Chapter 5-1: Introduction to Evolution

The work of Alfred Russell Wallace and Charles Darwin resulted in the concept of evolution. This concept is one of the foundations of modern biology. Evolution refers to the change that occurs over long periods of time in the characteristics and diversity of biological organisms. One of the driving forces behind evolution is the process of natural selection.

This plate contains two diagrams that represent two theories for evolution: the theory of acquired characteristics and the theory of natural selection. In both cases, changes occurring in a giraffe population are presented. You may use either dark or light colors, depending on the detail of the giraffes that you wish to preserve.

The concept of evolution was considered in ancient times by Greek philosophers and since then, the idea that different kinds of organisms might have arisen from ancestral forms has appeared in historical and biological writings. For example, during the mid-1700s, the Swedish botanist Carolus Linnaeus cataloged thousands of different plants and animals, and speculated on their origins.

In 1809, the French scientist Jean-Baptiste Lamarck concluded from his observations that complex organisms evolve from less complex organisms. He proposed the idea that individuals acquire traits during their lifetime that help them adapt to their environments. His theory, now discredited, came to be called the theory of acquired characteristics. These new characteristics, said Lamarck, are passed on to the offspring and result in generational changes.

Lamarck suggested that giraffes evolved their long neck during the course of their lives, in order to compete successfully for food. The diagram at the top describes his theory: originally, **giraffes had short necks (A)** and could only reach vegetation in the lower branches of **trees (B)**. However, as the vegetation in lower branches became sparse, the **giraffes stretched their necks (C_1)** to reach the higher branches. As this vegetation became more sparse, the **giraffe stretched even further (C_2)**. Their longer necks were genetically passed on to their offspring.

Scientists do not believe that the theory of acquired characteristics is a suitable explanation of evolution. For example, if one were to cut the tail off a mouse and breed it, the newborn mice would still have full-length tails, the acquired characteristic would not be passed along. Furthermore, the theory suggested that organisms developed certain traits as they needed them, which is not plausible to modern scientists.

We now concentrate on the second theory for evolution, the theory of natural selection. This theory, proposed by Darwin and Wallace, is now accepted. As you focus on the diagrams of this theory, read the paragraphs below and continue your coloring.

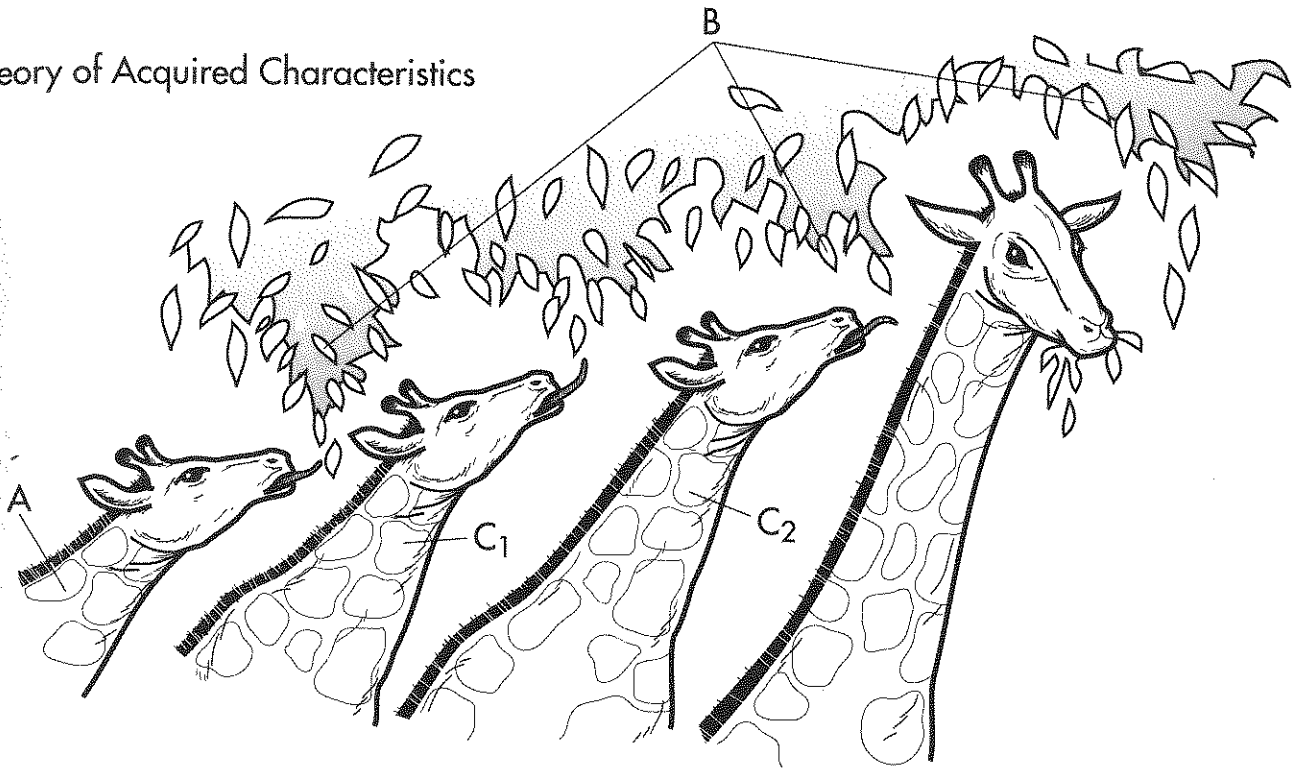
Charles Darwin and Alfred Russell Wallace traveled separately throughout the world, observing animals and plants in their natural settings. Independently, they developed ideas of evolution based on their observations and set the stage for the concept of natural selection. Wallace explored South America and Indonesia. Darwin's 1859 work, *The Origin of Species*, remains the definitive book describing evolution.

The Darwin-Wallace concept of evolution concerns changes that occur over long periods of time. It proposes that all present-day species have evolved in a slow, gradual process from a few early, primitive organisms. The key to Darwin's argument as proposed in *The Origin of Species* is the theory of natural selection. This theory proposes that variability exists in a population, and that the environment acts on this variation so that only the most fit individuals survive and reproduce.

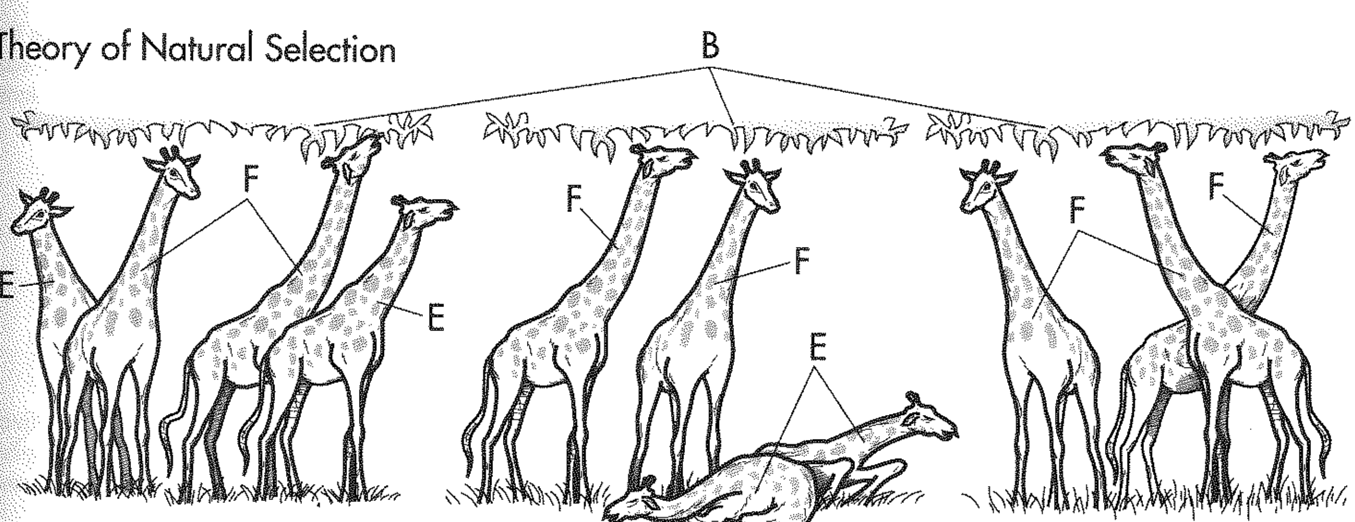
The theory of natural selection is shown in the second diagram. In the first view, we see a population of giraffes. Some are **short giraffes (E)** and others are **tall giraffes (F)**. The tall ones reach the leaves and vegetation above and obtain enough food to survive. In the second view, we see how the short giraffes have starved to death because their short necks did not permit them to reach as much food. The tall giraffes have been naturally selected to reproduce.

In the third view, we see that the tall giraffes survive and will continue to breed and reproduce to yield offspring that have long necks. This is what is meant by the phrase "survival of the fittest." Along with other processes, natural selection is a major factor in evolution. In succeeding plates, we will examine more of the evidence for evolution and review other processes by which evolution occurs.

Theory of Acquired Characteristics



Theory of Natural Selection



Introduction to Evolution

Theory of Acquired Characteristics

- ○ Short-necked Giraffe ..A
- ○ Vegetation ....B
- ○ Intermediate-necked Giraffe ....C_1
- ○ Long-necked Giraffe ....C_2

Theory of Natural Selection

- ○ Short Giraffe..........E
- ○ Tall Giraffe ....F

Chapter 5-2: Darwin's Finches

Perhaps the most significant event in the life of Charles Darwin was his appointment as naturalist in 1831 on the British survey ship, the HMS *Beagle.* During his five-year trip on the *Beagle,* Darwin visited Australia, several Pacific Islands, and South America. The ship also stopped at the Galapagos Islands, a remote chain of volcanic islands about six hundred miles off the coast of South America. Darwin recorded much information on plants, animals, rocks, climate, and the native peoples he encountered in his now-famous notebooks. He took particular note of the island's population of birds, especially the finches. The observation of these finches would inspire him to form his theory of descent by modification, which we call evolution. In this plate, we examine the finch population as observed by Darwin, and note how they illustrate the concept of evolution.

> The finches in this plate serve as an example of an evolutionary pattern known as adaptive radiation. In this pattern, there is an evolutionary explosion in the number of closely related species from a common ancestor.

Finches are notoriously poor distance fliers, so Darwin was surprised to see thirteen different species of finches on the Galapagos Islands. As noted above, the **Galapagos Islands (A)** lie approximately six hundred miles west of **Ecuador (B)** on the western border of South America. Darwin categorized the different species of finches based on the bird's eating habits and the shapes and sizes of their beaks.

It is postulated that a small number of finches found their way to the Galapagos Islands many thousands of years ago, perhaps rafting over on floating debris. They may have been the first birds on the islands, and with little competition, they multiplied into a large population. As they adapted to changing conditions on the islands, the finches underwent natural selection and developed into different species.

One species of Galapagos finch is the **warblerlike finch (C)**. This bird resembles a warbler very closely, but its eggs, nest, and courtship behavior are more similar to those of finches. The warblerlike finch evolved to resemble a warbler even though it is not of the same species; the absence of competition allowed its evolution. If true warblers had been present on the island, they would have occupied the niche normally held by warblers and this finch probably would not have appeared.

> With the warblerlike finch, we introduce the thirteen species of finches seen on the Galapagos Islands and nowhere else. Continue your reading below and notice how different finches have characteristics that vary according to their particular needs.

A second finch observed by Darwin was the **insect-eating finch (D)**. This finch lives in trees and has a heavy beak that allows it to grasp insects. Its body shape is adapted for life in the trees. Notice how its beak and general size compare to that of the warblerlike finch.

Another interesting species observed by Darwin was the **woodpeckerlike finch (E)**. This species has a beak like a woodpecker's (long and narrow) and it uses its beak for drilling holes in wood. However, it has no tongue for removing insects from the wood, and instead uses a cactus spine to dig insects out of the wood. If woodpeckers were present on the island, they would have occupied the niche for this type of animal and this finch would not have appeared.

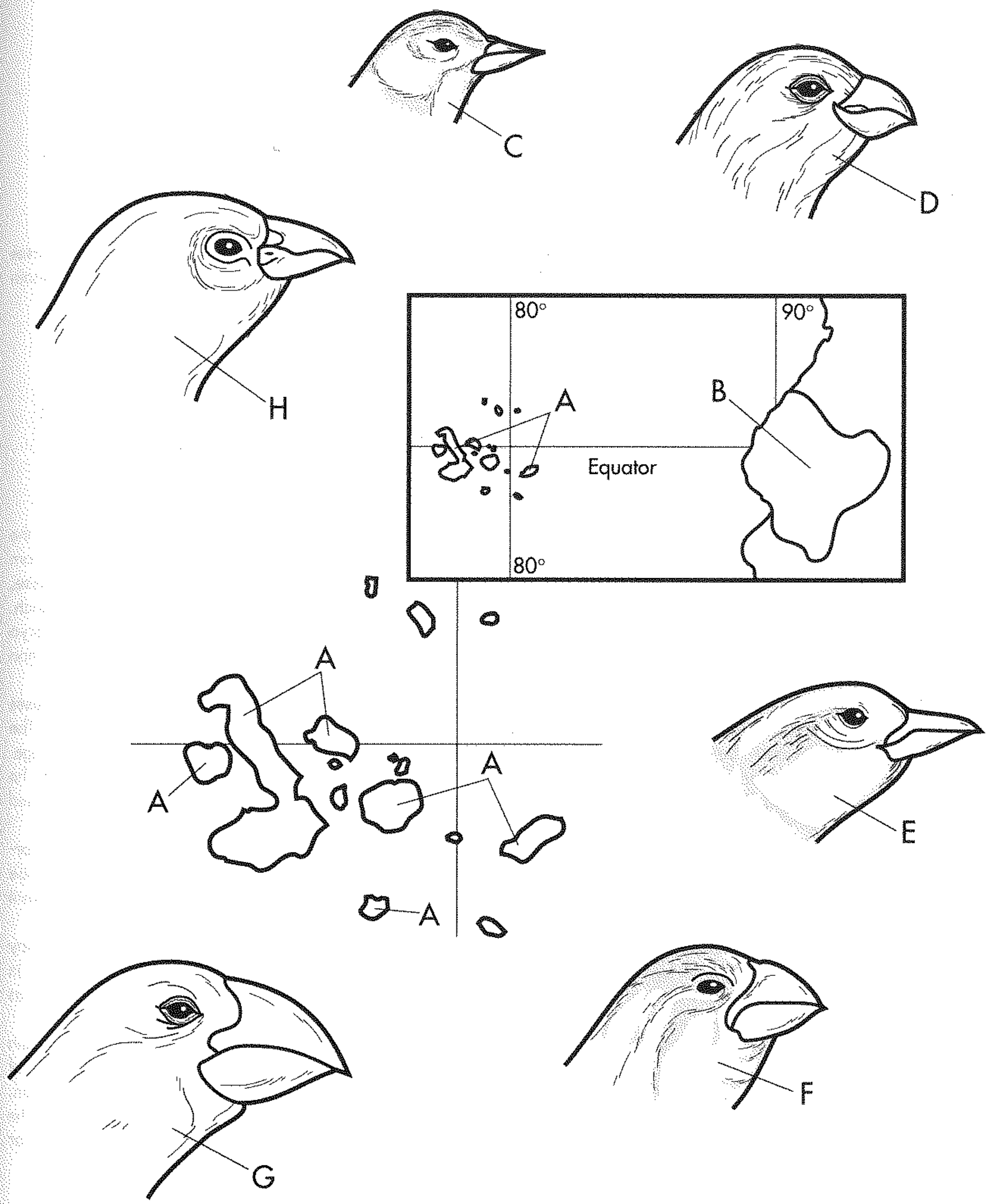
The next finch is the **plant-eating finch (F)**. Again, notice the different shape of the beak. This animal lives in trees and eats only plants. Its beak is designed for grabbing and tearing plants stems and roots.

> We have now seen four different types of finches found only in the Galapagos Islands. Differences are apparent in their sizes and beak shapes. We conclude the plate by observing two other finches that live on the islands. Continue your reading below as you color the appropriate pictures.

One of the more interesting finches is called the **ground finch (G)**. This bird has a massive head and beak, as the diagram shows. It feeds on large seeds and nuts and its beak is adapted for crushing their hard shells.

Another finch that feeds on the ground is the **cactus-eating finch (H)**. This bird subsists on cactus seeds. It uses its bill for crushing, but since cactus seeds are relatively soft, its bill is smaller.

The evolution of the thirteen species of finches from a common ancestor is an example of adaptive radiation. In adaptive radiation, different types of species radiate out as they adapt to different environmental conditions. As you'll see in the next plate, another type of adaptive radiation occurred when animals first invaded the land masses of the Earth.



Darwin's Finches

- ○ Galapagos Islands......A
- ○ Ecuador...............B
- ○ Warblerlike Finch......C
- ○ Insect-eating Finch....D
- ○ Woodpeckerlike Finch ..E
- ○ Plant-eating Finch ....F
- ○ Ground Finch ....G
- ○ Cactus-eating Finch....H

Chapter 5-3: Evidence for Evolution

According to the theory of evolution, all existing biological species are derived from previous ones; that is, all organisms, past and present, share a common ancestry. Data derived from various fields including paleontology, genetics, biochemistry, anatomy, and embryology provide an overwhelming mass of evidence consistent with evolutionary theory. Two important pieces of evidence for evolution are found in comparative anatomy and comparative embryology, as we see in this plate.

> As you look over the plate, you will notice that it has two sections: one devoted to comparative anatomy and one to comparative embryology. Read about comparative anatomy below, and focus your attention on the upper portion of the plate.

Comparative anatomy is basically the science of comparing the physical features of present-day organisms. The plate presents the forelimb of a human, dog, bird, and whale. The upper forelimb in the human is the **humerus (A)**, which is also found in the forelimb of the dog, bird, and the flipper of the whale. The same dark color should be used for each. Below the humerus is the **radius (B)**, and similar bones are found in the dog, bird, and whale. Parallel to the radius is the **ulna (C)**, and again, we find the same bone in all four animals.

Next come a set of small bones in the human wrist called **carpals (D)**, similar bones are found in the three other species. The carpals are followed by the **metacarpals (E)**, and all four creatures have the same bones. In the human, the metacarpals are found in the palm of the hand. The forelimb is completed with a set of **phalanges (F)**, which are also found in all four species.

The science of comparative anatomy shows us that homologous structures composed of the same bones are found in four different animals. At first glance, the forelimbs of humans, dogs, birds, and whales appear to have little in common. But from an evolutionary standpoint, the similarity of these homologous structures shows that the basic structure of the forelimb has been modified through natural selection into arms in humans, front legs in dogs, wings in birds, and flippers in whales. These anatomical similarities provide evidence for the evolutionary descent of the four animals from a common ancestor. Modifications for different purposes have occurred through time, but the supporting bones remain very similar.

> We now turn to the second piece of evidence for evolution; comparative embryology. Your focus should be on the lower half of the plate, where you will see four columns of embryonic, fetal, and newborn illustrations. As you read about comparative embryology, color the appropriate structures in the plate.

Evidence for evolution can also be seen by comparing the embryos of different animals. Looking across the first row from left to right, the plate shows the **embryos of a fish, tortoise, chick, and human (G_1–J_1)**. The same color can be used for each. Note the great similarity between the four embryos. (The embryo is the name of the structure from the early hours after fertilization until the point at which the organs are fully formed.)

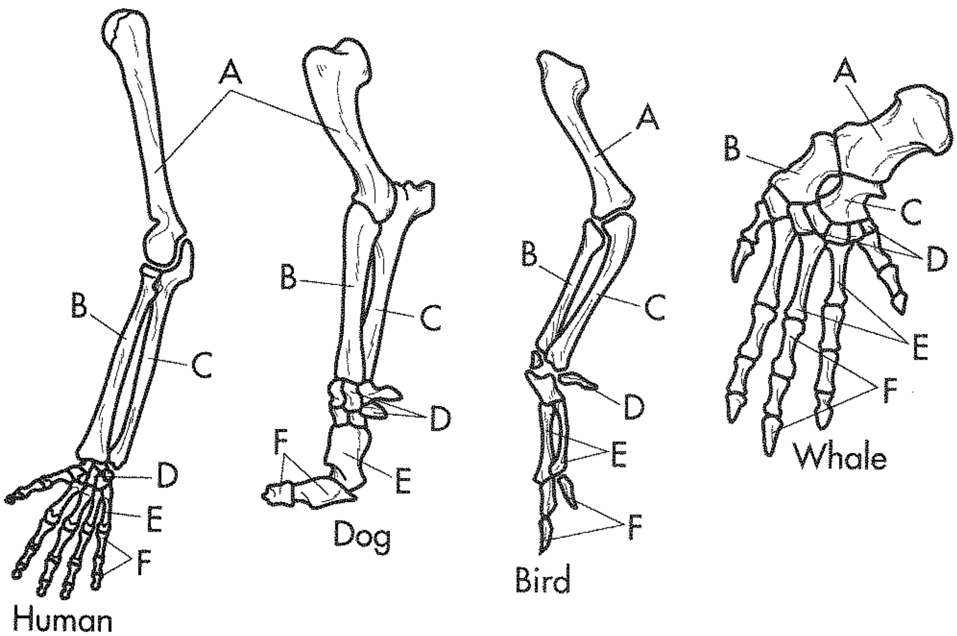
After the embryonic stage comes the fetal stage. The **fetuses (G_2–J_2)** of the four animals are shown in the second row. The same color may be used for the four to indicate the fetal stage. Notice that the fetuses appear different from one another. The fetal stage extends from the time that the organs are fully formed to the time of birth.

In the bottom row, we see the **newborn state of the fish, tortoise, chick, and human (G_3–J_3)**. The same light color may be used for all four. At this point we can see how extremely different the newborns are from one another.

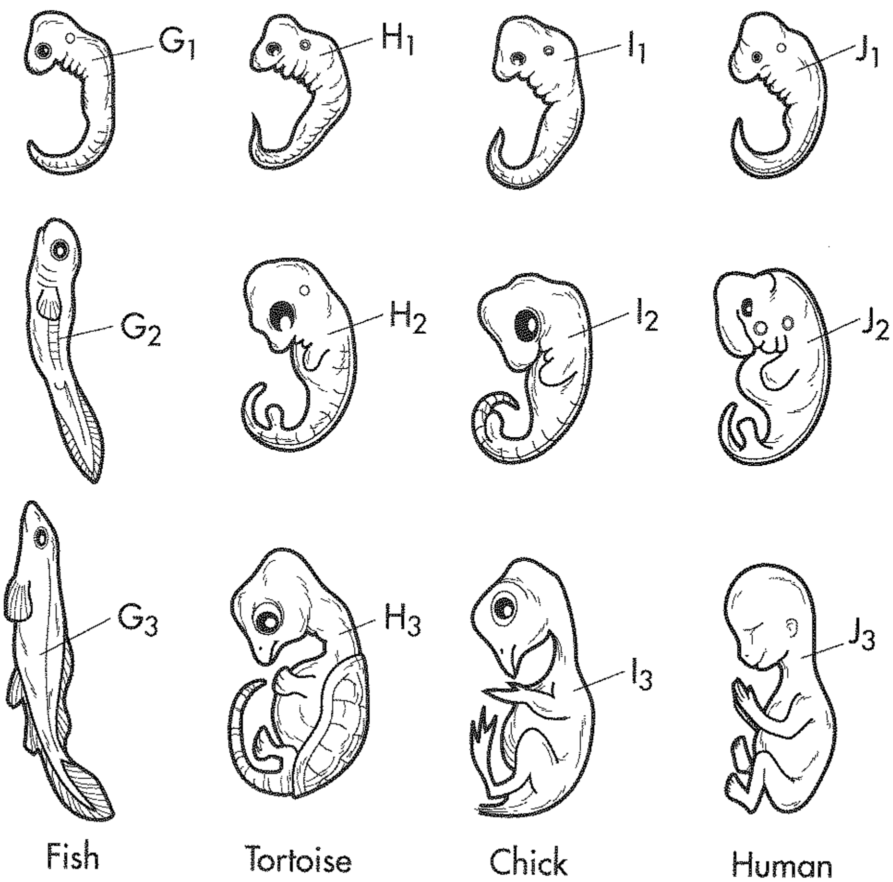
Early embryos of fish, tortoises, chicks, and humans all display fishlike structures, including arched blood vessels and gill slits. In fish, these gill slits develop to gills, while in animals such as humans, the gill slits never become functional.

The similarities of these embryos demonstrate that certain developmental processes remain constant during the evolution of animals. The similarities show that in the process of evolution, pre-existing structures were adapted to serve new functions. The parallels in embryonic structures would be difficult to account for in any way except through evolution.

Comparative Anatomy



Comparative Embryology



Evidence for Evolution

Comparative Anatomy

- ○ Humerus ....A
- ○ Radius..............B
- ○ Ulna C
- ○ Carpals ....D
- ○ Metacarpals ....E
- ○ Phalanges ....F

Comparative Embryology

- ○ Fish Embryo........G_1
- ○ Tortoise Embryo....H_1
- ○ Chick Embryo ......I_1
- ○ Human Embryo ......J_1
- ○ Fish Fetus ....G_2
- ○ Tortoise Fetus ....H_2
- ○ Chick Fetus........I_2
- ○ Human Fetus........J_2
- ○ Fish Newborn ......G_3
- ○ Tortoise Newborn ..H_3
- ○ Chick Newborn......I_3
- ○ Human Newborn......J_3

Chapter 5-4: An Example of Evolution

Evolution suggests that existing biological species are derived from previous ones by descent; that is, all organisms now on Earth share a common ancestry. For this reason, evolution is a unifying theme in biology. It provides a framework for the organization of diverse species into a linked pattern.

The evolution of the horse is a well-documented example of evolution. By comparing the bone structures and sizes of ancestral horses from several different periods, scientists have been able to trace the evolution of the modern horse from its ancient predecessor. In this plate, we will trace its evolution.

> This plate shows four ancestors of the modern horse, and the modern horse. You can see an overall increase in its size, which was determined through a study of the animals' fossilized bones. Begin your study at the bottom of the plate and work your way up.

The oldest known predecessor of the modern horse is ***Eohippus* (A)**. This animal should be colored in a light color, and the same color should be used for the animal's forelimb and skull. This horse-like creature was a small mammal that was approximately two feet tall and lived in forests where it hid from its predators. Its forelimbs ended in four toes, and its feet lay flat against the ground. This animal lived during the **Eocene Epoch (A_1)**, which occurred approximately sixty million years ago, and during this period it apparently diverged into two other **species that resembled horses (B)**.

> We will now turn our attention to a relative of *Eohippus* and point out the evolutionary changes that took place in *Eohippus* to give rise to a new species of ancestral horse.

After the Eocene Epoch, a new ancestral horse appeared, called ***Miohippus* (C)**. This animal arose during the **Oligocene Epoch (C_1)**, approximately forty million years ago, and was only slightly larger than Eohippus. Miohippus also inhabited the forest, and it had three functional toes, all of which touched the ground. The fourth toe originally present in *Eohippus* had regressed, and the horse's skull was larger.

At this point, environmental pressures caused *Miohippus* to diverge and a number of horse-like relatives arose. One of these horse-like relatives evolved into the third ancestral horse that we'll look at in this plate.

This third species was ***Merychippus* (D)**. This horse arose during the **Miocene Epoch (D_1)**. Its skull was larger than the skull of its predecessor, *Miohippus*. This animal was pony-sized and had three toes, with only one functional center toe. *Merychippus* lived in grasslands, which meant that it could not hide from its predators and had to outrun them. Evolution therefore favored a species that had longer and stronger legs, and could run quickly.

> We have seen that environmental changes caused the development of two successive types of horse from *Eohippus*. The remaining two types of horse are seen in the final sections of this plate. Continue your reading and color the animals in the plate as you proceed.

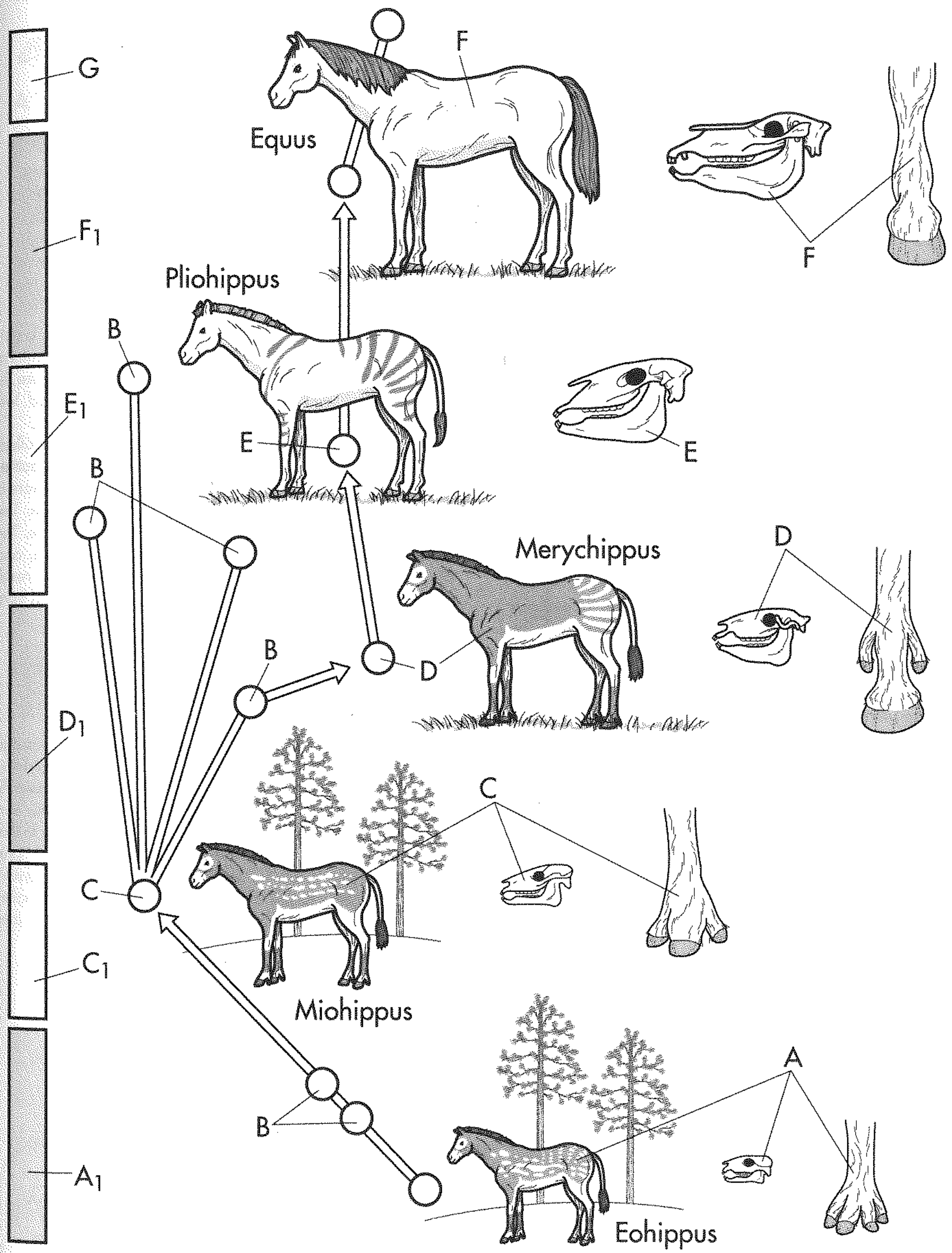
The **Pliocene Epoch (E_1)** occurred seven million years ago. By this time, *Merychippus* had evolved into a larger animal with a larger skull, called ***Pliohippus* (E)**. The foreleg remained a single hoof with two lateral toes, and the horse was a running animal that grazed in the extensive grasslands of its environment.

The modern horse, ***Equus* (F)** arose during the **Pleistocene Epoch (F_1)**, which occurred approximately two and a half million years ago. In the plate, you can see the modern horse with one large central toe, which is what we call a hoof. The front limb, however, retains vestiges of the lateral toes in the form of pairs of bones that are not prominent externally.

Through their study of a series of fossils, scientists have traced the evolution of the modern horse from its ancient ancestors. Natural selection caused changes in this animal that allowed it to adapt to its changing environment.

An Example of Evolution

○ *Eohippus* .... A	○ Oligocene Epoch ...... C_1	○ Pliocene Epoch .... E_1
○ Eocene Epoch .... A_1	○ *Merychippus* .... D	○ *Equus* .... F
○ Horse-like Species .... B	○ Miocene Epoch .... D_1	○ Pleistocene Epoch .... F_1
○ *Miohippus* C	○ *Pliohippus* .... E	○ Recent Epoch .... G


G
F_1
E_1
D_1
C_1
A_1
Equus
F
F
Pliohippus
B
E
E
B
Merychippus
D
B
D
C
C
Miohippus
B
A
Eohippus

Chapter 5-5: The Gene Pool

One key to understanding evolutionary mechanisms is to determine the factors that create genetic variation among members of a species. It is these variations that are acted on in the process of natural selection that bring about evolutionary change. Without variation, natural selection is not possible.

Genetic variation is brought about by the processes of gene flow and genetic drift, which are discussed in other plates. In this plate, we will explore how variation can be produced by variations in the gene pool.

In this plate, we will follow the history of a herd of animals that feed on a grassy plain. We will show how the animals are affected by a catastrophe and how this results in genetic variation. Once variation has taken place, natural selection may or may not follow.

The phenomenon of evolution is measured in the study of individuals, but individuals do not evolve; species do. Herds and populations, for example, are subject to the forces of variation and natural selection, both of which are agents of evolution. Populations undergo changes in genotype and phenotype, and are the smallest units of living organisms that undergo evolution.

Within populations, individuals possess different combinations of genes, and all members of the population contribute their genes to what is called a gene pool. In other words, the gene pool is the sum of all the individual genes in a population. The forces of evolution change the composition of the gene pool and in doing so, change the characteristics of the members of the population.

Variations of a gene are called alleles, and different combinations of alleles produce different phenotypes in individuals. In diagram 1, we see a large group of animals with different phenotypes. **Dark-skinned animals (A)** have two dominant B genes, **medium-skinned animals (B)** have a dominant B allele and a recessive b allele, and **light-skinned animals (C)** have two recessive b alleles. The different animals should be colored with three different bold colors. A light color should be used to outline the box and shade the gene pool. Notice that the gene pool consists of both B and b genes.

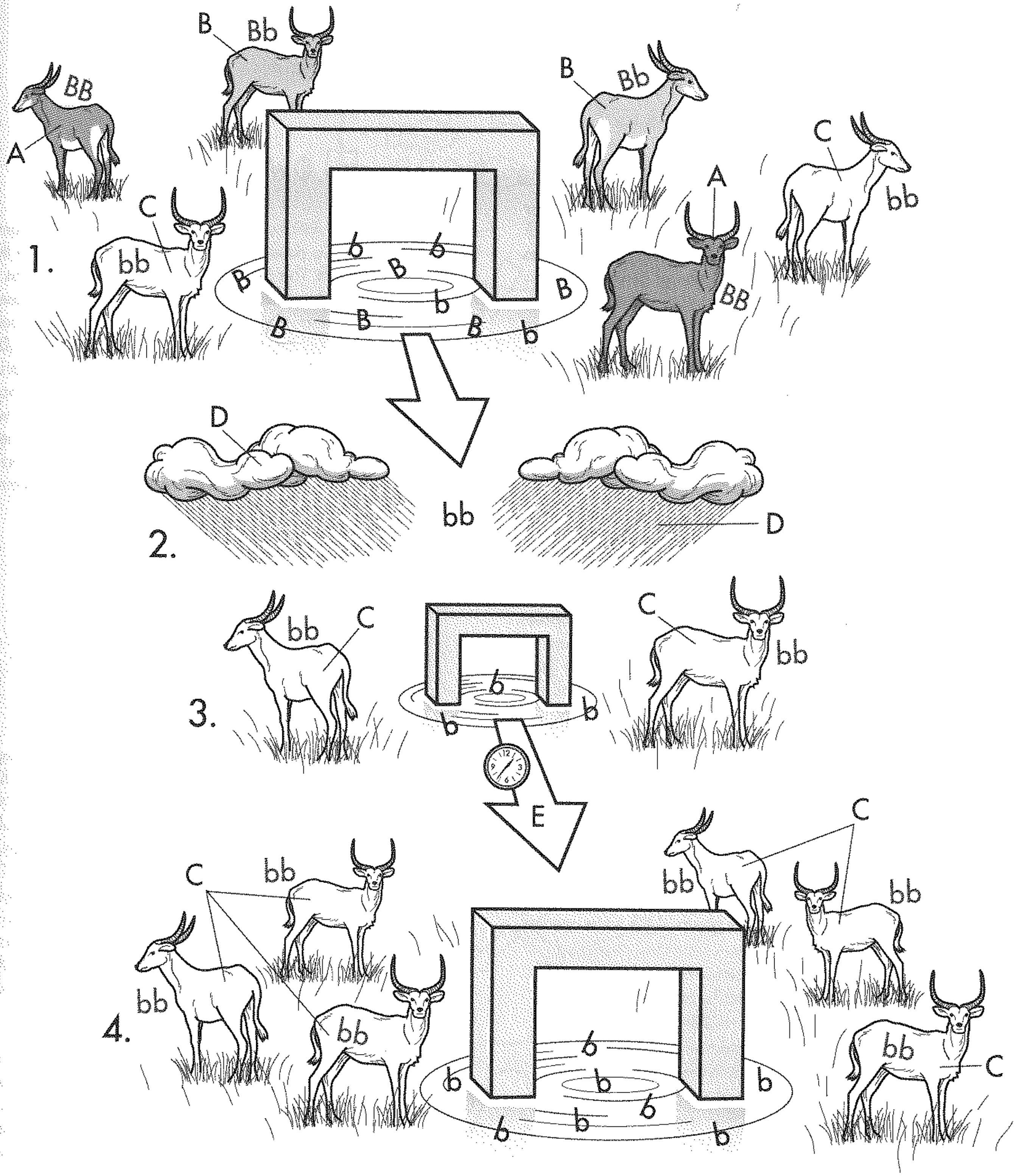
Having defined the gene pool, we will now see what happens when a catastrophe occurs that causes a change in the pool, which in turn affects the population. Your attention should now be directed to the second diagram.

Say that, at some point in the history of the population, a catastrophe strikes. We will use the example of a fierce rainstorm that eliminates all but two members of the population. We see, in diagram 3, that two light-skinned animals (C) have survived. We also note that the gene pool now consists solely of b genes.

An event such as this, in which many individuals are killed, leaving only a small number of survivors, is known as **the bottleneck effect (D)**. As you can see, the gene pool of the survivors is very different from the gene pool of the larger population. The animals are both light-skinned, reflecting a single phenotype. The small number of individuals surviving are called founders, and the phenomenon is called the founder effect. It need not result from catastrophe. Instead, two individuals might wander off from their herd, to found a new population.

Focus your attention on the fourth diagram to see the effect of the change on the gene pool.

Now a large amount of **time passes (E)**. In the art, this passage of time is represented by an arrow. One of the two surviving animals is male and one is female, and they breed to eventually produce a new population of animals. The gene pool of this new population is different from that of the original population, in that it consists solely of b genes. Moreover, the animals are all light-skinned. This may affect the population; for instance, predators might now be able to see the animals more easily, which makes them easier prey. Adaptations may be useful, detrimental, or they may have no effect on a population at all.



The Gene Pool

○ Dark-skinned Animals................A	○ Light-skinned Animals................C	○ Passage of Time........E
○ Medium-skinned Animals................B	○ Bottleneck ....D	

Chapter 5-6: Gene Flow

The forces of evolution take place within a population, which is defined as a group of interbreeding members of a species living in a geographical area. The collection of genes within this population is referred to as the gene pool. Gene flow is the addition of an immigrant's genes to the gene pool of a population that leads to altered allele frequencies in the population. In this plate, we examine how gene flow takes place in a population of fish as we explore its history.

> The history of the fish population is seen in four views, represented by the four rows of diagrams in the plate. As the history proceeds, we will see how new genes arise in a population, changing the character of it. Plan to use medium colors, and watch for the arrows, which are an integral part of the plate.

The process of gene flow begins with an original **fish population (A)** living in a lake. The fish are all of the same species, so the same medium color should be used for all of them. The gene pool in this population is stable and the phenotypes of all fish appear the same.

At some point in the history of the population, a climatic change occurs, and the lake begins to dry at a high area across its center. When this occurs, a **separation of the population (B)** occurs, indicated by the arrows. The result of this is seen in the second diagram, where the original fish population is split into two populations. You should use the same color that you used in the first diagram because the gene pool remains the same, despite the population division. One group has now been geographically isolated from another group of the same species.

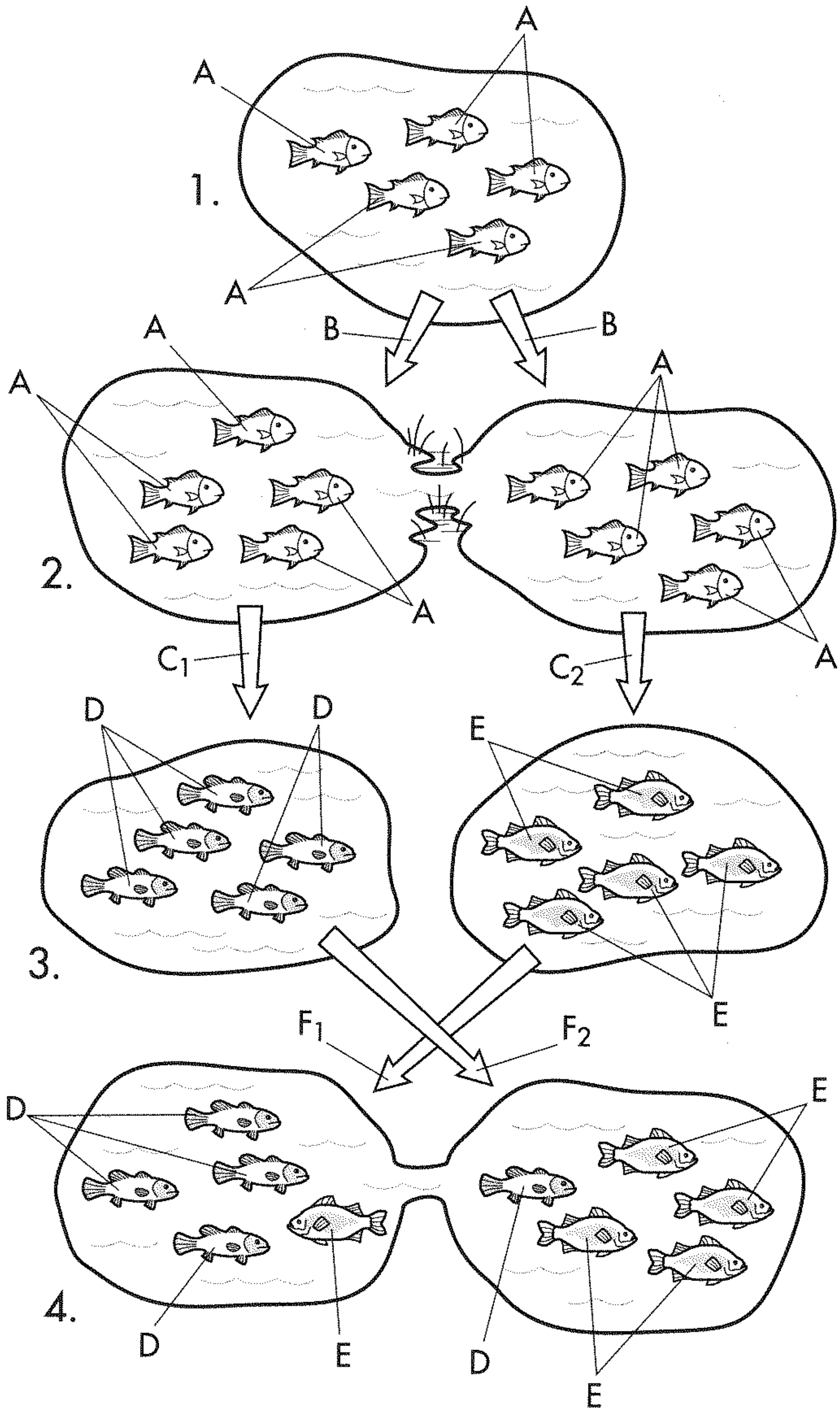
> Now we have seen how members of a population can become geographically isolated by an environmental change. Geographic isolation results when two populations are unable to interbreed. Note, however, the gene pool is still the same, despite the separation. We now continue with the history of the population and investigate the introduction of new genes.

The two fish populations continue to live separately. At some time in the future, it is possible that a mutation may occur in the population on the left. This is the **first mutation (C_1)**. While this is happening, a **second mutation (C_2)** may take place in the second fish population and a new gene will be introduced to both groups. In the lake on the left, there is **a new population (D)**, while in the lake on the right the **second new population (E)** arises. Different colors should be used for the fish, because they now have different genetic compositions. The gene pools of the two populations are different. It should be noted, however, that new species of fish have not arisen. Instead, some new genes have entered the population. The species remains the same because the fish in the two lakes can still breed with one another.

> Having established two different gene pools in two different populations of fish, we are now ready to examine the process of gene flow. Your attention should be focused on the fourth diagram as you continue your reading below. The same colors used in the third diagram should be used in the fourth, because the gene pool has not changed.

Let us suppose that at some time in the future, a climatic change causes a channel to form between the two lakes, so that the fish are no longer isolated geographically. As a consequence of the union, a fish of the second population swims into the first population in a **first exchange (F_1)**. Similarly, a fish of the first population swims to the second population, in a **second exchange (F_2)**. The addition of each immigrant fish brings its genes into the populations. Genes are exchanged between the two groups during interbreeding. If the stranger brings variations into the population, then the effect of gene flow is similar to that of a mutation. In this way, variability is introduced to the population and new combinations of genes are possible in the gene pool.

Contribution of gene flow to evolutionary change depends on the rate of immigration and the amount of genetic difference between the immigrants and the host population. For example, when the immigration rate is low (one fish has entered the population in our example), the effect on the host population's gene pool is small. By contrast, if many immigrants enter the population, the effect will be great and the contribution of gene flow to evolutionary change will be substantial.



Gene Flow

- ○ Original Fish Population ....A
- ○ Separation of Population ....B
- ○ First Mutation........C_1
- ○ Second Mutation ......C_2
- ○ First New Population ..D
- ○ Second New Population ..E
- ○ First Exchange........F_1
- ○ Second Exchange ......F_2

Chapter 5-7: Genetic Drift

The total number of genes in a population, also called the gene pool, can undergo changes that lead to variations in the physical characteristics of a population. One of the forces that changes the gene pool and leads to evolutionary change is genetic drift.

When the gene frequencies of a population change, genetic drift has taken place. The evolution that accompanies genetic drift occurs most often in small, isolated populations, as we will show in this plate. Larger populations are less susceptible to the force of genetic drift. The changes brought about by genetic drift are not necessarily adaptive, because pure chance brings them about. Genetic drift may work to the detriment of a population, rendering it more poorly adapted to its environment.

In this plate, we examine how genetic drift can change the gene pool of a population, and note how the rate of genetic drift is much greater for a smaller population than a larger one.

As you look over the plate, you will note that we are presenting two populations of fish in separate lakes. One population is relatively large, and the other is relatively small. We see three events in the history of the populations: the original populations in the first diagram, a removal of genes from the populations in the second diagram, and the result of the genetic drift in the third diagram. Only two colors should be used for this plate. We recommend red for the darker fish, and yellow for the lighter fish.

We begin our study of genetic drift by noting the two populations of fish. In the first lake, we see a small population of fish with two **red fish (A)** and four **yellow fish (B)**. In this case, the ratio of dark fish to light fish is 2:4. This ratio may be expressed as 0.5.

Looking at the second lake, we see a much larger population of fish. In this case, there are eight red fish (A) and sixteen yellow fish (B). The ratio of red to yellow fish is 8:16, or 0.5, the same as it was in the first lake. Thus, the ratio of red genes to yellow genes is the same in the two lakes.

Having established the gene pools of the two populations of fish, we will now see how a chance event affects each population. The random event removes a certain number of genes from each population. Focus your attention on the second diagram of the plate.

In the second diagram, we see that a fisherman has come to each lake. In each case, the fisherman has caught a red fish (A). This random event changes the characteristics of the gene pools of each lake and may change the evolutionary direction of the population.

In the third diagram, we see the effects of the random event. Because red genes have been removed from the populations, changes in the gene pools occur.

The loss of one fish in diagram 2 has resulted in changes in both populations. In the small population, there is now one red fish and four yellow fish, in a ratio of 1:4, or 0.25. Thus, the ratio of red to yellow genes has dropped from 0.5 to 0.25.

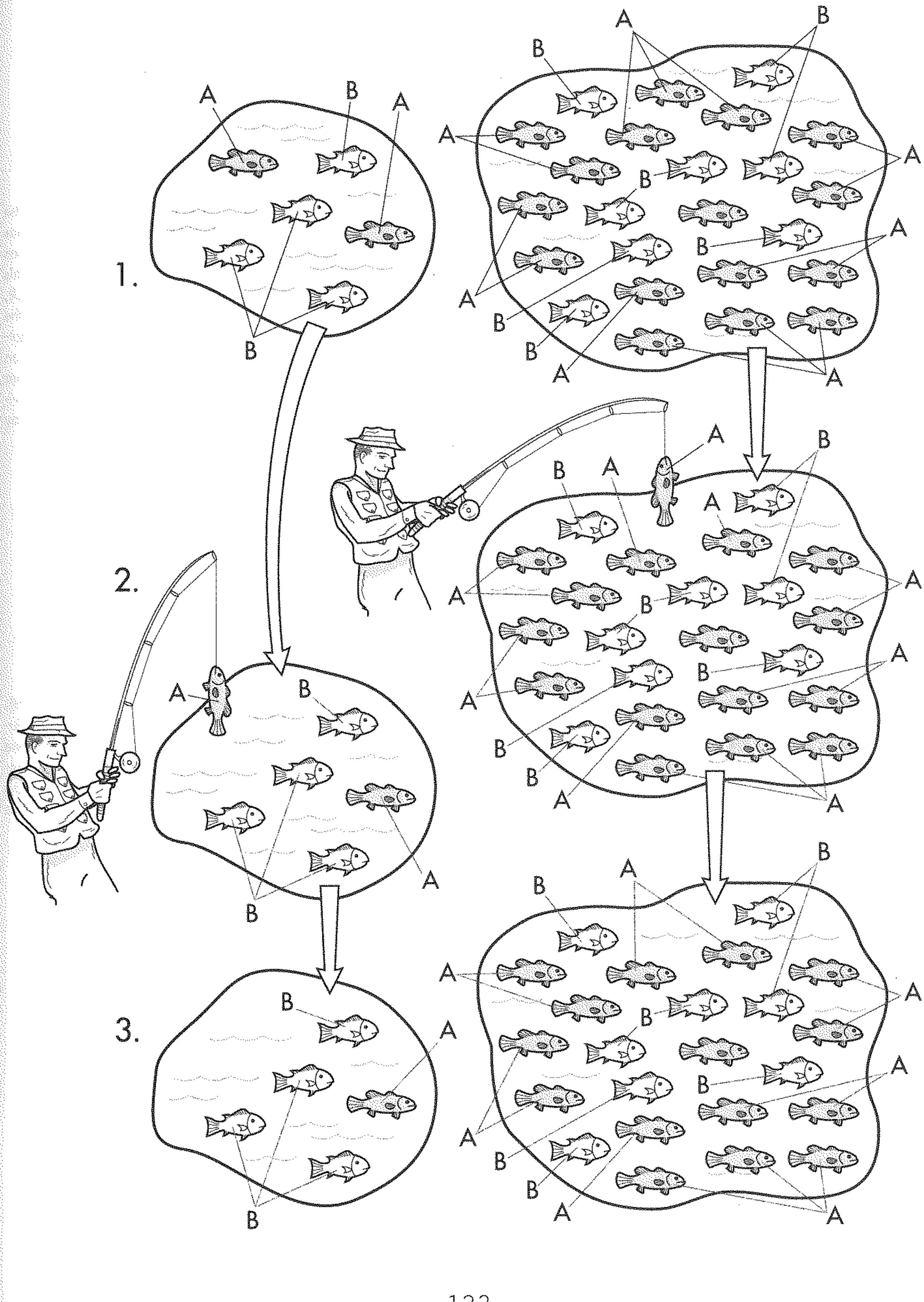
In the larger fish population, there are now seven red fish (A) and sixteen yellow fish (B). The ratio of red to yellow genes is now 7:16 or 0.4375. The ratio of genes has therefore dropped from 0.5 in the original population, to 0.4375. You can easily see that the ratio of the genes in the large population was affected much less by this chance occurrence than was the small population.

Notice that genetic drift has produced an alteration in the gene pool of the population but has not affected the population's chance for survival. Indeed, if a predator comes along that is attracted to red fish, the predator may snap up the remaining red fish from the smaller population, and the red genes will disappear entirely. The remaining population will then contain only yellow genes and will have undergone an evolutionary change. By contrast, the larger population is less likely to lose its red genes because the predator is less likely to consume all the red fish in the population. Thus, variability is less likely to be completely lost in the larger population.

Genetic Drift

○ Red Fish ....A

○ Yellow Fish...........B


1.
2.
3.
A
B

Chapter 5-8: Mutation and Natural Selection

Variation in the gene pool of a population occurs due to genetic drift, gene flow, and mutation. The effects of mutation will be examined in this plate.

Once variations are present in a population, natural selection occurs and shapes the evolution of organisms. Selective pressures brought about by the environment on a population of individuals effectively remove unfit individuals. Over long periods of time, the fit individuals multiply, as we will see in this plate.

This plate presents the history of a population of fish. We will see how a mutation occurs in the population and how the mutation results in fish that are better adapted to the environment. These better adapted individuals survive conditions in which others perish. This is the "survival of the fittest" phenomenon.

We begin with a large population of **original fish (A)**. These fish have lived for a long time in a body of water with a **cool temperature (G)**. The population is relatively stable, and all fish are of essentially the same type in the population. A dark color may be used to color them, but a light color should be used for the thermometer.

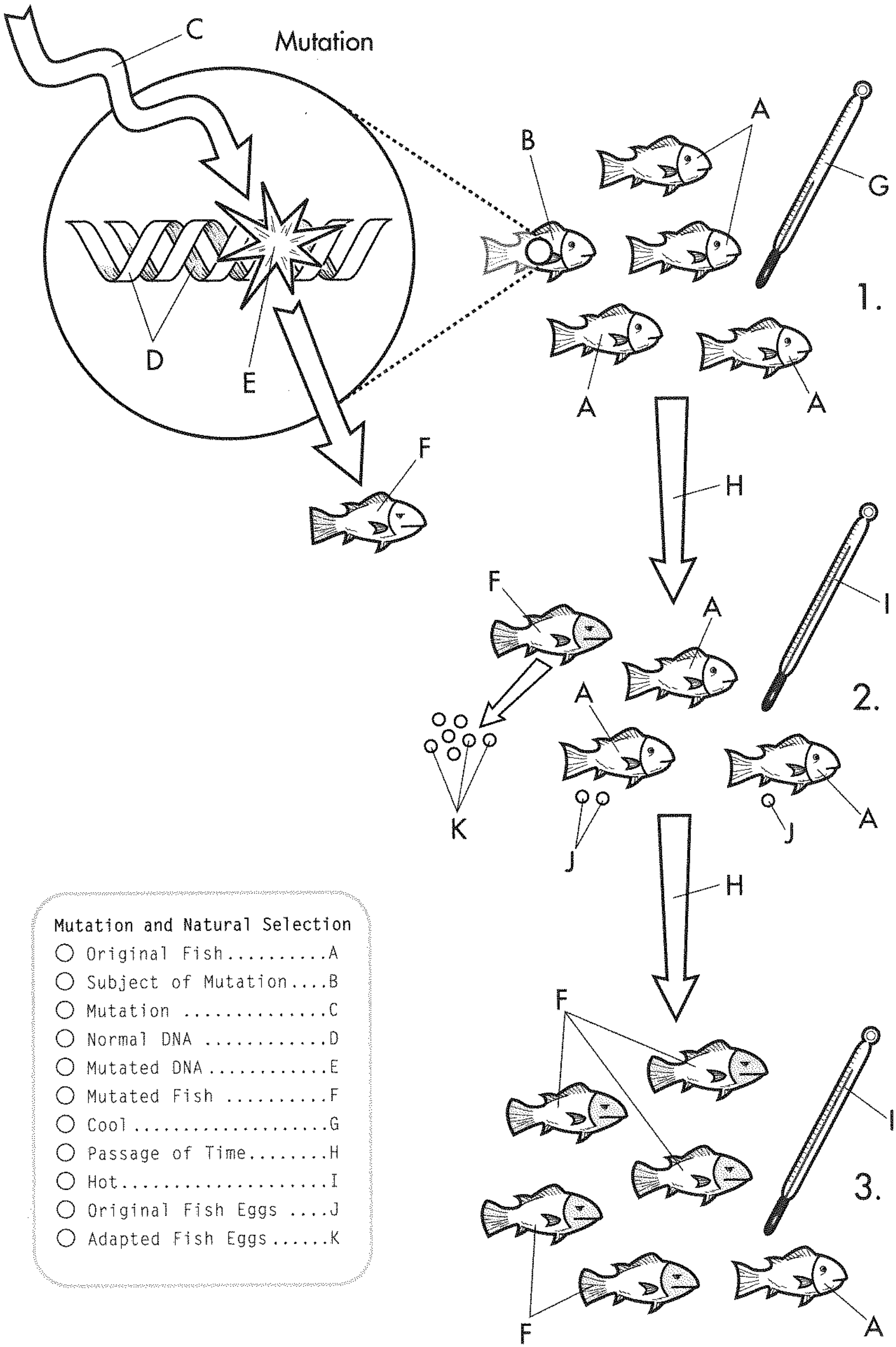
As diagram 1 indicates, a mutation occurs in the population. A mutation is an alteration in the DNA in an organism, which may or may not affect its characteristics. In this particular case, the **mutation occurs in one of the fish (B)** in the population. The **mutation (C)** can be caused by many factors, including an episode of ultraviolet light from the sun. Mutations occur within **strands of DNA (D)**, bringing about changes in the base sequence of a particular gene. They result in specific locations in DNA that are then considered **mutated (E)**. The fish that results is a **mutated fish (F)** with a new phenotype. In this case, the mutation is not lethal, so the fish will survive and remain in the population.

We have seen how a mutation brings about an alteration in the genes of one member of a population. Because the fish is alive and healthy, there is no apparent overall effect of the mutation on the population. However, that will change as the environment exerts a selective pressure, as we will see in the next few paragraphs. Continue your reading below as you continue to color.

Over long expanses of time, climatic shifts take place on the surface of Earth. Suppose that a long **passage of time (H)** has occurred. During this time, the temperature of the water has increased substantially and the water is now quite **hot (I)**. At this higher temperature, the original fish (A) produce their **eggs (J)**, but they produce fewer than the normal number because of the temperature change. Meanwhile, the mutated fish is well adapted to warmer temperatures. Part of its adaptation is that it can produce many more eggs than the original fish at the higher temperature. Thus it is fitter than the original fish and the environment has selected it out from the original population by favoring its reproduction.

At this point, we have seen how mutation and natural selection take place. The mutation changed the characteristics of the fish, and natural selection resulted in its increased reproductive capacity. We now see the effect of natural selection in the third diagram in the bottom of the plate. Here we see how the history of the population has changed. Continue your coloring as before and note the effects of natural selection.

Now the population experiences a brief passage of time (H). During this time, the **adapted fish eggs (K)** become new individuals, and the environment is now filled with adapted fish. Only one of the original fish (A) remains. The warmer water is the environment's selective pressure and the emergence of the adapted fish shows the result of the natural selection. In effect, this mutation has made the fish better prepared for the changing environment.



Mutation and Natural Selection

- ○ Original Fish..........A
- ○ Subject of Mutation....B
- ○ Mutation C
- ○ Normal DNA ....D
- ○ Mutated DNA............E
- ○ Mutated Fish ....F
- ○ Cool...................G
- ○ Passage of Time........H
- ○ Hot....................I
- ○ Original Fish Eggs ....J
- ○ Adapted Fish Eggs......K

Chapter 5-9: Natural Selection

Darwin and Wallace recognized that members of a population of organisms have unequal chances for survival and reproduction. They must compete for food and mates, safety from predators, safety from disease, and numerous other factors. In these struggles for existence, some individuals in a population will be more successful than others because of variations in their physiology, body structure, or behavior. The reproduction of fitter organisms is the basis for natural selection.

Both Darwin and Wallace believed that natural selection is the primary mechanism in the evolution of new species. Contemporary biologists attribute evolution to other phenomena such as gene flow and genetic drift, but natural selection remains an important factor.

In this plate, we examine the process of natural selection, and we show how a population changes as a result of it. We will see how fitness is a measure of an individual's ability to survive and reproduce and how some members of a population are more fit than others.

Look over the plate and color as you read the paragraphs below. There are four parts to be colored in this plate: an isolated island on which natural selection occurs, two types of animals from the population of the island, and a predator. You will only need four colors. We will follow the story of the island through five diagrams, beginning at the top of the page.

Historically, biologists wondered how animals and plants adapted, uniquely fitting to their environments, but they now know that variation and natural selection are responsible. Variations give certain individuals advantages over others, and they survive and reproduce as noted above. Natural selection encourages survival of the better-adapted individuals and acts on variations present in individuals within the population, rather than on the population as a whole.

Take a look at the first diagram. Two different animals exist on the **isolated island (I)**. The **first animal (A)** lives solely on the ground, has a pointed snout, and digs holes in the ground. The **second animal (B)** has a blunt snout and cannot dig holes, but can climb trees to obtain food. The first animal is unable to climb trees. Thus, we see a variation in both the physical characteristics and lifestyles of the two animals.

Contrasting colors should be used for the first animal (A) and the second animal (B). We have established a population of mixed animals in a geographically isolated environment. We will now see how natural selection causes a change in the gene pool of the population. Focus on the second diagram and use the same colors that you've been using.

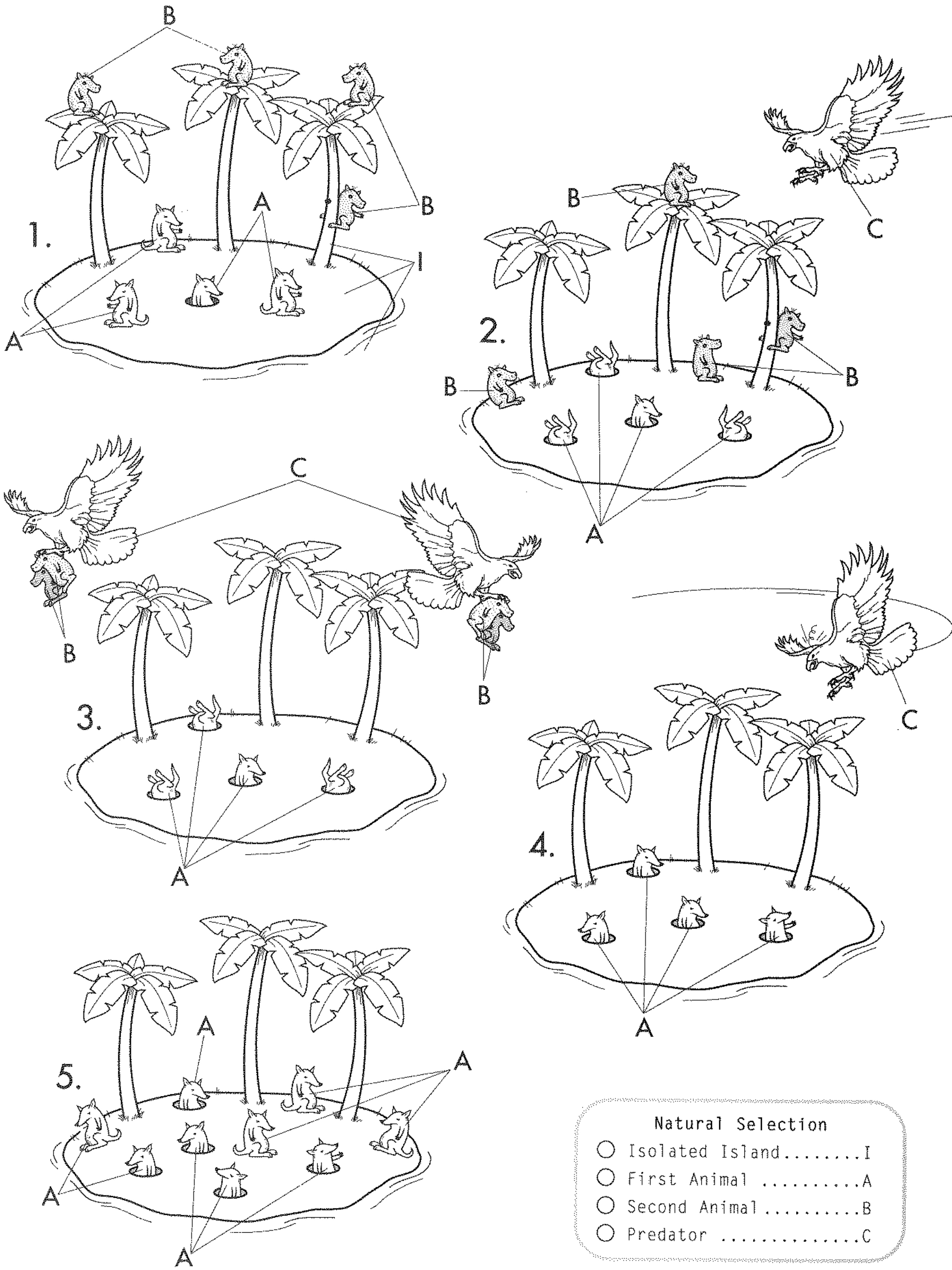
As we see in the second diagram, a **predatory bird (C)** now enters the environment. The first animals, which have pointed snouts (A), quickly dive into their holes in order to escape from the bird. The second animals (B), however, have blunt snouts and cannot dig holes into which they can escape.

In diagram three, we see that the birds (C) are carrying off the less fit animals (B), while the burrowing animals (A) are in their holes. Natural selection is now taking place; animals that are less fit for that environment are removed from the population and the more fit ones survive. It is a chance event based on the anatomical advantage of one of the animals.

In diagram four, we see the close of the episode of predation. The bird (C) cannot get at the animals that have pointed snouts (A). They have survived because they are suited to the environment and can use their qualities to their advantage. Soon, the birds will no longer hunt on this island since they will have exhausted the supply of tree-climbing animals that can be easily reached.

We close our story by looking at the last diagram in the plate. Some years have passed and we see the effect of the predatory event. Continue to use the colors you used before.

After time passes, the only animals present on the island will be those that have pointed snouts. These animals have reproduced and passed their characteristics to their offspring.


1.
2.
3.
4.
5.
A
B
C
I
Natural Selection
Isolated Island........I
First Animal ....A
Second Animal..........B
Predator C