2.4 Adaptations

Figure D2.22: A snail moves by creeping on a single "foot" located under its body.

If you've ever gone backpacking, you know how difficult it can be to carry your tent, sleeping bag, and other supplies on your back. This may help you appreciate snails—they carry their shelter on their backs all the time! What is even more remarkable is that snails hike around on just one foot. The band of muscles in the "foot" expand and contract in a rippling movement that propels the snails forward.

Despite being the origin for terms like "a snail's pace," these little animals have many interesting characteristics. For example, a snail's eyes are located on the top of its tentacles. Many land snails have an additional pair of tentacles equipped with sense organs that help them locate food. Once food is found, it's mashed between a hard ridge on the roof of the mouth and the tongue. What makes this extraordinary is that a snail's tongue contains from hundreds to thousands of tiny teeth.

Since most snails prefer a moist environment, snails in Alberta are found in freshwater ponds, lakes, streams, and creeks. If you've gone swimming in one of these places, you may have seen some freshwater snails. The five thermal springs on Sulphur Mountain form the only habitat for the Banff Springs snail, which is the most endangered species in Banff National Park. These snails are only found in these locations because they depend upon a steady supply of thermal spring water, which has a high mineral content and sufficient hydrogen sulfide.

Figure D2.23: The Banff Springs snail has a limited habitat.

Practice

25. Identify the proper term to describe a group of organisms, like the snails in Figure D2.23, which exist in a setting where immigration and emigration do not occur and numbers are affected only by births and deaths.

26. The Banff Springs snails are only about 5 mm long and live near the water's surface at the thermal springs. These tiny animals can be found clinging to rocks, branches, and leaves. Describe how people bathing in the water of the thermal springs could adversely affect this fragile population of snails.

A Wonderfully Beautiful and Delicate Architecture

In other parts of the world, where there is a warm and moist climate, different species of land snails can be identified by the intricate patterns on their shells.

Snail shells like these have been admired for centuries. The combination of colours, textures, and overall shape gives each shell its own character. Despite the artistic appeal of a snail's shell, these structures function as protection against predators and help to retain moisture.

Earth has gone through dramatic changes over geological time. You have also seen many examples of how organisms that are abundant life forms have changed throughout Earth's history in response to different environments. You may be surprised to learn that the characteristics of snails have allowed them to survive in a wide variety of environments for nearly 500 million years.

Figure D2.24: Snails can be identified by the patterns on their shells.

Fossil Evidence of Some Abundant Life Forms on Earth Throughout Geological Time

Millions of Years Ago	590	250	65	Present Time	
Era	Precambrian	Paleozoic	Mesozoic	Cenozoic	
Abundant Life Forms on Earth	Trilobites	Ammonites	Dinosaurs	Mammals	
	← Snails →				

Compared to the fossil evidence left by other organisms, snail fossils are quite common because their shells tend to be well preserved. The fact that land snails are slow-moving and tend to be restricted to a particular habitat is advantageous to the study of snail fossils: in one location it's possible to find the remains of hundreds—if not thousands—of **generations**.

While exploring an outcropping of rock near a beach on Grand Bahama Island, a paleontologist happened to notice that snail fossils preserved in the rocks provided a wonderful example of how snails in that area changed over a period of about 15 000 years. In the next investigation you will examine sketches of actual fossils from this site. You will see how the **morphology** of these shells changed over thousands of years. You will also be challenged to find patterns in the changes that have been preserved in the **fossil record**.

You can find sketches of the fossils in "The Desktop Fossil Record," which is a handout on the Science 20 Textbook CD.

- **generation:** a single step in the line of descent—grandmother, mother, and daughter represent three generations
- **morphology:** the detailed shape and form of an animal
- **fossil record:** the record of all life on Earth as preserved by all fossils that exist, whether dug up or still in the ground

Investigation

Investigating the Fossil Record: Plotting Changes Over Time

Science Skills
- ✓ Performing and Recording
- ✓ Analyzing and Interpreting
- ✓ Communication and Teamwork

Purpose

You will work with a team of students to develop a chart to show how the shells of land snails found in a rock outcrop have changed over time. The fossil record is not an easy thing to interpret—just like real fossils, the ones you'll be using from "The Desktop Fossil Record" lack definition. It is essential that you discuss any differences of opinion encountered within the group. Try to reach a consensus. Once you have completed your chart, you will display it alongside the charts completed by other groups.

Materials

- handout of "The Desktop Fossil Record" on the Science 20 Textbook CD
- scissors
- transparent tape
- coloured pencils
- large piece of poster paper or Bristol board (at least 60 cm × 50 cm)

Figure D2.25: The shells of land snails are used for protection.

Background

An outcropping of rock has recently been exposed on Grand Bahama Island. Several layers of fossils have been exposed. The fossils, arranged in the same layers where they were found, have been replicated on a separate sheet of paper known as "The Desktop Fossil Record." The top layer (closest to the surface) is labelled 1, and the oldest layer is labelled 5.

Procedure

step 1: On "The Desktop Fossil Record," carefully colour the shells in each row a different colour (e.g., red for layer 1, blue for layer 2, and so on). It is important to stay between the lines as you colour because you will be comparing the shells in one layer with the shells in other layers. Messy colouring will make this task more difficult. Colour the background behind the number of each row the same colour as the fossils in that row.

step 2: Cut out each shell and its letter as a small rectangle. Also cut out a square for the number of each row.

step 3: Place the oldest fossils, from layer 5, across the bottom of your poster paper. Place the number 5 on the far left; then place each fossil from layer 5 in alphabetical order, equally spaced across the bottom of your poster paper. See Figure D2.26. Since you are going to compare each shell in this row to shells in the next layer, it will be helpful to have your shells all oriented the same way—this includes having openings at the top. When your group is convinced that the arrangement of level 5 is satisfactory, attach the number 5 and each of the shells in layer 5 with transparent tape.

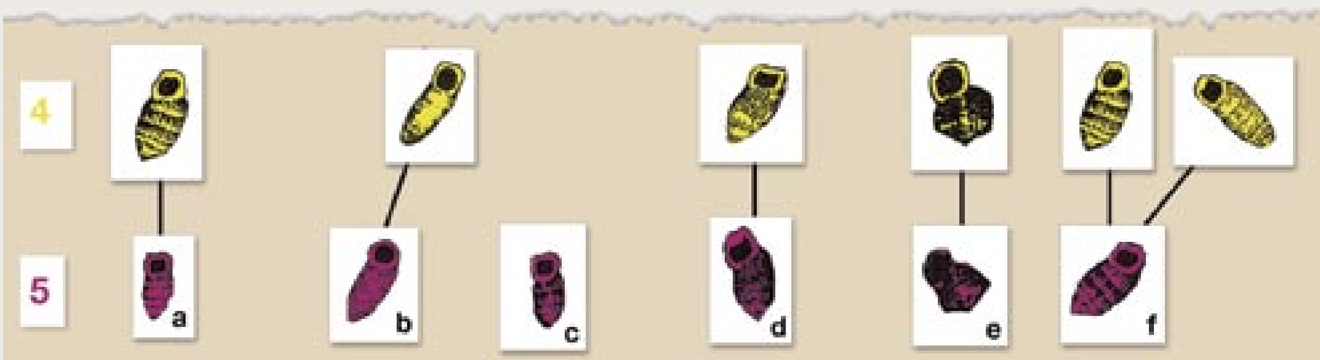


Figure D2.26: This graphic represents a partially completed chart.

step 4: The fossils from the other four layers will be placed above layer 5 one layer at a time. You must leave some space between the layers so the chart will fill the entire poster paper. Begin with layer 4. Paste the number 4 above the number 5 with a space in between.

step 5: Take one of the shells from layer 4 and decide which of the shells it most closely resembles from layer 5. If the shell from layer 4 is very similar to the shell in layer 5, place it vertically above the shell it matches from layer 5. If a shell in layer 4 is only slightly similar to a shell in layer 5, shift it slightly to the left or to the right but still above the shell it matches in layer 5. The greater the differences, the greater the amount of shift. Remember, if the shell is virtually identical, don't shift it at all. Not all shells in layer 5 have a corresponding matching shell in layer 4, while more than one shell in layer 4 may match a shell in layer 5. Review the placement of shells in layer 4. Do the shells line up to form a new horizontal row with the number 4? Is the vertical arrangement of the shells showing a similar alignment between layers 4 and 5? When your group is satisfied with the shell arrangement in layer 4, tape this layer into place.

step 6: Repeat steps 4 and 5 for layers 3, 2, and 1.

step 7: Now all shells should be attached to the chart. The next task is to add lines to show the vertical pattern of development of a shell. The lines go from older forms in lower levels to younger forms in higher levels. The table that follows describes how to draw the lines.

Type of Development Between Shells	Type of Line to Draw Between Shells	Example
A shell in one layer leads to a nearly identical shell in the next higher level.	Draw a vertical line between the shells.	
A shell in one layer leads to a slightly different shell in the next layer.	Draw a slightly slanted line from the lower shell to the higher shell.	
A shell in one layer leads to a shell in the next layer that is only slightly similar with some new characteristics.	Draw a more slanted line from the lower shell to the higher shell.	
A shell in one layer seems to lead to a shell in the layer above the next one. A layer appears to be skipped in this case.	Draw a dotted line from the lower shell to the shell in the layer above the next one.	

step 8: Post your finished chart in an area that displays the finished work of the other groups. Examine the charts produced by the other groups. Ask what criteria they used for deciding where a shell in a new layer was to be placed. Be prepared to defend your organization of these fossils.

Analysis

1. Assume that the youngest layer, layer 1, contains fossils that are determined to be 3000 years old and that the oldest layer, layer 5, contains fossils that are 15 000 years old. If the rate of sedimentation was constant over the entire time it took to build all these layers, give an approximate age of each other layer.
2. How can your chart be thought of as a graph with Time on the vertical axis and Morphology on the horizontal axis?
3. Describe an example from your chart where a shell in one layer clearly did not lead to any shells in the higher layers. Identify the proper name for the disappearance of species from a geographical area.
4. Describe an example from your chart where a long, nearly vertical line occurs that connects shells in adjacent layers. Use your answer from question 1 to help interpret the meaning of such a line.
5. Describe an example from your chart where a dotted line seems to show that a type of snail seemed to skip over a layer. Use your answer from question 1 to help interpret the meaning of such a line.
6. Despite the fact that each group produced a different chart, you should have noticed that shell *a* from layer 3 was not very similar compared to the other samples from layer 2. Is it correct to conclude that shell *f* from layer 3 suddenly disappeared? Justify your answer.

Communication and Teamwork

7. Compare your team's chart with those produced by other groups. List the similarities and differences.
8. Given information collected from other groups, if you were to chart the fossils again, what would you do differently?
9. Posting your chart is similar to a scientist publishing her findings. Based upon your answers to questions 7 and 8, is it possible for different scientists to interpret the same data differently?

Changes in Populations

As you saw in "Investigating the Fossil Record: Plotting Changes Over Time," the appearance of shells for a population of snails changes over time. Changes to the shape of shells sometimes occurred gradually between layers. Since these changes were slight, shells in the higher layer were only slightly shifted to the left or the right. Diagonal lines were used to show the slight changes in shape between layers. Very gradual changes within a population are called **gradualism**. In some cases, major changes to the shape of the snail shells occurred between adjacent layers. Since this more rapid change did not occur gradually over many layers, the shells in the higher layer were shifted a larger amount to the right or left. Horizontal lines were used to show these transitions. Since the shells in this model may remain relatively unchanged between layers and then suddenly diverge into forms with different shapes, this model is called **punctuated equilibrium**.

The key difference between gradualism and punctuated equilibrium is the rate of change. Gradualism explains that big changes within a snail population are the result of an accumulation of many slight alterations that occur over a long time. The sudden appearance of new forms with different shapes, after a period where no change was observed, demonstrates punctuated equilibrium.

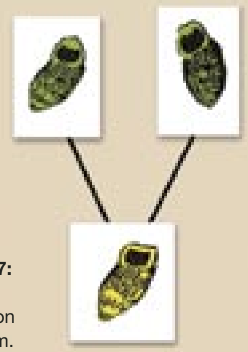


Figure D2.27: This is a representation of gradualism.

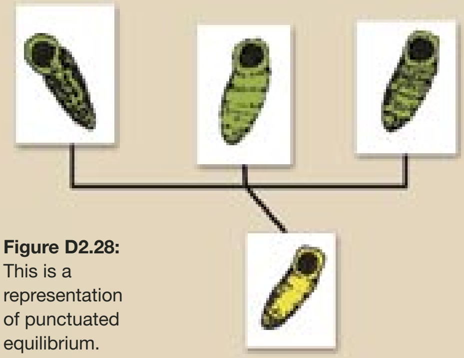


Figure D2.28: This is a representation of punctuated equilibrium.

gradualism: the theory that changes to the organisms in a population occur slowly and steadily over Earth's history

punctuated equilibrium: the theory that changes to the organisms in a population can occur in rapid spurts followed by long periods of little change

Punctuated Equilibrium and the Bighorn Sheep Population

Alberta's Rocky Mountains are the home of the largest bighorn sheep in North America. Hunters are only allowed to shoot rams if the animal's horns have curved to make almost a complete circle—a trophy sheep. The largest and strongest male sheep are the ones with the fully-curved horns. Since these sheep are being systematically removed from the population by hunters, the male sheep left to breed are the smaller and weaker ones with horns that never mature to trophy status. You can see why male sheep in the next generations tend to have reduced body mass and shorter horns. Hunting is inadvertently encouraging these characteristics by removing the larger males from the population before they can breed.

Data collected over the past 30 years have confirmed these changes in male sheep morphology. Thirty years may seem like a long time to you, but compared to geological time this is a rapid rate of change; that's why this is an example of punctuated equilibrium.

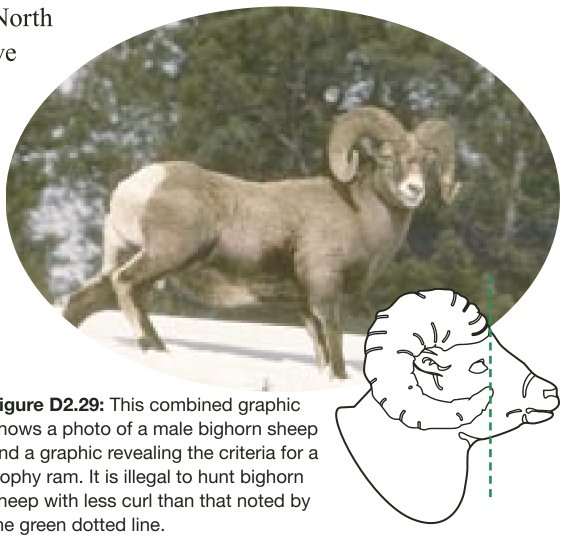


Figure D2.29: This combined graphic shows a photo of a male bighorn sheep and a graphic revealing the criteria for a trophy ram. It is illegal to hunt bighorn sheep with less curl than that noted by the green dotted line.

Genetics

Regardless of whether changes in shell appearance between the levels in your chart—as shown in Figures D2.27 and D2.28—showed a pattern of gradualism or punctuated equilibrium, changes in the physical characteristics of snails occur due to changes in genetic information that the organisms possess.

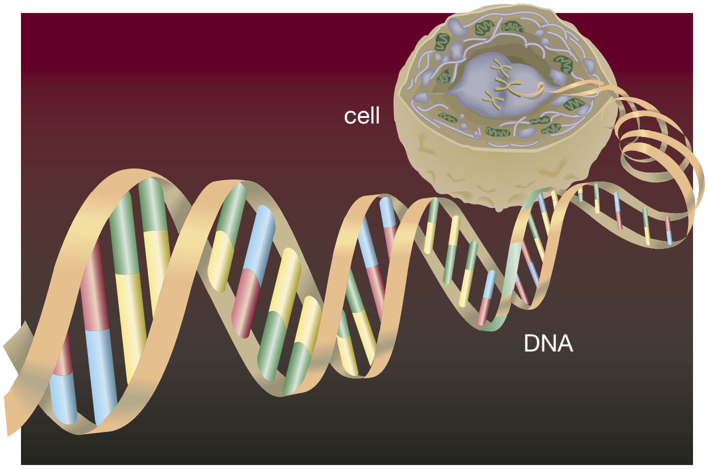
Subtle changes in genetic information account for the variation in traits seen within a population. These traits can be physical, behavioural, or biochemical. Larger changes in genetic information result in the development of new species.

The Mechanism of Inheritance

The development of the scientific discipline of genetics has resulted in a better understanding of both how and why the variation of a trait occurs within a population. Each organism has two sets of **genes** found in each cell. Genes determine most of an organism's characteristics. One set of genes present in each cell comes from each of the offspring's parents. Genes are instructions encoded in the larger sections of the DNA molecule that result in an organism's traits—they are the basic units of inheritance. Each offspring contains one copy of genes from each parent and, therefore, has a mixture of traits. Mixing traits results in the many varieties of a trait seen in a population and the variation of that trait within an entire population.

Genes are a set of instructions coded in a chemical form—they tell an organism's body how to look, when to grow, and what things to make. At times, such as before cells reproduce or create sex cells, the genetic instructions need to be recopied. During this recopying of the set of chemical instructions, mistakes can be made that result in the gene delivering a slightly different instruction. A change in instructions from a gene is called a **mutation**. The change in genetic information caused by mutations is another reason why variation occurs in a species.

The DNA Molecule



gene: the basic unit of inheritance passed from parent to offspring

mutation: a change in a genetic instruction

In the mass media, the word *mutation* is often associated with images of horrible science-fiction creatures or green superheroes; but these kinds of enormous changes rarely, if ever, happen. Most mutations are harmless and have no effect on an individual or its offspring, but sometimes they result in harmful characteristics. Exposure to ultraviolet (UV) rays, X-rays, radioactive substances, and cigarette smoke are all examples of things that have been found to increase the occurrence of mutations that could result in diseases like cancer.

Mutations can sometimes be beneficial. The development of a new characteristic—or one variety of a trait—might increase an organism's chances for survival.

Snails Can Multiply

You can gain a deeper understanding about how a mutation might increase an organism's chances of survival by returning to the example of land snails you studied earlier. Up to a month after mating, two snails can produce about 100 eggs. This means that if you start with only two snails, and none of the newly hatched snails die, in one month you will have about 100 more snails. These newly hatched snails are quite small and take about two years to reach maturity.

Practice

27. If the original two snails bred every month for two years, determine the total number of offspring created.

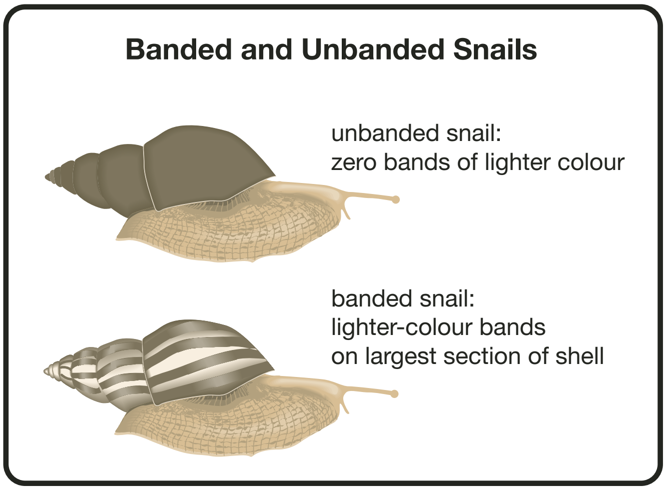
28. Approximately 25 months after the original pair began breeding, the 100 snails from the first hatching would be mature enough to start breeding.

- **a.** Determine the number of snails that could be created by the first 100 hatchlings in the 25th month.
- **b.** Why are there 5000 more snails created in the 26th month as compared to the 25th month?
- **c.** According to this arithmetic, if you begin with only two snails, at the end of two years you'd have thousands of snails, at the end of four years you'd have millions, and at the end of six years you'd have billions of snails. Identify the factors omitted from this simplistic analysis that explain why this trend is not observed in nature.

Camouflage for Snails

Figure D2.30: The photos show a forest floor and a grassland ecosystem.

In a stable ecosystem the population of land snails is usually stable. This is partly because the resources needed to support a population are limited. This means that there is a struggle for survival among the individuals in the local population of land snails. Only a tiny fraction of snails survives from each generation. Snails also have to avoid predators. Predation on snails is especially intense during the nesting season for birds because snails are an excellent source of calcium for birds preparing to lay eggs.



An important characteristic that helps a snail avoid predators like birds is the snail's ability to blend into its surroundings. As you saw in an earlier activity with "The Desktop Fossil Record," snails can show considerable **variation** in terms of band patterns on their shells. Researchers studying current populations of land snails have determined that the colour and patterns of banding on snail shells are traits that offspring inherit from their parents. These patterns have a direct impact on the snail's ability to avoid being preyed upon.

variation: a difference in the frequency of genes and traits among individual organisms within a population

Practice

29. Refer to the photographs in Figure D2.30, as well as the illustration of the "Banded and Unbanded Snails" as you answer this question.

a. The photograph of a forest floor shows that this area receives very little light—this makes it a dark environment. Which snail would have a better chance of avoiding predators if its habitat consisted of the leaf litter and debris on a forest floor?

b. The photograph of the grassland area shows a more open environment where sunlight could penetrate the ground to leave distinct shadows from the vegetation. Which snail would have a greater chance of avoiding predators if its habitat consisted of the ground under tall grasses and ferns?

Use the following information to answer questions 30 to 32.

This graph shows the distribution of shell-banding characteristics for a snail population.

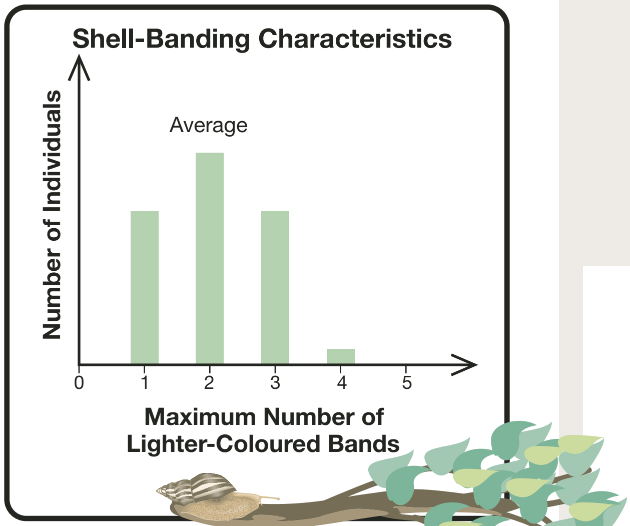


Figure D2.31: This graph shows a population of snails in a mixed vegetation area.

The habitat for this population of snails is an area of mixed vegetation containing low shrubs, small trees, and open areas of tall grasses.

30. Use the graph in Figure D2.31 to describe the most common shell pattern found in this population of snails.

31. Suppose that many years of climatic changes caused the low shrubs and trees to die off, leaving only tall grasses. The population of snails inhabiting this same area is now represented by the graph in Figure D2.32.

- **a.** Explain what advantage in avoiding predators banded snails have over unbanded snails because the environment is entirely composed of grassland.
- **b.** If more banded snails survive predators, what effect will this have on the number of banded snails seen in future generations?
- **c.** What does the graph in Figure D2.32 suggest might have happened to unbanded snails if there was no variation in the population and all the snails in the original population were unbanded?
- **d.** Suppose a mutation introduced into the population produced snails that were a solid dark-brown colour with no banding. Would the snails resulting from the mutation be at an advantage or a disadvantage in the new tall-grass environment?

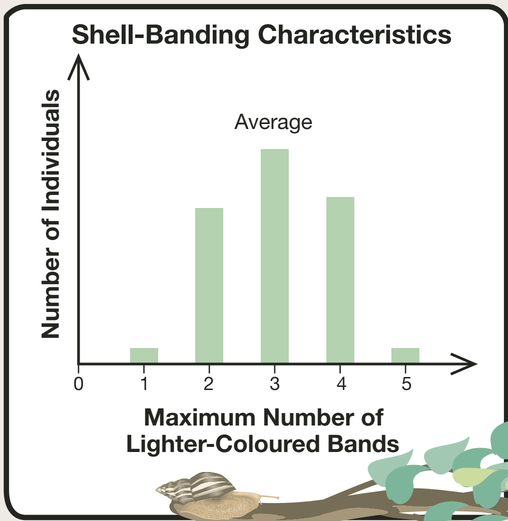


Figure D2.32: This graph shows an adjusted number of snails after low shrubs and trees have died.

32. Another possible change to this environment is that the process of succession acts on this ecosystem by changing it from the mixed vegetation of the low shrubs, small trees, and grassland to a climax forest consisting of a dense canopy of trees. For this scenario, during hundreds of years the snail habitat would become much darker with very little light reaching the forest floor.

- **a.** Describe the effect that this environmental change would have on future generations of this snail population. Answer by modifying the original graph presented in Figure D2.31.
- **b.** Explain your answer to question 32.a. by referring to the role played by genetics.
- **c.** What does the graph you sketched in question 32.a. suggest might have happened to this species of snail if there was no variation in the population and all snails in the original population had many light-coloured bands?
- **d.** Suppose a mutation was introduced into the population that produced snails of a solid dark-brown colour with no banding. Would the snails resulting from this mutation be at an advantage or a disadvantage in the dense forest environment?

Adaptation

As your answers to the practice questions indicated, variations made it possible for the snail population to adapt to changes within the environment. This is why a change within the snail population—such as having more light-coloured bands or fewer light-coloured bands—is called an **adaptation**.

adaptation: any structural trait or behavioural trait that improves an organism's success at surviving and reproducing in a particular environment

If you refer to "The Desktop Fossil Record" constructed earlier, you may note that each row contains snail shells that are different in appearance. Each different type of snail shell represents a new snail species.

Can you think of a reason why the appearance of snail shells has changed over time? Why did new species of snails appear in some layers? Can you think of reasons why some species seem to appear in many layers and then no longer appear?

In the next lesson you will see how Charles Darwin answered these questions by proposing a theory that explains how adaptations over time can lead to new species.

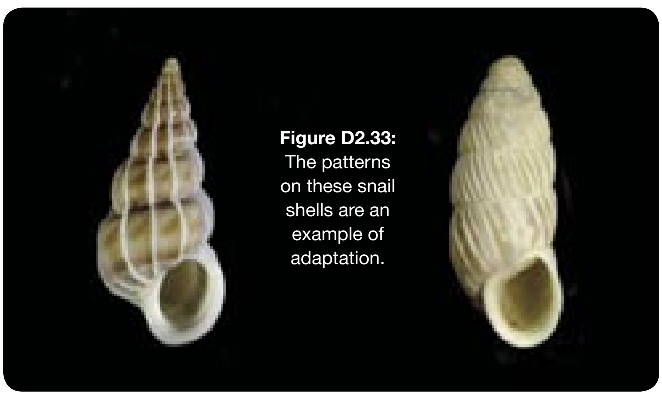


Figure D2.33: The patterns on these snail shells are an example of adaptation.

2.4 Summary

Genes are the basic units of inheritance. They are passed on from parents to offspring and they determine the organism's characteristics. Among other things, genes can determine the physical characteristics or traits of the organism. Mutations are changes that occur to a gene—these changes can be either harmful, beneficial, or neutral. Individuals within a population can have differences with respect to a trait. These differences are called variations, so mutations are responsible for variations within a species.

Adaptations are inherited characteristics that allow an organism to survive better in a particular environment. The adaptation can be either physical or behavioural and help the organism reproduce, find food, or not become food. Successful organisms are always well adapted to the habitat where they live.

2.4 Questions

Knowledge

1. Define each of the following terms.

a. fossil **b.** gradualism **c.** punctuated equilibrium **d.** gene **e.** mutation **f.** adaptation

Applying Concepts

2. Processes that occur over time as a species adapts to its environment are adaptation, mutation, and variation.

a. Design a flowchart that shows the order in which these processes occur.
b. Concisely explain the flowchart you constructed.

Use the following information and key ideas from this lesson to answer questions 3 to 6.

Due to mutations, the European land snail shows significant variation in the colours and patterns on its shell. The shells can be yellow, brown, or pink; and they may be unbanded or banded, with the banded shells having 1, 2, 3, 4, or 5 bands or stripes. Figure D2.34 shows two examples of variation in the shells of these snails.

Birds, like the song thrush, rely on land snails as a source of food. The snails most unlike their surroundings are the easiest ones for these birds to locate. Once captured, the song thrush holds the captured land snail in its beak and flies to a favourite rock. The song thrush then hammers the snail's shell against the rock until it breaks open. These rocks, known as thrush anvils, tend to be littered with broken snail shells by the end of the summer.

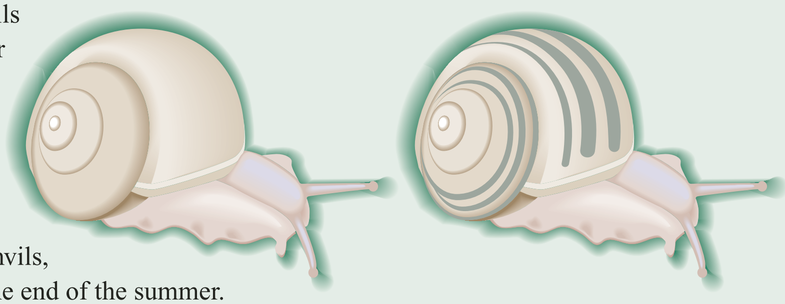


Figure D2.34: These are two examples of European land snails.

3. What process is responsible for the variation seen in the colouring and banding of snail shells?

4. Explain why it is a useful adaptation for snails to blend with their surroundings.

5. Explain why it is a useful adaptation for snails living in a grassland habitat to be both yellow and banded.

6. Dark-coloured shells tend to heat up more in direct sunlight than do light-coloured shells. In the cooler parts of northern Europe, dark-coloured snails tend to be found at vegetation locations higher above the ground than lighter-coloured snails. These higher locations increase the chances of being warmed by direct sunlight.

a. Explain how the darker colour is an advantage for snails living in the cooler northern climates, in terms of the regulation of body temperature.

b. Explain how the advantage of being a darker colour also becomes a disadvantage in terms of predation for these same high-climbing snails.

c. Is it always so clear-cut that a trait is an advantage or a disadvantage? Refer to questions 6.a. and 6.b. to justify your reasoning.

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Legend: t = top, m = middle, b = bottom, l = left, r = right

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