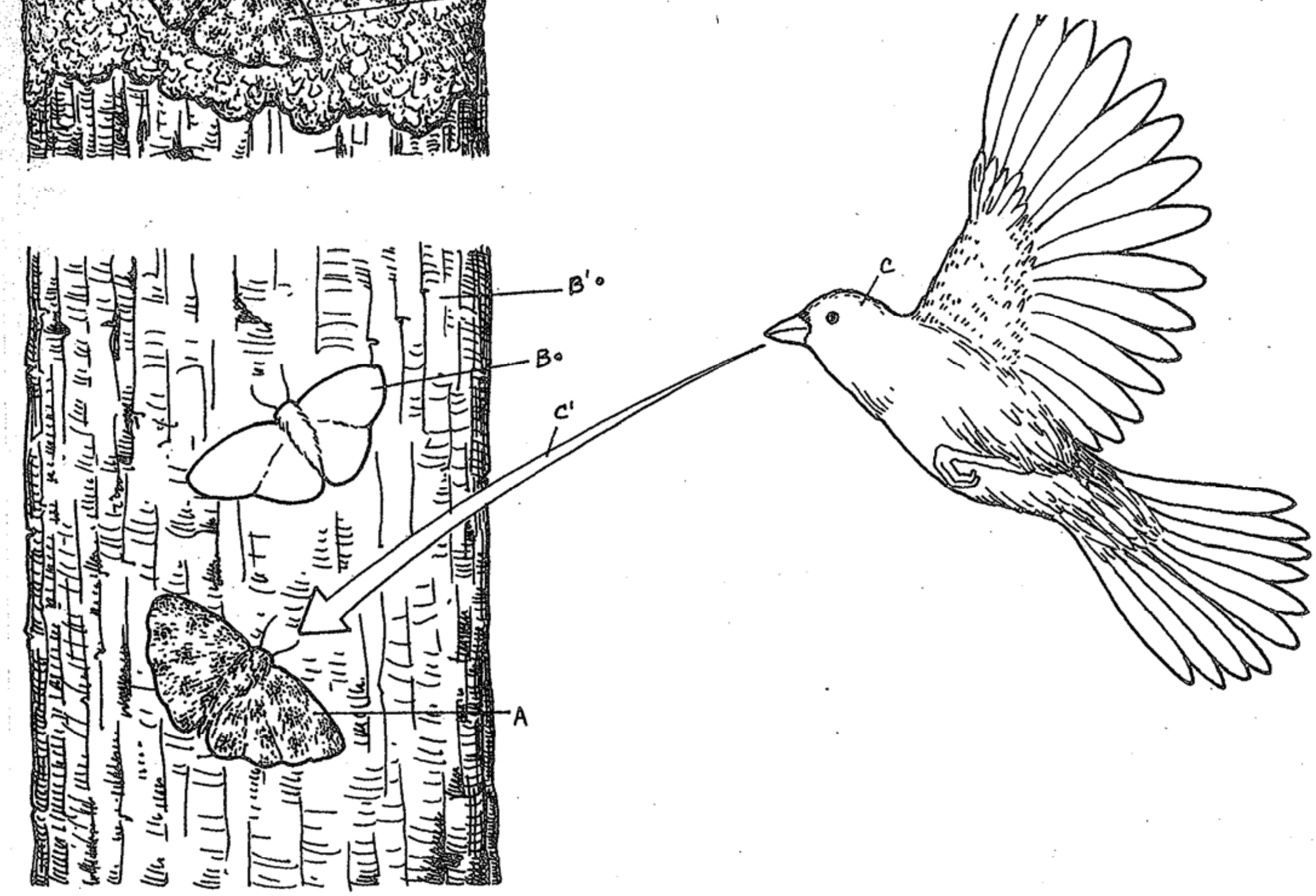
Kettlewell also found that geneticists had already established that the coloration of these moths was determined by a single pair of genes, with the peppered coloration recessive to black. Clearly, then, this was a case of natural selection in action. There was no "battle for survival" according to the "law of the jungle," as is sometimes mistakenly assumed to be a requirement for evolution. Survival or nonsurvival may depend on something as simple as the color of the background. Evolution, then, is simply the process of heredity, with all its lotterylike characteristics, extended over a long period of time, with the environment selecting which survive and which do not.

NATURAL SELECTION WE CAN SEE.

PEPPERED MOTH A
BLACK MOTH B
LICHEN A1
SOOT-COVERED TRUNK B1

PREDATOR C
CAPTURE PATH C1





CHARLES DARWIN

One of the most fundamental concepts of biology is that species change with time. The process by which this occurs was discovered by Charles Darwin and Alfred Wallace. They announced their results together (in 1858), but each made the discovery independently, and Darwin is given the greater credit, not only because he made the actual discovery first but also because he spent 28 years meticulously collecting, reviewing, and organizing a vast array of data and wrote a lengthy book explaining it all (*The Origin of Species,* published in 1859).

Darwin was born in England in 1809. His father and grandfather were wealthy physicians, and Charles himself studied medicine for several years but quit because he hated the sight of blood. He then studied for the clergy, but after completing those studies he decided that a career as a clergyman wasn't for him either. By a remarkable stroke of good luck there was a position open for a ship's naturalist on a voyage of exploration, and through the influence of one of his professors, who had noticed that he was a keen and ardent observer of nature, Darwin obtained that position. He sailed in 1831 on a ship called the *Beagle* and spent five years observing animals, plants, geologic formations, and fossils, primarily on the two coasts of South America.

Color title A and color over the the associated line tracing Darwin's voyage on the *Beagle.*

When Darwin departed on that voyage, he was convinced, like most people of his time, that species were fixed and unchanging. But the science of geology had been advancing rapidly. Many fossils had been found, and the science of paleontology had gotten its start. Although the fossil record was obviously incomplete, some groups of fossils clearly displayed a gradual change of some species over time. On the voyage, Darwin read a new book by his friend Charles Lyell, *Principles of Geology,* which presented convincing evidence that the earth was much older than people had thought, that it had been slowly changing over immense periods of time, and that it was still changing. At the same time, Darwin was discovering many fossils himself and seeing in the geology of South America more evidence to support Lyell's views. He was struck by the fact that many fossils resembled living forms, yet were different enough that they had to be regarded as different species.

Of all the areas visited by Darwin, it was the Galápagos Islands, 600 miles off the west coast of Ecuador, which had the most profound influence on his thinking. These almost barren islands had so much exposed volcanic rock that Darwin reasoned they must have been thrust up from the ocean floor quite recently, as geologic changes go. Darwin was struck by the fact that only a few of the species he had seen on the South American mainland were represented here. In particular, all the small birds present were finches, but they had differentiated into 14 species with remarkably different beaks, each especially well adapted to a particular food source.

Color the heading "Galápagos Finches" and the heading "Food Source."

Darwin knew that small land birds are often blown far to sea by storms and that plants are sometimes carried great distances by ocean currents, frequently with small animals as passengers. He theorized that the finches arrived soon after the islands were formed and, over a period that could have been several thousand years, gradually differentiated into 14 separate species, each adapted to a different "niche" in the environment. Biologists today call this process "adaptive radiation."

Color titles B through G and the remainder of the plate as each finch is discussed.

Geospiza fortis is a ground finch and feeds on *seeds.* Its beak is somewhat short and stoutly built to enable it to break those seeds open. *Geospiza scandens* is sometimes called the cactus finch because its principal food is the prickly pear cactus. Its beak is long and nearly straight for reaching into the *flowers of the cactus* to feed on nectar and the soft tissues. *Camarhynchus crassirostris* lives high in the trees in dense forests. It feeds primarily on buds, flowers, and *fruit* but does eat some seeds as well, so it has a strong beak for crushing. *Certhidea olivacea* is often called the warbler finch because it so greatly resembles a warbler that even Darwin was fooled at first. It eats *insects* and has a thin, sharp beak for capturing them. *Camarhynchus pallidus* is the most unusual of all. It has a spadelike beak, much like a woodpecker's, and feeds as a woodpecker does on insects and grubs it digs out from under bark. But it lacks the woodpecker's long tongue, so it uses a cactus spine or a twig as a *tool* to dig out its prey—the only known case of a tool-using bird.

CHARLES DARWIN

VOYAGE OF THE *BEAGLE* A

GALÁPAGOS FINCHES ★
BEAK B
FOOD SOURCE ★
SEEDS C
CACTUS D
FRUIT E
INSECT F
TOOL G