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Teacher view



(https://intercom.help/kognity)



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C4. Interaction and interdependence: Ecosystems / C4.2 Transfers of energy and matter

# The big picture

## ? Guiding question(s)

- What is the reason matter can be recycled in ecosystems but energy cannot?
- How is the energy that is lost by each group of organisms in an ecosystem replaced?

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.



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Life on Earth takes on many different forms, and thrives in many different locations; even in places beyond human reach. Take, for example, the McMurdo Dry Valleys in Antarctica, known for being one of the coldest, driest, and windiest



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places on Earth. Despite such inhospitable conditions, scientists have discovered life in the form of microbial communities in the soil, subsurface ice, and even inside rocks. Similarly, in the dark depths of the ocean near hydrothermal vents, where sunlight cannot reach, extremophiles such as tube worms, giant clams, and certain bacteria thrive despite the intense pressure and high temperatures.



**Figure 1.** The McMurdo Dry Valleys in Antarctica.

Credit: copyright Jeff Miller, Getty Images

These bacterial communities, along with their nonliving environments, are what make up an ecosystem. Regardless of an ecosystem's size or type, its proper functioning relies on two fundamental processes: the flow of energy and the cycling of nutrients. Every organism, including humans, requires a continuous supply of energy for survival. But in such remote places like the McMurdo Valleys and deep-sea hydrothermal vents, the question arises: Where does the energy come from, and how is it transferred among organisms?

**Video 1** provides a glimpse into the world of hydrothermal vents and the unique organisms that have adapted to thrive in this challenging environment.



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## The Depths Below - Life on a Vent



### Video 1. Life at hydrothermal vents.

#### Prior learning

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

- The principles and reactions of cell respiration (see [subtopic C1.2](/study/app/bio/sid-422-cid-755105/book/big-picture-id-43538/) )
- The events that take place in photosynthesis (see [subtopic C1.3](/study/app/bio/sid-422-cid-755105/book/big-picture-id-43539/) )

C4. Interaction and interdependence: Ecosystems / C4.2 Transfers of energy and matter

## Flow of energy and matter

C4.2.1: Ecosystems as open systems    C4.2.2: Sunlight as the principal source of energy that sustains most ecosystems

C4.2.3: Flow of chemical energy through food chains    C4.2.4: Construction of food chains and food webs



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#### Learning outcomes

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



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- Explain the concept of ecosystems as open systems.
- Describe the role of sunlight in ecosystems.
- Outline the flow of energy through food chains and food webs.
- Construct food chains and food webs to represent feeding relationships in a community.

What would happen if the sun suddenly disappeared? Would life on Earth still continue? **Video 1** examines the hypothetical scenario of the sun's sudden disappearance and the profound consequences it would have on life as we know it.

What If the Sun Suddenly Disappeared?



**Video 1.** What if the sun suddenly disappeared?

## Ecosystems as open systems

Ecosystems consist of multiple communities interacting with their non-living, or abiotic, environment. Within an ecosystem, organisms transfer both energy and matter among themselves.



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**Matter** is defined as anything that occupies space and has mass. In the context of ecosystems, matter refers to nutrients, gases, and other substances that are essential for the functioning of living organisms. On the other hand, **energy** is the ability to perform work or cause change. In ecosystems, energy is required for various biological processes, such as growth, reproduction, and movement.

Thermodynamics is a branch of physics that deals with the study of energy transfers and transformations. In biology, thermodynamics helps us understand how energy flows through biological systems, such as in cells, organisms, and even ecosystems.

Thermodynamics classifies systems into three types: open, closed, and isolated. An **open system** allows both energy and matter to be exchanged with its surroundings. Ecosystems, such as tropical rainforests and grasslands, are examples of open systems due to the continuous inputs and outputs of energy and matter.

A **closed system** allows for the exchange of energy with the surrounding environment but restricts the flow of matter. This means that while energy can enter and exit the system, matter remains largely contained within. Closed systems are typically artificially created or rare in nature. A mechanical system, for example, a hair dryer, is considered a closed system as it requires energy input but the mass of the object remains fixed. Another example of a closed system includes mesocosms, which are controlled experimental environments designed to simulate natural ecosystems on a smaller scale for scientific purposes. [Section D4.2.4 \(/study/app/bio/sid-422-cid-755105/book/models-id-46658/\)](#) provides further details on the applications and elaboration of mesocosms.

**Isolated systems** are ideal systems in which neither energy nor matter are exchanged with the surroundings. These systems do not naturally occur in our everyday environment. An example of an isolated system is the universe itself, as it is often regarded as a closed system where no energy or matter can enter or

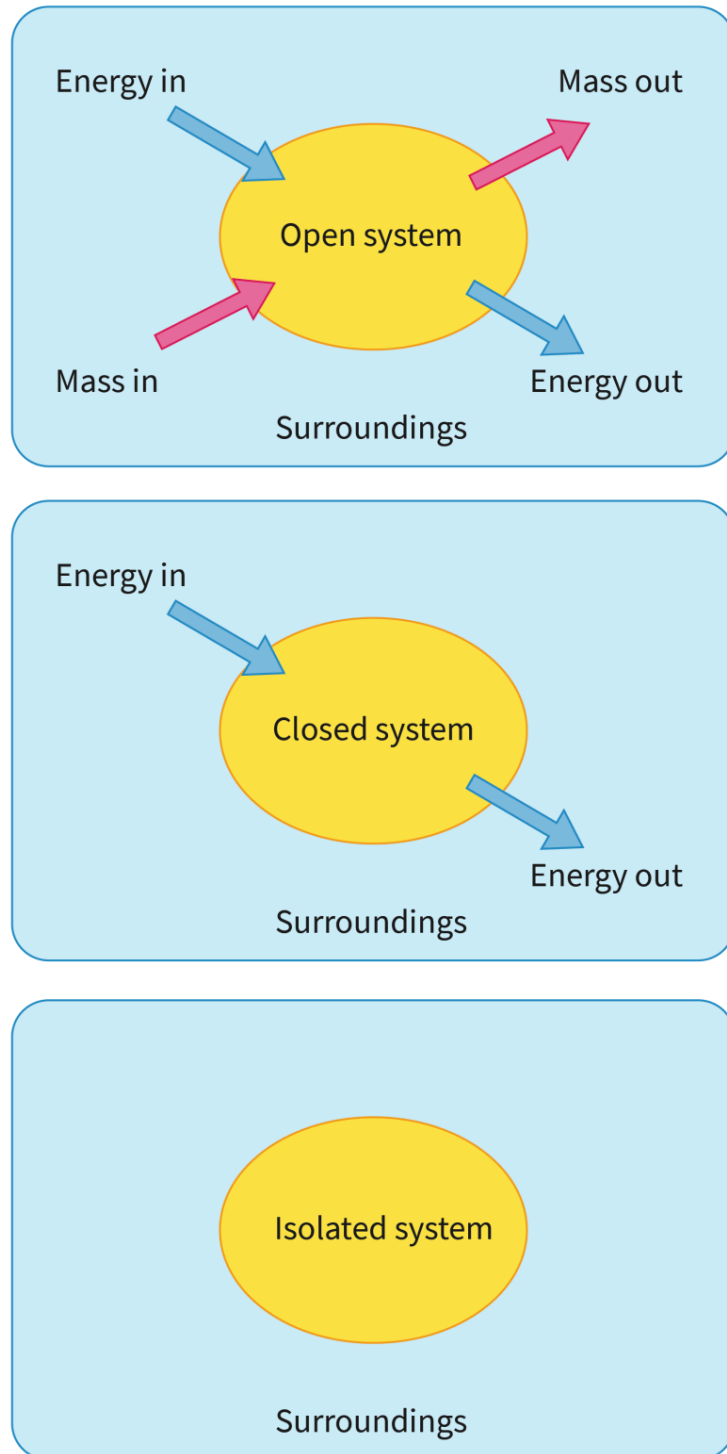


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leave. However, it is important to note that the concept of a truly isolated system is purely theoretical, as even the universe may interact with other external forces or systems that we have yet to fully understand.



**Figure 1.** The exchange of matter and energy across the boundary of open, closed, and isolated systems.

More information for figure 1



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The diagram illustrates three types of systems: open, closed, and isolated. Each system is represented as a yellow oval with the surrounding environment colored blue.



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### 1. Open System:

2. Located at the top, enclosed with arrows labeled "Energy in," "Mass in," "Energy out," and "Mass out." These arrows indicate that both energy and mass are exchanged with the surroundings.

### 3. Closed System:

4. Positioned in the middle, it has arrows labeled "Energy in" and "Energy out," signifying that only energy, not mass, is exchanged with the surroundings.

### 5. Isolated System:

6. At the bottom, there are no arrows, illustrating that neither energy nor mass is exchanged with the surroundings. It is a theoretical concept because such a system doesn't naturally occur.

Each system is depicted in a separate part of the diagram, with labels marking their respective interactions with the surroundings.

[Generated by AI]

## Energy flow in ecosystems

Energy is essential in ecosystems as it fuels the metabolic processes necessary for organisms to survive. This energy must be transferred among organisms to sustain life within the ecosystem. Sunlight serves as the primary source of energy that sustains most ecosystems on Earth. Through the process of photosynthesis, green plants and other photosynthetic organisms convert sunlight into chemical energy, which can be further utilised by other living organisms to survive. This is why plants are often referred to as **producers**, as they convert energy into a usable form to sustain other forms of life. Refer to [subtopic C1.3 \(/study/app/bio/sid-422-cid-755105/book/big-picture-id-43539/\)](/study/app/bio/sid-422-cid-755105/book/big-picture-id-43539/) to learn more details about the process of photosynthesis.



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The energy-rich organic compounds produced by plants are subsequently transferred through the food chain by feeding interactions. Herbivores consume plants, extracting energy from the stored organic compounds. Carnivores, in turn, feed on herbivores, continuing the transfer of energy up the food chain. This energy flow from one organism to another forms the foundation of food chains. Further details on feeding interactions and modes of nutrition can be found in [subtopic B4.2 \(/study/app/bio/sid-422-cid-755105/book/big-picture-id-43537/\)](/study/app/bio/sid-422-cid-755105/book/big-picture-id-43537/).

## Nature of Science

### Aspect: Theories

Unlike theories, which provide explanations for phenomena, laws focus on describing the observed patterns without delving into the underlying mechanisms. However, like theories, laws can be used to make predictions about future observations or outcomes. In the context of scientific inquiry, you should develop the ability to identify and outline the key features of useful generalisations, understanding their role in summarising and predicting natural phenomena.

**Video 2** further explains the differences between laws and theories.

What's the difference between a scientific law and theory? ...



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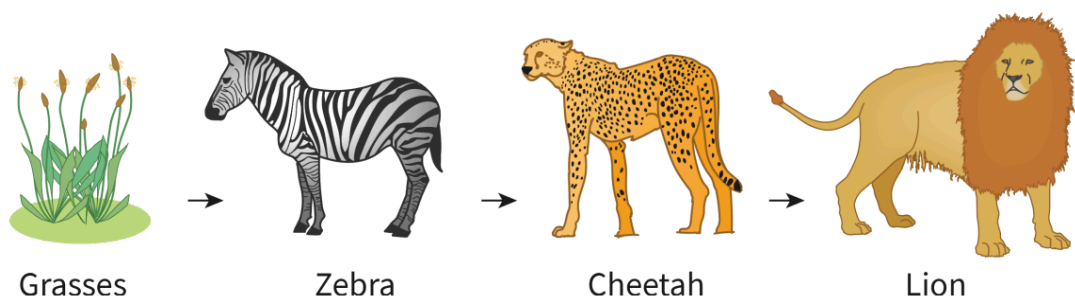
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## Video 2. What's the difference between a scientific law and a theory?

While sunlight is the primary source of energy for most ecosystems, it is important to acknowledge that some exceptions exist. Within environments characterised by limited or absent sunlight, such as caves and the deep ocean, organisms have evolved to depend on alternative energy sources. In these sunlight-limited environments, chemosynthetic organisms play a significant role. These specialised bacteria extract energy from inorganic compounds like minerals and sulfur, instead of relying on sunlight. Through the process of chemosynthesis, these bacteria convert inorganic molecules into organic compounds, effectively serving as the foundation for the food web within these particular ecosystems.

## Food chains and food webs

Food chains are models that illustrate the transfer of energy through a sequence of organisms in an ecosystem. In a food chain diagram, the arrows always indicate the direction in which energy and matter are flowing. **Figure 2** provides an example of a food chain within the grassland ecosystem of the African savannah.



**Figure 2.** Food chain of an African grassland ecosystem.

More information for figure 2

The image displays a food chain diagram of an African grassland ecosystem. It includes four main components: grasses, a zebra, a cheetah, and a lion. The diagram indicates the flow of energy through the ecosystem with directional arrows. The energy starts with grasses as the primary producers, followed by a zebra as the herbivore that consumes the grasses. Next, the cheetah is shown as the carnivore that



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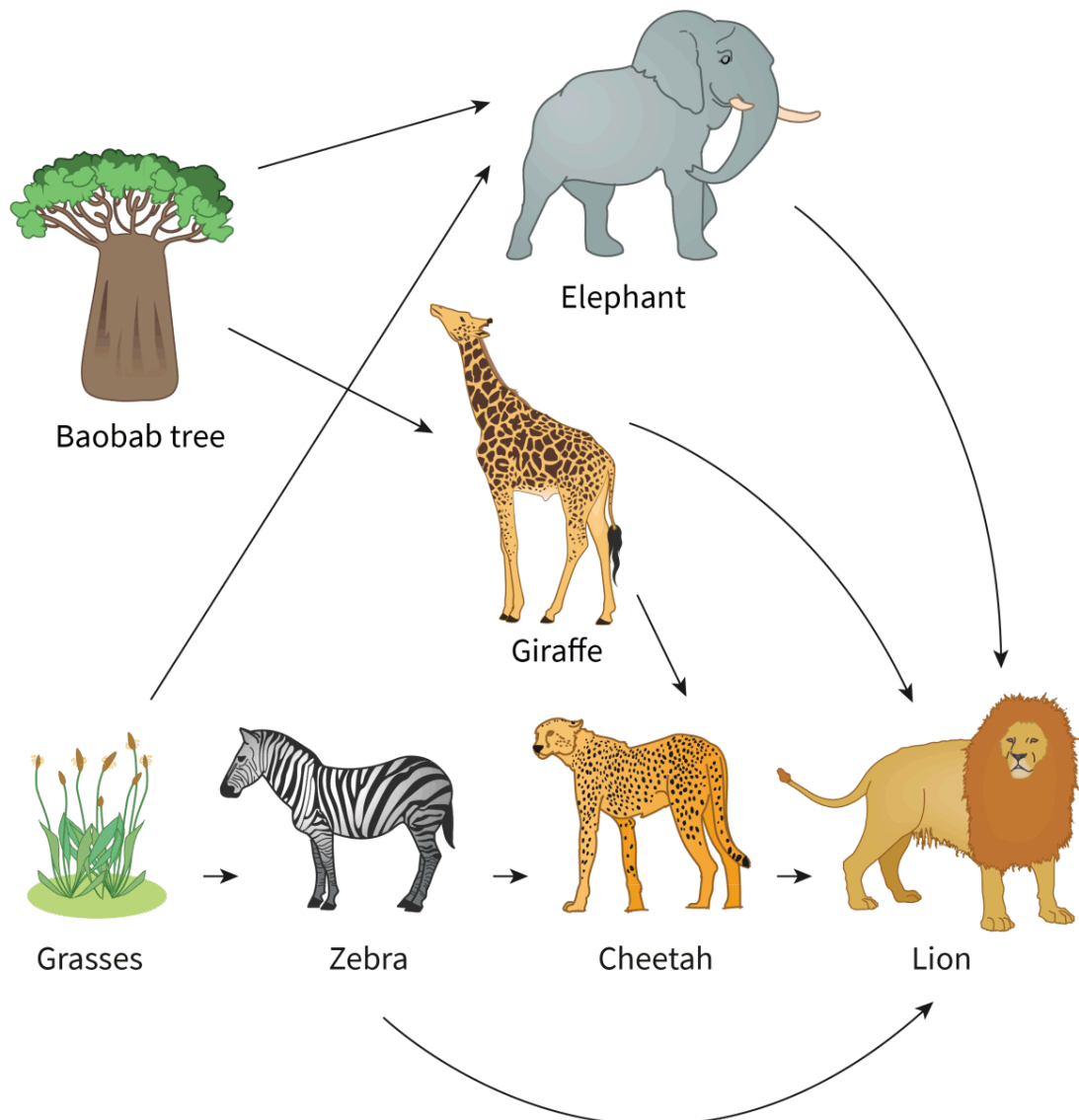
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preys on the zebra. Finally, the lion is depicted as an apex predator that may prey on the cheetah. Each organism is visually represented, and the directional arrows indicate the sequence and direction of energy transfer.

[Generated by AI]

While food chains are helpful in understanding energy transfers, they do not fully capture the complexity of feeding relationships that occur within an ecosystem.

**Food webs** are models that consist of many interconnected food chains. **Figure 3** represents a possible food web within the grassland ecosystem of the African savannah.



**Figure 3.** Food web of an African grassland ecosystem.



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[More information for figure 3](#)

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The image is a diagram representing a food web of an African grassland ecosystem. It includes various species with arrows indicating feeding relationships. Starting from the bottom left, there are grasses which are consumed by zebras. The zebras are prey for cheetahs, and both cheetahs and zebras are prey for lions. Additionally, baobab trees are eaten by elephants and giraffes. There are arrows pointing from the baobab tree to both the elephant and the giraffe, indicating them as consumers. Lastly, there are arrows leading from both the cheetah and the zebra to the lion, showing that the lion is a top predator in this ecosystem.

[Generated by AI]

Performing the following activity will help you gain a better understanding of food chains and the complex feeding relationships that occur within an ecosystem.



## Activity

- **IB learner profile attribute:** Inquirer
- **Approaches to learning:** Thinking skills — Designing procedures and models
- **Time required to complete activity:** 20 minutes
- **Activity type:** Pair activity

### Introduction

In this activity, you and a partner will construct a food chain and a food web using local examples as the focal point. Your findings can be presented in any format that shows your creativity while maintaining scientific accuracy.

### Your task

1. Begin by selecting a non-human organism from your local community. It could be a plant, an animal, or even a microorganism. Take some time to research and gather information



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about its characteristics, habitat, diet, predators, and any symbiotic relationship it may have.

2. Using your chosen organism as the starting point, create a food chain that effectively demonstrates the flow of energy within its ecosystem. Identify at least three other organisms that are involved in the transfer of energy. For each organism, include its name and specify its role in the food chain (producer, carnivore, omnivore, etc.)
3. Expand your food chain by identifying additional species that feed on the organisms already present in your food chain. Include these new relationships to create a comprehensive food web.

### Questions

1. Create a table like **Table 1** to compare and contrast the effectiveness of food chains and food webs in representing energy transfers within an ecosystem. Use the example below as a guide to highlight the strengths and weaknesses of each model.

**Table 1.** Food chains and food webs: strengths and weaknesses

	Food chains	
Advantages		
Disadvantages		

## 5 section questions ▾

C4. Interaction and interdependence: Ecosystems / C4.2 Transfers of energy and matter

# Autotrophs and heterotrophs

C4.2.5: Supply of energy to decomposers

C4.2.6: Autotrophs

C4.2.7: Photoautotrophs and chemoautotrophs

C4.2.8: Heterotrophs



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## Learning outcomes

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

- Describe the role of decomposers in nutrient cycling.
- Distinguish between autotrophic and heterotrophic modes of nutrition.

All organisms require some form of nutrients to obtain the energy necessary for survival. While it is common knowledge that animals acquire their energy by consuming other organisms, have you ever wondered how organisms like plants and fungi ‘feed’? Moreover, what happens to an organism’s biomass and nutrients once it dies? This section will explore the different modes through which organisms obtain and utilise nutrients essential for survival.

## Decomposers

Organisms known as **decomposers** play a crucial role in ecosystem processes by breaking down dead organisms and organic matter. Such organisms, which include bacteria, fungi, and invertebrates, can extract energy and nutrients from decaying materials such as leaf litter, wood, animal carcasses, and even animal faeces. Without decomposers, the world would be filled with a massive accumulation of dead plant material, deceased animals, and animal waste, likely making ecosystems unsustainable.

When an organism dies, decomposers begin the process of decomposition. Through the secretion of enzymes, they break down complex organic compounds into simpler molecules. These enzymatic reactions enable them to obtain energy and nutrients for their own survival while simultaneously releasing essential nutrients back into the environment. These nutrients released during decomposition, such as carbon, nitrogen, and phosphorus, become readily available for plants to acquire, supporting their own growth and development.



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Saprotrophs are decomposers that obtain organic nutrients from dead organisms through external digestion. These organisms secrete hydrolytic enzymes (see [section B1.1.1–3 \(/study/app/bio/sid-422-cid-755105/book/chemical-bonding-andpolymerisation-id-44681/\)](/study/app/bio/sid-422-cid-755105/book/chemical-bonding-andpolymerisation-id-44681/)) that break down complex organic compounds into simpler molecules. Once molecules are broken down, saprotrophs absorb and assimilate the nutrients into their own body tissues. Some examples of saprotrophic organisms include fungi and bacteria. Refer to [section B4.2.3–7 \(/study/app/bio/sid-422-cid-755105/book/types-of-nutrition-id-46625/\)](/study/app/bio/sid-422-cid-755105/book/types-of-nutrition-id-46625/) for a more comprehensive understanding of saprotrophic nutrition.



**Figure 1.** The fungus *Amanita muscaria*, like many other fungi, serves as an example of a saprotroph.

Credit: Jacky Parker Photography, Getty Images

Detritivores are decomposers that obtain nutrients from detritus by internal digestion. Unlike saprotrophs, detritivores directly ingest and consume dead organic matter, breaking it down internally using digestive enzymes. Some examples of detritivores include earthworms, millipedes, sowbugs, dung beetles, and certain species of snails and slugs.



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**Figure 2.** Dung beetles (*Scarabaeus sacer*) are detritivores that feed on animal faeces..

Credit: Paul Souders, Getty Images

Decomposers play an essential role in maintaining the balance and sustainability of ecosystems due to their ability to cycle nutrients.

## Autotrophs

Autotrophs, also known as primary producers, are organisms capable of synthesising organic molecules from inorganic ones using an external energy source. Like decomposers, autotrophs also play a vital role in ecosystem functioning by producing organic matter that serves as a source of energy and nutrients for other organisms in the community.

The chemical reactions that allow autotrophs to produce their own food are anabolic, so they require an energy input to occur. In the majority of autotrophs, this energy is acquired from sunlight, however other energy sources do exist. Examples of essential anabolic reactions that autotrophs perform include carbon fixation (see [section C1.3.15–17 \(/study/app/bio/sid-422-cid-755105/book/calvin-cycle-hl-id-46522/\)\)](#) and the synthesis of macromolecules.



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# Photoautotrophs

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Photoautotrophs are organisms that use light as an external source of energy to synthesise organic compounds from inorganic molecules. These include plants, algae, and certain bacteria. Most photoautotrophs derive their energy through the process of photosynthesis, which involves converting sunlight, carbon dioxide, and water into glucose and other organic compounds. Refer to [subtopic C1.3](#) ([/study/app/bio/sid-422-cid-755105/book/big-picture-id-43539/](#)) to read details about the process of photosynthesis.

## Chemoautotrophs

Chemoautotrophs are organisms that obtain energy through the oxidation of inorganic compounds, including iron, sulfur, and magnesium. These oxidation reactions release energy that is utilised for carbon fixation and the synthesis of macromolecules. Chemoautotrophs are predominantly bacteria or protozoa typically found in hostile environments, such as deep-sea hydrothermal vents and sulfur-rich hot springs.

An example of a chemoautotroph are the iron-oxidising bacteria. These bacteria are found in iron-rich environments, such as acidic mine drainage or iron-rich soil. By oxidising iron, they convert the released energy into a usable form for synthesising organic compounds. Iron-oxidising bacteria are essential contributors to the cycling of iron and other elements in ecosystems and their presence significantly influences nutrient dynamics.

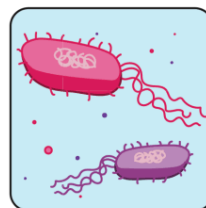
An autotroph is an organism that produces its own food:



Plants



Algae



Some bacteria



Phytoplankton

**Figure 3.** Examples of autotrophic organisms.



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# Heterotrophs

**Heterotrophs** are organisms that cannot produce their own organic molecules and rely on consuming other organisms or organic matter to obtain energy and nutrients for survival. They are often referred to as **consumers** because they depend on consuming other organisms to survive. Examples of heterotrophs include herbivores, carnivores, omnivores and decomposers.

Heterotrophs obtain energy by breaking down complex organic compounds derived from autotrophs or other heterotrophs. They rely on external or internal digestion to break down complex organic compounds, such as proteins and nucleic acids.

**External digestion** is typically observed in organisms like fungi and some bacteria. These organisms release hydrolytic enzymes into their surrounding environment to break down complex organic compounds present in their food. Once nutrients are broken down, they are readily absorbed by the organism.

**Internal digestion** occurs in most heterotrophs, including animals. It involves the ingestion of food, and digestion takes place within specialised organs, such as the stomach and intestines. These smaller molecules are absorbed through the intestinal lining and transported to the cells for assimilation.

Regardless of the mode of digestion, all heterotrophs use the nutrients obtained from their food as building blocks to construct molecules required for their own growth and reproduction. This involves the synthesis of essential organic molecules like proteins, nucleic acids, and lipids. These newly synthesised carbon compounds are then utilised to support metabolic activities and provide energy essential for biological functions.



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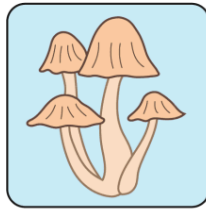


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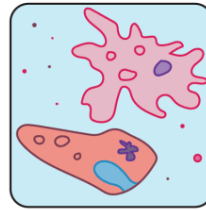
A heterotroph is an organism that does not make its own food:



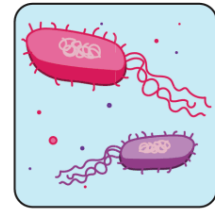
Animals



Fungi



Most protozoa



Most bacteria

**Figure 4.** Examples of heterotrophic organisms.

More information for figure 4

The image consists of four illustrations each representing different types of heterotrophic organisms. The text at the top reads, "A heterotroph is an organism that does not make its own food:" Below this text are four panels. Starting from the left, the first panel shows an illustration of a zebra labeled "Animals." Next, there is a panel with an illustration of two mushrooms labeled "Fungi." The third panel contains an illustration of a pink protozoan with various cell structures called out, labeled "Most protozoa." The last panel on the right shows two bacterial cells, one round and one rod-shaped, with flagella-like structures, labeled "Most bacteria." These representations are all set against a light blue background.

[Generated by AI]

Some organisms have the unique ability to acquire nutrients through both autotrophic and heterotrophic means, known as mixotrophs (see [section B4.2.3–7 \(/study/app/bio/sid-422-cid-755105/book/types-of-nutrition-id-46625/\)\)](#). An example of a well-known mixotroph is the Venus flytrap (*Dionaea muscipula*), a carnivorous plant that can capture small insects for nutrients while also performing photosynthesis. Watch **Video 1** for a glimpse of a Venus flytrap plant trapping an insect.



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## Venus Flytrap Eats Wasps || ViralHog



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### Video 1. A Venus Flytrap Capturing a Small Insect.

More information for video 1

An interactive video displays how a Venus flytrap plant (*Dionaea muscipula*) catches a wasp.

The video begins with a close-up view of several Venus flytrap plants, highlighting their hinged traps. Each trap consists of two lobes with spine-like teeth lining the edges. The interiors of the lobes in some of the plants are red, while in others, both the interior and spikes are red. The coloring in the plants helps to attract prey.

As the video progresses, a wasp is seen to enter into the trap of a Venus plant. After some time as the wasp exits the plant, the two lobes of the plant come closer slowly and lock in with the spikes on either side showing the users how the trapping is done.

As the video progresses, a wasp flies in and lands inside one of the traps, which contains a drop of water and spines on the inner surfaces of the lobes. While the wasp drinks the water, the trap snaps shut, trapping the wasp inside. The video then shows the wasp struggling to escape, but the interlocking spines and the closed lobes prevent it from getting out.

In one instance, it is shown how a wasp escapes the trap of the Venus plant.

This video highlights how Venus flytrap plants detect and capture prey and obtain nutrition from it.

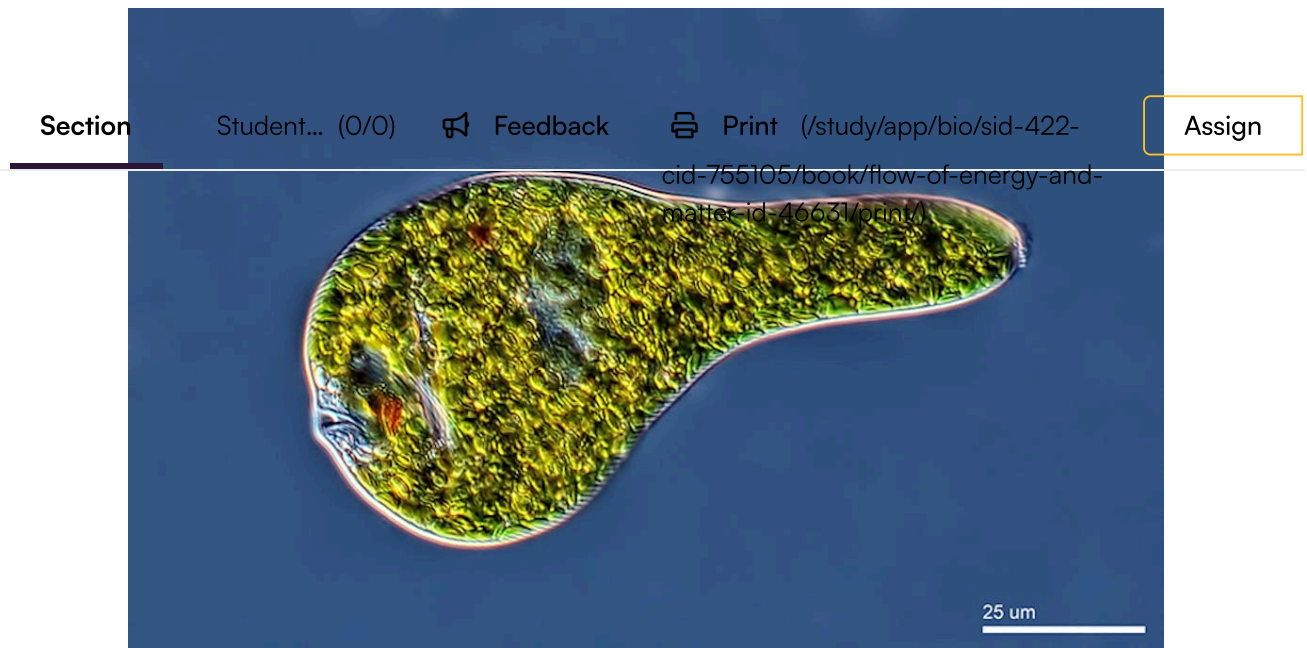


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Another example of a mixotroph is the *Euglena* algae, which are single-celled organisms capable of synthesising organic molecules using light as an energy source. However, they can also supplement their nutrient intake by ingesting other organisms or organic matter. The versatility of mixotrophs allows them to adapt to various environmental conditions and optimise their nutrient acquisition strategy based on resource availability.



**Figure 5.** *Euglena gracilis*, an organism that is both autotrophic and heterotrophic.

Source: "Euglenoid movement

([https://commons.wikimedia.org/wiki/File:Euglenoid\\_movement.jpg](https://commons.wikimedia.org/wiki/File:Euglenoid_movement.jpg))" by Rogelio Moreno is in the public domain

## Theory of Knowledge

**How does language impact the acquisition and communication of knowledge?**

In the field of biology, precise and accurate language is crucial in describing and categorising different organisms and their characteristics. However, it is important to recognise that sometimes language can fall short in capturing the full complexity of scientific concepts. Nuances and limitations can arise that go beyond the scope of



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language, leading to potential ambiguities or multiple interpretations. As a result, ongoing debates and revisions in scientific understanding occur as scientists strive to refine and expand their knowledge.

Try **Interactive 1** where you need to drag and drop the labels into the correct place to describe the different methods of nutrition.

**Drag and drop each of the concepts into their corresponding blank space.**

1. \_\_\_\_\_ are organisms that derive their energy from oxidation reactions and do not rely on sunlight as an energy source.
2. Organisms that obtain energy by consuming other organisms or organic matter are called \_\_\_\_\_.
3. \_\_\_\_\_ play a crucial role in breaking down dead organisms and releasing nutrients back into the ecosystem.
4. Organisms that use light as an external energy source for their metabolic processes are called \_\_\_\_\_.
5. \_\_\_\_\_ are organisms that synthesise organic molecules from inorganic ones using an external energy source.
6. \_\_\_\_\_ are organisms that can acquire nutrients through both autotrophic and heterotrophic means.

heterotrophs

decomposers

mixotrophs

autotrophs

chemoautotrophs

photoautotrophs

✓ Check

### Interactive 1. Classifying Organisms by Energy Sources.

The following activity will help you apply the concepts covered in this section by investigating the different modes of nutrition of organisms found within your local environment.



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## Activity

- **IB learner profile attribute:** Inquirer
- **Approaches to learning:** Thinking skills — Being curious about the natural world
- **Time required to complete activity:** 30 minutes
- **Activity type:** Individual/pair activity

In this activity, you will have the opportunity to explore the different modes of nutrition among organisms in your local environment. Before you begin, make sure you have a clear understanding of the definitions for autotrophs, heterotrophs, mixotrophs, and decomposers. By examining these energy sources, you will gain insights into the dynamics of the ecosystem in your local environment.

### Materials

- Mobile phone or photo device with a camera
- Internet access
- Field guides or other resources for organism identification in your area
- **iNaturalist**  (<https://www.inaturalist.org/>) app or website (optional)
- Presentation software (such as PowerPoint, Google Slides, Keynote, or any preferred software)

### Your task

1. With the permission of your parent or guardian, go for a walk in your neighbourhood or a nearby area where you might encounter different kinds of organisms. Take a mobile phone or photo device with you.
2. During your walk, observe and photograph at least 8 different organisms. Try to capture a wide range of organisms, including plants, animals, insects and any other living things you come across. Take clear pictures, focusing on capturing details that will help with identification later.
3. Upon returning home, use field guides or any reliable resource specific to your local area to identify each of the organisms you



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photographed. You can also explore the option of using the iNaturalist app, which assists in organism identification using pictures.

4. After identifying each organism, investigate how it obtains its energy. Consider whether it is an autotroph, heterotroph, mixotroph, or decomposer.
5. Create a presentation using your preferred presentation software. Include:
  - Title slide.
  - One slide showcasing the photos of autotrophs you found. For each organism, include its common and scientific name, and its main sources of nutrients.
  - One slide showcasing the photos of heterotrophs you found. For each organism, include its common and scientific name, its main sources of nutrients, and specify if any autotrophic decomposers were found.
  - One slide showcasing the photos of mixotrophs that you found, if any.
6. Design your presentation creatively to make it visually appealing.
7. Optional: Share your digital presentation with your classmates, present it to the class, or consider sharing it on a class website or discussion forum.

## Questions

1. Reflecting on the organisms you encountered, what would be the potential impact on the ecosystem if a particular group of organisms, such as autotrophs or decomposers, were to significantly decline in population?
2. Why are autotrophs and decomposers essential for the functioning of an ecosystem? How does their importance compare to that of heterotrophs?

## 5 section questions ▾



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C4. Interaction and interdependence: Ecosystems / C4.2 Transfers of energy and matter



# Trophic levels

Overview

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C4.2.9: Release of energy by oxidation of carbon compounds in cell respiration

C4.2.10: Classification of organisms into trophic levels      C4.2.11: Construction of energy pyramids



## Learning outcomes

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

- Classify organisms into trophic levels based on their position in a food chain or food web.
- Construct an energy pyramid based on ecological data.

Have you ever wondered how living organisms obtain energy from the food they consume? How is this energy distributed and transferred within an ecosystem? While matter is cycled in an ecosystem, energy follows a different path. Instead of being recycled, it flows through the ecosystem, continuously entering and exiting. In this section, we will explore the flow of energy among different organisms in an ecosystem.

## Release of energy by cell respiration

Cell respiration is a vital and shared process among both autotrophs and heterotrophs. This process involves the oxidation of carbon compounds, where organisms can extract energy from organic molecules and convert it into a usable form, predominantly adenosine triphosphate (ATP). However, not all of the energy released during cell respiration is captured in the form of ATP. A portion of the energy is lost as heat, which dissipates into the surrounding environment. This heat loss is a natural consequence of the energy conversion process and is a result of the inefficiencies in energy transfer and utilisation within living systems.

[Subtopic C1.2 \(/study/app/bio/sid-422-cid-755105/book/big-picture-id-43538/\)](/study/app/bio/sid-422-cid-755105/book/big-picture-id-43538/) covers the process of cellular respiration in more detail.



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# Trophic levels

Overview

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In ecology, trophic levels represent an organism's position in a food chain or a food web, defining its role in energy transfer.

The first trophic level is occupied by **producers**, such as plants, algae, and some bacteria. As mentioned in [section C4.2.5–8 \(/study/app/bio/sid-422-cid-755105/book/autotrophs-and-heterotrophs-id-46632/\)](/study/app/bio/sid-422-cid-755105/book/autotrophs-and-heterotrophs-id-46632/), these organisms use an external energy source, such as sunlight, to convert inorganic molecules into organic compounds, serving as the foundation of energy for the entire ecosystem. These organisms occupy the base of the food chain, providing food and nutrients for all the trophic levels that follow.

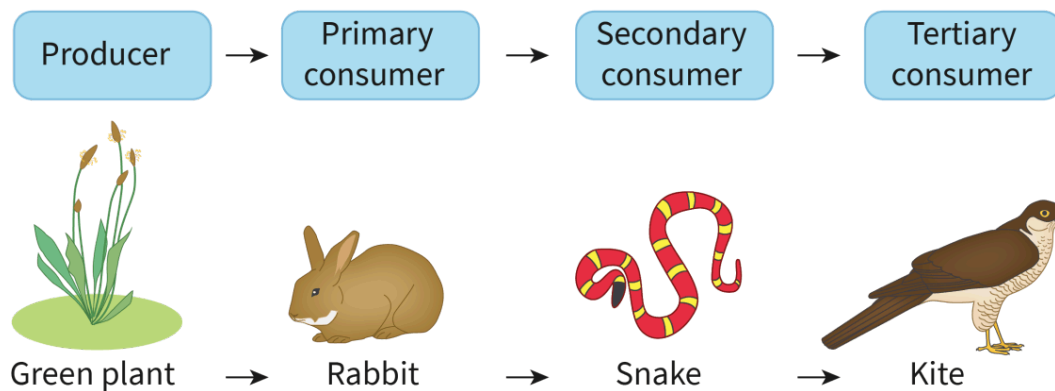
The second trophic level consists of **primary consumers**. These organisms are herbivores or omnivores that directly consume producers to obtain energy. Examples of primary consumers include insects, small mammals, and some birds. As primary consumers, they occupy the second trophic level and play an important role in transferring energy from producers to higher-level consumers.

The third trophic level consists of **secondary consumers**. These organisms feed on primary consumers as their main source of energy. Secondary consumers feed on herbivores or omnivores and transfer energy to higher trophic levels. Examples of secondary consumers include larger mammals, certain predatory birds, and some reptiles.

Finally, at the top of the food chain, we find the **tertiary consumers**. These top-level predators feed on other organisms, including both primary and secondary consumers. They represent the highest trophic level in a food chain, and their diet typically consists of large predators or other top-level consumers. Examples of tertiary consumers include large carnivores like lions, tigers, and killer whales.



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**Figure 1.** Trophic levels in a food chain.

 More information for figure 1

The diagram illustrates a food chain, depicting different trophic levels in a linear sequence. It begins with the "Producer," represented by a green plant. An arrow points to the "Primary consumer," which is illustrated by a rabbit. The next arrow points to the "Secondary consumer," represented by a snake. Finally, an arrow points to the "Tertiary consumer," depicted by a hawk or kite. Each stage in the food chain indicates flow of energy as one organism consumes another, moving from plants to various levels of consumers.

[Generated by AI]

While categorising organisms into trophic levels simplifies how we see energy transfers in ecosystems, it is important to note that some organisms can occupy more than one trophic level in different food chains. Certain species may display dietary flexibility, allowing them to adapt their feeding habits based on the availability of food sources. Omnivores, which feed on both plants and animals, can be considered both primary and secondary consumers.

## Pyramids of energy

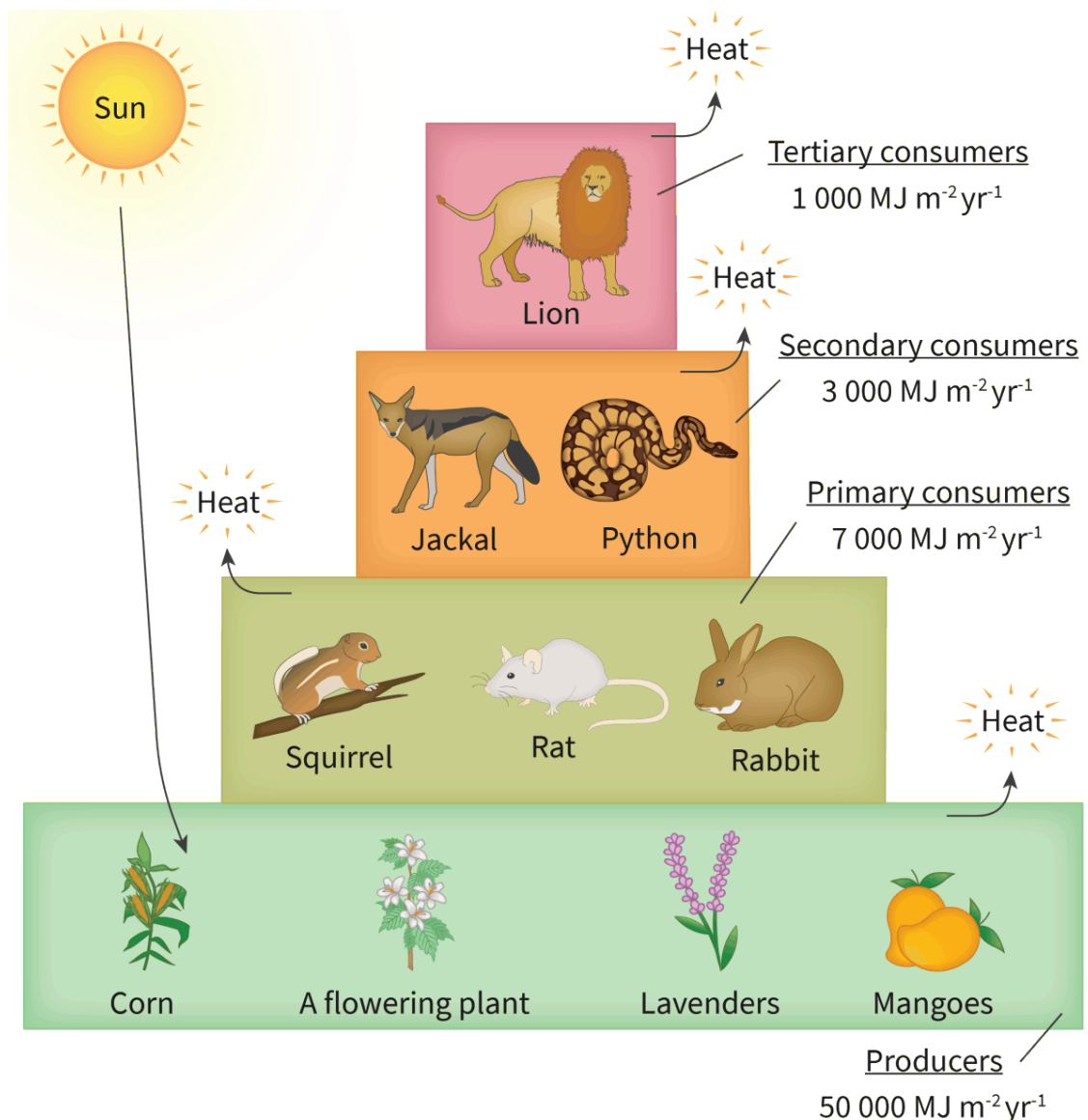
The term biomass refers to the total dry mass of a group of organisms in a specific area or volume. It is measured in units of mass per unit area, such as grams per square metre. Since the tissues of organisms are composed of organic compounds which contain energy, biomass inherently contains energy.



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Obtaining the biomass of organisms is a challenging process that often raises ethical concerns. Measuring biomass requires organisms to be completely dehydrated, hence they do not survive the process. However, measuring biomass in a food chain over time enables ecologists to estimate the energy availability at each trophic level and assess the efficiency of energy transfers. This allows scientists to compare energy transfer efficiencies between ecosystems and gain insights into the functioning of different ecological systems.

The amount of energy available at each trophic level can be represented by using an **energy pyramid**. In energy pyramids, each trophic level is represented by a horizontal bar, which indicates the amount of energy units per area per time (e.g.  $\text{kJ m}^{-2} \text{ year}^{-1}$ ). When constructing energy pyramids, it is essential that the length of each bar is drawn to scale to accurately represent the amount of energy at each trophic level.



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**Figure 2. Pyramid of energy for a typical grassland ecosystem.**

More information for figure 2

The diagram is an energy pyramid for a typical grassland ecosystem. At the base of the pyramid are the 'Producers,' which include corn, a flowering plant, lavenders, and mangoes, providing  $50,000 \text{ MJ m}^{-2} \text{ yr}^{-1}$  of energy. Next level features 'Primary consumers,' such as a squirrel, rat, and rabbit, with  $7,000 \text{ MJ m}^{-2} \text{ yr}^{-1}$  of energy. Above them are 'Secondary consumers,' represented by a jackal and a python, with  $3,000 \text{ MJ m}^{-2} \text{ yr}^{-1}$  of energy. At the top are 'Tertiary consumers,' characterized by a lion, with  $1,000 \text{ MJ m}^{-2} \text{ yr}^{-1}$  of energy. The sun is shown as the energy source, and heat is depicted as being lost at each level.

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As you can observe from **Figure 2**, a significant amount of the energy available at each trophic level is not efficiently transferred to the next level. This results in a decrease in available energy at each successive trophic level. As a result, energy pyramids always take the shape of a stepped pyramid. Section C4.2.12–14 (</study/app/bio/sid-422-cid-755105/book/energy-losses-id-46634/>) provides a more detailed explanation of the sources and factors contributing to these large energy losses.

## Constructing pyramids of energy

To construct an energy pyramid, begin by gathering data on the biomass or energy content of organisms at each trophic level over a specific time period within a particular ecosystem. This data can be obtained through scientific studies or ecological surveys. Once you have collected the data, organise it in a hierarchical manner to represent each trophic level as a horizontal bar in the pyramid. Ensure that the bars are drawn to scale and include appropriate units. For a more detailed explanation of the process of constructing energy pyramids, watch **Video 1**.

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## IB Biology-Constructing a Pyramid of Energy



### **Video 1.** Overview of trophic level pyramids.

The activity below can help you practise constructing an energy pyramid.



### **Activity**

- **IB learner profile attribute:** Inquirer
- **Approaches to learning:** Thinking skills — Designing procedures and models
- **Time required to complete activity:** 30 minutes
- **Activity type:** Individual activity

In this activity, you will have the opportunity to construct energy pyramids based on real ecological data from specific ecosystems. Energy pyramids represent the flow of energy and the amount of energy available at each trophic level in a food chain or food web. Your model can be presented in any creative format of your choice while ensuring scientific accuracy is maintained.

### **Your task**

1. **Research:** Start by selecting a specific ecosystem or habitat that interests you. It could be a forest, grassland, marine ecosystem, or any other ecosystem of your choice.



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2. **Data collection:** Find reliable sources, such as scientific articles, research papers, or ecological studies, that provide data on the amount of energy or biomass at different trophic levels within your chosen ecosystem. Look for information on producers, primary consumers, secondary consumers, and tertiary consumers. You may consider using Google Scholar, which is an open resource where you can find peer-reviewed academic articles and research papers.
3. **Analysis:** Analyse the data and determine the energy transfer between trophic levels. Calculate the percentage of energy transfer efficiency between trophic levels. This can be done by dividing the energy available at a higher trophic level by the energy available at the trophic level below it and multiplying by 100.
4. **Construct the energy pyramid:** Using the data you collected, create an energy pyramid for your chosen ecosystem. You can choose to represent your energy pyramid in any creative format of your choice. Start with the primary producers at the base of the pyramid and build upward, making sure that each level is accurately represented to scale. Your pyramid must include the following aspects:
  - (a) A descriptive title
  - (b) Horizontal bars drawn to scale, representing each trophic level
  - (c) Appropriate labels, numbers, and units for each trophic level
  - (d) Energy transfer efficiency between levels
  - (e) List of sources with appropriate citations
5. **Discuss:** Once your energy pyramid is completed, compare your model with your classmates and discuss changes in energy efficiencies between different ecosystems.

### Questions

1. What are the factors that influence the energy available at the first trophic level?
2. What factors influence energy transfer efficiency in different ecosystems?



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C4. Interaction and interdependence: Ecosystems / C4.2 Transfers of energy and matter

# Energy losses

C4.2.12: Energy losses between trophic levels    C4.2.13: Heat loss to the environment during cell respiration

C4.2.14: Restrictions on number of ecosystem trophic levels due to energy losses



## Learning outcomes

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

- Explain the factors that contribute to energy losses in food chains.
- Outline the causes and consequences of heat dissipation in food chains.
- Describe the factor that restricts the number of trophic levels in a food chain.

As we examine food chains and trophic pyramids, it becomes apparent that the transfer of energy between trophic levels is highly inefficient. This inefficiency arises from significant energy losses as it progresses through the trophic levels. On average, only about 10% of the energy stored as biomass is actually passed on to the next trophic level. However, this percentage varies among ecosystems as primary production relies on climatic conditions like temperature and precipitation. If we assume that the rule of 10% is true, where does the other 90% of energy actually go?

## Energy losses in food chains

According to the law of conservation of energy, energy cannot be created or destroyed but it can only be converted from one form to another. This principle applies to living systems as well. Energy losses between trophic levels occur due to several factors, including:



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- **Incomplete consumption:** Organisms often do not consume all parts of the organism they feed on, resulting in uneaten biomass. For example, a predator feeding on its prey may consume the most nutritious or easily digestible parts while leaving behind certain organs, bones, or tough tissues. This uneaten biomass may then go through the process of decomposition, as described in [section C4.2.5–8 \(/study/app/bio/sid-422-cid-755105/book/autotrophs-and-heterotrophs-id-46632/\)](/study/app/bio/sid-422-cid-755105/book/autotrophs-and-heterotrophs-id-46632/).
- **Inefficient digestion:** Organisms are unable to absorb all the energy contained in the consumed food during digestion. This leads to a significant amount of biomass being released as waste, such as faeces.
- **Inefficient energy conversion and storage:** Not all energy obtained from food is efficiently converted and stored in the organism's tissues.
- **Used in metabolic processes:** Organisms use energy for their own metabolic processes, including respiration, movement, and growth.
- **Heat dissipation:** Energy dissipates as heat as a consequence of cellular respiration and other metabolic reactions, as discussed in the upcoming text.

Although decomposers and detritus feeders are not typically included as part of food chains, they play a vital role in the energy transformations that occur within an ecosystem. As covered in [section C4.2.1–4 \(/study/app/bio/sid-422-cid-755105/book/flow-of-energy-and-matter-id-46631/\)](/study/app/bio/sid-422-cid-755105/book/flow-of-energy-and-matter-id-46631/), these organisms obtain their energy from the breakdown of complex organic matter derived from dead organisms and waste materials. During this process, they release simple inorganic compounds back into the environment, making these available for use by other organisms, such as producers.

## Heat loss

When energy is being transformed from one form into another, the conversion is never 100% efficient. This principle applies to both mechanical and biological systems. In cell respiration, organisms use the chemical energy stored in organic compounds, such as glucose, and convert it into ATP. However, not all of the chemical energy can be fully captured and converted into ATP. As a result, some

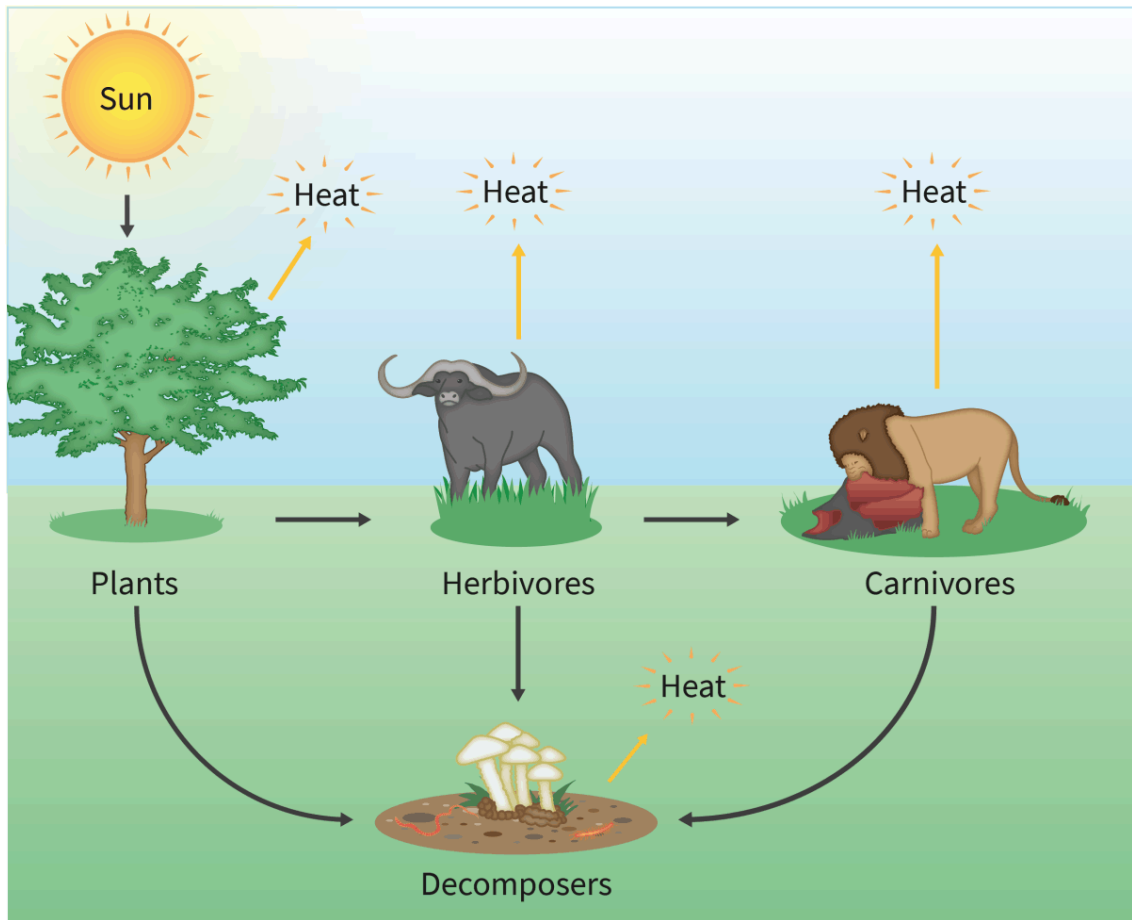


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energy is inevitably lost as heat. Since living organisms cannot utilise heat as a source of energy, we say that this energy is 'lost' from ecosystems as it dissipates into the surrounding environment.



**Figure 1.** A simplified energy flow.

More information for figure 1

The diagram illustrates the flow of energy in an ecosystem. At the top left, the sun emits energy, which is absorbed by plants labeled "Plants." An arrow directs from the sun to the plants, indicating the transfer of solar energy. The plants transfer energy to herbivores, depicted as a buffalo eating grass, with an arrow pointing from the plants to the herbivores. Alongside this transition, a small icon labeled "Heat" shows that some energy is lost as heat. Next, the herbivores transfer energy to carnivores, shown as a lion eating. Again, an arrow points from the herbivores to the carnivores with a nearby "Heat" label. Below, decomposers, illustrated with mushrooms and worms, receive energy from both plants and carnivores, shown by arrows pointing from these sources to the decomposers as heat loss is indicated throughout the process.



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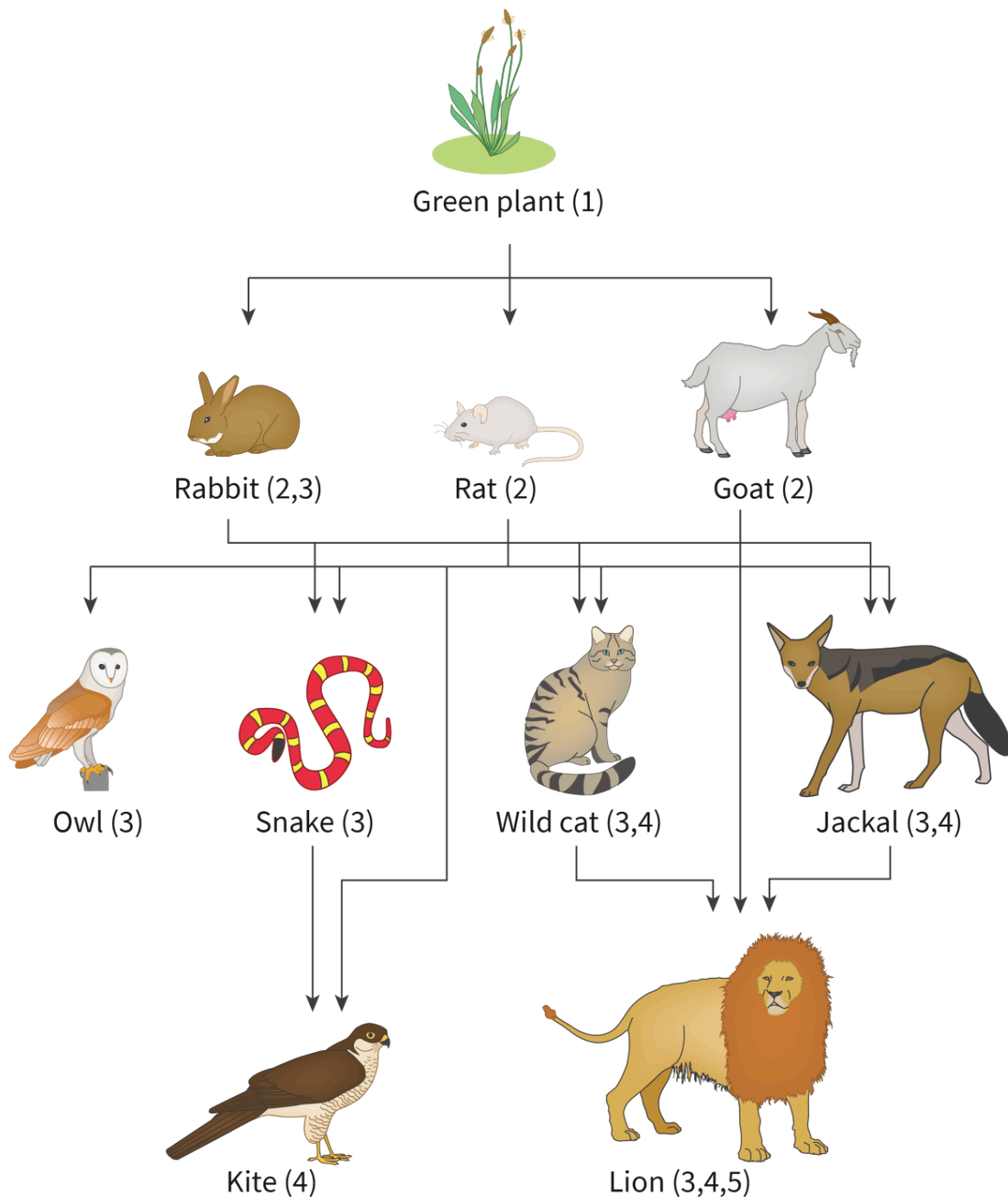
# The length of food chains

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Energy losses between trophic levels cause a great decrease in the amount of energy stored as biomass at each successive trophic level. As energy moves up the food chain, the amount of energy available eventually becomes insufficient to sustain an additional trophic level. This limitation is what restricts the number of trophic levels present in a food chain, which typically have a maximum of four.

This decline in energy availability also results in a decrease in the number or size of organisms as we move up the food chain. It is important to note that, although the total biomass decreases, the energy content per unit mass is not reduced.



**Figure 2.** A food web including the trophic level numbers for each organism.



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[More information for figure 2](#)

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The image depicts a food web diagram, illustrating the relationships between different organisms along with their trophic level numbers. At the base is the green plant marked as trophic level 1. It connects upwards to three primary consumers: the rabbit, rat, and goat, with trophic levels 2 and 3 for the rabbit, level 2 for the rat, and level 2 for the goat. Secondary consumers include the owl and the snake, both at level 3, which are linked to the rabbit. The snake also connects to the rat, and the owl connects to the rabbit. The wild cat and jackal, both at levels 3 and 4, are also part of the network, preying on the rat, rabbit, and the goat. Finally, there is a kite at level 4 linked to the snake, and a lion at levels 3, 4, and 5, linked to the wild cat, jackal, and goat. This diagram effectively demonstrates the energy flow and predator-prey relationships in an ecosystem.

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The activity below will help you get a better understanding of the flows of energy into and out of an organism.



## Activity

- **IB learner profile attribute:** Inquirer
- **Approaches to learning:** Thinking skills — Designing procedures and models
- **Time required to complete activity:** 30 minutes
- **Activity type:** Individual/pair activity

In this activity, you will create a graphic model to visually represent the flow of energy within an organism of your choice, and highlight the various processes involved in energy transfer.

### Your task

1. **Choose an organism:** select any living organism that interests you. It could be a plant, animal, fungi, or even microorganism. Consider



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the organism's characteristics, habitat, and energy requirements when making your choice.

- 2. Research energy inputs:** Investigate the sources of energy that your chosen organism relies on. These must be represented in your model as energy coming into your organism of choice.
- 3. Identify energy outputs:** Determine the ways in which the organism uses and releases energy. Energy outputs must be represented by arrows coming out of your organism.
- 4. Create model:** Use your creativity to create a graphic model that represents the energy inputs and outputs of your chosen organism. You can choose any format that suits your style, such as a flowchart, diagram, or concept map. Make sure to include labels and arrows to accurately indicate the direction of energy flow.
- 5. Share your model:** If possible, present your model to your class or discuss it with your peers. Explain the key components of your model, including the energy inputs and outputs, and the processes involved in energy transfer within the organism. Use your research findings to support your explanations and ensure scientific accuracy.

## Questions

1. What are the main inputs of energy for your chosen organism? How would you classify your organism based on its mode of nutrition? (autotroph, heterotroph, etc.)
2. What are the major energy outputs of your organism? How does it release or utilise these forms of energy?
3. How did you visually represent the energy inputs and outputs in your graphic model? Describe the design choices you made to accurately depict the energy flow within the organism. Discuss any challenges you faced in representing the complex processes of energy transfer.

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C4. Interaction and interdependence: Ecosystems / C4.2 Transfers of energy and matter

# Ecological productivity



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C4.2.15: Primary production

C4.2.16: Secondary production



## Learning outcomes

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

- Compare and contrast primary and secondary productivity.
- Explain the factors that affect primary productivity in an ecosystem.

Have you ever wondered about the consequences of a world with no plants or any kind of photosynthesisers? Imagine a scenario where all producers simply vanish into thin air. This would quickly turn our beautiful planet into a barren wasteland – no more lush greenery to please the eye. Yet, the repercussions extend far beyond the visual aesthetics.

The absence of autotrophs would strip us, along with other organisms, of our oxygen supply and primary sources of food. We heavily rely on these organisms for our survival. After all, producers serve as the fundamental building blocks of all ecosystems. So how do scientists even measure the production of food by primary producers? Moreover, what factors influence the quantity of biomass generated across different ecosystems?

**Video 1** explains the profound impacts that the loss of trees can have on our planet.



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## What If All The Trees On Earth Disappeared Overnight?



### Video 1. What if all the trees on Earth disappeared

## Primary production

**Primary production** refers to the rate at which **producers**, including plants, algae, and cyanobacteria, accumulate carbon compounds in their biomass. Biomass accumulates as organisms grow or reproduce. Primary productivity is measured in units of mass per unit area per unit time, such as grams per square metre per year ( $\text{g m}^{-2} \text{yr}^{-1}$ ). Although the majority of Earth's producers are photoautotrophs, chemoautotrophic organisms also contribute to primary production in some ecosystems (refer to [section C4.2.1–4 \(/study/app/bio/sid-422-cid-755105/book/flow-of-energy-and-matter-id-46631/\)](/study/app/bio/sid-422-cid-755105/book/flow-of-energy-and-matter-id-46631/)). Learning about productivity of an environment is important because higher producer biomass supports a greater number and diversity of consumers within an ecosystem.

It is important to note that the rate at which primary producers accumulate biomass varies by region and season. Factors such as temperature, precipitation, and amount of nutrients in the soil greatly affect primary production. Regions with abundant sunlight, water, and nutrient-rich soils tend to show higher primary productivity. Among Earth's biomes, tropical rainforests and open oceans have the highest overall primary productivity.



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**Gross primary productivity (GPP)** refers to the total amount of energy captured as biomass by primary producers in an ecosystem. It represents the rate at which carbon is converted into organic matter by autotrophs. However, not all the energy captured through photosynthesis is stored as biomass. Some of the energy is used by autotrophs for their own metabolic processes, resulting in energy losses. The energy that remains after subtracting these losses is known as **net primary productivity (NPP)**. NPP represents the energy available to consumers at higher trophic levels and supports growth, reproduction, and storage within the ecosystem. Net primary productivity can be calculated by the following equation:

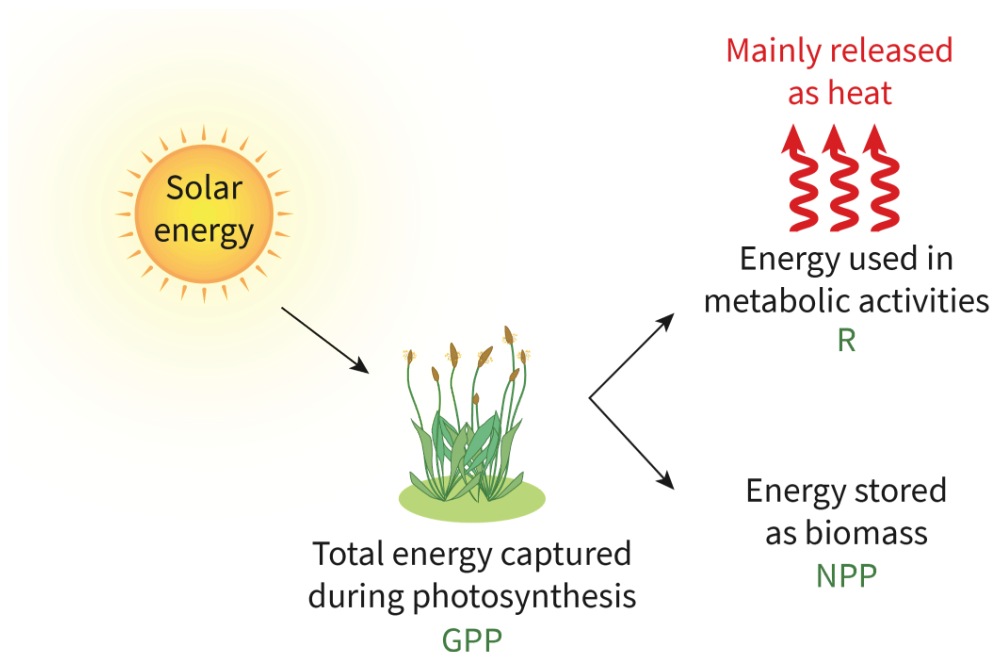
$$NPP = GPP - R$$

Where,

NPP – Net primary production

GPP – Gross primary production

R – Respiration losses



**Figure 1.** Representation of primary productivity.

More information for figure 1



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The diagram illustrates the processes involved in primary productivity, showing three main components: Gross Primary Production (GPP), Respiration (R), and Net Primary Production (NPP). It depicts solar energy being captured by plants through photosynthesis. Arrows indicate the flow of energy. The total energy captured during photosynthesis (GPP) is shown entering the plant. Two pathways extend from the plant: one showing energy used in metabolic activities (R), which is released mainly as heat, and the other pathway showing the energy stored as biomass (NPP). This diagram visually represents the balance between energy capture, utilization, and storage in an ecosystem.

[Generated by AI]

## Secondary production

As consumers feed on plants or other organisms, they are able to incorporate these carbon compounds into their own biomass through assimilation. **Secondary production** refers to the rate at which **consumers** accumulate carbon compounds as part of their own biomass. Heterotrophs play a crucial role in energy and nutrient transfer within ecosystems through processes such as predation, herbivory, and scavenging, which are further explained in [section C4.1.9–10 \(/study/app/bio/sid-422-cid-755105/book/intraspecific-interactions-id-44712/\)](/study/app/bio/sid-422-cid-755105/book/intraspecific-interactions-id-44712/).

Like producers, heterotrophs also experience a loss of biomass during cell respiration, where carbon compounds are converted into carbon dioxide and water. This loss of biomass results in lower secondary production compared with primary production in an ecosystem.

**Gross secondary productivity** (GSP) refers to the total biomass assimilated by heterotrophs in an ecosystem. It is determined by measuring the mass of food consumed by organisms and subtracting the mass lost through faecal excretion. Similar to primary producers, heterotrophs utilise some of the consumed energy for cellular respiration, meaning that not all of the assimilated biomass is available for transfer to higher trophic levels. The biomass that remains after



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accounting for respiratory losses is referred to as **net secondary productivity** (NSP). NSP represents the energy available to sustain higher trophic levels and contributes to the overall flow of energy within the ecosystem.

Human activities have the potential to greatly impact the productivity of ecosystems. The activity below will help you explore the various consequences of human impact on ecosystem productivity.



## Activity

- **IB learner profile attribute:** Knowledgeable
- **Approaches to learning:** Thinking skills — Applying key ideas and facts in new contexts
- **Time required to complete activity:** 30 minutes
- **Activity type:** Pair/group activity

In this activity, you will work in pairs or small groups to investigate and discuss the effects of various human activities on primary productivity in various ecosystems.

### Your task

1. Form small groups (2-3 people) and choose one human activity from the provided list: deforestation, pollution, use of fertilisers, aquaculture, climate change, introduction of non-native species, or overfishing.

#### Section

2. Using reliable sources, investigate the following questions related to your chosen human activity:

- (a) What type of ecosystem does the activity take place in?
- (b) What does the activity involve?
- (c) How does the activity affect the primary productivity of the ecosystem? What about secondary productivity?
- (d) Discuss the short-term and long-term consequences of human activity on primary productivity and ecosystem dynamics.
- (e) How does the impact on primary productivity potentially affect



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## biodiversity and ecosystem stability?

3. Make sure to appropriately cite the sources you used for your research.
4. Share an overview of your findings with the class.

### Extension

1. Suggest any potential solutions or mitigations to minimise the negative effects of the chosen human activity on primary productivity. Collaborate with your group members, share your findings, and engage in meaningful discussions to gain a comprehensive understanding of the topic.

## 5 section questions ▾

C4. Interaction and interdependence: Ecosystems / C4.2 Transfers of energy and matter

# The carbon cycle

C4.2.17: Constructing carbon cycle diagrams    C4.2.18: Ecosystems as carbon sinks and carbon sources



## Learning outcomes

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

- Construct an accurate diagram of the carbon cycle.
- Explain the factors influencing an ecosystem's capacity to function as a carbon sink or a source.
- Discuss the impact of deforestation on the carbon cycle.



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The chemical properties of carbon make it capable of forming a wide range of molecules that are vital for supporting all forms of life (refer to [section B1.1.1–3 \(/study/app/bio/sid-422-cid-755105/book/chemical-bonding-andpolymerisation-id-44681/\)\)](#)). Carbon atoms play a fundamental role in the formation of phospholipids, which are a major component of cell membranes, as well as proteins that function as enzymes and antibodies. Additionally, carbon is necessary for carbohydrates, the main energy source, and nucleic acids, which constitute DNA and RNA. Given the significance of carbon in sustaining life as we know it, it is often referred to as the foundation of ‘carbon-based life’ on Earth.

Carbon atoms not only exist in living organisms but also occur in the non-living environment, such as in fossil fuels, atmospheric gases, and sedimentary rocks. These atoms are in constant motion, transferring to different locations within ecosystems and contributing to the construction of numerous structures. So, what are the processes that facilitate the cycling of carbon between living and nonliving things?

**Video 1** provides an overview of the processes that occur as part of the carbon cycle.

The carbon cycle - Nathaniel Manning



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### Video 1. The carbon cycle

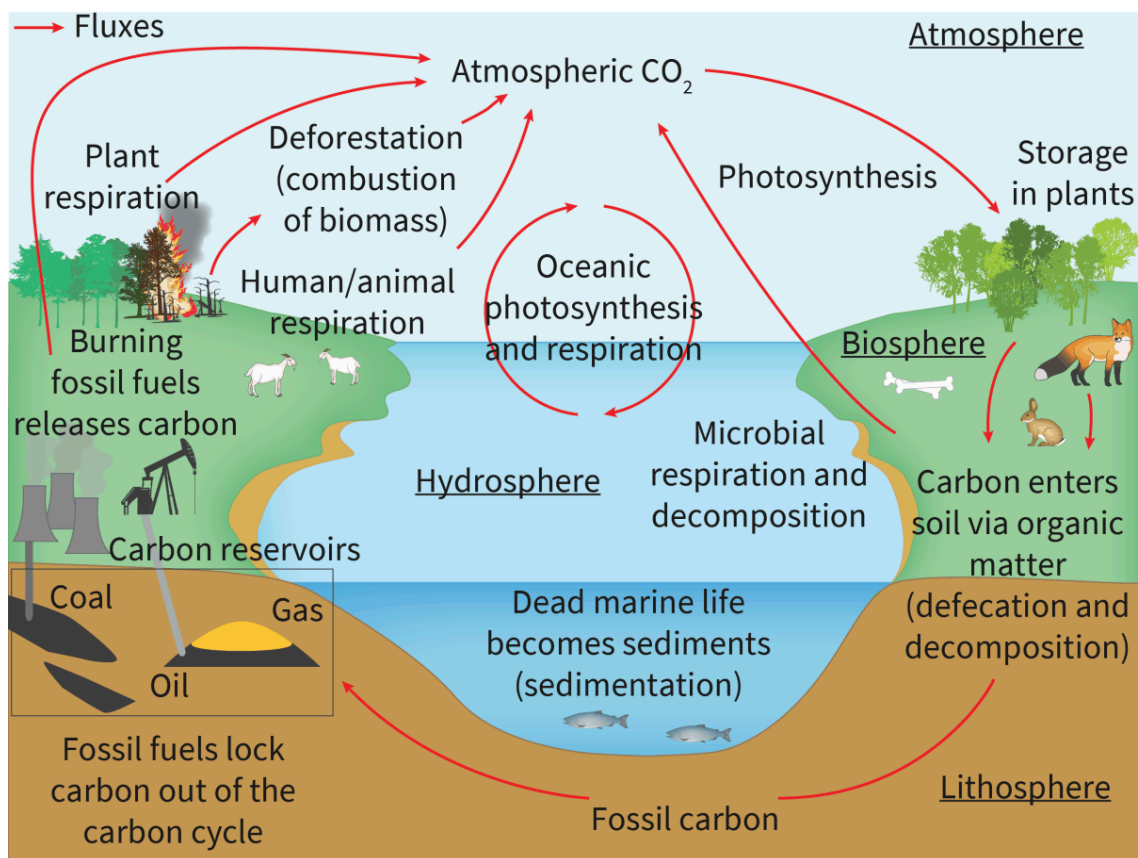


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# Carbon sinks, sources and fluxes

In ecosystems, the cycling of matter is a vital process that ensures the efficient use and reuse of resources. Unlike energy, which flows through ecosystems and eventually dissipates as heat, matter, such as carbon atoms, is recycled and exchanged between organisms and their surrounding environment. The carbon cycle is a fundamental process that allows carbon atoms to be exchanged between the Earth's systems. **Figure 1** shows a simplified illustration of the components that make up the carbon cycle.



**Figure 1.** The carbon cycle.

More information for figure 1

The image is a diagram illustrating the carbon cycle. It includes multiple components and processes that exchange carbon between different Earth systems. Starting with the atmosphere, atmospheric CO<sub>2</sub> is depicted as participating in photosynthesis, a process that leads to carbon storage in plants. The biosphere section shows animals and plants, indicating processes such as plant respiration and human/animal respiration, which release carbon back into the atmosphere.



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The diagram highlights deforestation and the combustion of biomass as additional sources of atmospheric CO<sub>2</sub>.

In the hydrosphere section, processes like oceanic photosynthesis and respiration are illustrated.

Microbial respiration and decomposition play a role in moving carbon into the soil as organic matter in the biosphere.

Beneath these layers, the lithosphere contains fossil carbon, with dead marine life becoming sediments through sedimentation. Fossil fuels such as coal, oil, and gas are shown, indicating that they lock carbon out of the cycle when stored underground. Burning fossil fuels releases this stored carbon back into the atmosphere.

Overall, the image uses arrows to indicate the flow of carbon between these systems, visually representing the dynamic cycles of carbon transformation and storage.

[Generated by AI]

In the carbon cycle, carbon is stored in various reservoirs known as carbon **sinks**. A carbon sink is any environment that absorbs more carbon dioxide from the atmosphere than it releases. Think of them as storage compartments that hold carbon in various forms. Examples of carbon sinks include forests, the ocean, and soil. These sinks are essential for counteracting greenhouse gas emissions by storing carbon. Forests, for example, continuously absorb carbon from the atmosphere to use for photosynthesis.

On the other hand, carbon **sources** are locations or processes that release more carbon into the atmosphere than they absorb. They contribute to the increasing levels of atmospheric carbon dioxide, which is a greenhouse gas that can affect Earth's climate. A significant carbon source is the burning of fossil fuels to obtain energy. This activity rapidly releases large amounts of carbon dioxide that had been stored in the Earth's crust for millions of years. Other examples of carbon sources include forest fires, volcanic eruptions, and cellular respiration of organisms.



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As you can see, carbon atoms on Earth don't stay in one place; they constantly move between the Earth's systems: the atmosphere, the lithosphere, the hydrosphere, and the biosphere. These movements of matter are known as **fluxes**.

In this section, it is important that you are able to create a simplified diagram of the carbon cycle. It is essential that you clearly illustrate how carbon is recycled in ecosystems through the processes of photosynthesis, feeding, and respiration.

## Ecosystems as carbon sinks and sources

Section

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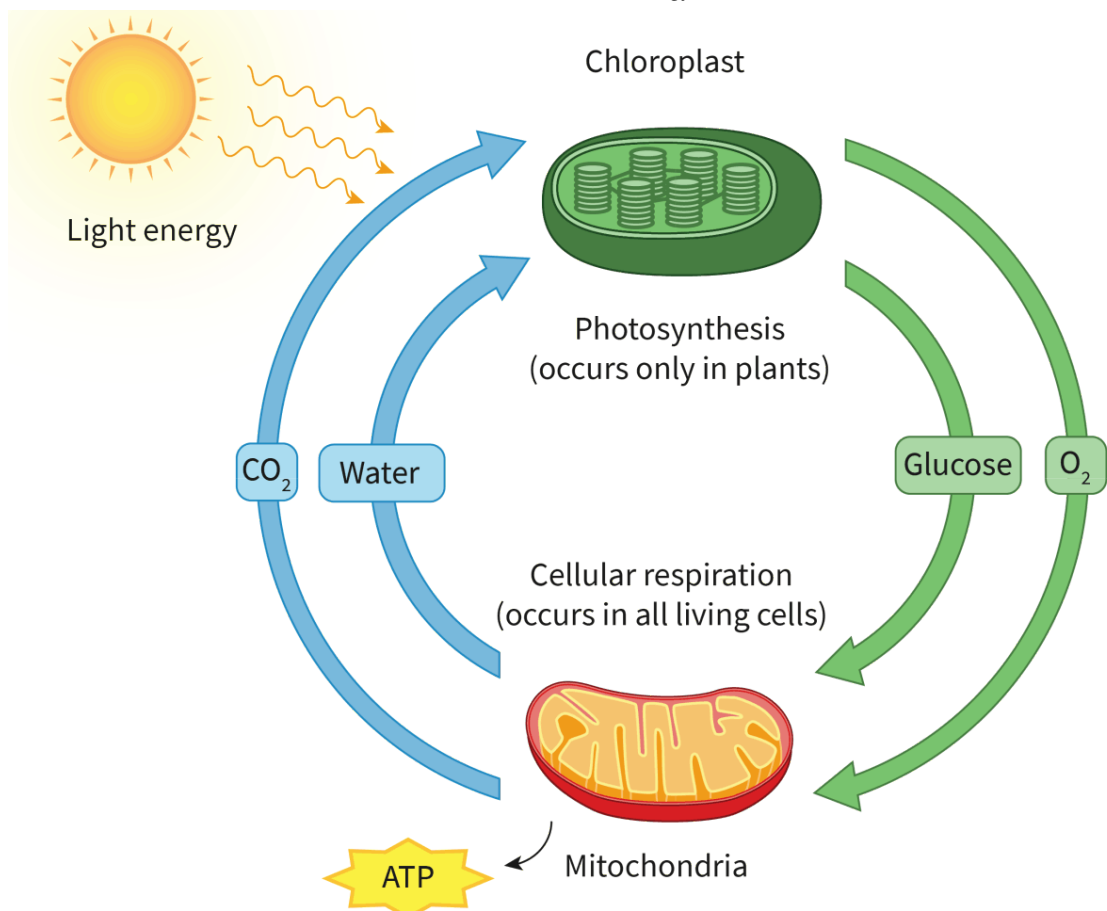
~~When it comes to ecosystems, their role in the carbon cycle is dynamic, as they can~~  
act as both carbon sinks and sources. Whether an ecosystem is a sink or a source is dependent on the balance that exists between two essential metabolic processes: photosynthesis and cellular respiration.

Photosynthesis is an essential process in the carbon cycle, as it allows autotrophs to capture carbon dioxide (CO<sub>2</sub>) from the atmosphere and incorporate into organic compounds (refer to subtopic C1.3 (/study/app/bio/sid-422-cid-755105/book/big-picture-id-43539/))). Respiration, on the other hand, is a complementary process that releases CO<sub>2</sub> back into the atmosphere as organisms break down organic compounds to obtain energy (refer to subtopic C1.2 (/study/app/bio/sid-422-cid-755105/book/big-picture-id-43538/))). **Figure 2** shows the relationship between photosynthesis and respiration.




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**Figure 2.** Photosynthesis and cellular respiration.

 More information for figure 2

The diagram illustrates the processes of photosynthesis and cellular respiration and their interconnectedness. On the left, a sun represents light energy. Arrows indicate that this energy is used in the chloroplasts, shown as a green organelle with stacks labeled as occurring only in plants. Photosynthesis converts carbon dioxide (CO<sub>2</sub>) and water (H<sub>2</sub>O) into glucose and oxygen (O<sub>2</sub>), represented by arrows and respective labels. On the right, the mitochondria, illustrated as a red organelle, engages in cellular respiration, which occurs in all living cells. This process uses glucose and oxygen to produce ATP, shown as a yellow starburst. The cellular respiration process releases CO<sub>2</sub> and H<sub>2</sub>O, completing the cycle back to photosynthesis.

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Within an ecosystem, when photosynthesis rates exceed cell respiration rates, there is a net uptake of carbon dioxide from the atmosphere, making ecosystems



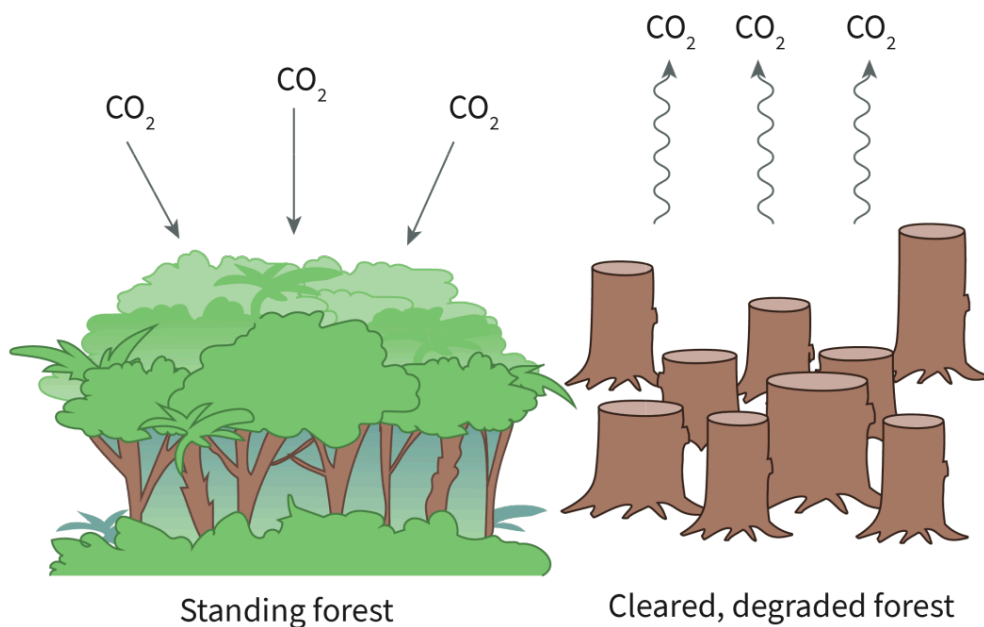
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act as carbon sinks. Forests are significant carbon sinks due to their ability to sequester carbon through photosynthesis and long-term storage in tree trunks, branches, and roots.

Conversely, when cell respiration rates exceed photosynthesis rates, there is a net release of carbon dioxide into the atmosphere, making ecosystems act as carbon sources. Ecosystems with high rates of respiration relative to photosynthesis, such as decaying organic matter or actively respiring microbial communities, function as carbon sources, releasing more carbon than they absorb. The image below showcases the transition of a forest from a carbon sink to a carbon source, emphasising the impact of deforestation on the carbon cycle.



**Figure 3.** Forests can act as carbon sinks and sources.

More information for figure 3

The image is a diagram illustrating the impact of deforestation on carbon dioxide levels. On the left, there is a depiction of a lush, standing forest titled "Standing forest," with arrows labeled "CO<sub>2</sub>" pointing downwards, indicating that the forest is absorbing carbon dioxide. On the right, there is an illustration of a cleared, degraded forest titled "Cleared, degraded forest," represented by numerous tree stumps. Here, arrows labeled "CO<sub>2</sub>" are pointing upwards, suggesting that the cleared forest is releasing carbon dioxide into the atmosphere. This visual explains the transition of forests from carbon sinks to carbon sources due to deforestation.

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## International Mindedness

Preserving standing forests is crucial for climate change mitigation and requires international collaboration. Recent research has emphasised the significant role of forests in combating climate change by serving as crucial carbon sinks, sequestering approximately twice the amount of carbon dioxide they emit.

Forests not only contribute to climate change mitigation but also play a vital role in biodiversity conservation and the provision of ecosystem services. They regulate water cycles, prevent soil erosion, and provide food and habitats for numerous species.

As forests transcend national boundaries, their preservation becomes a global concern that demands international cooperation. Through collective efforts to protect and sustainably manage forests, we can effectively safeguard these ecosystems and secure the essential benefits they offer for future generations.

The following activity provides an opportunity to practise constructing a model that accurately represents the carbon cycle.



## Activity

- **IB learner profile attribute:** Thinker
- **Approaches to learning:** Thinking skills — Designing procedures and models
- **Time required to complete activity:** 20 minutes
- **Activity type:** Individual/pair activity



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## Introduction



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The carbon cycle describes how carbon is recycled and exchanged between organisms and the environment through different metabolic processes. In this activity, you will illustrate the carbon cycle by creating a model that accurately represents the movement of carbon among Earth's systems.

### Materials

You will need paper, coloured pencils or markers, and any other art supplies you prefer for creating your diagram.

### Your task

1. Before creating your model, gather information about the carbon cycle to solidify your understanding of how carbon moves through feeding, photosynthesis, and cell respiration.
2. Begin by sketching the primary carbon reservoirs. Use text boxes or small drawings to represent each. Use arrows to indicate the flow of carbon between these components.
3. Label each component of the carbon cycle in your diagram, including the processes of photosynthesis, feeding, and respiration. Add brief annotations or explanations to clarify how carbon is recycled in each step.
4. Once you complete your diagram, compare it with your classmates' models and discuss any additional information or details that may have been overlooked.

### Questions

1. What roles does photosynthesis have in the carbon cycle? How does it contribute to carbon sinks?
2. How do feeding and respiration contribute to carbon sources in the carbon cycle?
3. What are some human activities that impact the carbon cycle, and how do they affect the balance between carbon sinks and sources?
4. Why is it important to understand and study the carbon cycle in the context of climate change and environmental sustainability?



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## 5 section questions ▾



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C4. Interaction and interdependence: Ecosystems / C4.2 Transfers of energy and matter

# Human impact on the carbon cycle

C4.2.19: Release of carbon dioxide into the atmosphere during combustion C4.2.20: Analysis of the Keeling Curve

## Learning outcomes

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

- Describe how combustion of fossil fuels and biomass affects the carbon cycle.
- Analyse and explain the short-term and long-term trends shown in the Keeling Curve.

Have you ever questioned how your energy choices impact the carbon cycle? Throughout history, humans have relied on combustion to harness energy, but this comes at a cost. It is widely acknowledged that burning fossil fuels for electricity, heat, and transportation is the largest contributor to greenhouse gas emissions. But what does this mean for our planet? How does it affect global warming and climate change? And how do the emissions from natural events like wildfires and volcanic activity compare with those resulting from human activities? This section will explore the impacts of human activity on the carbon cycle.

## Impact of combustion on the carbon cycle

Over the years, humans have used the combustion of different substances as a source of energy. The combustion of carbon-rich reservoirs such as biomass, peat, coal, oil, and natural gas has resulted in significant modifications to the carbon cycle, leading to the release of substantial amounts of carbon dioxide emissions into the atmosphere.



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Fossil fuels are derived from ancient organic matter that has been buried and transformed over millions of years. When these fuels are burned for energy, transportation, or industrial purposes, large amounts of CO<sub>2</sub> are released into the atmosphere. In the carbon cycle, producers absorb CO<sub>2</sub> during photosynthesis, converting it into organic compounds and storing it as biomass. This process helps to regulate the amount of CO<sub>2</sub> in the atmosphere. However, the combustion of fossil fuels reintroduces carbon that has been sequestered for millions of years into the relatively-short carbon cycle.



**Figure 1.** Carbon emissions from the combustion of fossil fuels.

Credit: Stuart Westmorland, Getty Images

The increased concentration of CO<sub>2</sub> in the atmosphere from fossil fuel combustion has several effects on the carbon cycle. First, it enhances the greenhouse effect, trapping more heat and contributing to global warming and climate change. Second, it alters the equilibrium between carbon sinks and carbon sources. Natural carbon sinks, such as forests and oceans, can absorb some of the excess CO<sub>2</sub>, but they have limits to their capacity. If the rate of CO<sub>2</sub> release exceeds the capacity of these sinks, the excess CO<sub>2</sub> accumulates in the atmosphere, leading to higher concentration and further climate impacts.



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## Natural combustion

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Combustion following lightning strikes is a natural phenomenon that contributes to the release of CO<sub>2</sub> into the atmosphere. Lightning strikes can ignite wildfires, which in turn lead to the burning of vegetation, and other organic matter. During the process of combustion, the carbon stored within these organic compounds is released in the form of carbon dioxide.

It is important to note that while these natural events have occurred throughout Earth's history, their impact on the carbon cycle is relatively small when compared to human-induced combustion. Human activities, including the burning of fossil fuels and the combustion of biomass, have a much greater influence on the modification of the carbon cycle and contribute significantly to climate change and global warming.



**Figure 2.** Lightning strikes can spike wildfires, contributing to the release of CO<sub>2</sub>.

Credit: Nic Leister, Getty Images



## International Mindedness



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In 2019, unprecedented wildfires occurred in the Amazon rainforest, leading to the destruction of 9060 square kilometres of the Amazon biome in Brazil, Paraguay, and Peru. These fires not only caused the loss



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of numerous trees, but also had serious impacts on biodiversity, indigenous communities, and the global climate.

Research later revealed that these fires primarily occurred in areas that had experienced significant deforestation the previous year, which was driven by agricultural activities, illegal logging, and the expansion of cattle ranching. The widespread clearing of land weakened the natural defences of the rainforest and created favourable conditions for the rapid spread of fires.

The Amazon rainforest is often called the 'lungs of the Earth' as it plays a crucial role in absorbing carbon dioxide and producing oxygen.

Therefore, the destruction of this ecosystem carries significant implications for climate change. Given the global impact associated with the destruction of the rainforest, addressing this issue requires the involvement and cooperation of multiple international organisations.

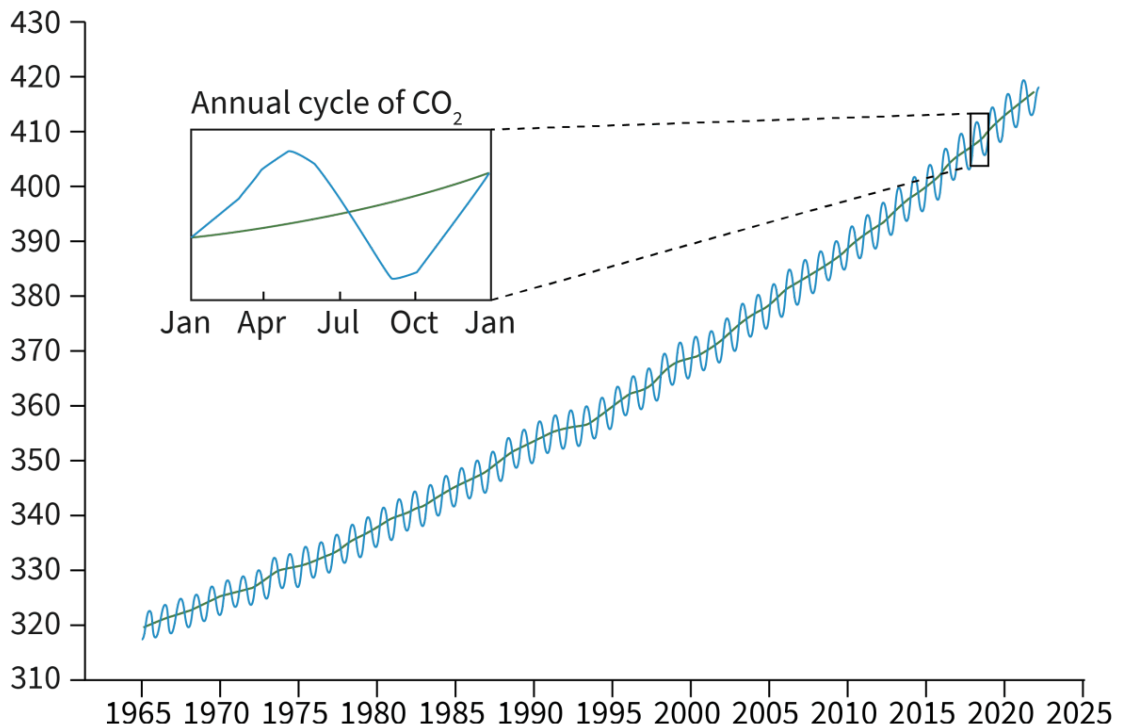
The significance of the Amazon rainforest extends beyond the countries directly affected by the wildfires. Its role in regulating global climate, preserving biodiversity, and safeguarding indigenous cultures makes it a matter of global concern.

## The Keeling Curve

The Keeling Curve is a graph that shows the concentrations of carbon dioxide in Earth's atmosphere over time. The annual fluctuations observed in the Keeling Curve reflect the seasonal patterns of photosynthesis and respiration. During the growing season, plants undergo photosynthesis, absorbing CO<sub>2</sub> from the atmosphere and reducing its concentration. This leads to a decline in CO<sub>2</sub> levels, represented by a dip in the curve. In contrast, during the dormant season, when photosynthesis rates are lower and respiration continues, CO<sub>2</sub> levels increase, resulting in an upward trend in the curve. These annual fluctuations are demonstrated in **Figure 3**.

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**Figure 3. The Keeling Curve.**

[More information for figure 3](#)

The image is a graph known as the Keeling Curve, which depicts the concentration of carbon dioxide (CO<sub>2</sub>) in Earth's atmosphere over time. The x-axis represents the years from 1965 to 2025, and the y-axis represents the concentration of CO<sub>2</sub> in parts per million, ranging from 310 to 430. The graph features a sawtooth pattern, with annual fluctuations reflecting seasonal variations—peaks in CO<sub>2</sub> during dormant seasons and dips during growing seasons. In the inset, a detailed annual cycle of CO<sub>2</sub> is illustrated with months labeled from January to January, showing a clear cycle of rise and fall within a year. Overall, there is a consistent upward trend, indicating a long-term increase in CO<sub>2</sub> concentrations due to human activities such as fossil fuel combustion.

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The long-term trend observed in the Keeling Curve is of great concern, as it shows a consistent increase in CO<sub>2</sub> levels over the years. This upward trend is primarily attributed to the significant impact of human activities, particularly the combustion of fossil fuels.

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## Creativity, activity, service

### Strand: Activity

#### Learning outcomes:

- Demonstrate engagement with issues of global significance
- Recognise and consider the ethics of choices and actions

### Addressing the unequal impacts of global warming

The impacts of global warming are not evenly distributed, disproportionately affecting vulnerable populations, especially those living in poverty. These communities often lack the resources and infrastructure needed to adapt to and mitigate the effects of climate change. Rising temperatures, sea-level rise, extreme weather events, and disruptions in agricultural productivity further exacerbate existing social and economic inequalities.

Given these challenges, it is crucial to raise awareness about the unequal impacts of global warming and the importance of collective action. Activities that promote awareness and support efforts to alleviate global warming effects include:

- engaging in community projects,
- fundraising for climate resilience initiatives,
- advocating for equitable climate policies, and
- supporting sustainable development projects that empower marginalised populations.

Carbon dioxide is just one of several atmospheric gases that contribute to the greenhouse effect and climate change. The activity below will give you an opportunity to investigate and analyse the effects of various atmospheric gases on our climate.



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## Activity

- **IB learner profile attribute:** Knowledgeable
- **Approaches to learning:** Thinking skills — Combining different ideas in order to create new understandings
- **Time required to complete activity:** 25 minutes
- **Activity type:** Individual/pair activity

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### Introduction

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This activity will allow you to investigate and analyse the changes in atmospheric gas concentrations in different regions of the Earth. By utilising a reliable data source, you will investigate the trends and patterns of these concentrations over the past three decades, considering the specific characteristics and geographical locations of each region.

### Your task

1. Visit the website <https://ourworldindata.org/atmospheric-concentrations> (<https://ourworldindata.org/atmospheric-concentrations>)
2. Select an atmospheric gas category of interest from the provided data, such as carbon dioxide, methane, nitrous oxide, etc.
3. Use the data source to research and gather information on the changes in atmospheric gas concentrations in different regions. Focus on the past three decades and explore how these concentrations have evolved over time.
4. Consider the geographical locations of the regions being studied. Analyse the potential factors that contribute to the observed changes in atmospheric gas concentrations, such as industrial activities, land use changes, or natural processes. Relate these factors to the specific characteristics of each region.
5. Identify any patterns or trends in the changes of atmospheric gas concentrations. Look for similarities or differences among regions and investigate the potential drivers behind these patterns. Use visual representations, such as graphs or charts, to support your analysis.



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6. Assess the potential impacts of the observed changes in atmospheric gas concentrations. Discuss the implications for climate change, ecosystem health, human well-being, and other relevant aspects. Consider both the local and global scale effects of these changes and evaluate their significance.
7. Organise a group discussion to share your research findings and collectively analyse the insights gained from your analysis.

### Questions

1. What patterns or trends did you observe in the changes of atmospheric gas concentrations in different regions?
2. How do the geographical locations of the regions relate to the observed changes in atmospheric gas concentrations?
3. What potential factors contribute to the variations in atmospheric gas concentrations among different regions?
4. What are the impacts of these changes in atmospheric gas concentrations on climate change, ecosystems, and human societies?
5. How can we address and mitigate the effects of changing atmospheric gas concentrations on a global scale?

## 5 section questions ▾

C4. Interaction and interdependence: Ecosystems / C4.2 Transfers of energy and matter

# Ecosystem sustainability

C4.2.21: Relationship between aerobic respiration and photosynthesis

C4.2.22: Recycling of all chemical elements in ecosystems



### Learning outcomes

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



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- Explain the significance of photosynthesis and aerobic respiration in sustaining life on Earth.
- Explain the importance of cycles of matter in the functioning of ecosystems.

As we now know, one of the fundamental principles of ecosystems is the recycling of matter. While energy flows through ecosystems, matter is continuously recycled, ensuring the continual availability of essential elements for life. In fact, the atoms that build the molecules within our bodies have existed throughout Earth's history.

The carbon cycle serves as a prime example of nutrient cycling, being transferred and transformed via photosynthesis, respiration and feeding. However, other essential matter cycles also exist. So, which elements participate in these cycles? How do they move through the environment, interacting with organisms and their abiotic environment?

## The link between photosynthesis and respiration

Aerobic respiration and photosynthesis are two linked processes vital for life on Earth to exist. As covered in [subtopic C1.2 \(/study/app/bio/sid-422-cid-755105/book/big-picture-id-43538/\)](/study/app/bio/sid-422-cid-755105/book/big-picture-id-43538/), aerobic respiration is a process that relies on the presence of atmospheric oxygen produced through photosynthesis. This process produces carbon dioxide as a waste product, which is then released into the atmosphere. Carbon dioxide is in turn essential for photosynthesis to occur.

This reciprocal relationship between aerobic respiration and photosynthesis forms an essential interaction between autotrophic and heterotrophic organisms. The massive fluxes of oxygen and carbon dioxide involved in these two processes continuously occur on a global scale, making them necessary for maintaining life on Earth. **Video 1** provides a visual overview of photosynthesis and aerobic respiration, and explains the connections between these two.



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## Photosynthesis and Respiration



**Video 1.** The link between photosynthesis and respiration.

## Other cycles of matter

In addition to carbon, all the chemical elements required by living organisms are recycled within ecosystems. This recycling process ensures the continual availability of essential elements for maintaining life. As covered in [section C4.2.5–8 \(/study/app/bio/sid-422-cid-755105/book/autotrophs-and-heterotrophs-id-46632/\)](#), decomposers play a vital role in this recycling of matter by breaking down organic compounds and returning the nutrients back into the environment.

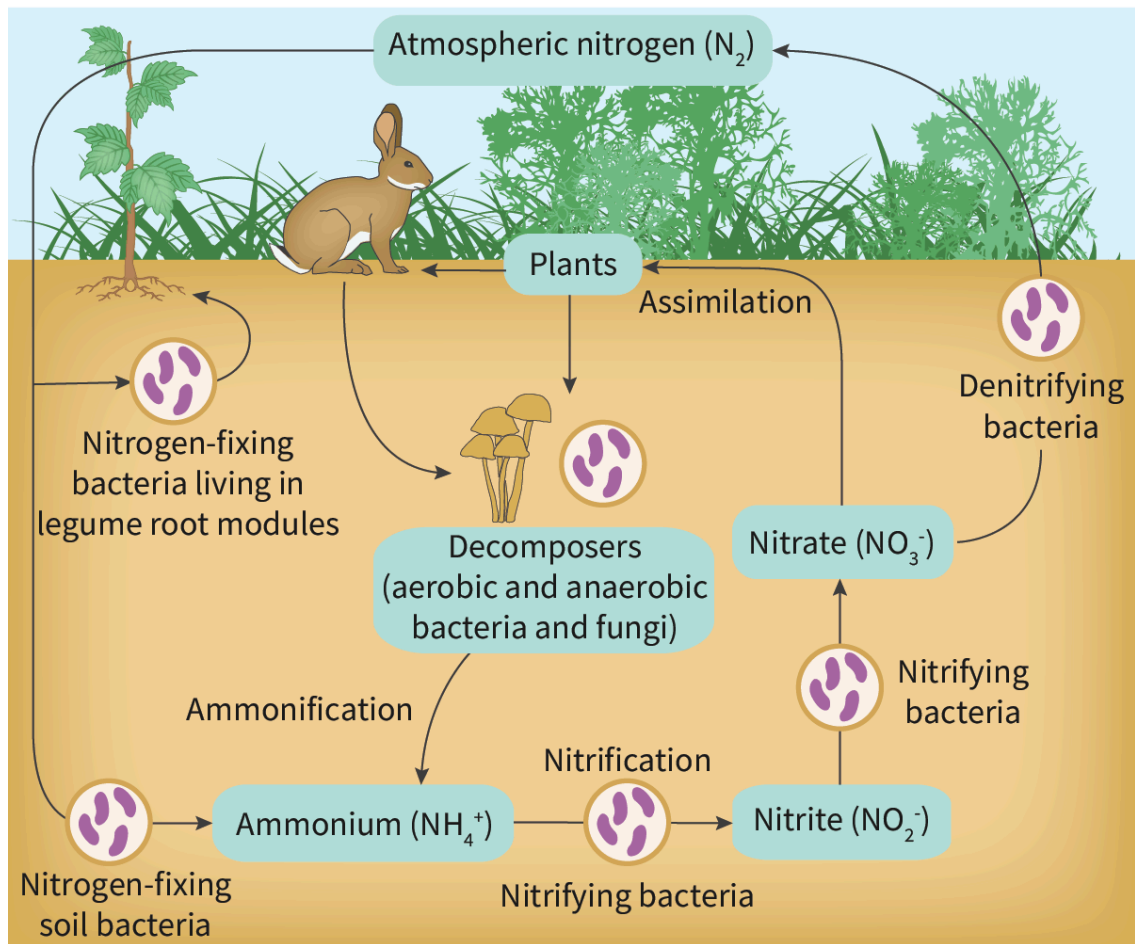
While carbon is a key element, it is important to acknowledge that other elements, such as nitrogen, phosphorus, sulfur, and various trace elements, are also essential for living organisms. These elements are cycled through different [biogeochemical processes](#), involving various organisms and environmental factors. **Figure 1** illustrates an overview of the nitrogen cycle.



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**Figure 1.** The nitrogen cycle.

More information for figure 1

The diagram illustrates the nitrogen cycle. It shows several key components and steps in the process. At the top, atmospheric nitrogen ( $N_2$ ) is captured by nitrogen-fixing bacteria in legume root nodules and soil bacteria. These convert atmospheric nitrogen into ammonium ( $NH_4^+$ ), a process called ammonification. This ammonium is further processed by nitrifying bacteria, transforming it into nitrite ( $NO_2^-$ ) and then into nitrate ( $NO_3^-$ ) through nitrification.

Plants assimilate nitrate, using it to grow and develop. Animals, represented by a rabbit, eat these plants, incorporating nitrogen into their own biological systems. Decomposers, including aerobic and anaerobic bacteria and fungi, break down organic matter, returning ammonium to the soil. Some nitrate is converted back to atmospheric nitrogen by denitrifying bacteria, completing the cycle.

The flow of nitrogen through these stages is indicated by arrows, depicting the movement between atmospheric nitrogen, ammonium, nitrite, nitrate, and biological assimilation by plants and animals.



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Although specific details of nutrient cycles, such as the nitrogen and phosphorus cycles, are not required knowledge for the purposes of this course, it is important to appreciate that the recycling of all elements is essential for the sustainability of ecosystems.

The activity below will help you gain insights into the direct relationship between photosynthesis and aerobic respiration.



## Activity

- **IB learner profile attribute:** Inquirer
- **Approaches to learning:** Thinking skills — Designing procedures and models
- **Time required to complete activity:** 30 minutes
- **Activity type:** Individual activity

In this activity you will create a model to illustrate the relationship between photosynthesis and aerobic respiration. Use any format you prefer and use different colours to represent connections.

### Materials

Gather art supplies such as coloured paper, scissors, glue, and any other useful materials you have available. You will also need a poster board or large paper.

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### Your task

1. Plan your model with your group. Discuss how to include all components effectively.
2. Required elements for your model:

- Two graphic representations: one for photosynthesisers and one for organisms performing aerobic respiration.
- Accurate chemical reactions for photosynthesis and aerobic respiration.

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- Any inputs and outputs of energy.
- Arrows to demonstrate the flow of matter.

### Questions

1. Identify the atoms that are recycled during photosynthesis and respiration.
2. State the cell organelle where photosynthesis and cellular respiration occur.
3. Considering your model, discuss the plausibility of the hypothesis that a meteor impact caused a prolonged period of darkness due to atmospheric debris, leading to dinosaur extinction.
4. Explain concisely the relationship between autotrophs and heterotrophs.

## 5 section questions ▾

C4. Interaction and interdependence: Ecosystems / C4.2 Transfers of energy and matter

## Summary and key terms

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- Ecosystems transfer both energy and matter among organisms, with sunlight as the primary energy source for most ecosystems.
- Food chains and food webs illustrate the flow of energy in ecosystems.
- Autotrophs synthesise organic compounds from inorganic molecules using sunlight or inorganic compounds as energy sources.
- Heterotrophs rely on consuming other organisms or organic matter to obtain energy and nutrients for survival.
- Decomposers break down dead organisms and organic matter, releasing essential nutrients back into the environment.
- Energy flows through ecosystems in a unidirectional manner, and trophic levels categorise organisms based on their position in the food chain or web.



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- Energy pyramids represent the amount of energy available at each trophic level.
- Energy transfer between trophic levels is highly inefficient. Energy losses occur due to incomplete consumption, inefficient digestion, inefficient energy conversion and storage, metabolic processes of organisms, and heat dissipation.
- Heat loss is a consequence of energy conversion during cell respiration.
- Energy losses between trophic levels limit the number of trophic levels in a food chain.
- Primary production is the rate at which producers accumulate carbon compounds in their biomass.
- Secondary production is the rate at which consumers accumulate carbon compounds as part of their biomass through assimilation.
- In the carbon cycle, carbon atoms are recycled and exchanged between the Earth's systems.
- Ecosystems can act as both carbon sinks and sources depending on the balance between photosynthesis and cellular respiration.
- Burning fossil fuels releases large amounts of carbon dioxide (CO<sub>2</sub>) into the atmosphere, disrupting the natural balance of the carbon cycle.
- The relationship between photosynthesis and aerobic respiration allows life on Earth to continue.

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## 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. An \_\_\_\_\_ is a complex network of interactions between organisms and their physical environment. Within an ecosystem, organisms occupy different \_\_\_\_\_, representing their position in the \_\_\_\_\_.
2. Organisms that convert inorganic compounds into organic ones for energy are known as \_\_\_\_\_, while \_\_\_\_\_ rely on feeding on other organisms to obtain energy. Organisms who rely on dead organisms and organic matter are crucial for the cycling of nutrients are known as \_\_\_\_\_.
3. Ecological \_\_\_\_\_ is a measurement that refers to the rate of production of biomass in an ecosystem. \_\_\_\_\_ productivity measures the productivity of producers, while \_\_\_\_\_ productivity measures the productivity of consumers.
4. Human activity, mostly the combustion of \_\_\_\_\_, has greatly impacted the \_\_\_\_\_ cycle by releasing large amounts of \_\_\_\_\_ into the atmosphere.

ecosystem

fossil fuels

carbon dioxide

carbon

food chain

consumers

trophic levels

productivity

Primary

producers

decomposers

secondary

✓ Check

### Interactive 1. Ecosystem Dynamics and Energy Flow.



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# Checklist

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## What you should know

After studying this subtopic you should be able to:

- Explain the concept of ecosystems as open systems.
- Describe the role of sunlight in ecosystems.
- Outline the flow of energy through food chains and food webs.
- Construct food chains and food webs to represent feeding relationships in a community.
- Describe the role of decomposers in nutrient cycling.
- Distinguish between autotrophic and heterotrophic modes of nutrition.
- Classify organisms into trophic levels based on their position in a food chain or food web.
- Construct an energy pyramid based on ecological data.
- Explain the factors that contribute to energy losses in food chains.
- Outline the causes and consequences of heat dissipation in food chains.
- Describe the factor that restricts the number of trophic levels in a food chain.
- Compare and contrast primary and secondary productivity.
- Explain the factors that affect primary productivity in an ecosystem.
- Construct an accurate diagram of the carbon cycle.
- Explain the factors influencing an ecosystem's capacity to function as a carbon sink or a source.
- Discuss the impact of deforestation on the carbon cycle.
- Describe how combustion of fossil fuels and biomass affects the carbon cycle.

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- Analyse and explain the short-term and long-term trends shown in the Keeling Curve.
- Explain the significance of photosynthesis and aerobic respiration in sustaining life on Earth.
- Explain the importance of cycles of matter in the functioning of ecosystems.

C4. Interaction and interdependence: Ecosystems / C4.2 Transfers of energy and matter

# Investigation

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- **IB learner profile attribute:** Knowledgeable
- **Approaches to learning:** Research skills – Using search engines and libraries effectively
- **Time required to complete activity:** 50 minutes
- **Activity type:** Individual activity

## Your task

In this investigation, you will explore multiple connections within an ecosystem of your choice. Be prepared to present your findings as a presentation, keep record of all the sources you utilised to be listed at the end.

1. **Investigate a random animal:** Use a random animal generator online to assign you an individual animal species from a specific ecosystem. Research and gather information about your assigned animal, including its major food sources, its role as a prey or predator, its habitat and geographical range, and any other relevant details.
2. **Construct a food chain:** Based on the information you have gathered, construct a food chain that accurately represents the energy transfers among



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organisms in the ecosystem. Your food chain must include your assigned animal, its prey and/or predators, and specific examples of producers and decomposers found within the region. If information is available, add additional trophic level interactions to create a more complex food web.

3. **Determine trophic levels:** Create a table to classify organisms in your food web based on their trophic levels. Include organisms that occupy multiple levels in all applicable categories.
4. **Construct an energy pyramid:** Research data on the biomass or energy at different trophic levels and use it to construct an energy pyramid. Your pyramid must include appropriate units, energy transfer efficiency between levels, and represent energy losses in the form of heat.
5. **Investigate carbon sinks, sources and fluxes:** Describe the major carbon sinks, sources and fluxes in your given ecosystem. Explain how carbon is cycled and exchanged between different components of the ecosystem.
6. **Analyse human activity and nutrient recycling:** Research and identify specific human activities occurring near or around the ecosystem where your assigned animal exists. Outline how these human activities have influenced the recycling of nutrients in the area, considering factors such as deforestation, pollution, agriculture, or urbanisation.

Remember to cite your sources appropriately to acknowledge the information you used in your investigation.

## Discussion questions

1. What is the primary source of energy in the ecosystem you investigated, and how is it utilised by organisms?
2. Discuss the different ways in which energy is lost and replaced within the ecosystem. How does this impact the overall energy flow?
3. How would you describe the primary productivity of the ecosystem you investigated? What are the key factors that contribute to its level of productivity?
4. Explain the reason why matter can be recycled in ecosystems, but energy cannot.



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## 5. Discuss the role of decomposers in the transfer and transformation of matter and energy within the ecosystem.

C4. Interaction and interdependence: Ecosystems / C4.2 Transfers of energy and matter

# Reflection

Section

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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 question introduced in [The big picture \(/study/app/bio/sid-422-cid-755105/book/big-picture-id-43545/\)](/study/app/bio/sid-422-cid-755105/book/big-picture-id-43545/).

- What is the reason matter can be recycled in ecosystems but energy cannot?
- How is the energy that is lost by each group of organisms in an ecosystem replaced?

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

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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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Submit

### Rate subtopic C4.2 Transfers of energy and matter

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