B4.2 Teacher view

Ecological niches

Index

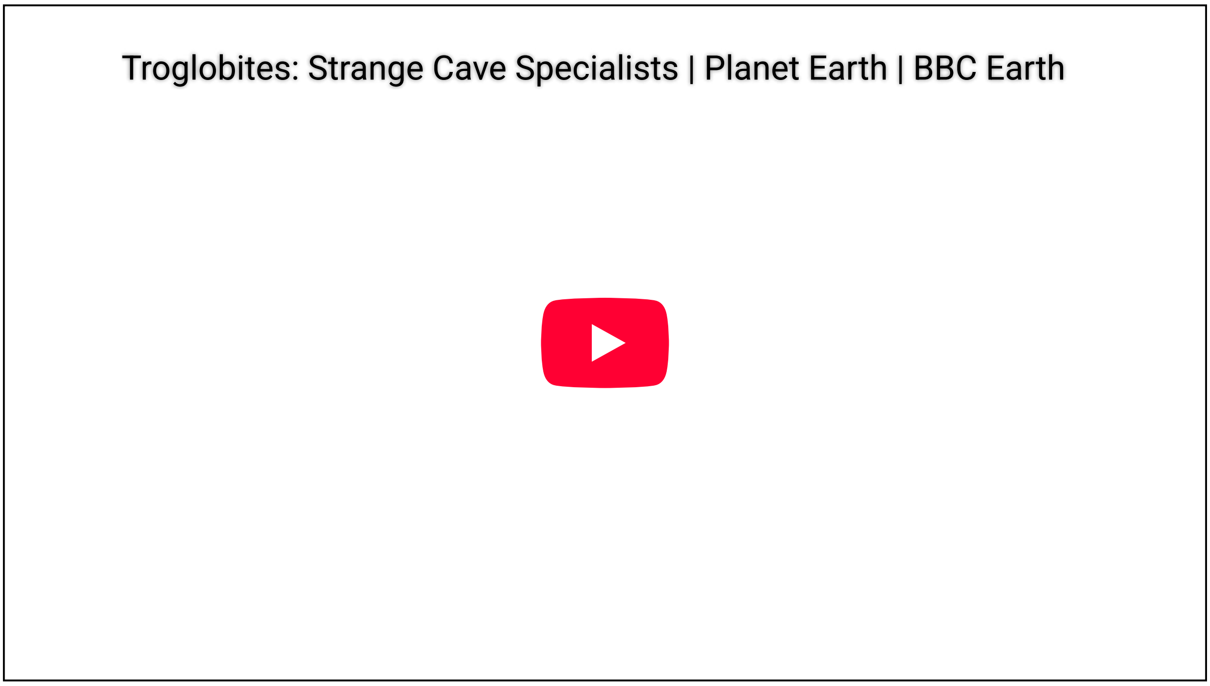
The big picture

? **Guiding question(s)**

- What are the advantages of specialised modes of nutrition to living organisms?
- How are the adaptations of a species related to its niche in an ecosystem?

Keep the guiding questions in mind as you learn the science in this subtopic. You will be ready to answer them at the end of this subtopic. The guiding questions require you to pull together your knowledge and skills from different sections, to see the bigger picture and to build your conceptual understanding.

If you could create the most inhospitable environment for life, you might make it dark, cold and have limited oxygen. You might assume that nothing can live in such limited conditions. However, you might be surprised to find that even there, life has evolved to be able to not only survive but thrive! Troglobites are organisms that are bound to specific caves (see **Video 1**). They have evolved to cope in very low light levels and have weak or no eyes; they have reduced their energy needs and can slow their metabolism. What other adaptations have organisms evolved to cope with specific conditions? This is what we'll learn about in this subtopic.



Video 1. Cave-dwelling troglobites have evolved specialised features.

Not only is the niche the 'home' of the organism, but it also refers to the jobs that they do within that location. Some organisms are so important that, without them, the environment suffers. One interesting example is the cleaner wrasse from the genus *Labroides*. There are five species of cleaner wrasses that perform vital cleaning tasks. These fish are extremely useful in that they will fastidiously clean off parasites, dead and damaged scales, and mucus from a whole host of different organisms. They are an essential part of maintaining the health of a coral reef. A study (https://royalsocietypublishing.org/doi/abs/10.1098/rsbl.2011.0458) showed that when they are not present, there is a decrease in the species richness of the fish life on a reef, and that the health of these fish is far better when the cleaner wrasse are around (see **Video 2**).

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view

0:00 / 1:58

Video 2. Cleaner wrasse are used to clean up parasites from many species of fish.

More information for video 2

1

00:00:00,433 --> 00:00:03,533

narrator: These are the beauty

salons of the reef,

2

00:00:03,600 --> 00:00:06,067

and they're often run

by a pair of wrasse,

3

00:00:06,133 --> 00:00:09,467

small fish with a stripe running

from head to tail.

4

00:00:10,767 --> 00:00:15,300

These committed cleaners regularly

tend to a host of different creatures.

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5

00:00:16,033 --> 00:00:18,233

They provide a vital service,

6

00:00:18,300 --> 00:00:22,200

removing the dead skin

and parasites from outside

7

00:00:22,267 --> 00:00:24,967

and even inside their clients' bodies.

8

00:00:26,267 --> 00:00:28,667

It may seem like a thankless task,

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9

00:00:28,933 --> 00:00:31,800

but the cleaner fish are getting

a good meal out of it.

10

00:00:31,867 --> 00:00:34,033

[soft music plays]

11

00:00:34,100 --> 00:00:38,433

And of all their clients, the manta rays

are their star customers.

12

00:00:40,933 --> 00:00:43,633

The manta rays surrender

themselves completely.

13

00:00:46,467 --> 00:00:50,167

Within seconds,

a host of fish rush to their side.

14

00:00:51,367 --> 00:00:55,267

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view

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Each fish tends to a very specific part

of the manta's body,

15

00:00:56,433 --> 00:00:59,067

and the cleaning can last a full hour.

16

00:01:00,833 --> 00:01:03,633

For the most part,

the service is second to none.

17

00:01:04,133 --> 00:01:08,000

But occasionally, the cleaners

can get a little carried away.

18

00:01:09,433 --> 00:01:13,300

A female wrasse has taken a nibble out

of the manta ray's flesh.

19

00:01:14,500 --> 00:01:18,167

She's broken the rules,

and there's a price to pay.

20

00:01:18,700 --> 00:01:20,633

Her partner chases after her.

21

00:01:20,967 --> 00:01:24,400

It's the cleaner fish equivalent

of a stern telling off.

22

00:01:27,400 --> 00:01:30,900

If the bite is a one-off,

the manta ray will return.

23

00:01:31,533 --> 00:01:34,467

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But research has shown that

if it happens too often,

24

00:01:34,867 --> 00:01:38,067

the pair risks driving

regular visitors away.

25

00:01:41,367 --> 00:01:45,167

Fortunately, it seems her indiscretion

hasn't put their client off.

26

00:01:46,400 --> 00:01:49,633

The manta is back,

and business has resumed.

27

00:01:56,267 --> 00:01:57,667

[music fades out]

Prior learning

Before you study this subtopic make sure that you understand the following:

- The biological species concept (see section A3.1.1—4 (/study/app/bio/sid-422-cid-755105/book/what-is-a-species-id-43227/)).
- The causes of the biodiversity crisis and ecosystem loss (see subtopic A4.2 (/study/app/bio/sid-422-cid-755105/book/big-picture-id-43529/)).
- The adaptations of organisms to their environment (see subtopic B4.1 (/study/app/bio/sid-422-cid-755105/book/big-picture-id-43536/)).
- That interactions between organisms regulates population size (see subtopic C4.1 (/study/app/bio/sid-422-cid-755105/book/big-picture-id-43544/)).

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Interactions with the environment

B4.2.1: Ecological niche as the role of a species in an ecosystem

B4.2.2: Obligate anaerobes, facultative anaerobes and obligate aerobes

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Learning outcomes

By the end of this section you should be able to:

- Explain what biotic and abiotic interactions are and how they influence growth, survival and reproduction, including how a species obtains food.
- Explain the differences between obligate anaerobes, facultative anaerobes and obligate aerobes.

The drive to survive

Have you ever seen a koala in the wild? You will only have had that chance if you have visited Australia. These animals (*Phascolarctos cinereus*) have a very limited region in which they live with a very narrow set of conditions as they only feed on the leaves of the eucalyptus tree. It is therefore called a specialist species.

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Figure 1. Koala (*P. cinereus*) are a specialist species.

Credit: Mark Newman, Getty Images

Other organisms can survive in a broader range of environments like Black rats (*Rattus rattus*) and are called generalist species. Which one do you think would have a better chance of evolving for changing or fluctuating environmental conditions? How do we describe the places in which an organism lives and how can it be important to their survival? This section will answer these questions.

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Environmental factors

The term ‘ecological niche’ refers to several things. It is not only where an organism lives but also on what it does, its role and its impacts on the ecosystem. The distribution of species is determined by interactions from the environment of both biotic and abiotic factors. Biotic factors refer to the living parts of an ecosystem. It refers to the interactions with the living parts of the environment such as competition with other species for resources, disease, predators and parasites. The abiotic factors are the non-living parts of the ecosystem such as the temperature, precipitation, wind, the amount of sunlight, the pH of the water, and the soil that the organism lives in.

These factors all work together in a fine balance and together create a specific ecosystem in which only certain organisms can survive. For example, many bryophytes require moderate temperatures, a substrate to grow on, a certain amount of water and indirect light in order to grow. A cactus on the other hand needs less water, higher temperatures and can grow in poor, sandy soil.

Effect of species on the environment

Not only does the environment impact the distribution of species, but certain organisms can elicit a huge impact on their environment. For example, beavers are able to stem the flow of rivers by building dams which results in flooding the local area and provides wetland regions which can drastically improve biodiversity.

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Figure 2. Beaver dams create wetlands that increase biodiversity.

Credit: Chase Dekker Wild-Life Images, Getty Images

Creativity, activity, service

Strands: Creativity and Service
Learning outcomes:

- Demonstrate how to initiate and plan a CAS experience
- Demonstrate the skills and recognise the benefits of working collaboratively

Worms are not just wiggly creatures in the soil. They interact with their environment to improve the quality of the soil. In their activity they break down the dead components increasing the nutrient content of the soil. They improve the drainage and make a better soil structure.

Why not combine with a few other students and make a worm farm for your home or school garden?

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You can use the instructions here (https://www.keepscotlandbeautiful.org/climate-action-schools/eco-schools/topics/litter-waste/build-a-wormery/) to help you.

Caution: Working with soil always requires good hygiene because of microorganisms that live in the soil, so ensure you always wash your hands.

Modes of respiration

Throughout the natural world, there are several methods that have evolved for organisms to generate the molecule used for energy, ATP. Some microorganisms will only respire in situations where there is no oxygen, and cannot survive in air. In fact, oxygen is toxic to them. Rather than oxygen as the electron acceptor for respiration they use other compounds such as sulfate, nitrates, iron, manganese, mercury or carbon monoxide. They are called obligate anaerobes. The oxygen molecule is very reactive and these obligate anaerobes lack certain enzymes that enable them to deal with the oxygen, and hence it becomes toxic. *Clostridium difficile* is one such anaerobe and infects the bowel and can cause diarrhoea.

In contrast, another microorganism is able to make ATP using oxygen if it is present, but if it is absent, it can switch to fermentation. This kind of microorganism is called a facultative anaerobe. They have evolved to survive extreme environments and can use alternative electron acceptors in the electron transport chain. Although they can use both methods of respiration, they grow better in aerobic (with oxygen) conditions as they give much higher yields of ATP than with fermentation. An example of a facultative anaerobe is *Escherichia coli*. These have become of increasing interest to researchers (https://earth.stanford.edu/news/wastewater-project-harnesses-anaerobic-bacteria-save-energy), as they are able to treat wastewater and effluent.

The final kind is an obligate aerobe, which requires oxygen as a final electron acceptor in order to carry out respiration and release energy. An example is *Mycobacterium tuberculosis*.

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The different kinds of respiration used by these organisms can be found by doing a simple experiment growing bacteria in a special culture medium containing thioglycolate. This media allows the movement of the bacteria, has a low amount of sugar and removes the oxygen from the media. The top of the tube is exposed to air and over time, oxygen diffuses into the media and so allows more oxygen at the top of the tube. Tubes containing sterilised media are inoculated with the bacteria and are maintained at a constant, optimal temperature. The bottom of the tube is devoid of oxygen. The bacteria will migrate to the portion of the media where they can survive. Therefore those that are obligate aerobes will migrate to the top of the tube. Those that are obligate anaerobes will move to the bottom of the tube, and the facultative anaerobes will be somewhere in the middle.

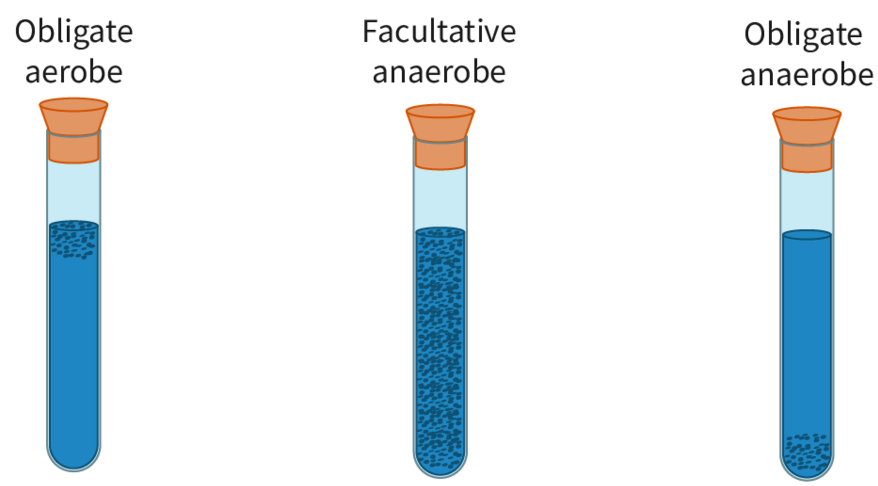

Figure 3. Different organisms have different respiration requirements.

More information for figure 3

The image depicts three test tubes, each representing a different type of bacterial respiration requirement. The first test tube, labeled 'Obligate aerobe,' shows bacteria gathering at the top, indicating a need for oxygen. The second test tube, labeled 'Facultative anaerobe,' has bacteria distributed throughout, showing they can survive with or without oxygen. The third test tube, labeled 'Obligate anaerobe,' displays bacteria concentrated at the bottom, indicating they thrive in oxygen-free environments. This setup visually explains how bacteria position themselves in the culture medium based on their respiration type.

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Try the drag and drop activity below to help with your understanding of respiration methods.

Activity

- **IB learner profile attribute:** Knowledgeable
- **Approaches to learning:** Thinking skills — Being curious about the natural world
- **Time required to complete activity:** 5 minutes
- **Activity type:** Individual activity

Use the drag and drop interactive to move the terms under the correct headings in the table.

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Obligate aerobes	Facultative anaerobes	Obligate anaero
Can use aerobic respiration and fermentation	Does not die in the presence of oxygen	In a culture tub organisms move t
In a culture tube organisms are dispersed throughout	Can use fermentation	Dies in the absenc oxygen
Must use aerobic respiration	Can live in the presence of oxygen	Needs oxyger
Does not need oxygen	In a culture tube organisms move to bottom	Dies in the presen oxygen

Check

Interactive 1. Characteristics of Organisms.

5 section questions

B4. Form and function: Ecosystems / B4.2 Ecological niches

Types of nutrition

Student view

B4.2.3: Photosynthesis as the mode of nutrition B4.2.4: Holozoic nutrition in animals

B4.2.5: Mixotrophic nutrition in some protists B4.2.6: Saprotrophic nutrition in some fungi and bacteria

Learning outcomes

By the end of this section you should be able to:

- Summarise the process of photosynthesis as the mode of nutrition in plants, algae and several groups of photosynthetic prokaryotes.
- Explain the various modes of holozoic, mixotrophic, saprotrophic nutrition.
- Give details of the diversity of nutrition in archaea.

Nutrition as a process of life

Nutrition is one of the fundamental processes of life. Some organisms can generate their own source of nutrition and are known as producers. Others need to take in their nutrition from external sources and are called consumers.

Biology is always wonderfully surprising, and some organisms are intriguing as they have evolved a combination of ways to gain energy. The oriental hornet (*Vespa orientalis*) has the ability to use the normal method of taking in food, but can also absorb sunlight using specialised pigments in its outer cuticle. This can be used to convert sufficient electrical energy to carry out some metabolic processes similar to the liver.

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Figure 1. The oriental hornet (*V. orientalis*) can convert light energy into electrical energy.

Credit: mohamed1, Getty Images

So, what are the varied ways in which living organisms can gain their nutrition? Scroll down to learn more.

Photosynthetic nutrition

Producers normally use energy from the sun to generate their nutrition. Such organisms are called autotrophic from the Greek *auto* (self) and *trophe* (nourishment). Organisms that need to take their nutrition from external sources are called heterotrophic from the Greek *hetero* (other or different). Examples of autotrophs are plants, algae and some prokaryotes. Most animals are heterotrophs – including humans!

Most autotrophs use the chemical process of photosynthesis as their means to generate their source of nutrition. The Greek word *phōtos* means light and *synthesis* refers to putting something together. This is a method that uses light energy and converts it into chemical energy. The equation for photosynthesis is

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carbon dioxide + water ⇢ oxygen and glucose

$$6CO_2 + 6H_2O \dashrightarrow C_6H_{12}O_6 + 6O_2$$

Specialised organelles called chloroplasts contain photosynthetic pigments that capture the light energy and convert it to organic molecules which can be stored within the plant, algae or prokaryote. It can then be metabolised when needed. You will learn much more detail about this process in subtopic C1.3 (/study/app/bio/sid-422-cid-755105/book/big-picture-id-43539/). Respiration is the biological process used to release the energy stored in order to conduct cellular activities. Cellular respiration is the biological process used by organisms to convert this stored energy made during photosynthesis into energy that is readily available for the cell (ATP). You can learn more about this process in subtopic C1.2 (/study/app/bio/sid-422-cid-755105/book/big-picture-id-43538/).

Chloroplasts can most commonly be found in the leaves of plants, however they may also be present in the stems of some plants. Algae are very diverse and come in varied sizes from microscopic to kelp that can grow to 65 m! They lack the structure of plants, and do not have leaves. However, some do have flattened blades called a thallus. Chloroplasts are found within these cells and conduct the photosynthesis.

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Figure 2. Kelp can grow up to 65 m in length.

Credit: Douglas Klug, Getty Images

Photosynthetic prokaryotes lack membrane-bound chloroplasts and instead have infoldings of their plasma membrane on which photosynthesis takes place.

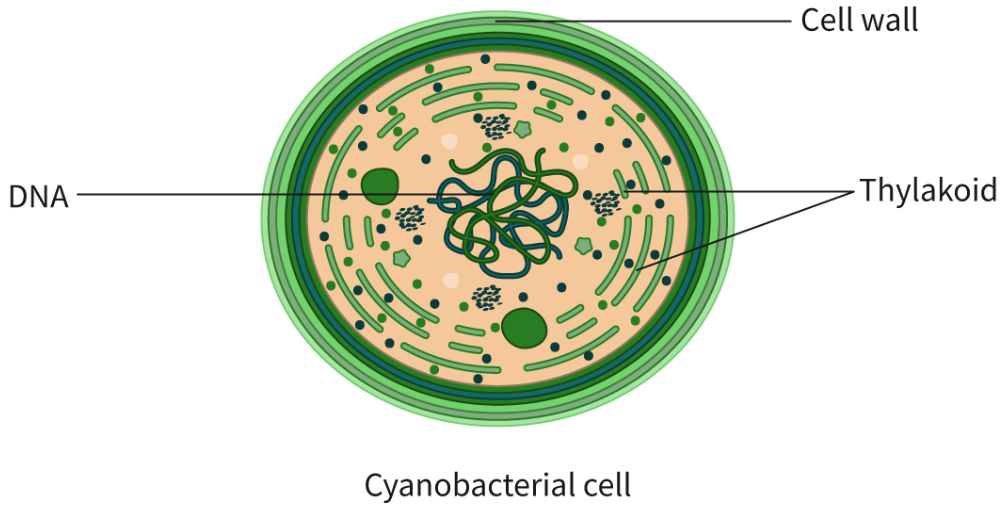

Figure 3. Infoldings in bacteria have evolved to conduct photosynthesis.

More information for figure 3

The image is a labeled diagram of a cyanobacterial cell, depicting the internal structure and major components. The cell is depicted as a circular structure with a labeled "cell wall" forming the outer boundary. Inside, the plasma membrane forms several infoldings known as "thylakoids," which are shown as a series of concentric layers. In the center of the cell, "DNA" is illustrated as a coiled, dark green strand. Various other components and shapes, such as ribosomes and storage granules, are dispersed throughout the cytoplasm, contributing to the cell's detailed structure.

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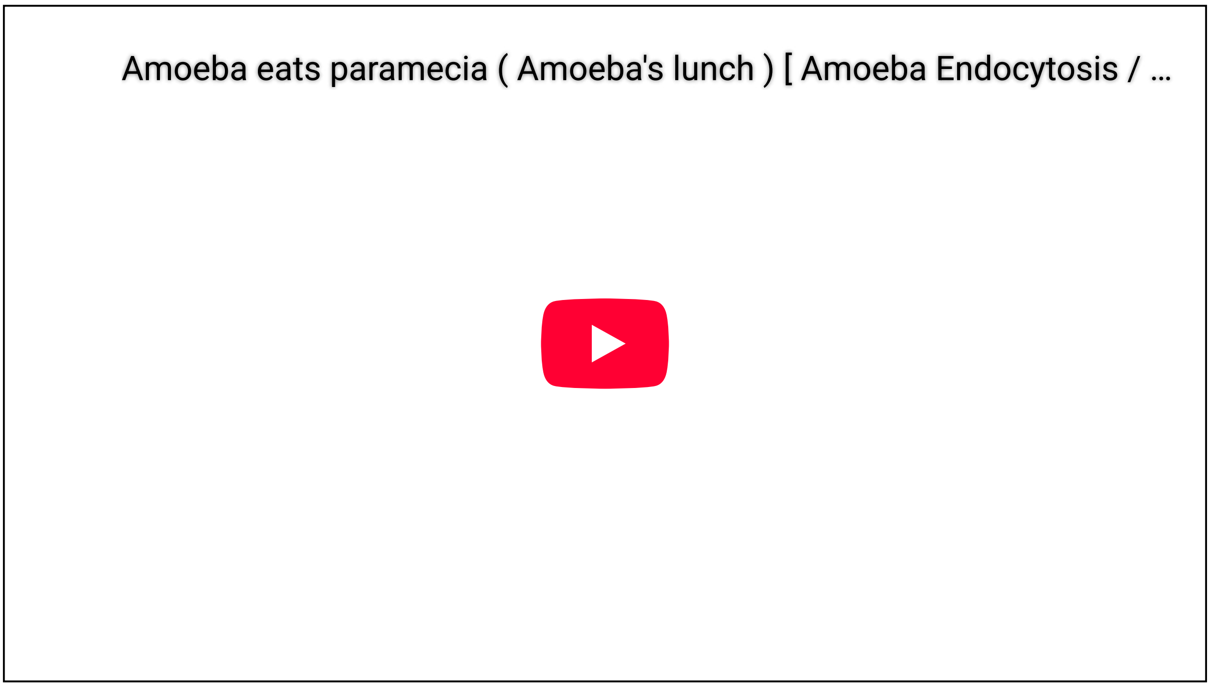
Holozoic nutrition

Heterotrophic organisms take in their food as their source of nutrition. Holozoic nutrition refers to organisms that take in solid or liquid food internally. Most animals are holozoic, but protozoa and *Amoebas* also use this method. After the food is brought inside the organism, it will be digested (broken down) into organic building blocks. These are then used to build up new materials for the growth and development of the organism.

Watch **Video 1** to see *Amoeba* using holozoic nutrition.



Video 1. *Amoeba* consumes its food using holozoic nutrition.

More information for video 1

The video provides a close-up, microscopic view of an amoeba performing holozoic nutrition, demonstrating how certain unicellular organisms acquire and process food. Seen at a magnification of x400 and a playback speed of x2, the amoeba—transparent and slightly granular—extends its finger-like projections, to approach and surround a smaller, oval-shaped organism located nearby. The setting includes floating, translucent particles in the background, which offer context to the dynamic, aquatic environment in which this process unfolds.

As the amoeba moves, its pseudopodia slowly extend outward and begin to envelop the smaller organism. This moment visually represents the phase where the amoeba takes in solid food. The movement is deliberate and purposeful, showing the flexible, adaptive nature of the amoeba's body.

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Once the projections surround the prey, they fuse to form a circular enclosure, trapping the smaller organism within the amoeba’s body.

On-screen text x400 and x2 is consistently displayed in the corner, offering viewers a reference point for the scale and speed of this biological event. As the smaller organism is fully engulfed, it is drawn further into the amoeba’s interior, where digestion begins. Internally, the food is broken down into simpler organic molecules that the amoeba can absorb and use for energy, growth, and maintenance.

Mixotrophic nutrition

Mixotrophic organisms are able to use a combination of methods of generating their nutrition and are neither fully autotrophic or heterotrophic. It is an important nutritional strategy that is found in both terrestrial and aquatic ecosystems. Mixotrophy is thought to favour marine environments making up almost all marine plankton. Mixotrophic microbes are able to photosynthesise like a plant and therefore take in carbon dioxide, but can also take in nutrition like an animal. As they respire they then release carbon dioxide. It is thought that mixotrophic marine plankton can act as early indicators of the effects of climate warming. (https://www.britishecologicalsociety.org/warming-climate-could-turn-ocean-plankton-microbes-into-carbon-emitters/) In experiments analysing warming of the aquatic environment, it was found that mixotrophic organisms shifted away from an autotrophic system towards a heterotrophic system. As heterotrophs release carbon dioxide as a waste product, this would result in an accelerated warming of the oceans, further compounding global warming. Mixotrophs can be divided into two main categories: facultative and obligate mixotrophs. Facultative mixotrophs can switch between autotrophic and heterotrophic modes of nutrition depending on the conditions within the environment. Euglena is an example of a facultative mixotroph. Obligate mixotrophs must use both modes.

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view

Figure 4. The mixotrophic *Paramecium bursaria* can eat bacteria for its nutrition or use *Chlorella* algae to perform photosynthesis to get energy and carbon.

Credit: NNehring, Getty Images

Saprotrophic nutrition

Look around a woodland, and you are likely to see lots of mushrooms near the base of trees. These mushrooms are fungi, and are an example of a saprotroph. Saprotrophic nutrition is a method by which the organism secretes digestive enzymes that are able to break down the dead organic material, including the tough components of dead plants such as cellulose, hemicellulose and pectin. The enzymes break up the material into simpler molecules which are then absorbed by the organism. Other examples of saprotrophs include certain bacteria (*Escherichia coli*), yeast (*Saccharomyces cerevisiae*) and water moulds (Oomycota). These organisms are vital to break down dead leaves and logs. Without them forest floors would be piled high with organic 'litter' and so are really important to recycle carbon and nitrogen from dead organic matter.

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Figure 5. Oak tree trunk covered with moss and mushrooms.

Credit: Santiago Urquijo, Getty Images

Watch **Video 2** to see how *Cordyceps*, a genus of parasitic fungi, are capable of killing ants.

Video 2. *Cordyceps* is a genus of fungi that are parasitic mainly on insects and other arthropods.

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Creativity, activity, service

Strands: Creativity and Service
Learning outcome: Demonstrate engagement with issues of global significance

Do a waste food audit in your school canteen.

How much is wasted? Are some days worse than others? What kind of food is more commonly thrown away?

Use a resource like this (https://greenmountainfarmtoschool.org/wp-content/uploads/2016/01/Guide-to-Staring-a-School-Compost-Program.pdf) to help you build a compost bin and to start generating your own compost that can be used in the school garden, or once the food has rotted down, it could be given to the local community for their gardens. You can also educate the community about the vital role that earthworms as saprophytes play in the complex process of soil formation. They do this by aiding in the decomposition of organic material so that the nutrients can be recycled and taken back into plants.

Nutrition in archaea

Classification of living organisms has always been controversial. A five kingdom classification system was replaced by a three domain system in 1990. These domains are Bacteria, Archaea and Eukarya. Originally grouped together, Archaea is now presented distinctly from Bacteria.

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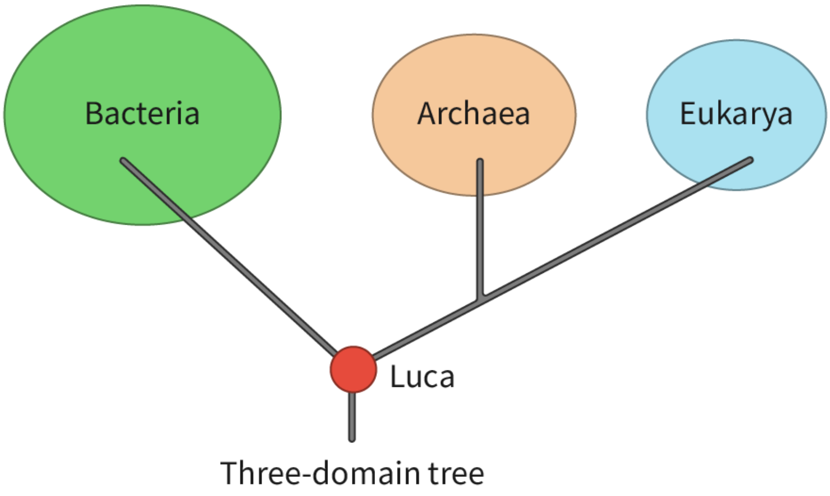

Figure 6. Phylogenetic tree of the three domains of living things.

More information for figure 6

The image depicts a phylogenetic tree illustrating the three domains of life. It is a diagram with a central node labeled 'Luca' (Last Universal Common Ancestor) connected by lines to three balloon-like shapes representing the domains: 'Bacteria' on the left in green, 'Archaea' in the center in orange, and 'Eukarya' on the right in blue. The lines radiating from Luca indicate the evolutionary relationship between the last universal common ancestor and the three domains. The structure clearly distinguishes Archaea from Bacteria, reflecting their unique evolutionary paths.

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Archaea are similar to bacteria in that they are unicellular and have no true nucleus but they have different biochemistry that separates them from the domain of bacteria. They also differ in their cell walls. Peptidoglycan is the component of bacterial cell walls whereas polysaccharides make up the archaeal cell walls. It is thought that archaea are the most ancient organisms on the planet.

Members of the archaea are those that have an ability to survive in extreme environments. These archaeans have evolved the enzymes needed to allow them to survive these extraordinary conditions. Some can tolerate extreme salt levels

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and are called halophiles. Others can cope with very low or very high pH. Still others can tolerate high temperatures or high sulfur. Such organisms can be found in hot springs and in deep sea hydrothermal vents.

The method in which they derive their energy is very diverse and they can use a wide variety of sources.

Some are able to use oxidation of inorganic chemicals such as sulfur, hydrogen sulfide, iron or ammonia for their metabolism and are called chemoautotrophs. Others are photoautotrophs and use light as their source of energy. Others are heterotrophs and need to gain their energy from organic compounds. Some of these use carbon dioxide or other organic compounds to produce methane gas through methanogenesis.

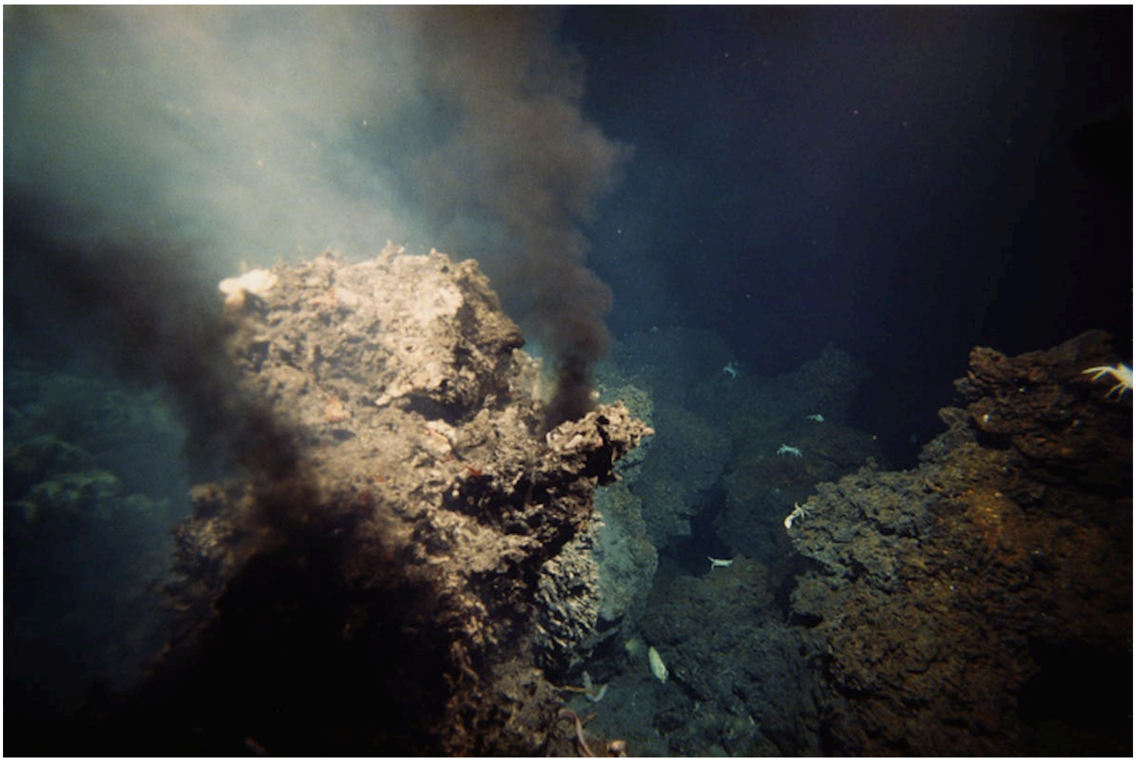

Figure 7. Some archaea live in hostile environments such as deep hydrothermal vents.

Credit: Ralph White, Getty Images

Play the loop game in the activity below to test your understanding of different types of nutrition.

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Activity

- **IB learner profile attribute:** Communicator
- **Approaches to learning:** Social skills — Working collaboratively to achieve a common goal
- **Time required to complete activity:** 20 minutes
- **Activity type:** Group activity

Preparation

Download and print off the types of nutrition questions and answers from the loop game button below, and cut them into strips. Your teacher may do this in advance of the activity starting.

Loop game
(https://d3vrb2m3yrmyfi.cloudfront.net/media/edusys_2/content_uploads/Biol
B4.2.3-7 ACTIVITY.500d4bd2bb82f08b109f.pdf)

Your task

Sit so that you can all easily see and hear each other in the class, you might like to sit in a circle.

You will randomly be given a strip of paper from your teacher.

On the left side of the paper is an answer, and on the right side a question.

One person will be given the start piece. It says **First person**.

They start by reading the question. One student in the room will have the answer to this question. It might be that several of you have to read out your answers, and you decide as a class which is the correct answer. When you have decided the correct answer, that person then reads out their question, and so on.

5 section questions

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B4. Form and function: Ecosystems / B4.2 Ecological niches

Dentition

B4.2.8: Relationship between dentition and diet

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Learning outcomes

By the end of this section you should be able to:

- Summarise the relationship between dentition and the diet of omnivorous and herbivorous representative members of the family Hominidae.
- Infer the diet of several hominid species from anatomical features.

Cookiecutter sharks

Marine explorers have been baffled by regularly shaped, cookiecutter like holes that have been found in marine organisms, submarines and also humans! For a long time, it was unclear what was gouging these perfectly round plugs. It is now known that the cookiecutter shark (*Isistius brasiliensis*) is responsible. This little known species of shark is small with the adult males only reaching 42 cm long. It has unusual dentition with 30–37 small teeth in the upper jaw and between 25–31 larger triangular shaped teeth in the lower jaw. The shark secures itself to its prey and then pulls back its tongue to generate a vacuum while using its lips to ensure a tight seal. With its wide gape it then uses the upper teeth to anchor itself as the lower teeth slice into the prey. A quick rotation of the body then removes a circular cookiecutter chunk from its prey.

Scientists can find out a lot of information about a species if they are able to study the dentition or even just a single tooth from an organism.

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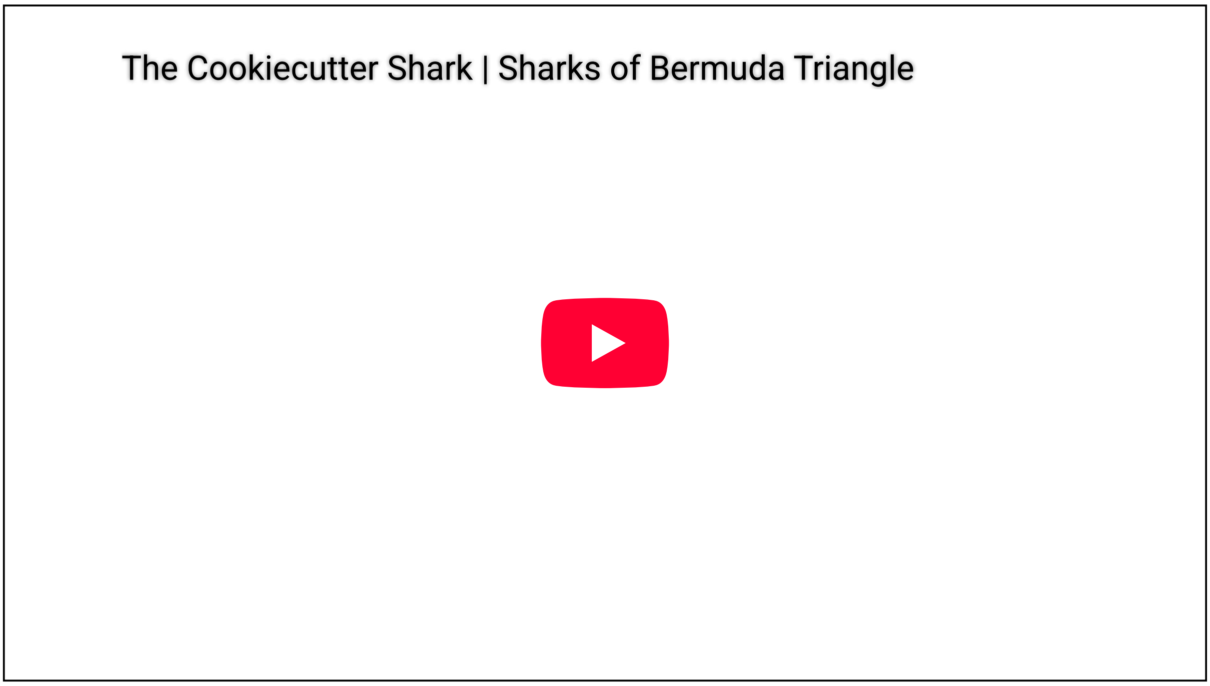
Figure 1. A preserved cookiecutter shark displaying its teeth.

Source: "Isistius brasiliensus SI (https://commons.wikimedia.org/wiki/File:Isistius_brasiliensis_SI.jpg)" by Jennifer Strotman is in the public domain

Watch **Video 1** to learn more about the cookiecutter shark’s bite.



Video 1. Cookiecutter shark.

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Nature of Science

Aspect: Observations

Deductions can be made from theories. Observation of living mammals has led to theories relating dentition to herbivorous or carnivorous diets. Observation of the small markings made on teeth by the food that is eaten can help indicate the diet. This is called dental microwear and has proven useful in indicating possible diets of extinct mammals. Other studies have involved sampling isotopes of carbon, strontium, calcium and barium in skeletal tissues. The assumption is made that the process of metabolism results in the fractionation of these elements. When compared with modern mammals, inferences can be made about the different trophic steps in a diet. Theories on the diets of extinct mammals can therefore be made.

Since many organisms are holozoic, they need teeth to properly consume their meals. How do the teeth of these sharks differ from humans?

Humans (*Homo sapiens*) are found in the family Hominidae. This grouping also includes our fossil ancestors. Due to the fact that teeth are highly mineralised, they are well preserved. They are even more resilient than bone and so there is a large presence of teeth in the fossil record. Thanks to archaeologists, much is known about the dentition of hominids. Examination of the skulls and teeth of our ancestors allows us to make some deductions about their diet.

Hominins refers to all modern and extinct humans and their immediate ancestors whereas hominids include not only the hominins but also the great apes (such as gorillas, chimpanzees and orangutans). Early hominin dentition is often compared with other hominids (which includes chimpanzees, gorillas and orangutans). Humans are by far the most diverse in their diets and are generalists with teeth capable of eating plant and animal products. The Hadza of Tanzania

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(https://education.nationalgeographic.org/resource/the-hadza-of-tanzania/) are the world's last hunter-gatherers and feed on a plant-rich diet with some meat. In contrast, the Inuit eat mostly meat products.

Early hominin dentition

Early ancestors ate fibrous plant material, and needed to consume a large volume in order to get enough energy. Once more higher energy meat started to be eaten, this meant that the digestive system could be reduced – giving more energy for building a brain. The tooth count and jaw size were then reduced as they needed to do less chewing than on the fibrous plant material.

Certain researchers have divided the extinct hominins into four groups. We will only discuss two of these groups. In general, over time, the face has become more vertical, the canines and jaws have become shorter. The teeth in modern humans are arranged into a tight U shape.

This interactive timeline (https://humanorigins.si.edu/evidence/human-evolution-interactive-timeline) shows the evolution of different hominids.

The first group we will study is the Archaic megadont hominins which include *Paranthropus robustus*.

Paranthropus robustus existed about 1.8 to 1.2 million years ago in South Africa. They had large teeth with very thick enamel and chewed at the back of their jaw. They had large chewing muscles which resulted in them having a wide face. A large bone called the sagittal crest is a line of bone that runs along the midline of the skull towards the nose. The presence of this shows that this hominin had strong jaw muscles and was given the name Nutcracker Man. They had the ability to grind tough and fibrous foods. These are believed to be herbivores and to have eaten tough grasses and sedges.

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Rotate these 3D simulations of three different hominin skulls and examine them from all angles.

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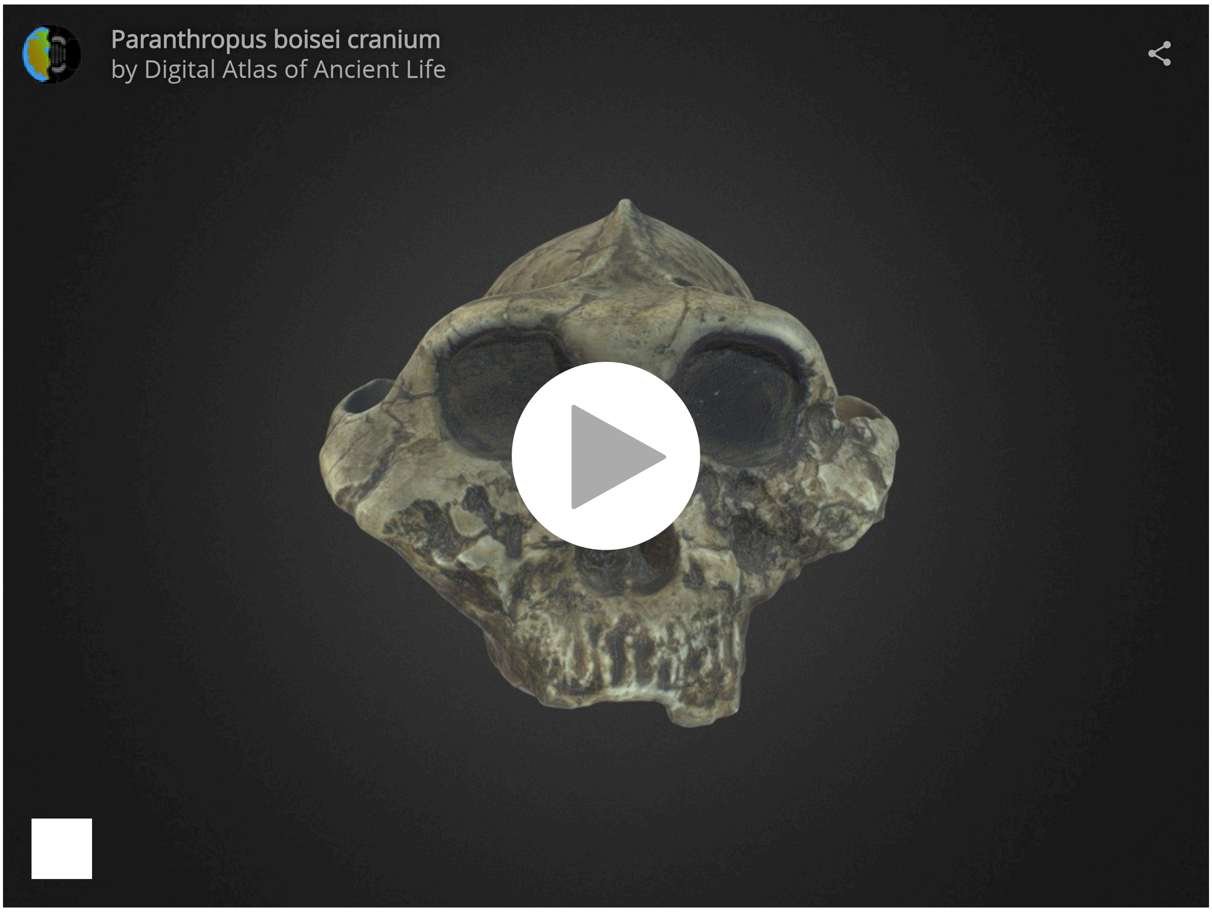

Interactive 1. 3D Simulation of Paranthropus boisei Cranium.

More information for interactive 1

This 3D visualization presents a detailed view of the skull of Paranthropus boisei Cranium, an early hominin species that lived between 1.8 and 1.2 million years ago in South Africa. By rotating the skull, we can observe its unique adaptations for chewing tough plant material.

From the front, the skull appears wide, with large cheekbones and a broad face. The eye sockets are positioned slightly forward, and the skull has a strong, thick structure. The most striking feature is the pronounced sagittal crest on the top of the skull, which provided extra space for large chewing muscles. The large molars and thick enamel show clear evidence of a diet that required heavy chewing.

The sagittal crest is clearly visible along the midline of the skull, running from the top of the head towards the back. This feature is crucial for supporting the powerful jaw muscles needed for chewing tough foods.

The skull of Paranthropus boisei Cranium provides key insights into how early hominins adapted to their environment. The strong jaw, large teeth, and sagittal crest indicate that they specialized in eating tough vegetation, such as grasses and sedges. These adaptations earned them the nickname “Nutcracker

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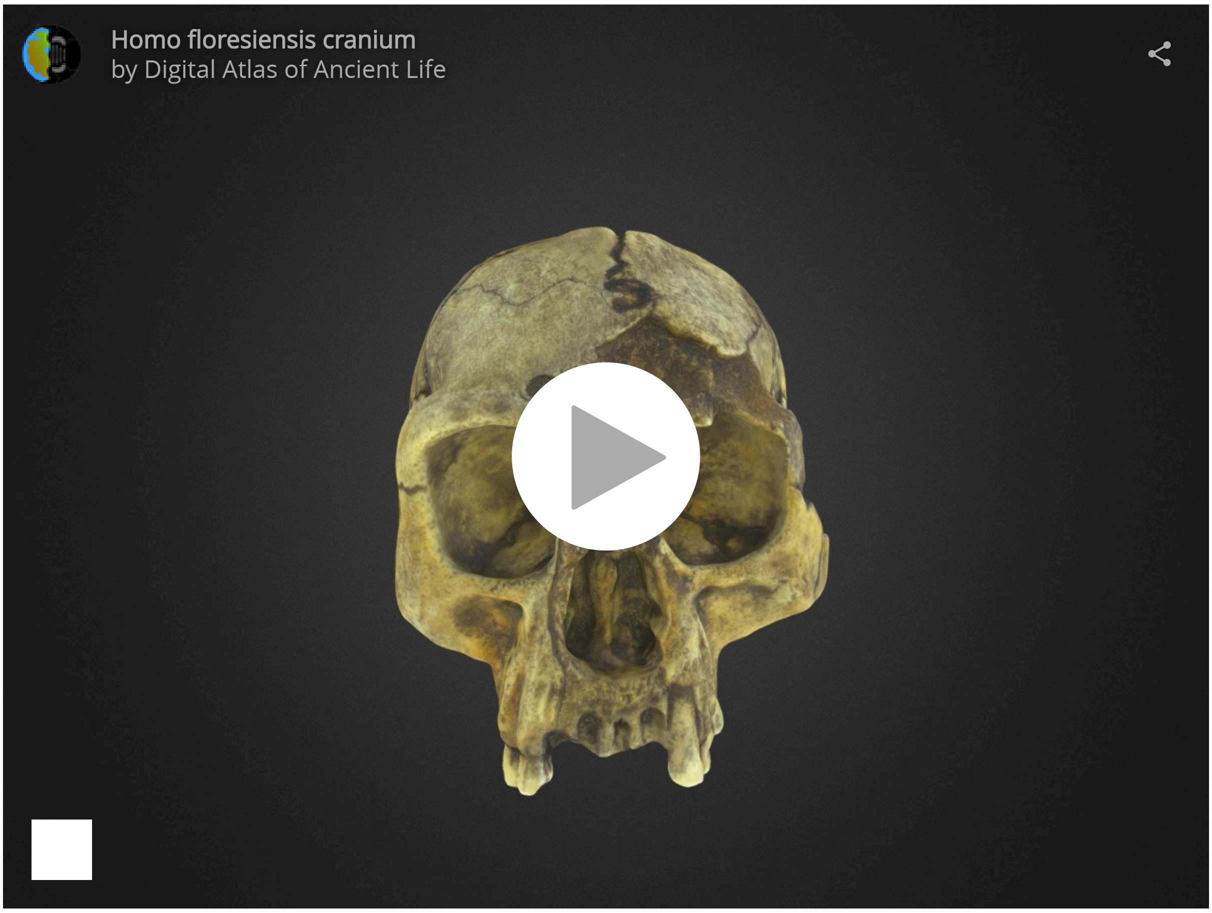
Man."

This 3D model offers an excellent opportunity to explore these unique features and understand how Paranthropus boisei Cranium thrived in its environment millions of years ago.



Interactive 2. 3D Simulation of Homo floresiensis Cranium.

More information for interactive 2

The 3D interactive model of a Homo floresiensis skull offers an in-depth view of this fascinating hominin species. The visualization allows for full rotation, enabling examination from multiple angles to better understand the unique cranial features of this extinct human relative.

The skull has large eye sockets and a more projecting face compared to modern humans. Unlike Homo sapiens, they had thicker skull bones and a smaller, sloping forehead. Despite their small brains, they possessed large teeth relative to their skull size. Evidence suggests that they were omnivorous, consuming both plant-based foods and raw meat. This conclusion is based on wear patterns on their teeth, which indicate a diet rich in tough, fibrous foods requiring extensive chewing.

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Throughout this interactive, the rotation of the skull model offers a comprehensive understanding of the species' unique morphology. The detailed visualization enhances our appreciation of Homo floresiensis as a distinct yet enigmatic member of the human evolutionary lineage.

Interactive 3. 3D Simulation of Mordern Homo sapiens Cranium.

Source: Sketchfab - *Paranthropus boisei* cranium (https://skfb.ly/oDCwL), *Homo floresiensis* cranium (https://skfb.ly/oCVXy), Modern Homo sapiens cranium (https://skfb.ly/oDGSA)

More information for interactive 3

A 3D interactive model of a Homo sapiens cranium skull allows users to rotate and explore it. Users can observe its unique structure from multiple angles, providing insight into the evolutionary traits that distinguish Homo sapiens from earlier hominins.

The skull is globular in shape with a high forehead. The face is flatter and more vertical, with a smaller jaw and smaller teeth than earlier human ancestors. Brow ridges are reduced as compared to earlier human ancestors.

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The shape of the skull tells us a lot about how Homo sapiens evolved. A larger brain, smaller teeth, and a lighter jaw allowed for more advanced thinking, communication, and tool-making. These features helped humans adapt to different environments and spread across the world.

This 3D model gives a clear view of what makes Homo sapiens unique, helping us understand how our species developed over time.

The second group we will discuss is the Pre-modern Homo which includes both *Homo floresiensis* and *Homo sapiens*.

The much more recent hominin found on the island of Flores, Indonesia has given rise to the name *Homo floresiensis*. This species *was* present between 100 000 to 50 000 years ago. They were only about 107 cm tall and so have been nicknamed ‘Hobbit’. They had small brains but large teeth for their skull size. It is believed that they were omnivores and that their diet included both plant and uncooked meat. The evidence for this is the markings on their teeth that show wear that coincides with eating a tough fibrous diet that required a lot of chewing.

Watch **Video 2** for an explanation of *Homo floresiensis* and how they lived.

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Video 2. An explanation of the hominin *Homo floresiensis*.

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The *Homo sapiens* were found from 300 000 years ago to the present day, and all humans on the planet are of this genus and species. Although they likely evolved in Africa, they are now found throughout the entire planet. They gathered food and hunted, and were able to develop methods to help them survive with changing conditions. The jaws are also less heavily developed, with smaller teeth.

Theory of Knowledge

Does the list of knowledge claims /opinion included in, or excluded from, the natural sciences change from one era to another, or from one culture or tradition to another?

Categorise images in the activity below to determine whether features shown in the images belong to herbivores or meat eaters (omnivores or carnivores).

Activity

- **IB learner profile attribute:** Thinker
- **Approaches to learning:** Thinking skills — Being curious about the natural world
- **Time required to complete activity:** 15 minutes
- **Activity type:** Individual activity

Use the information on dentition visible in the images in **Interactive 2** to identify the Herbivores (mammals that eat plants) and mammals that Can eat meat. Drag and drop the correct labels to the images.

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Herbivore

Can eat meat
(omnivore or carnivore)

Check

Interactive 2. Identify Traits That Help Organisms Eat Plants or Meat.

5 section questions

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B4. Form and function: Ecosystems / B4.2 Ecological niches

Adaptations of diet

Learning outcomes

By the end of this section you should be able to:

- Describe the adaptations of herbivores for feeding on plants and of plants for resisting herbivory.
- Describe the adaptations of predators for finding, catching and killing prey and of prey animals for resisting predation.
- Describe the adaptations of plants for harvesting light.

Adaptations of herbivores

Herbivores refers to animals that eat only plant material. Examples of herbivores are invertebrates, cows, goats, buffalo, sheep, hippopotamuses among others. It isn't often that you think of herbivores as being killer animals, but the hippo is actually the most dangerous land mammal on the planet and kills more people than lions, leopards, hyenas all together! So what causes this herbivore to attack? In this section we will examine different adaptations of animals to find prey and resist predation.

Herbivores have specialised ways to be able to take in plant material and be able to break it down. Some insects have evolved to have a strong pair of mandibles on each side of their head and they use them to cut, tear, crush and chew their food. Other insects feed off fluids internal to the plant and use a unique straw-like device, called a stylet to access these. The aphid feeds on phloem by inserting its 1 cm proboscis into the tissue. A gel-like saliva is secreted which forms a sheath around the stylet, seals the holes made in cell membranes and assists in the extraction of the fluids.

In herbivorous mammals, their front incisors are long and flat and work like scissors to cut the plant material. The back molars are large, flat surfaces where the plant material can get macerated in a sideways grinding movement to increase the surface area for digestive enzymes to break it down. You may have observed the way a cow or a goat eats their food with a sideways chewing motion. Due to the constant grinding, herbivores can wear their teeth down and therefore have constant teeth growth. The space between the incisors and molars is called a diastema, and this area allows the tongue to move the food from the front of the mouth towards the molars for grinding.

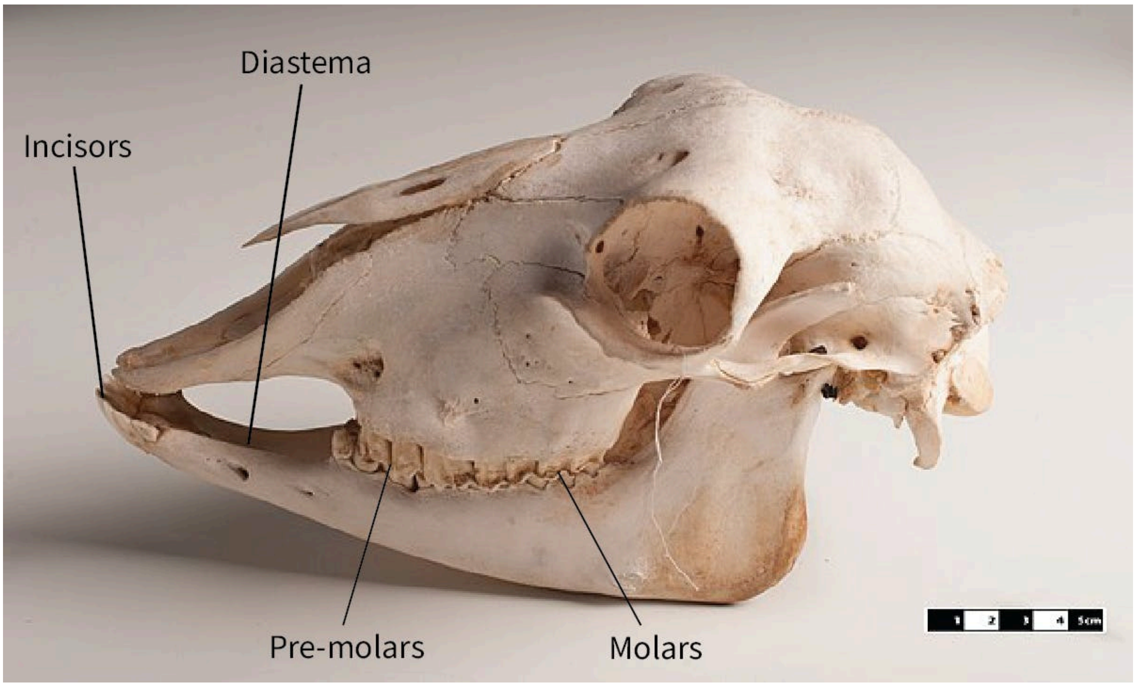

Figure 1. Goat skull showing their specialised teeth.

Source: "Ovine skull 01 (https://commons.wikimedia.org/wiki/File:Ovine_skull_01.jpg)" by Museum of Veterinary Anatomy FMVZ USP is licensed under CC BY-SA 4.0 (https://creativecommons.org/licenses/by-sa/4.0/deed.en)

More information for figure 1

The image shows a side view of a goat skull. Key anatomical features are labeled, including the incisors at the front, the diastema which is the gap between the incisors and pre-molars, followed by the molars at the back. The incisor teeth are positioned at the front end of the jaw, flat and suitable for cutting plant material. The diastema is the space that allows the tongue to move food from the incisors to the back molars for grinding. Below the diastema, pre-molars are labeled, leading to the larger surface area of the molars which are used to macerate the food. The background is neutral, enhancing the visibility of the skull structure and the labeled parts.

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The hippos' canine and incisor teeth grow throughout their lives and without being ground down can in some cases reach to be 50 cm in length! They are not needed for feeding but are used for defence or when fighting for a mate with other male hippos. This is why we should be cautious around these creatures!

Herbivores need to be aware of predators around them and so have eyes that are far apart on either sides of their head to increase their visual field so that they can respond more quickly to danger.

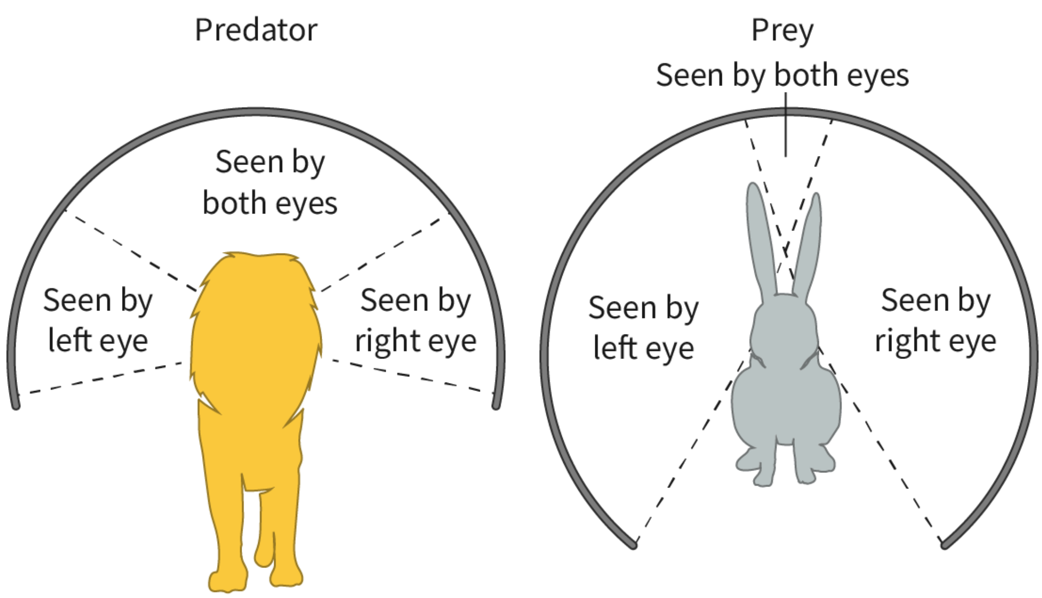

Figure 2. The wide set eyes on prey allow them to have a larger field of view.

More information for figure 2

The image is a diagram illustrating the field of view for a predator and a prey animal. On the left side, there's a depiction of a predator, likely a lion, facing away from the viewer. The field of view is shown as a semi-circle divided into three sections: "Seen by left eye," "Seen by both eyes," and "Seen by right eye." This indicates a narrower field of vision focused forward, typical for predators. On the right side, a prey animal, likely a rabbit, is similarly depicted facing away, but its field of view encompasses two wide sections primarily titled "Seen by left eye" and "Seen by right eye," with a smaller overlapping area for

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"Seen by both eyes." This illustrates how prey animals have wider peripheral vision for detecting predators. The diagram is labeled with text to identify the fields of vision and categorizes the animals as predator and prey accordingly.

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Adaptations of plants to avoid herbivory

Some plants make toxic secondary compounds. This means that the compound is not directly involved with the growth and life of the plant, but may be toxic to those that eat it, including humans. Generating these compounds is an adaptation used to prevent herbivory. Some animals have responded to this selective pressure by evolving to have special enzymes that enable them to metabolise these compounds and therefore not be affected by them. In further response to this, some plants have evolved non-toxic chemicals that only become toxic after ingestion by the animal! This back and forth of attack has now been given the term ‘animal plant warfare’.

These plant compounds, called phytochemicals, can be put into four groups: terpenes, phenolics, polyketides and alkaloids. Some modern medicines have been derived from these secondary compounds as they have surprisingly been shown to have useful features. Artemisinin is a drug that has been used successfully against malaria. Unfortunately the microbes causing malaria is now becoming resistant to this chemical. Paclitaxel is a chemical used to treat many forms of cancer. Both of these chemicals are from the terpene group.

Some species can not only resist these secondary metabolites but can employ them to protect them from predation. Monarch butterflies can eat toxic milkweed (*Asclepias*) and keep it within their bodies which deters predators from eating them.

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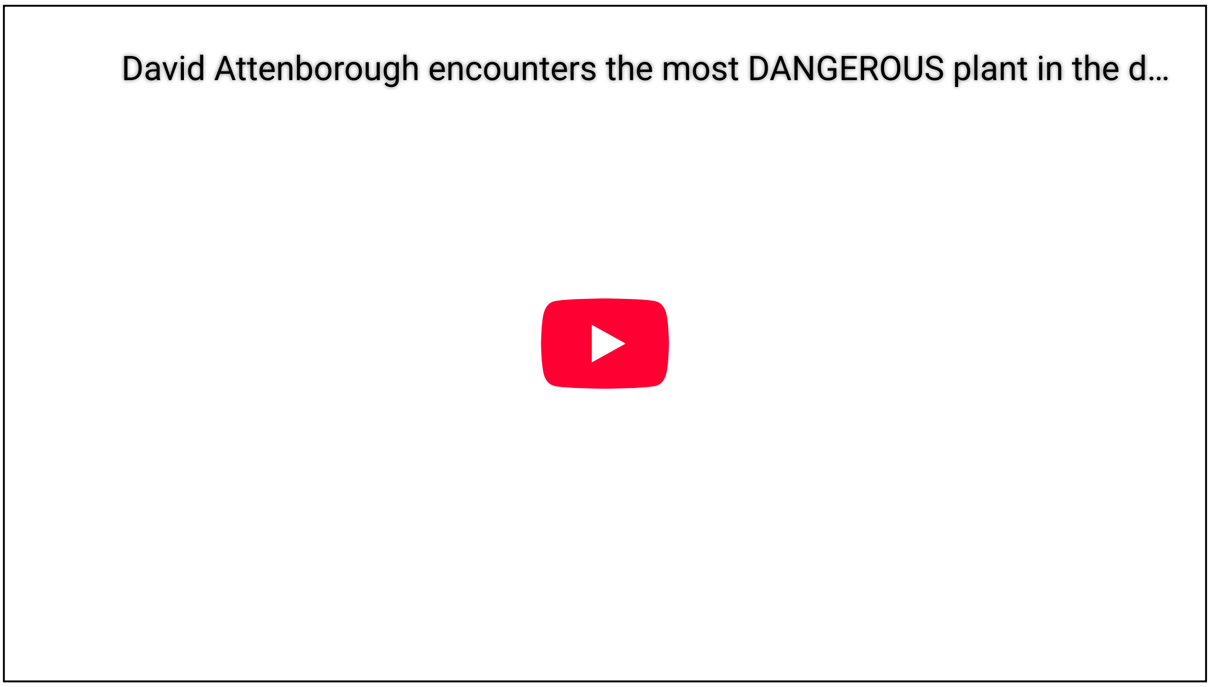
International Mindedness

The use of plant compounds as medicines have been used in ancient civilisations. Many herbal medicines are used in traditional cultures. Chemicals that have been isolated from plants have now been synthesised and have been shown to be very effective in modern medicine.

Various fascinating processes make plants unpalatable to avoid consumption by herbivores. There are structural adaptations such as having thick, rigid leaves which are difficult to chew. Other plants have spiny thorns which are sharp extensions of the epidermis that prevent large herbivores from consuming the plant. Some plants have microscopic thorns called trichomes which deter much smaller herbivores like insects. These can stop eggs from attaching or limit the movement of the insect. When these microscopic spikes are combined with chemical adaptations they might release sticky resin or chemicals that cause irritation to the herbivore.

Watch **Video 1** to see the most dangerous plant in the desert in action.



Video 1. The deceptively cuddly Teddy Bear Cactus (*Cylindropuntia bigelovii*).

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Other plants adopt a way of hiding from predators. The *Lithops* are one such plant that have adapted ways to avoid being seen. These succulents have two fleshy padded leaves with a groove between them. They are small and grow to a maximum of 2.5 cm and sit just above the surface of the ground, thus avoiding detection.

Figure 3. *Lithops* succulent plants look like stones and avoid predation.

Credit: Surasak Suwanmake, Getty Images

Adaptations of predators to kill prey

Physical

Many predators are carnivores and use speed and agility, sharp claws and teeth with which they can hunt and then capture their prey. They also have digestive systems that are capable of breaking down the prey. Predators have very finely tuned sensory systems. An eagle can spot potential prey from about 3 km away. A mole has a fine sense of smell for identifying their prey. Owls can hear the smallest movement of a mouse, and pit vipers can detect body heat of nearby prey.

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Watch **Video 2** to see a lion (predator) catching a wildebeest (its prey).

Video 2. A lion (*Panthera leo*) catches a wildebeest (*Connochaetes taurinus*) and takes it down.

Chemical

Some predators release certain chemicals that work to either poison or paralyse their victims. These chemicals are cocktails of salts and proteins and are generally referred to as toxins. Some work by interfering with normal biological processes and can be very effective – even to the point of death! It is believed that the various venom systems have evolved many times.

The Brazilian fire ant (*Solenopsis saevissima)* is indigenous to South America. It bites onto its prey with a pair of clamp-like mandibles and then uses a stinger on its abdomen to inject the venom, resulting in a powerful and painful, burning sting. The sting contains alkaloids chemicals called solenopsins (2-methyl-6-alkylpiperidines). These chemicals give rise to many different toxic properties.

Another strategy is that of the cone snail (*Conus geographus*) that injects the venom into its prey via a harpoon. This includes insulin which soon gets into their bloodstream. The insulin causes the sugar levels to drop, and shuts the fish down.

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The fish are then taken into the large mouth of the snail and swallowed whole.

Watch **Video 3** to see a venomous cone snail catching their prey.

Video 3. Venomous cone snails catch their prey.

However, some prey can withstand the venom. The North American opossum (*Didelphis virginiana*) is unaffected by the bite of the western diamondback rattlesnake (*Crotalus atrox*). Certain proteins in the serum of the opossum can neutralise the compounds in the venom. These proteins are now being artificially generated to use as effective anti-venoms.

Behavioural

Dolphins have developed the ability to work together to swim in a circular motion, and by beating their tail fin they stir up the sea bed to create a ring of mud. This works like a fishing net to catch their prey. The fish are effectively trapped and can only escape by jumping out of the water, and straight into the dolphins' mouths.

Watch **Video 4** to see a behavioural method used by dolphins to catch their prey.

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Video 4. Dolphins use a behavioural method to catch their prey.

The Margay (*Leopardus wiedii*) is a predator of the Tamarin monkey (*Saguinus* sp.) in South and Central America. The cunning Margay is a good mimic and can make a call that sounds just like a distress call similar to the pied tamarin monkey. As the parent comes to save their offspring, the Margay will pounce and catch its prey.

Adaptations of prey to resist predation

Physical

Just as the predators have adapted to catch their food, prey have likewise evolved many adaptations to protect themselves. Many use camouflage to hide themselves and make them difficult to spot by making their coats blend into the background. Zebra stripes enable them to blend into the grasses in their habitat. Being quick and agile to escape predators is also a tool many use which allows them to evade capture. Some have defensive mechanisms such as the hedgehog that has between 5000 and 7000 3 cm spines which keeps predators away. Some prey have bright colours and patterns that often indicate containing toxic substances, and so deter predators.

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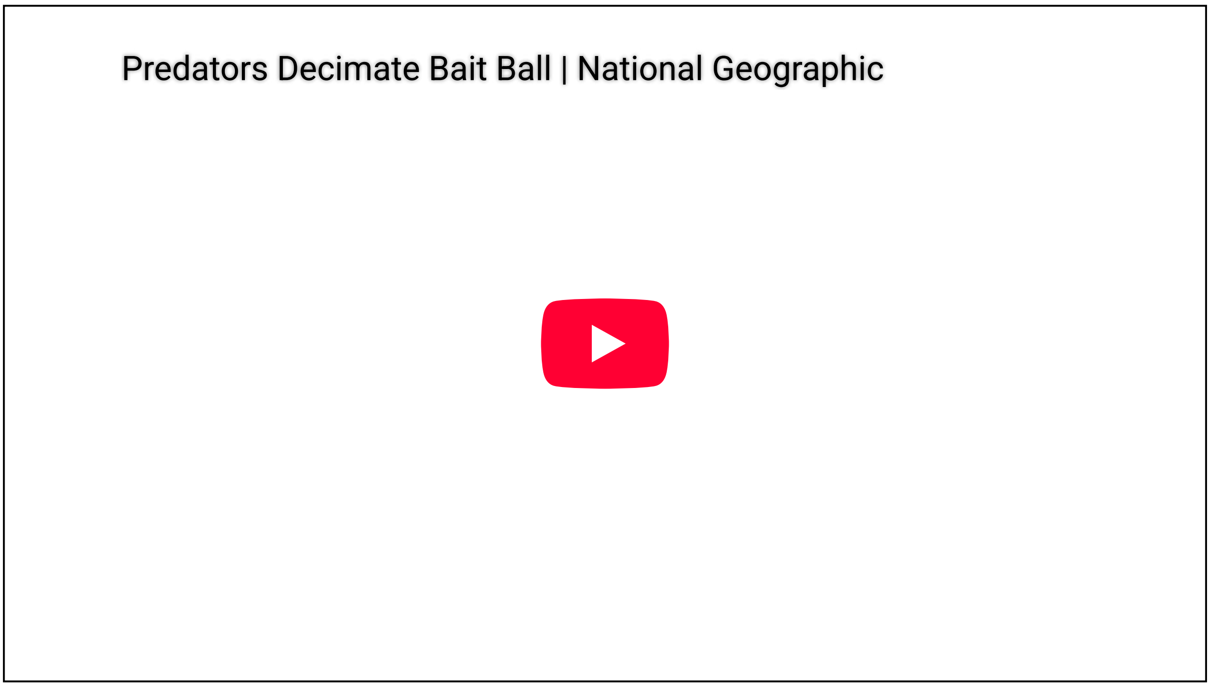
Chemical

Chemicals can be released by prey that protect them from predation. These can be released into the air, or water. They are often noxious odours and so deter the predator. However, they can also be toxic and injure or harm the predator. A skunk will spray a pungent liquid containing thiols from their anal glands when they are frightened or threatened. The smell of a skunk can linger for weeks up to 1 km away.

Behavioural

Some prey species will work together in order to look like one larger organism. Many species of fish will collaborate to form a ball in an effort to scare predators. Mackerel use this strategy in an attempt to protect themselves.

Watch **Video 5** to see mackerel (*Scomber scombrus*) working together to protect themselves from predators.



Video 5. Mackerel work together to form a ball to protect themselves from predators.

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Adaptations of plants to harvest light

All plants need a source of light in order to conduct photosynthesis. For those plants that live in forest ecosystems, their access to light may be limited by the forest canopy. They therefore have adapted strategies to reach the light. One example are lianas or drip tips that are climbing plants. They have aerial roots of up to 300 m and can climb the tallest trees in the rainforest.

Some plants are epiphytes and are unusual as they are not rooted in the ground. They grow entirely on the branches of another plant. They use the moisture from the plant as their source of water, rather than gaining it from the soil. Strangler epiphytes like the strangler fig start as sticky seeds high up on a tree and then grow their roots down to the ground and encompass the trunk of their host. It can eventually kill the host and is given the name 'matapalo' (tree-killer) in Spanish. In the shrub layer of the forest, plants are shade-tolerant and have leaf modifications such as increasing the surface area by having large broad but thin leaves to enable maximum sunlight to hit them. On the forest floor, a carpet of plants called the herb layer exists. These plants have soft stems and include grasses, ferns and wildflowers. These can also tolerate low light conditions.

Figure 4. The roots of a strangler fig (*Figus* genus) encompasses the host plant.

Credit: Image Source, Getty Images

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Research methods for plant resistance to herbivores in the activity below.

Activity

- **IB learner profile attribute:** Communicator
- **Approaches to learning:** Communication skills — Clearly communicating complex ideas in response to open-ended questions
- **Time required to complete activity:** 20 minutes
- **Activity type:** Pair activity

There are two principal approaches to measuring plant resistance to herbivores:

1. Antibiosis (how suitable the plant is for the herbivore):

   (a) Herbivore fitness or performance (e.g. fertility rate or larval development time)
   (b) Intrinsic plant traits (chemical, physical) underlying herbivore fitness.

2. Antixenosis (how much damage or how many herbivores a plant attracts):

   (a) Herbivore presence (number of eggs, larvae, or adults)
   (b) Herbivore damage (e.g. percentage leaf area removed).

In pairs research for both approaches for measuring the resistance to herbivory and suggest examples for each category.

Compare both approaches to decide the impact of resistance to herbivory on the ecosystem.

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B4. Form and function: Ecosystems / B4.2 Ecological niches

Competitive exclusion

B4.2.12: Fundamental and realised niches B4.2.13: Competitive exclusion and the uniqueness of ecological niches.

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Learning outcomes

By the end of this section you should be able to:

- Describe and explain the differences between the fundamental and the realised niches.
- Explain the concept of competitive exclusion and the uniqueness of ecological niches.

Fundamental and realised niches

The niche of an ecosystem in which an organism can live and reproduce is called the fundamental niche. This takes into account the environmental and social limitations for that organism. However, there may be other constraints including the presence of other species, that mean that the organisms *actual* niche is very much smaller. This is called the realised niche and is where the organism is best adapted and is able to live and reproduce.

Realised niche is formed when the species within a fundamental niche has to deal with the pressure of co-existing with the other species in the environment. The species is forced to live in a smaller niche. An example of how a realised niche is formed is the coexistence of wolves and coyotes living across North America. Because both species inhabit the same area, coyotes would then compete for food and territory. The realised niche for coyotes was small due to the more aggressive nature of wolves. When European settlers came to the continent, hunting reduced the population of wolves. This favoured the coyotes, and thus, their realised niche

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expanded. It is fascinating that the realised niche width for a species can expand or reduce by the change in the population of other species. Is this nature's way of managing populations?

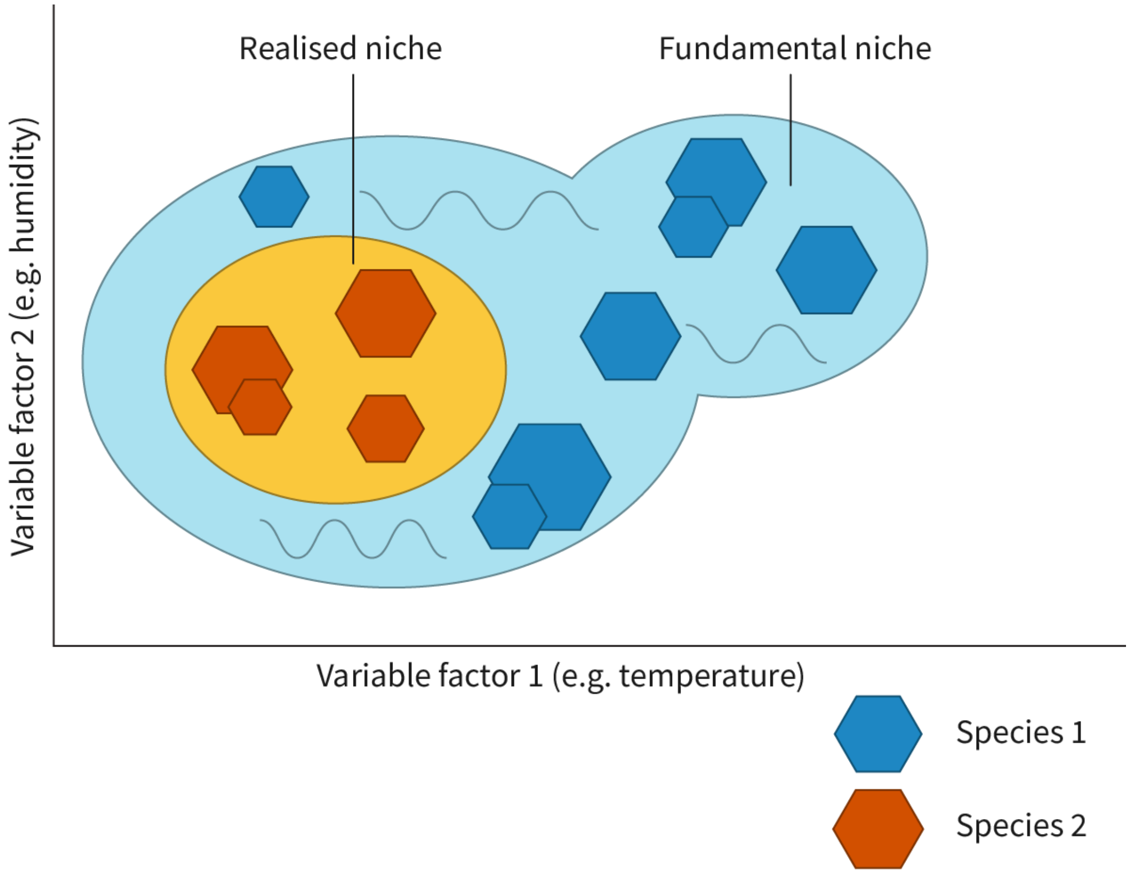

Figure 1. Graph depicting how a realised niche fits within a fundamental niche depending on varying abiotic factors.

More information for figure 1

The image is a graph illustrating the concept of realized and fundamental niches based on two variable factors, likely abiotic ones such as temperature and humidity, as indicated by their respective labels. The X-axis represents 'Variable factor 1 (e.g., temperature)', while the Y-axis indicates 'Variable factor 2 (e.g., humidity)'.

There are two overlapping areas portrayed as ovals. The larger, lighter blue oval is labeled 'Fundamental niche', indicating the potential living area of a species under optimal conditions without competition. Within this larger oval is a smaller yellow area labeled 'Realized niche'. This smaller region within the fundamental niche represents the actual area occupied by a species when environmental constraints like interactions with other species are in effect.

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Inside these areas, hexagon symbols are used to depict two species—Species 1 in blue and Species 2 in orange. Most blue hexagons (Species 1) are spread across the fundamental niche area, with some extending into the realized niche, while the orange hexagons (Species 2) are mainly located in the realized niche, denoting reduced space due to competition.

The background and layout visually explain how abiotic factors and species interactions lead to the formation of realized niches within fundamental niches.

[Generated by AI]

Coexistence with other species

Whenever there are more than one species that are competing for the same resource, there will be competition. It is not possible for two species to occupy the same niche for a long period of time, and one will outcompete the other. This is called the competitive exclusion principle and is sometimes called Gause's law.

A well-known example of this is between two protozoan species *Paramecium aurelia* and *Paramecium caudatum*. They both have similar needs for nutrition and space. If they are grown in separate containers, they can both thrive, but if they are combined within the same container, they will compete with each other leading to the extinction of *P. caudatum*.

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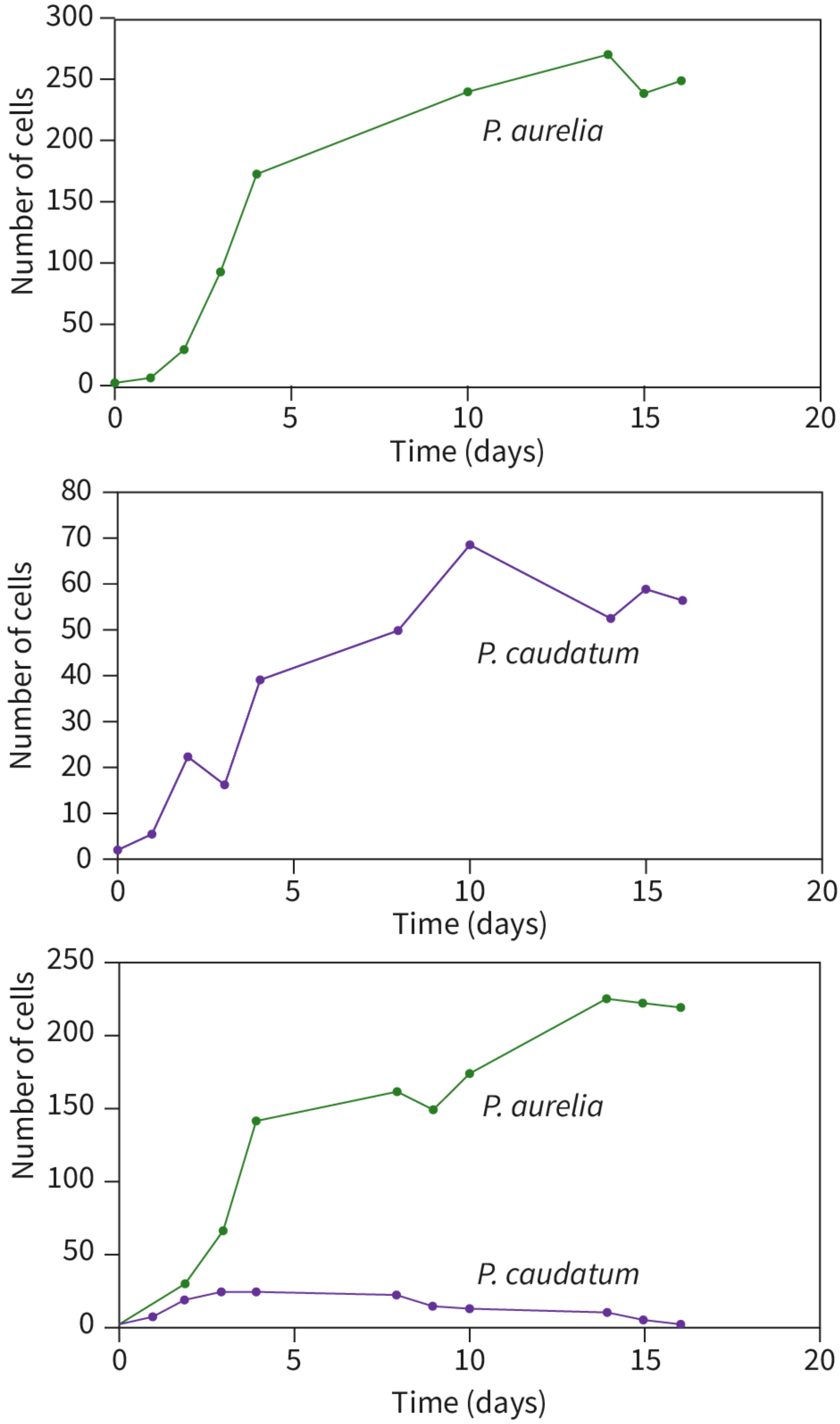

Figure 2. Both protozoans grow well separately, but they cannot both thrive when grown together.

More information for figure 2

The image contains three line graphs. The first graph shows the number of Paramecium aurelia cells over time, with the X-axis labeled 'Time (days)' ranging from 0 to 20 days, and the Y-axis labeled 'Number of cells' ranging from 0 to 300 cells. The graph illustrates a steady increase in cell numbers over time, reaching around 250 cells.

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The second graph displays the growth of Paramecium caudatum, featuring the same X-axis as the first graph and a Y-axis ranging from 0 to 80 cells. It shows a fluctuating pattern where the number peaks at around 70 cells and then dips slightly while still maintaining overall growth.

The third graph combines the data for both species. The X-axis is labeled 'Time (days)' ranging from 0 to 20 days, and the Y-axis is labeled 'Number of cells' ranging from 0 to 250 cells. It shows that P. aurelia grows steadily to around 200 cells, while P. caudatum shows minimal growth and declines over time, indicating competitive inhibition when grown together.

[Generated by AI]

Niche partitioning

Competition will often cause there to be adaptations in order for both species to both survive. A concept called niche partitioning was described which showed how natural selection permits competing species to occupy close areas or niches. Two types of niche partitioning are spatial partitioning and temporal partitioning.

Spatial partitioning

An investigation on five different Warbler bird species by MacArthur in 1956 showed that these birds had very small differences and requirements. They were found to occupy different heights on coniferous trees, where they had different nesting times and so had different food requirements. What other kinds of ways can organisms occupy similar niches at the same time?

Student view

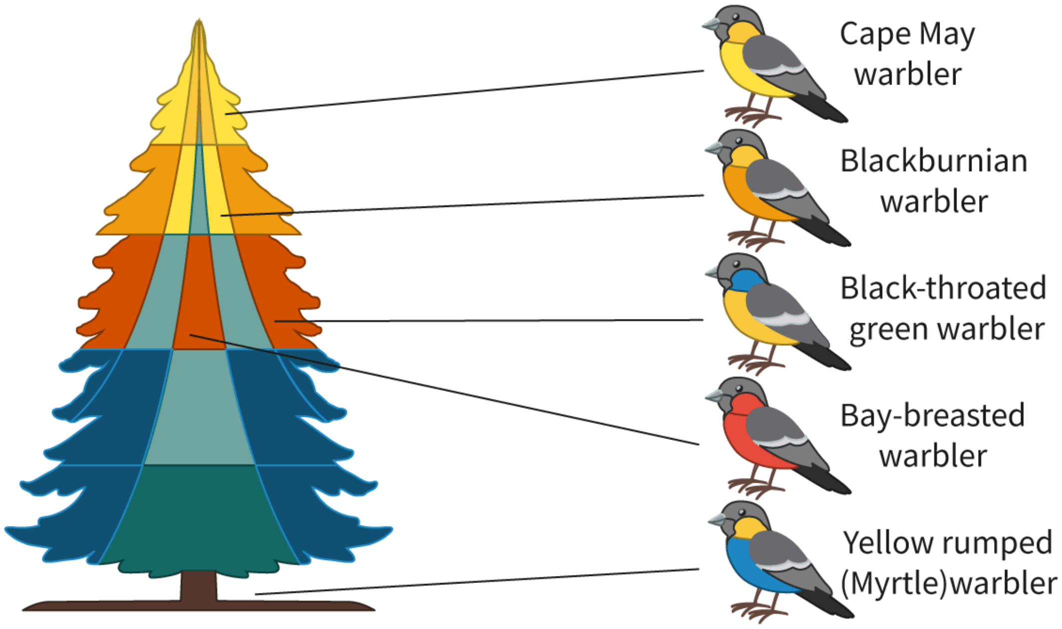

Figure 3. Warbler species have preferences for different areas on conifer trees.

More information for figure 3

The image is a diagram illustrating how different Warbler species prefer various sections of a conifer tree. The tree is divided into segments, each labeled with a specific type of Warbler. Starting from the top of the tree, the Cape May warbler occupies the highest part. Below that, the Blackburnian warbler is situated. The Black-throated green warbler is shown in the middle segment of the tree. Further down, the Bay-breasted warbler is labeled. At the bottom, the Yellow-rumped (Myrtle) warbler occupies the lowest segment of the tree. Each species is depicted with a corresponding illustration, indicating their preferred habitat area on the tree.

[Generated by AI]

Temporal partitioning

The common spiny mouse (*Acomys cahirinus*) co-exists in the deserts of Israel with the golden spiny mouse (*Acomys russatus*). The common spiny mouse is active during the night whereas the golden spiny mouse is active during the day. Temporal partitioning is the way that these mice have evolved to cope with existing in the same habitat.

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Test your understanding of the competitive exclusion principle in the activity below.

Activity

- **IB learner profile attribute:** Inquirer
- **Approaches to learning:** Thinking skills — Providing a reasoned argument to support conclusions
- **Time required to complete activity:** 20 minutes
- **Activity type:** Individual activity

Competitive exclusion principle

This is the idea that two species cannot coexist if they have the same niche. The principle is demonstrated in this simulation (https://www.biologysimulations.com/post/competitive-exclusion-principle) by Biology Simulations.

Download the worksheet (https://docs.google.com/document/d/1JtfTuZj__Ei52VexOKtztWWhz0RnaNtF
complete the tasks using the instructions and guidance given in the worksheet.

5 section questions

B4. Form and function: Ecosystems / B4.2 Ecological niches

Summary and key terms

Section Student... (0/0) Feedback Print (/study/app/bio/sid-422-cid-755105/book/summary-and-key-terms-id-46628/print/) Assign

- The ecological niche of a species is dependent on biotic (living) and abiotic (non-living) interactions within an ecosystem; these may influence the growth, survival and reproduction of a species as well as how it obtains food.

Student view

- Organisms have various tolerances to the amount of oxygen present in their environment. They can be classified as obligate anaerobes (survive in the absence of oxygen), facultative anaerobes (can survive with or without oxygen) and obligate aerobes (must have oxygen for survival).
- Photosynthesis is the mode of nutrition in plants, algae and several groups of photosynthetic prokaryotes. Autotrophically, they are able to harness energy from the sun and convert it into chemical energy that can be used for metabolism.
- Animals are heterotrophs, engaging in holozoic nutrition, food is ingested, digested internally, absorbed and assimilated.
- Oceanic plankton and some protists, such as the Euglena, utilise mixotrophic nutrition. They are both autotrophic and heterotrophic, some mixotrophs are obligate and others are facultative.
- Saprotrophic nutrition is used in some fungi and bacteria. This involves the secretion of digestive enzymes followed by the absorption and assimilation of the organic compounds. This method of nutrition is common in decomposers.
- There are three domains of life – Eukarya, Bacteria and Archaea. The archaea are metabolically very diverse. Unlike the other domains, they may use either light, oxidation of inorganic chemicals or oxidation of carbon compounds to provide energy for ATP production.
- Since humans are holozoic, they need teeth to properly consume their meals. Scientists have used evidence found in fossils of members of the family Hominidae to establish a relationship between dentition and the diet of omnivores and herbivores.
- All organisms have adaptations necessary for survival. Herbivores are designed for eating plants. Predators and prey use chemical, physical and behavioural adaptations in the fight for survival. Additionally plants have many adaptations for harvesting the most light possible in their environment.
- Each organism has its own niche or role in an environment. Their fundamental niche is the potential role of a species based on their adaptations and tolerance limits while their realised niche is the actual niche the organism plays when in competition with other species. If two species occupy the same niche, competitive exclusion will occur potentially

eliminating one of the competing species or restrict both species to a part of their fundamental niche.

Key terms

Review these key terms. Do you know them all? Fill in as many gaps as you can using the terms in this list.

1. The of a species is dependent on biotic and abiotic interactions within an ecosystem.
2. lack a particular enzyme and this makes oxygen toxic to their survival.
3. Organisms that ingest their food, internally digest and assimilate it are called .
4. A type of organism that is able to utilise both autotrophic and heterotrophic modes of nutrition are called .
5. , on the other hand, secrete digestive enzymes onto their food source and then absorb the nutrients and assimilate them.
6. Members of the Domain are the most metabolically diverse group of organisms.
7. Thanks to scientists are able to establish modes of nutrition in the evolutionary history of hominids.
8. The of an organism is the potential role of a species based on their adaptations and tolerance limits.
9. The role an organism actually plays in its environment is called its .
10. Predators, prey, herbivores and plants all have acquired a variety of (thanks to evolution) in the hopes of their survival.

ecological niche | adaptations | Saprotrophs
realised niche | mixotrophs | Obligate anaerobes
fundamental niche | Archaea | holozoic | dentition

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Nutrition and Ecological Roles.

B4. Form and function: Ecosystems / B4.2 Ecological niches

Checklist

Section Student... (0/0) Feedback Print (/study/app/bio/sid-422-cid-755105/book/checklist-id-46629/print/) Assign

What you should know

After studying this subtopic you should be able to:

- Explain what biotic and abiotic interactions are and how they influence growth, survival and reproduction, including how a species obtains food.
- Explain the differences between obligate anaerobes, facultative anaerobes and obligate aerobes.
- Summarise the process of photosynthesis as the mode of nutrition in plants, algae and several groups of photosynthetic prokaryotes.
- Explain the various modes of holozoic, mixotrophic, saprotrophic nutrition.
- Give details of the diversity of nutrition in archaea.
- Summarise the relationship between dentition and the diet of omnivorous and herbivorous representative members of the family Hominidae.
- Infer the diet of several hominid species from anatomical features.
- Describe the adaptations of herbivores for feeding on plants and of plants for resisting herbivory.
- Describe the adaptations of predators for finding, catching and killing prey and of prey animals for resisting predation.
- Describe the adaptations of plants for harvesting light.
- Describe and explain the differences between the fundamental and the realised niches.

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- Explain the concept of competitive exclusion and the uniqueness of ecological niches.

B4. Form and function: Ecosystems / B4.2 Ecological niches

Investigation

Section Student... (0/0) Feedback Print (/study/app/bio/sid-422-cid-755105/book/investigation-id-46630/print/) Assign

- **IB learner profile attribute:** Inquirer
- **Approaches to learning:** Research skills – Comparing, contrasting and validating information
- **Time required to complete activity:** 45 minutes
- **Activity type:** Individual activity

Your task

Two million years before Charles Darwin and the crew of HMS Beagle set foot on the Galápagos Islands, a small group of finches flew 600 miles from South America to make their home on this fiery, volcanic archipelago. They arrived as one species. By the time the Beagle landed, the finches had evolved into more than a dozen species, distinct from each other in size, vocalisations and, most notably, beak shape.

Today, Darwin's finches are the classic example of adaptive radiation, the evolution of groups of plants or animals into different species adapted to specific ecological niches. On the Galápagos, finches evolved based on different food sources – long, pointed beaks served well for snatching insects while broad, blunt beaks work best for cracking seeds and nuts.

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This diversity of beak shapes is well studied from an evolutionary and biological perspective, but little is known about how these shapes came to be from a developmental, mathematical and physical perspective.

What is the niche of finches?

The ecological niches exert the selection pressures that push the populations in various directions. On various islands, finch species have become adapted for different diets: seeds, insects, flowers, the blood of seabirds and leaves. The ancestral finch was a ground-dwelling, seed-eating finch.

Research and present how the adaptations for finches relate to its niche in an ecosystem.

You can include:

1. Types of finches found on the Galápagos Islands
2. Ecological niche and the mode of nutrition for each type of finch
3. Adaptation/share of the beak that supports the mode of nutrition
4. For each form of nutrition, what are the unique inputs, processes and outputs?
5. Can different types of finches coexist?

Extend the research to answer:

What are the relative advantages of specificity and versatility of ecological niches on the Galápagos Islands that support the population of finches?

B4. Form and function: Ecosystems / B4.2 Ecological niches

Reflection

Student view

Section Student... (0/0) Feedback Print (/study/app/bio/sid-422-cid-755105/book/reflection-id-46880/print/) Assign

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Teacher instructions

The goal of this section is to encourage students to reflect on their learning and conceptual understanding of the subject at the end of this subtopic. It asks them to go back to the guiding questions posed at the start of the subtopic and assess how confident they now are in answering them. What have they learned, and what outstanding questions do they have? Are they able to see the bigger picture and the connections between the different topics?

Students can submit their reflections to you by clicking on 'Submit'. You will then see their answers in the 'Insights' part of the Kognity platform.

Reflection

Now that you've completed this subtopic, let's come back to the guiding questions introduced in The big picture (/study/app/bio/sid-422-cid-755105/book/big-picture-id-43537/).

- What are the advantages of specialised modes of nutrition to living organisms?
- How are the adaptations of a species related to its niche in an ecosystem?

With these questions in mind, take a moment to reflect on your learning so far and type your reflections into the space provided.

You can use the following questions to guide you:

- What main points have you learned from this subtopic?
- Is anything unclear? What questions do you still have?
- How confident do you feel in answering the guiding questions?
- What connections do you see between this subtopic and other parts of the course?

⚠ Once you submit your response, you won't be able to edit it.

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