# 1-3: How can natural and artificial selection influence changes in populations?

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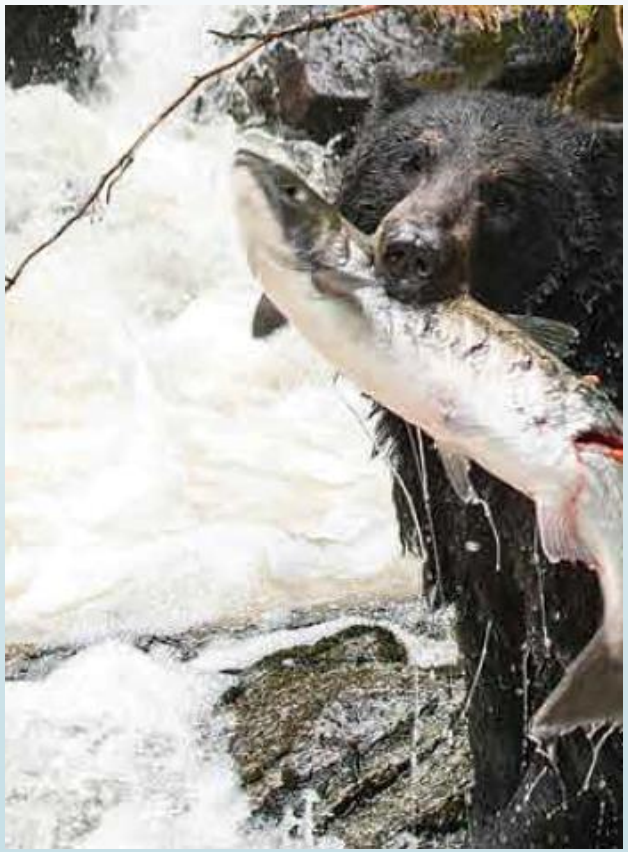
# Key Vocabulary

- Mutation
- Frameshift mutation
  - Insertion mutation
  - Deletion mutation
- Point mutation
  - Silent mutation
  - Missense mutation
  - Nonsense mutation
- Selective advantage
- Natural selection
- Population
- Individuals
- Adaptation
- Species
- Speciation
- Adaptive radiation
- Extinction
- Mutagen
- Carcinogen
- Artificial selection
- Monoculture

# Topic 1.3: How can natural and artificial selection influence changes in populations?

- DNA mutations produce genetic diversity within a population.
- Natural selection favours traits that make an organism better suited to its environment.
- Natural selection can lead to the formation of new species.
- Environmental factors can cause mutations.
- Humans select desired characteristics in organisms to be passed on to the next generation.



# Concept 1: DNA mutations produce genetic diversity within a population.

- Variety exists within the same species because of genes.

Figure 1.21: The kittens in this litter have different fur colour and patterns, partly because each kitten inherited a different combination of alleles from its parents.

# Mutations

- Mutations are a source of genetic variation.
- **Mutations:** a permanent change in the genetic material of an organism
  - Can occur during DNA replication.
  - Some mutations can be harmful and can cause a cell to die, malfunction, or multiply uncontrollably.
  - Some mutations can be beneficial, while others have no effect.

# Mutations

Types of mutations (see worksheet for details)

- Frameshift
  - Insertion
  - Deletion
- Point Mutation (substitution)
  - Silent
  - Missense
  - Nonsense

# Discussion Questions

1. What is a mutation? Are all mutations harmful? Explain.

2. Explain why mutations are the starting point for genetic variation.

# Concept 2: Natural selection favours traits that make an organism better suited to its environment.

- Some mutations may provide a selective advantage in changing conditions.
- **Selective advantage:** a genetic advantage that improves an organism's chance of survival*, usually in a changing environment

* Compared to other organisms in the same population

# Selective Pressure

- **Adaptation:** structural or behavioural feature or physiological process that improves the organism's chance of surviving in its environment to reproduce
- Organisms that have an advantageous mutation may survive better in a changing environment.

# Natural Selection

- **Natural selection:** the process by which characteristics of a population change over many generations as organisms with heritable traits survive and reproduce, passing their traits to offspring

# Evolution by Natural Selection

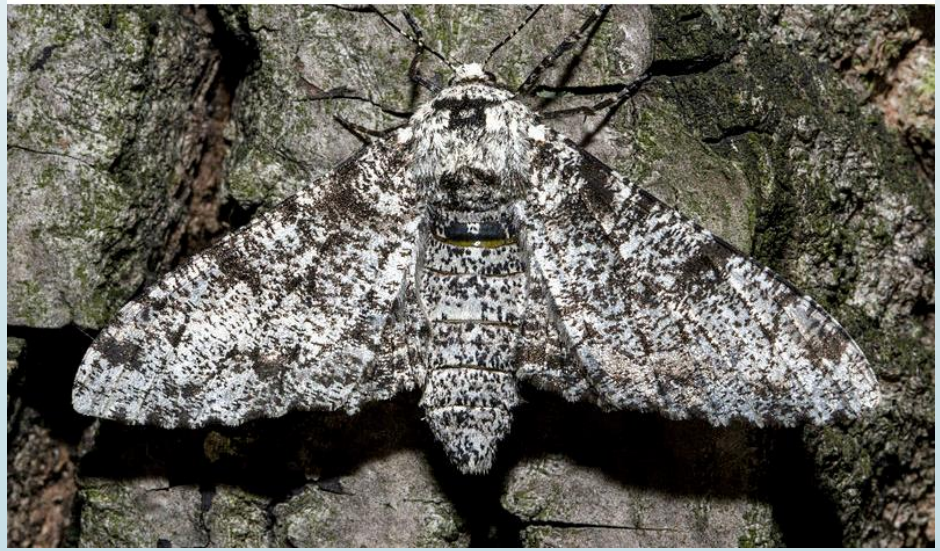
**3 Steps:**

1. Variation exists in population
2. Environment exerts selective pressures on population, favours some variants over others. These variants have a higher rate of survival and reproduction, and their genes are more heavily represented in the next generation.
3. Over time, the population evolves: the frequency of traits changes.

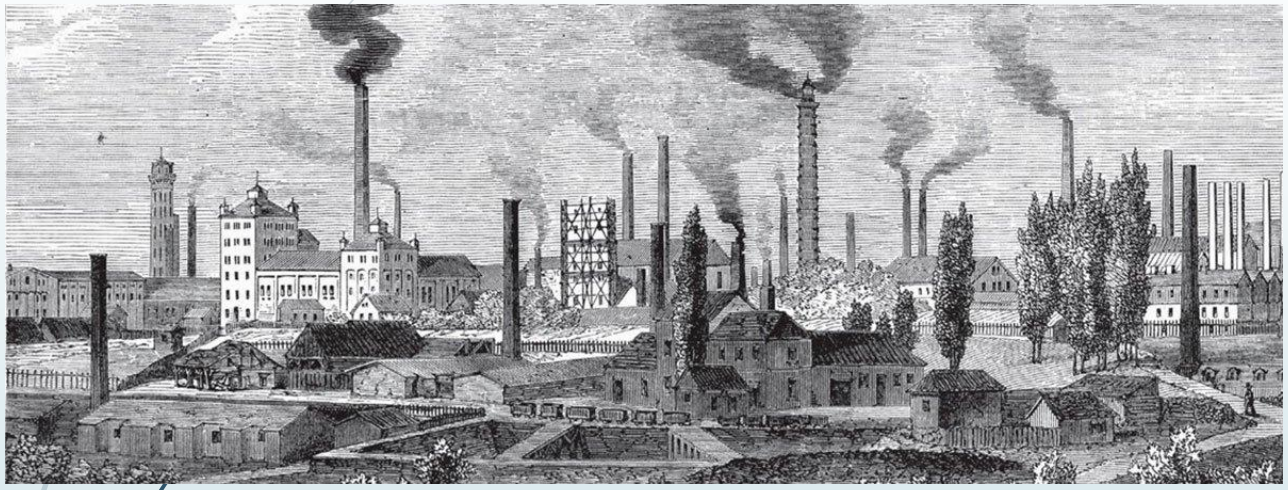
# Evolution by Natural Selection

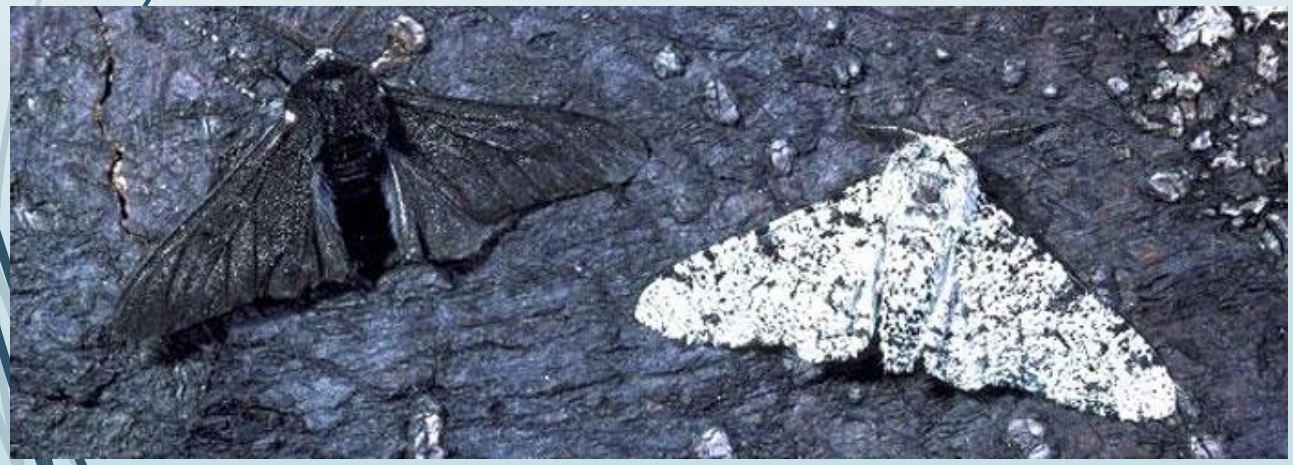
**3 Steps:**

1. Variation exists in population



# Evolution by Natural Selection

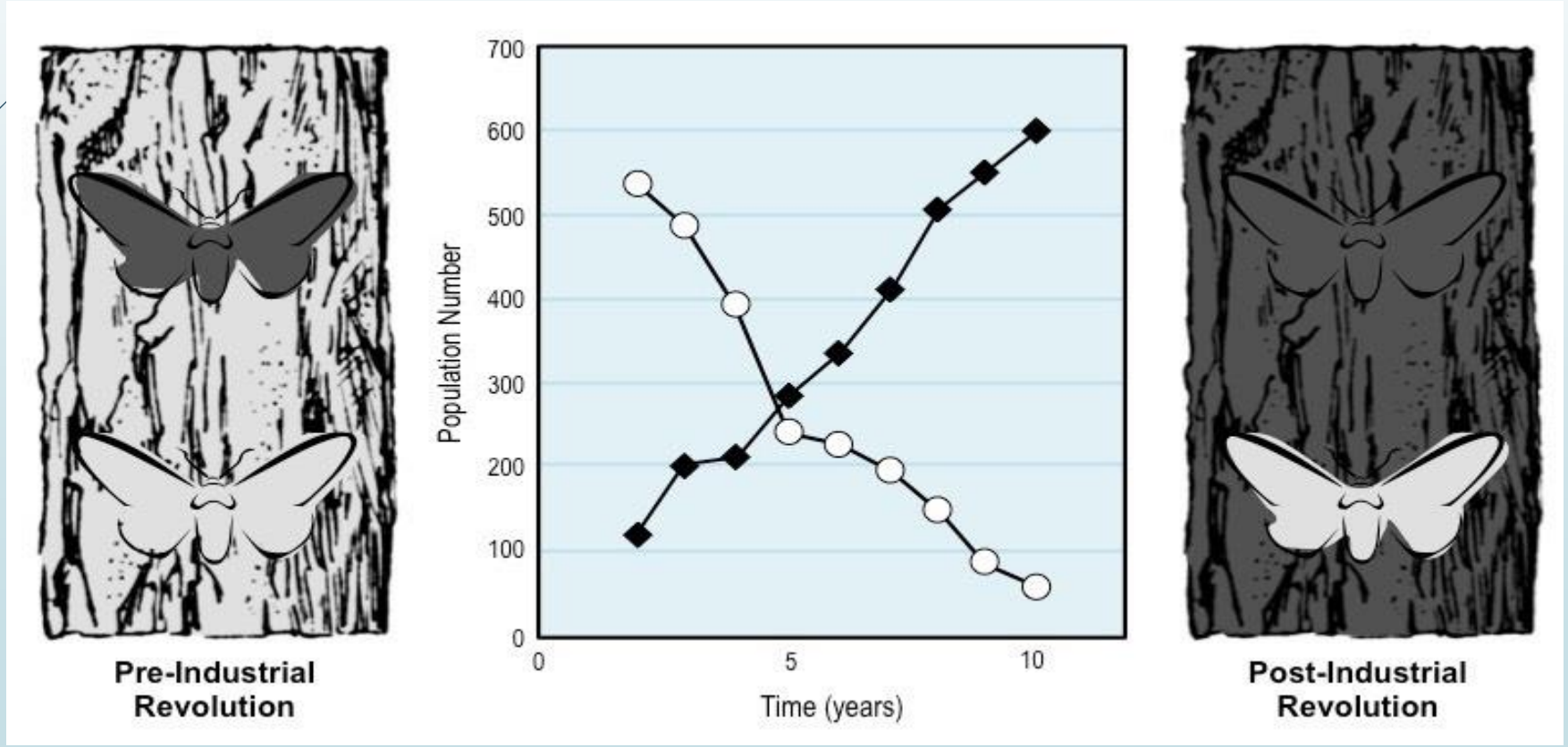




2. Environment exerts selective pressures on population, favours some variants over others. These variants have a higher rate of survival and reproduction, and their genes are more heavily represented in the next generation.

# Evolution by Natural Selection

3. Over time, the population evolves: the frequency of traits changes.



# Natural Selection Acts on Populations

- The environment exerts selective pressures that result from predators, parasites, and competition for limited resources.
- Over time, the *population* changes because individuals with favourable characteristics survive and reproduce.

# Natural Selection Is Situational

- Natural selection is situational.
- A trait that may be a disadvantage to an individual at one time may be advantageous to its survival later.
- Alleles for this trait will be passed on to the next generation to the offspring.

# Discussion Questions

1. Why does genetic variation make it possible for changes in populations to occur through natural selection? Explain your answer.

2. Using the example shown in Figure 1.23, make a graphic organizer to show the steps by which natural selection favours a population of plants to grow in a shady environment.

# Concept 3: Natural selection can lead to the formation of new species.

- Individuals of the same **species** can interbreed to produce fertile offspring.
- Sometimes members of a population change so much that they are no longer able to produce fertile offspring with members of the original population.
- This leads to **speciation**, where new species are formed.

# One Type of Speciation: Adaptive Radiation

- **Geographic barriers** can isolate a population, resulting in new species that are unable to interbreed.
- Examples of geographic barriers include a glacier, a lava flow, and an island.

# One Type of Speciation: Adaptive Radiation

- **Adaptive radiation:** the diversification of a common ancestral species into a variety of differently adapted species
- Finches on the Galapagos Islands have different beak shapes due to their diverse diets.

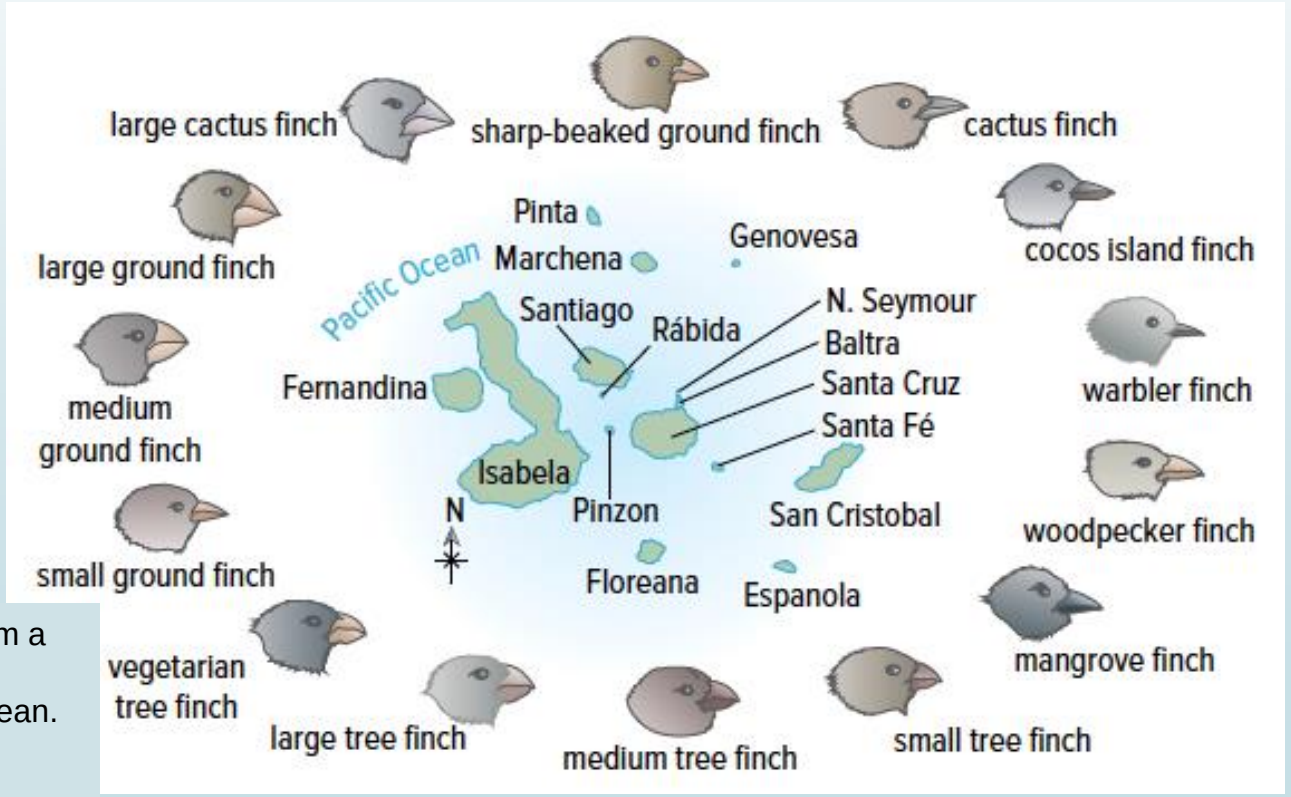



Figure 1.25: One common example of new species forming from a common ancestor are finches on the Galapagos Islands. The Galapagos Islands are located on the equator in the Pacific Ocean. The islands are volcanic in origin and contain a number of ecosystems, ranging from dry and desert-like to humid forests. Notice the difference in the shape and size of the birds' beaks.

# Adaptive Radiation (Another Example)

- Tortoises on the Galapagos Islands are all different due to mutations, natural selection, and adaptive radiation.

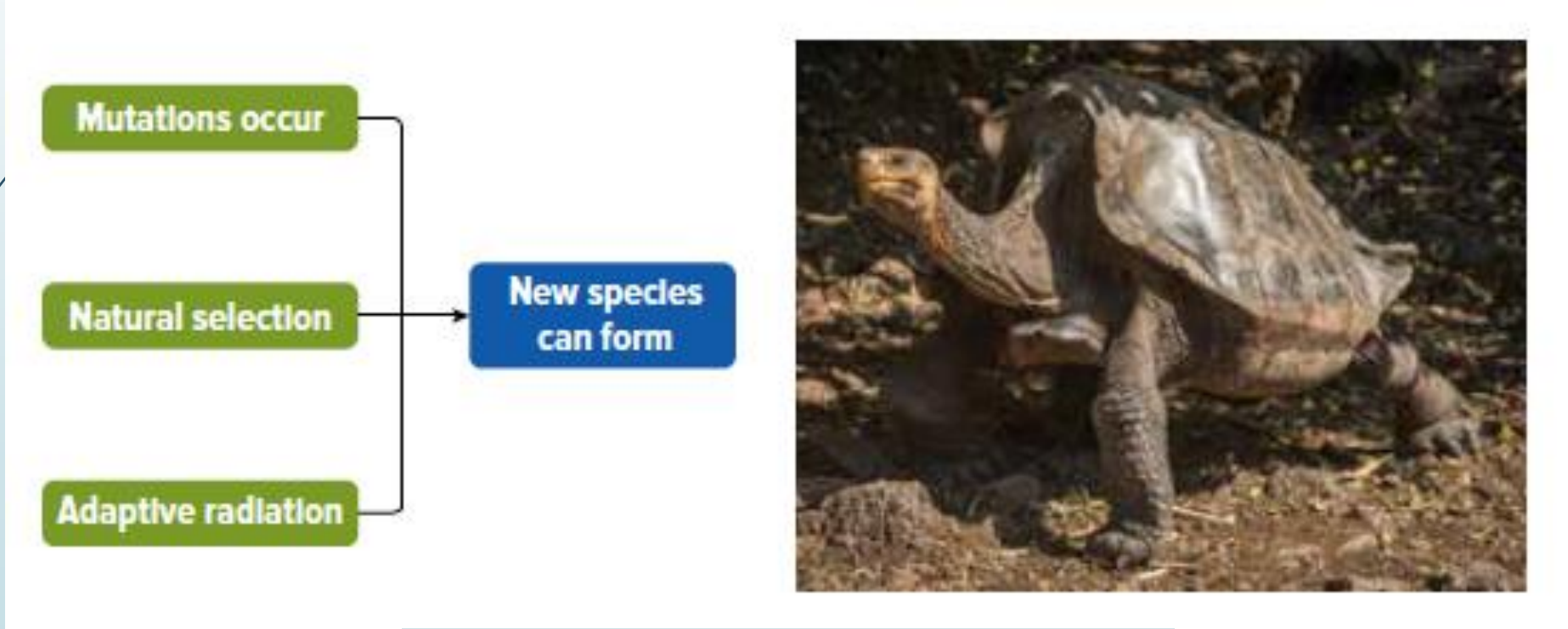



Figure 1.26: This figure illustrates how the various factors interact to form a new species.

# Extinction and Selective Pressure

- **Extinction:** occurs when a species completely disappears from Earth
- Mass extinctions result in a decline in the number of species.

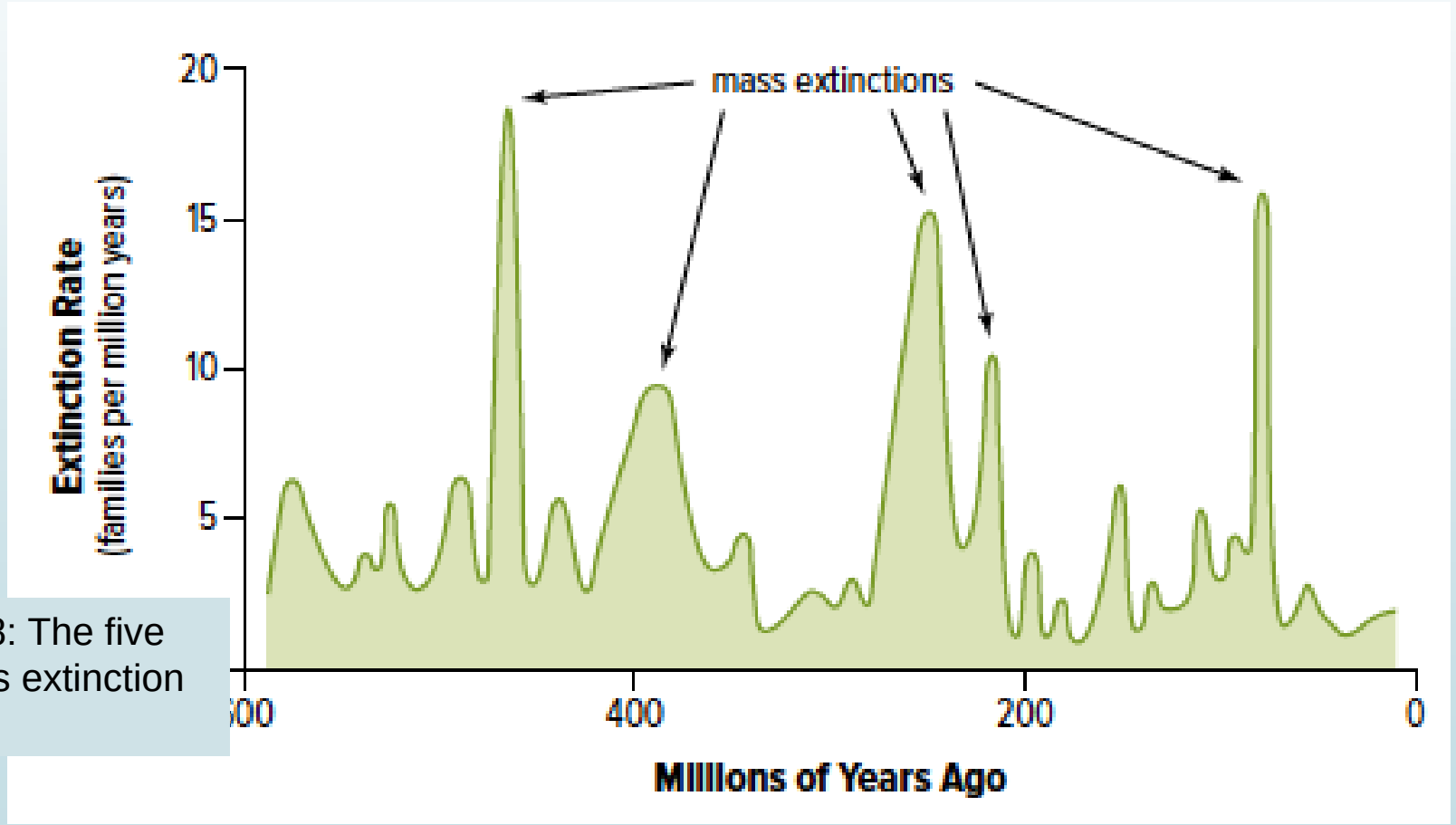



Figure 1.28: The five major mass extinction events.

# Discussion Questions

1. What is adaptive radiation?

2. Explain why it would have been possible for an ancestral finch species, having arrived on one of the Galapagos Islands, to have diversified and evolved into other species over time.

3. How is extinction related to selective pressure?

# Concept 4: Environmental factors can cause mutations.

- Mutations are important to natural selection and speciation.
- Mutations provide genetic variation.
- **Mutagen:** a substance or event that increases the rate of mutation

- *Physical mutagens* cause physical changes in the DNA (i.e., X-rays and UV radiation).
- *Chemical mutagens* can chemically react with DNA (i.e., nitrites and gas fumes).

Not testable: physical vs chemical mutagens

# Carcinogens

- **Carcinogen:** a substance or agent that causes cancer
- Some mutagens are carcinogenic.
  - Examples include UV radiation, cigarette smoke.
  - Wearing sunscreen, a hat, and sunglasses can reduce the exposure to UV radiation.

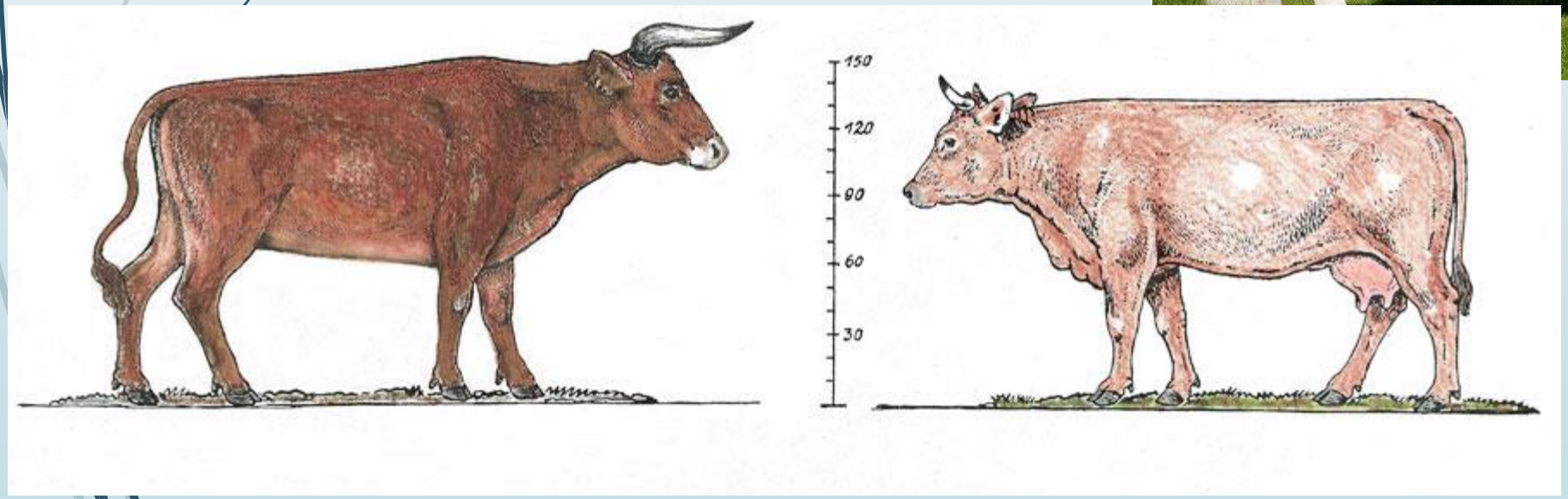
Figure 1.29: Applying sunscreen before going out in the sun can help reduce a person's exposure to ultraviolet radiation.

# Discussion Questions

1. What is a mutagen?

2. Explain how mutagens and the production of proteins are related.

# Concept 5: Humans select desired characteristics in organisms to be passed on to the next generation.


http://www.cambridgeblog.org/2016/02/cattle-domestication-from-aurochs-to-cow/ https://www.npr.org/sections/thesalt/2016/03/18/470938624/gigi-the-cow-broke-the-milk-production-record-is-that-good-for-cows

# Concept 5: Humans select desired characteristics in organisms to be passed on to the next generation.

# Artificial Selection

**What do you think the sausage dog was selectively bred for?**

- Hunting lions
- Guard dog
- For aristocracy to rest their feet on
- Chasing rabbits down their holes

Concept 5: Humans select desired characteristics in organisms to be passed on to the next generation.



# Concept 5: Humans select desired characteristics in organisms to be passed on to the next generation.

- **Artificial selection:** selective pressure exerted by humans on populations in order to improve or modify desirable traits
- Humans breed cows that produce more milk, chickens that produce large numbers of eggs, and pigs with large muscles for meat.

# Artificial Selection and Food Crops

- Humans breed crops to resists drought, disease, and insect infestations.
- Through selective breeding, the wild mustard plant is used to produce six other plants.

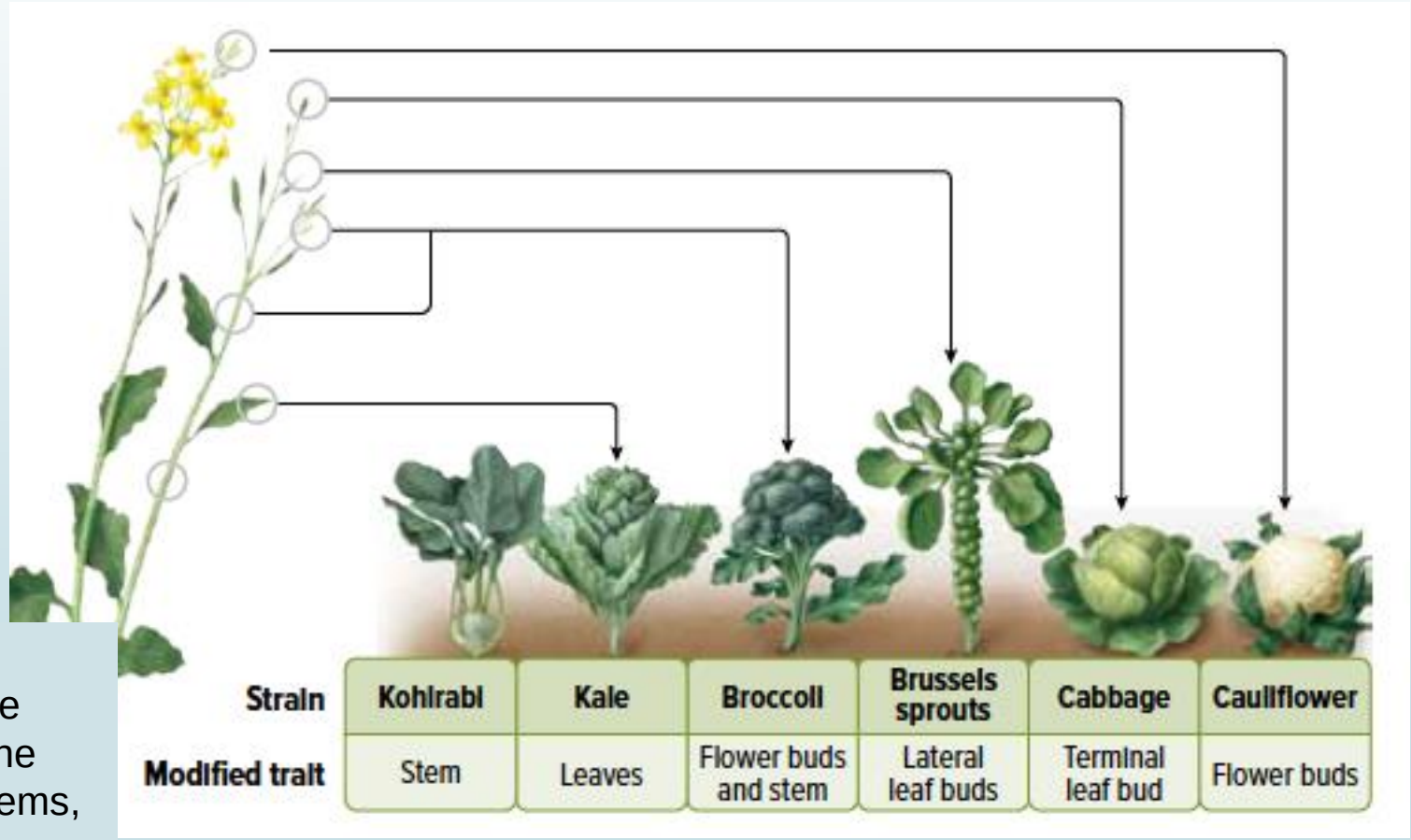



Figure 1.31: These six agricultural plants look very different from each other, but they carry much of the same genetic material as the wild mustard plant. The differences affect the formation of flowers, buds, stems, and leaves.

# Consequences of Artificial Selection

- Some selectively bred animals have health problems (i.e., English bulldogs have respiratory problems and German shepherds have hip problems).
- Selectively bred plants lack genetic diversity because they are all similar.
- **Monoculture:** repeated planting of the same varieties of a species over large expanses of land
  - Decreased diversity → potential effects?

# Discussion Questions

1. What is artificial selection?

2. What are some benefits and risks associated with artificial selection of agricultural crops?

# Topic 1.3: How can natural and artificial selection influence changes in populations?

- DNA mutations produce genetic diversity within a population.
- Natural selection favours traits that make an organism better suited to its environment.
- Natural selection can lead to the formation of new species.
- Environmental factors can cause mutations.
- Humans select desired characteristics in organisms to be passed on to the next generation.

# TOPIC 1.3

## How can natural and artificial selection influence changes in populations?

There are thousands of species of birds on Earth. Some, such as the Steller's jay shown here, have beaks that enable them to open the hardest seeds and nuts. Others eat fish, like the belted kingfisher shown below. Some birds eat insects, some eat rodents and other small animals, some eat seeds, and some feed on the nectar from flowers. Why are there so many variations in birds, and why are there so many different kinds of beaks? In this Topic, you will learn about the relationship between different adaptations of an organism, such as a bird's beak, and the organism's environment.

### Key Concepts

- DNA mutations produce genetic diversity within a population.
- Natural selection favours traits that make an organism better suited to its environment.
- Natural selection can lead to the formation of new species.
- Environmental factors can cause mutations.
- Humans select desired characteristics in organisms to be passed on to the next generation.

### Curricular Competencies

- Experience and interpret the local environment.
- Contribute to care for self, others, community, and world.
- Contribute to finding solutions to problems.



## Starting Points

**Choose one, some, or all of the following to start your exploration of this Topic.**

1. **Identifying Preconceptions** Explain to a partner how the following terms are related, and discuss your ideas: organism, species of organisms, and populations of organisms. Compare your ideas with the class, and make sure everyone understands.
2. **Inferring** Can you spot the peppered moth in the photo below? Birds are more likely to prey on moths that are easier to see. Light-coloured moths are harder to detect on tree trunks covered with white lichen. In mid 19th century England, soot from industrial pollution covered the trees. The once rare, dark-coloured form of the moths became predominant. When the air became cleaner in the 1970s, the light-coloured form of the moths became more common again. How could you explain how the colour of the moths in the population changed over time?

3. **Considering First Peoples Perspectives** The original North American horse became extinct 10 000 years ago. After the Spanish brought them back to the Americas in the 1400s, horses became essential to the way of life for many Indigenous groups. They became experts not only in raising and riding horses, but also in using selective breeding to develop unique breeds. Find out which modern breeds of horses owe their existence to First Peoples knowledge of selective breeding.

## Key Terms

There are 10 key terms that are highlighted in bold type in this Topic:

- mutation
- selective advantage
- natural selection
- adaptation
- adaptive radiation
- extinction
- mutagen
- carcinogen
- artificial selection
- monoculture

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

# DNA mutations produce genetic diversity within a population.

## Activity

**Getting a Message Through**

Form a line of at least eight people. Your teacher will whisper a message to the first person in line. Whisper-share this message from person to person, and have the last person say it out loud. Did the message change in any way? Keep this experience in mind as you discuss how changes in DNA from one generation to the next might affect an organism and a population of these organisms over time.

**mutation** a permanent change in the genetic material of an organism; a source of new genetic variation

You and your classmates are all the same species, but there is a great deal of variety among the individual members of your species. This variation is the result of genes. Offspring have a combination of genetic material from both biological parents. Through sexual reproduction, parents pass on genes to their offspring. How does genetic variation occur in a species or population? Why does genetic variation happen at all? **Mutations** are changes in the DNA of an organism. Mutations provide new alleles and are a source of new genetic variation when inherited.

Mutations happen continuously in the DNA of any living organism. They can occur spontaneously when DNA is copied before a cell divides. Mutations may also result from environmental agents such as ultraviolet radiation.

When there is a mutation in the DNA, a cell may exhibit new characteristics. Mutations that significantly alter DNA can be harmful. For example, a cell could die, malfunction, or multiply more than it should. However, not all mutations are harmful. Many mutations have no effect, and some mutations can be beneficial.

Whatever the result, if the mutation occurs in a somatic (body) cell, the mutation disappears from the population when the organism dies. However, if the mutation alters the DNA in a gamete, the mutation may be passed on to succeeding generations as a new allele. For example, if the kittens in Figure 1.21 have mutations in their egg or sperm cells, these mutations could be passed on to their offspring. These mutations were not present in their parents' DNA. Thus, mutations are the starting point for genetic variation in populations.

**Figure 1.21** The kittens in this litter have different fur colour and patterns, partly because each kitten inherited a different combination of alleles from its parents.

## Before you leave this page . . .

1. What is a mutation? Are all mutations harmful? Explain.
2. Explain why mutations are the starting point for genetic variation.



CONCEPT 2

# Natural selection favours traits that make an organism better suited to its environment.

## Activity

**What are the advantages?**

Study the photos of organisms provided by your teacher. Identify the traits that each organism has that give it an advantage for surviving in its environment. Share your ideas with other groups. How were your ideas similar and/or different?

Mutations that were once no advantage, or even a disadvantage, may become favourable in a changing environment. In this situation, the mutation provides a selective advantage. A **selective advantage** is a genetic advantage of one organism over its competitors. Over time, a selective advantage enables the organism to be favoured in terms of survival and reproduction. In other words, a selective advantage helps an organism survive changing environmental conditions and reproduce.

**selective advantage** a genetic advantage that improves an organism's chance of survival, usually in a changing environment

**natural selection** the process by which characteristics of a population change over many generations as organisms with heritable traits survive and reproduce, passing their traits to offspring

**adaptation** a structural or behavioural feature or physiological process that helps an organism survive and reproduce in a particular environment

## Natural Selection

**Natural selection** is the process that results when the characteristics of a *population* of organisms change over many generations. This change, or evolution, happens because *individuals* with certain inherited traits are more successful in specific local environmental conditions and, as a result, may pass on their alleles to the next generation through reproduction. For natural selection to occur, there must be genetic diversity, or variation, within a species.

## Selective Pressure

*Staphylococcus aureus*, shown in Figure 1.22, is a common bacterium that can affect human health by causing infections. Each individual bacterium reproduces asexually very quickly. Such rapid reproduction helps **adaptation** to occur very quickly. Each bacterium that has an advantageous mutation may survive a changing environment and reproduce; bacteria without an advantageous mutation may not. The surviving bacteria reproduce quickly. This rapid adaptation often leads to problems when doctors treat a *Staphylococcus aureus* infection (or other bacterial infection) with an antibiotic.

**Figure 1.22** These *Staphylococcus aureus* bacteria appear to be identical, but some may have a mutation that makes them resistant to antibiotics.

## Natural Selection Acts on Populations

An antibiotic is a drug used to treat infections caused by bacteria. The problem is that some individuals of the bacterial species may have a new allele, from a random genetic mutation, that makes them resistant to the antibiotic. Only the individuals with the new allele are able to survive and reproduce. They can then pass on the genetic information that resulted in resistance to that particular antibiotic to their daughter cells. Individual members of the population do not change during their lifetime. Rather, over time, the population changes in its ability to resist certain antibiotics. It is important to emphasize that the *population* changes, not *individuals*.

In the population of *Staphylococcus aureus*, the individual members of the population were *selected for* by their environment. An abiotic (non-living) environmental condition can be said to select *for* certain characteristics in some individuals and select *against* different characteristics in others. In this way, the environment exerts *selective pressure* on a population. Selective pressure may result from biotic factors as well, such as predators, parasites, and competition for resources.

As another example of selective pressure, consider the forest shown in Figure 1.23. Those individual trees that are able to grow successfully in the shade of the taller trees will reproduce and pass on the alleles to the next generation, increasing the abundance of shade-tolerant alleles. In the next generation, the abundance of the alleles to be more successful in shady conditions will increase in the population, because more of the individuals will have survived and reproduced. Over time, the population of smaller, shade-tolerant trees will be able to grow, survive, and reproduce in the shady conditions. If a change were to occur to the environment, such as a big increase in the light levels the trees were exposed to, the trait for resisting these conditions will no longer be an advantage. In fact, if no single member in the population can withstand the increased light levels, the population may not survive in that environment.

**Figure 1.23** The forest shown here is very dense. As a result, little sunlight reaches the ground where young trees are growing. Populations become adapted to their environment over many generations through natural selection. The environmental pressures result in some individuals being more likely to survive and pass along their genetic traits to their offspring. The trees able to grow in an environment with low light levels are more likely to be able to survive, reproduce, and pass on to their offspring the alleles that helped them survive.



## Natural Selection Is Situational

Natural selection has no will, purpose, or direction. Instead, natural selection is situational. A trait that at one time in one situation seems to have no apparent relevance to survival may be the trait that, at a different time in a different situation, helps certain individuals in a population survive and reproduce. The alleles for this trait will then be inherited by the offspring of the survivors. As a result, over many generations, there will be more and more individuals that inherit the allele for the trait that helps them survive the change in environment. Those individuals form a population that is better adapted to their environment.

### Activity

#### Modelling Natural Selection

Using the background information and materials provided by your teacher, work in small groups and follow the steps below.

1. Your teacher will give you a bag of 20 "berries." In a data table like the one shown on the right, record the total number of berries, the number of blueberries, and the number of raspberries. Give your table a title. Allow for four populations of berries.
2. Read all the steps and predict what will happen to the numbers of berries.

| | Total Number of Berries | Number of Blueberries | Number of Raspberries |
|---|---|---|---|
| Population 1 (Season 1) | | | |
| | | | |

3. Each bear in the group "eats" four berries each year. Where bears prefer blueberries over raspberries, to "eat" four berries, remove four counters and place them in a container. If you do not have four blueberries (blue counters) in your bag, then eat whatever blueberries you do have, plus one to three raspberries (red counters) for a total of four berries.
4. A season passes. Each berry left in your bag produces five new berries of the same colour, for a total of 20 for the next season. Replenish your supply of berries from your teacher to make up the correct complement of berries for the next season.
5. Repeat steps 3 and 4 for three more populations/seasons of berries.
6. Graph each population result. Use your results to answer the following questions.
   - What happened to each population of berries? Explain your answer.
   - Is this an accurate model for natural selection? Explain your answer.
   - Evaluate your prediction.

### Before you leave this page . . .

1. Why does genetic variation make it possible for changes in populations to occur through natural selection? Explain your answer.
2. Using the example shown in Figure 1.23, make a graphic organizer to show the steps by which natural selection favours a population of plants to grow in a shady environment.

CONCEPT 3

# Natural selection can lead to the formation of new species.

## Activity

### Two Species or One?

Do you think the owls in **Figure 1.24** are the same species? Why or why not? What other information would you want to know to help you decide? For example, in the past, biologists defined species in terms of their physical form. What other characteristics could be useful to distinguish species?

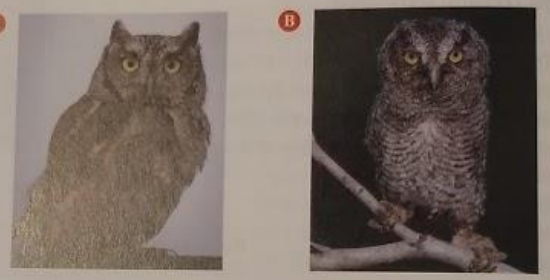



**Figure 1.24** The Western Screech-Owl (*Megascrops kennicottii*) in A is found in Alberta and British Columbia whereas the Eastern Screech-Owl (*Megascrops asio*) in B is found in in Ontario and Quebec.

Recall that a species is a population or group of populations in nature whose members can interbreed to produce fertile offspring that also can interbreed. Earlier in this Topic, you learned that various factors cause changes within populations. When some members of a sexually reproducing population change so much that they are no longer able to produce fertile offspring with members of the original population, speciation has occurred. *Speciation* is the formation of new species from existing species.

## One Type of Speciation: Adaptive Radiation

Sometimes a population is split into two or more isolated groups by a geographical barrier. Eventually, the gene pool of the split population becomes so distinct that the two groups are unable to interbreed even if they are brought back together. Examples of geographical barriers that can lead to the formation of new species include a glacier or lava flow that isolates populations, fluctuations in ocean levels that turn a peninsula into an island, and a few individuals reaching a geographically separate habitat.

Over time, natural selection and other factors act on each of the populations. Mutations that result in new traits that are advantageous to individuals in their environment are passed from one generation to the next. In some cases, after a longer geological timeframe, the two populations are so different from each other that they are no longer the same species. This concept is illustrated in **Figure 1.25** on the next page.



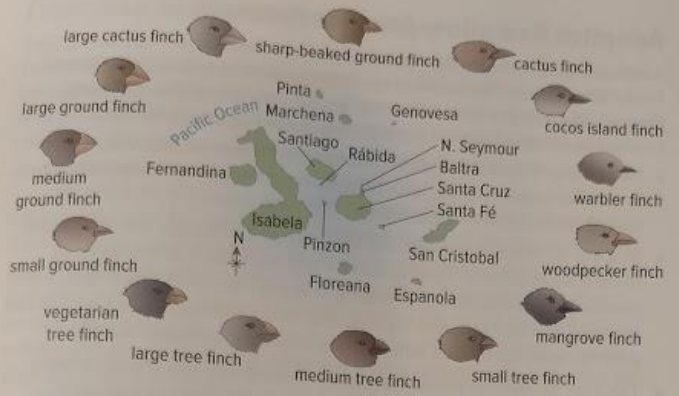



**Figure 1.25** One common example of new species forming from a common ancestor are finches on the Galapagos Islands. The Galapagos Islands are located on the equator in the Pacific Ocean. The islands are volcanic in origin and contain a number of ecosystems, ranging from dry and desert-like to humid forests. Notice the difference in the shape and size of the birds' beaks.

At some time in the past, members of the ancestral finch species reached one of the islands in the Galapagos, perhaps by being blown off course during a tropical storm. With no other land birds on this island, the ancestral finch species had many unoccupied ecosystems to move into. During the time that this occurred, individual finches were subjected to different types of selective pressures, and some may have flown to nearby islands with still more unoccupied ecosystems to live in.

As a result, over time, the ancestral species divided into different populations, and some of these evolved into new species—the species that now populate the many islands of the Galapagos. This type of speciation, in which a common ancestral species diversifies into a variety of differently adapted species, is called **adaptive radiation**. Islands are excellent places to study adaptive radiation, and biologists sometimes refer to them as living laboratories. Islands give organisms that have dispersed from a parent population the opportunity to change in response to new environmental conditions in relative isolation.

**adaptive radiation** the diversification of a common ancestral species into a variety of differently adapted species

## Activity

### Galapagos Finches

Use **Figure 1.25** to answer the following questions about the 14 species of finches on the Galapagos Islands.

1. What is the major physical difference among the species illustrated? Form a hypothesis that might explain the difference between the large tree finch and the cactus finch.
2. Ground finches that depend primarily on seeds as a source of food mostly live on solidified lava beds. How can you explain the differences in beak size and shape among the different types of ground finches? What about the tree finches?

## Adaptive Radiation: Another Example

Another example of how new species can form also comes from the Galapagos Islands. The tortoises on the individual islands are all different. Figure 1.26 and the points below outline the conditions that may have resulted in the speciation of the tortoises in the Galapagos Islands.

- Individuals from a species of South American tortoise found their way to the Galapagos Islands, and different ones were better suited to each specific island's new environment.
- As these tortoises looked for and ate food on the islands, the differences in their traits allowed them to survive and reproduce in the different environmental conditions, resulting in some tortoises living longer, being stronger or better fed, and reproducing more. (Mutations ensure that the genetic make-up of each individual in a species is slightly varied.)
- The next generation would have more individuals with characteristics that enabled them to have greater success in the new environment.
- Through natural selection, the descendants of the ancestral tortoise population began to change. Over time, new species arose.

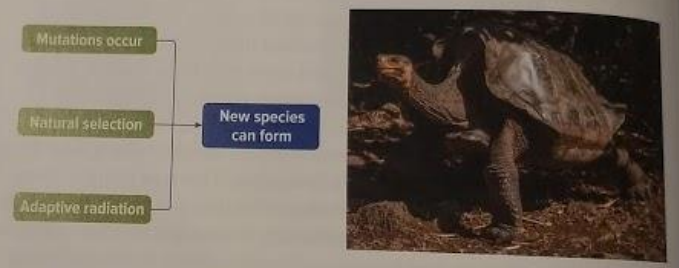



Figure 1.26 This figure illustrates how the various factors interact to form a new species.



Adaptive radiation does not occur just on islands. In 1991, two biologists at the University of British Columbia, Anna Lindholm and Craig Benkman, studied a particular type of finch, called a red crossbill, to demonstrate speciation. The twisted beak of the crossbill, shown in Figure 1.27, allows it to pry open closed conifer cones.

The beaks of seven birds, which specialize in eating the tightly closed cones of western hemlock, were "uncrossed" by trimming them with nail clippers—a painless procedure. The scientists observed that birds with clipped bills were as effective as those with crossed bills at getting seeds from open cones. However, birds with clipped bills could not open closed cones. As their bills grew back and began to cross again, the birds gradually became better at opening the closed cones.

The development of the crossed bill did not arise all at once. The crossed bill changed gradually by selective pressure, one generation after the next, until the birds were expert at opening tightly closed cones. The crossed bill gave these birds an advantage over other bird species in the same habitat because it allowed them to eat food no other bird could. Individuals with this variation were then able to radiate into other habitats.

Figure 1.27 The crossed bill of the red crossbill (*Loxia curvirostra*) enables it to extract seeds from even the most tightly closed of conifer cones.



## Extinction and Selective Pressure

You have learned one way that new species can form, but how do species end? The environment is a strong influence on both the formation of new species as well as their **extinction**. Environmental influences create selective pressure, and these influences can have positive and negative outcomes. In some cases, new species will arise. In other cases, existing species may go extinct.

**extinction** occurs when a species completely disappears from Earth

One of the most famous examples of extinction is that of dinosaurs 65 million years ago. Recent scientific research supports the hypothesis that this extinction event was triggered by the impact of a large asteroid. This may have caused massive forest fires. As a result, huge amounts of soot and other particles may have been thrown into the air, blocking the Sun for months. During this time period, more than half the existing marine species and many families of terrestrial plants and animals, including the dinosaurs, became extinct.

Overall, biological diversity has increased since about 500 million years ago. While the general trend has been an increase in the number of species, there have also been several sharp declines in the number of species. These are known as mass extinction events. Five major mass extinctions have been identified, as shown in Figure 1.28. After each extinction event, the number of species decreased. For example, after an extinction event about 250 million years ago, about 96 percent of all species are thought to have gone extinct.

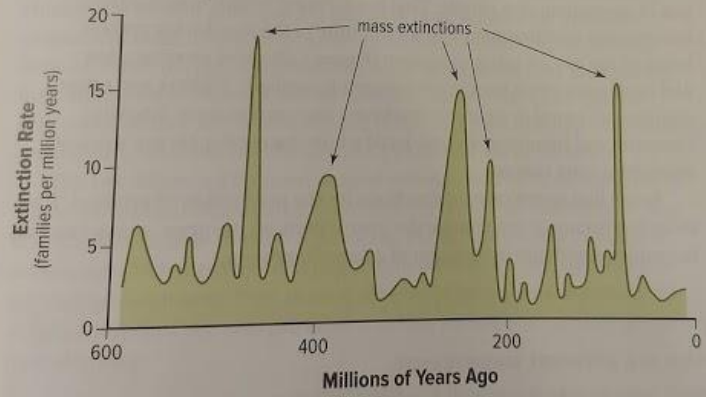



Figure 1.28 The five major mass extinction events

### Before you leave this page . . .

1. What is adaptive radiation?
2. Explain why it would have been possible for an ancestral finch species, having arrived on one of the Galapagos Islands, to have diversified and evolved into other species over time.
3. How is extinction related to selective pressure?

CONCEPT 4

# Environmental factors can cause mutations.

## Activity

### Increased Cancer Risk

Work with your group to make a list of substances or activities that are associated with an increased risk of cancer. Compare your list with other groups and agree on a list as a class. Discuss how you know the substances or activities are associated with the development of cancer.

**mutagen** a substance or event that increases the rate of mutation

**carcinogen** a substance or agent that causes cancer

Mutations are important to the process of natural selection and the formation of new species, because mutations are a key source of variation in genes. Certain environmental factors can increase the rate of mutation. A **mutagen** is a substance or event that increases the rate of mutation. *Physical mutagens* cause physical changes to the structure of DNA. Examples include X-rays and ultraviolet (UV) radiation. *Chemical mutagens* are molecules that can enter the nucleus of a cell and chemically react with DNA. Examples include nitrites, which are used in food preservation, and gasoline fumes.

Some mutagens are carcinogenic. A **carcinogen** is a substance or agent that causes cancer. Exposure to ultraviolet radiation increases a person's risk of developing skin cancer. That is why many health organizations recommend avoiding spending a lot of time in the sun during certain hours of the day, or using sunscreen (Figure 1.29), and wearing a hat and sunglasses when people are exposed to sunlight. Nitrites and other compounds found in cigarette smoke are also carcinogens. Smoking cigarettes and breathing second-hand smoke increase a person's risk of developing lung cancer.

Figure 1.29 Applying sunscreen before going out in the sun can help reduce a person's exposure to ultraviolet radiation.

Recall that genes carry instructions for the production of proteins. If a mutation occurs, it can change the instructions on the gene, which can lead to problems with the production of a specific protein.

## Activity

### How effective are different sunscreens?

Your teacher will provide your group with a set of beads that are sensitive to UV radiation. Your teacher will also provide you with information and a worksheet about how to test the effectiveness of sunscreens.

## Before you leave this page . . .

1. What is a mutagen?
2. Explain how mutagens and the production of proteins are related.



CONCEPT 5

# Humans select desired characteristics in organisms to be passed on to the next generation.

## Activity

### Tomato, Tomahto?

Study the photos of tomatoes provided by your teacher. What traits do you think were chosen for each type of tomato based on their appearance? What other traits might gardeners or farmers choose when breeding tomatoes?

**artificial selection** selective pressure exerted by humans on populations in order to improve or modify desirable traits

Natural selection occurs in a population in response to changes in the environment. However, people have been artificially selecting organisms for particular traits for thousands of years. This process, called artificial selection, is sometimes referred to as selective breeding. **Artificial selection** is selective pressure exerted by humans on populations in order to improve or modify particular desirable traits. It has had a huge impact on human survival.

Most of the food we eat—grains, fruits, vegetables, meat, and milk—comes from species that have been selectively bred. For instance, artificial selection has resulted in cows that produce more milk. Some varieties of chicken are bred to grow quickly and have large muscles for increased amounts of meat. Other varieties of chicken have been bred to produce large numbers of eggs. Some animals, such as domestic cats, are bred for their appearance (Figure 1.30). All domestic cats are the same species, *Felis catus*, so they can interbreed and produce fertile offspring. Over many generations, breeders can change how a particular cat breed looks.

The key difference between natural selection and artificial selection is that in natural selection, the environment plays the role that humans play in artificial selection. In natural selection, the environmental conditions determine which members of a population will survive and reproduce in the current conditions. This, in turn, affects the gene pools of individuals of future populations, because those that survive will pass on their genes to their offspring.

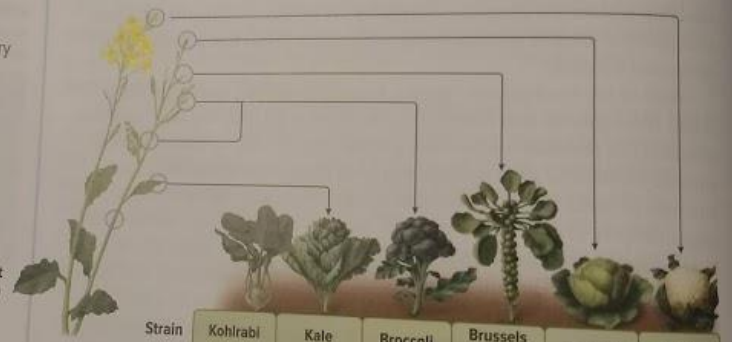
Figure 1.30 By selecting the parents that carry the genetic material that breeders are interested in, cat breeders produce cats with distinctive features. All the cats shown here carry the same kinds of genes (for example, for fur, size, and ear length). However, the alleles for these genes differ among the cats, allowing humans to select for or against certain characteristics.

## Artificial Selection and Food Crops

The food crops that we depend on for most of our diet—rice, corn, wheat, and vegetables—are the result of selective breeding. Figure 1.31 shows how one example—the wild mustard plant (*Brassica oleracea*)—has been modified by selective breeding to create many common food crops.

Plant breeders began to modify the traits of the wild mustard plant over 4000 years ago in Europe and Asia, where the plant is a native species. The traits of the artificially selected varieties all differ from the wild plant, but they are members of the same species and can interbreed and produce fertile offspring. For example, you may have seen broccoflower in your grocery store, which is a cross between cauliflower and broccoli.

We breed food crops to resist drought, disease, or insect infestation. Artificial selection has its limits, though. If plants are bred to grow quickly, they may not tolerate poor soil conditions. Crop breeders now understand that selective breeding must be balanced to maintain genetic variation within the crops and the ability of the plants to respond to environmental change.




| Strain | Kohlrabi | Kale | Broccoli | Brussels sprouts | Cabbage | Cauliflower |
|---|---|---|---|---|---|---|
| Modified trait | Stem | Leaves | Flower buds and stem | Lateral leaf buds | Terminal leaf bud | Flower buds |

**Figure 1.31** These six agricultural plants look very different from each other, but they carry much of the same genetic material as the wild mustard plant. The differences affect the formation of flowers, buds, stems, and leaves.

### Activity

#### Selective Breeding

The original ancestor of corn was a small, weed-like grass called teosinte. Humans have selectively bred teosinte for so long that the characteristics of our modern, artificially selected corn bear almost no resemblance to the original corn ancestors. Compare the cob of wild teosinte and modern corn shown in the photo. What traits do you think early plant breeders selected for? Create a flowchart that shows a series of steps that may have been followed to produce modern corn from teosinte. Include the terms *variation*, *inherited*, and *selected* in your answer.



## Consequences of Artificial Selection

Artificial selection has negative as well as positive consequences. For example, English bulldogs are selectively bred for different traits, such as their flat faces. This trait results in severe respiratory problems. German shepherds and many other breeds of dogs have been selectively bred for their large size. An unfortunate consequence of this is hip dysplasia, a disorder that leads to a loss of function of the hip joints.

One of the main goals of domestication is to produce organisms that are all similar. This means *reducing* genetic diversity. Plants are specialized through selective breeding to produce the specific qualities that growers want, so plants that have been selectively bred lack genetic diversity.

**Figure 1.32** This monoculture shows the vast expanse that is covered by one crop (wheat), made up of plants that are artificially selected to be similar.

For example, most agriculture in the world is based on extensive plantings of the same varieties of a species over large expanses of land, like that shown in Figure 1.32. This practice is called **monoculture**. It is certainly easier to manage fields in which there is only one kind of plant growing. This is particularly true today when herbicides, insecticides, and fertilizers are manufactured specifically to meet the needs of specific crop species. However, with monoculture comes a significant risk. The lack of genetic diversity means that disease or environmental changes will affect all plants of the monoculture in the same way. As a result, the whole population—the whole crop—could be wiped out or severely damaged.

**monoculture** repeated planting of the same varieties of a species over large expanses of land

### Extending the Connections

#### Food and Artificial Selection

All the major crops that we depend on for food have been domesticated over thousands of years. These crops include rice, wheat, varieties of squash, potatoes, and varieties of beans. Choose one of these crops, or a domesticated plant or animal of your choice, and research your selection using Internet and print resources. Sketch the original ancestor and the modern offspring. Compare the original and current forms. Describe at least three traits that humans appear to have selected for.

### Before you leave this page . . .

1. What is artificial selection?
2. What are some benefits and risks associated with artificial selection of agricultural crops?

# Check Your Understanding of Topic 1.3

OP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating AI Applying and Innovating C Communicating

## Understanding Key Ideas

1. Explain how mutations are a source of new alleles. PA

2. In a population of sparrows, most birds have a beak that is about 10 mm long. Some birds, however, have beaks that are slightly longer or slightly shorter than the average. Explain why this variation within the population is important in terms of survival of individual sparrows. PA C

3. Why does genetic variation make it possible for changes in populations to occur through natural selection? Explain your answer. E C

4. How does natural selection influence adaptation? PA

5. Explain how the ability of a population of insects to withstand the effects of an insecticide is an example of natural selection. C

6. Severe flooding results in a river changing course. Explain how a species of mouse that now lives on both sides of the river might eventually become two different species. What about a species of bird that now lives on both sides of the river? Explain. OP C

7. The Greater Antilles is a group of islands in the Caribbean. These islands include Cuba, the Dominican Republic, Haiti, Jamaica, and Puerto Rico. Each island is home to many lizard species that look very similar. DNA analysis shows that the similar-looking lizards from different islands are not alike genetically. Explain this. E C

8. Use a graphic organizer of your choice to identify and describe different types of mutagens and examples of each. C

9. Give an example of how people have used selective breeding to create a new variety of plant. Describe two possible consequences of the new variety. PA C

## Connecting Ideas

10. Many antibacterial soaps and sprays are available without a prescription. Why might your doctor suggest that you avoid using (or restrict your use of) these products? AI

## Making New Connections

11. The medium ground finches (*Geospiza fortis*) of the Galapagos Islands use their strong beaks to crush seeds. They prefer the small seeds that are abundant during wet years. During dry years, fewer small seeds are produced. Therefore, the finches also have to eat larger seeds, which are more difficult to crush. Researchers have measured the depth (dimension from top to bottom) of the finches' beaks, which relates to strength. The deeper the beak, the stronger it is. Use the graph to answer these questions. PA E

   a) Years 1, 4, and 6 were drought years. Year 8 was wet. What do you notice about the average beak depth in the finch population during dry years compared with wet years?

   b) How do the data relate to selective pressure and natural selection?

Changes in Beak Depth of *Geospiza fortis* over Eight Years