HL IB Biology

Your notes

Transfer of Energy & Matter

Contents

Your notes

Ecosystems as Open Systems

Ecosystems

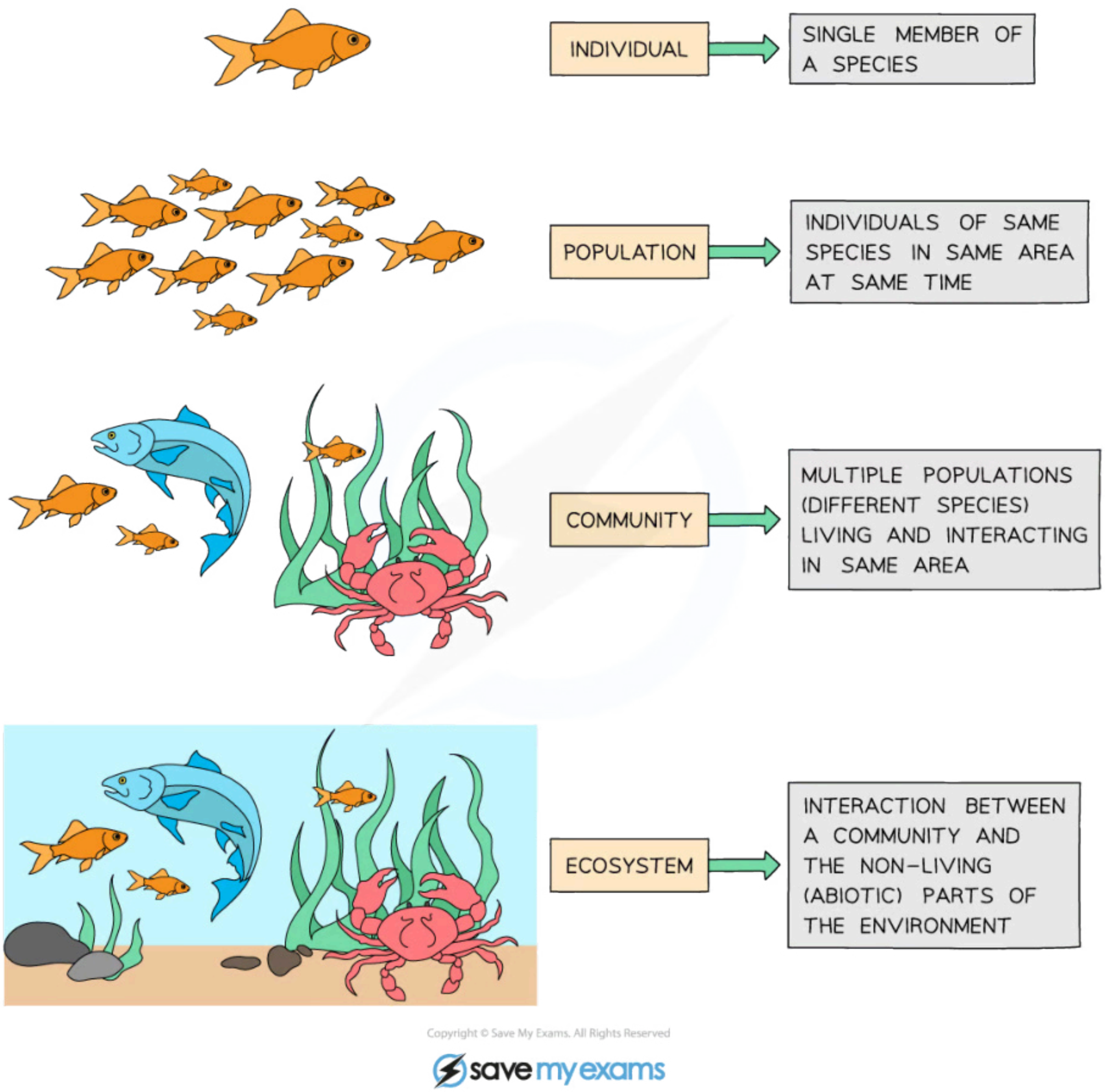
- An ecosystem can be defined as:

A group of organisms interacting with each other and with the non-living parts of the environment

- There are both biotic components and abiotic components within an ecosystem
- Ecosystems **vary greatly in size and scale**
  - Both a small pond in a back garden and the open ocean could be described as ecosystems
- Ecosystems **vary in complexity**:
  - A desert is a relatively simple ecosystem
  - A tropical rainforest is a very complex ecosystem

Ecosystem example

- An ocean is an example of a complex ecosystem
- There is a large community of organisms, including fish, crustaceans, corals, algae, plants and microorganisms
- The **abiotic components** of the ecosystem include the salinity, pH, temperature, light intensity, and mineral availability
- The abiotic components of the ecosystem **influence** the community of organisms, e.g. by providing **habitat**, **nutrients** and other resources organisms need in order to survive and reproduce



Ecosystems include communities and their interactions with the abiotic environment

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Ecosystems as open systems

- Ecosystems are **open systems**, meaning that **both energy and matter can enter and exit the system**
- **Energy** can enter and exit as follows:
  - Energy enters **in the form of sunlight**, and flows through an ecosystem in the form of stored chemical energy
  - Energy can also enter an ecosystem **stored in the tissues of any organisms** that migrate into the system

- When energy is stored in the molecules of an organism and that individual leaves the ecosystem, that **stored energy is removed**
- **Matter** can enter and exit as follows:
  - Matter enters an ecosystem **when an organism arrives**, in the form of all of the molecules of its cells and tissues, e.g. when a bird migrates into an ecosystem
  - Matter is removed **when an organism leaves an ecosystem**, e.g. dead plant matter could be washed away by the waves on a beach and carried to a new ecosystem, or trees are cut down and the timber removed
- It is worth noting that most of the organisms in an ecosystem **remain inside the system** throughout their lives, and the matter and energy stored in their tissues is **recycled within the ecosystem** when an individual dies
  - While ecosystems are open, they are considered to be **largely self-contained**

- Open systems are different to **closed systems**
  - In a closed system:
    - Matter can only be **recycled** within the system and **cannot enter or leave**
    - Energy **can enter and leave**
  - Earth is an example of a closed system; energy enters and leaves but matter is recycled

Your notes

Your notes

Sunlight as a Source of Energy

- The sun is the **initial source of energy** for most food chains
  - **Light energy** from the sun is **converted** by producers into **chemical energy** stored in the tissues of plants during the process of photosynthesis
  - Chemical energy stored in the tissues of plants **passes to primary consumers** when they ingest plants, and **on to secondary consumers** when the primary consumers are themselves ingested
- There are a few **unusual exceptions** to this, such as:
  - Food chains located in **deep sea volcanic vents** and **underground caves** where no light can penetrate; these rely on bacteria gaining **energy from chemical processes**
    - Note that some caves may receive energy stores from the earth's surface that originally gained their energy from the sun, e.g. if water flows through the cave

NOS: Laws in science are generalised principles, formulated to describe patterns observed in nature. Unlike theories, they do not offer explanations, but describe phenomena

- Laws **describe patterns** that occur in nature; they are developed by scientists **after carrying out observation** and they **do not seek to explain** why something is happening
  - E.g. the first law of thermodynamics states that energy cannot be created or destroyed
- Theories go further than this; they are **explanations of phenomena** observed in nature
  - E.g. a theory known as 'systems theory' seeks to *explain* open and closed systems
- Both laws and theories can be used to **make predictions**, e.g. about the effect of change on a system

Useful generalisations

- The statement that 'the sun is the initial source of energy for food chains' is an example of a **useful generalisation**; this is because it is true for most food chains, but there are examples of food chains that do not directly rely on the sun as a source of energy

Your notes

Energy Flow in Ecosystems

Flow of Chemical Energy

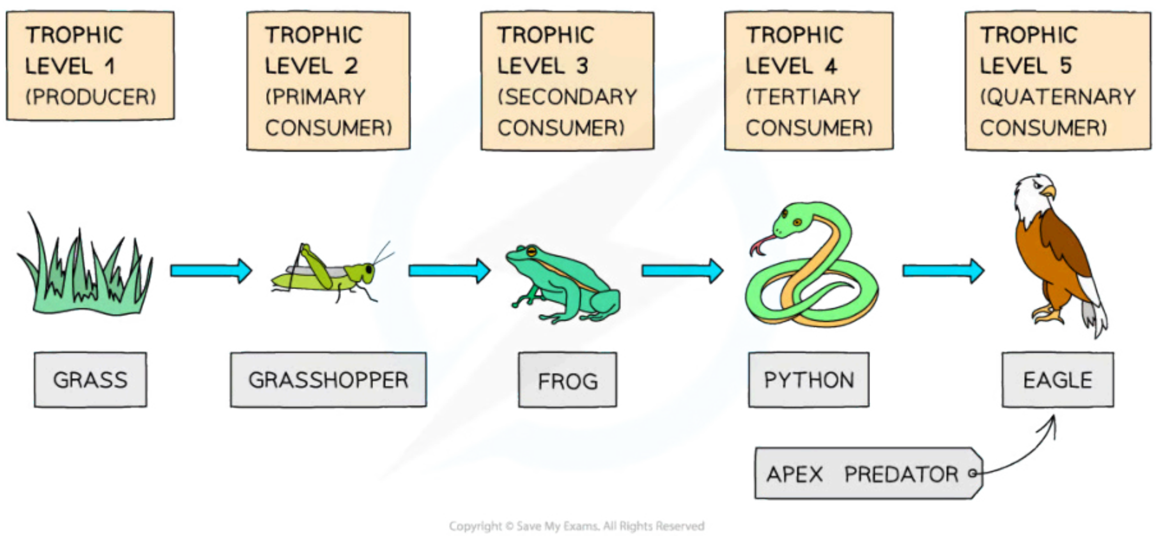
- **Photosynthesis** is the process of **converting light energy into chemical energy**
  - Light energy is used by plants to power several processes which result in the **production of organic molecules**, or carbon compounds, including:
    - Glucose, which is used in respiration or stored in plant cells in the form of starch
    - Lipids
    - Amino acids
- Chemical energy, stored in **carbon compounds** in plant tissues, is **passed to the primary consumer** when the plant is **ingested**
  - The primary consumer **digests** the plant tissues and **absorbs** the carbon compounds containing **stored chemical energy**
  - These carbon compounds can either be used to fuel **respiration** or to build up animal tissue, meaning that the **stored chemical energy is transferred** to the tissues of the primary consumer
- When the primary consumer is ingested, the **carbon compounds in its tissues,** along with their **stored chemical energy**, pass to the **secondary consumer**, and so on up the food chain
- When an organism dies, the chemical energy stored in carbon compounds in its tissues passes to **detritivores** and **saprotrophs**

Constructing Food Chains & Food Webs

Food chains

- Food chains shows the **feeding relationships** between the organisms in an ecosystem
- In a food chain, the arrows represent the **transfer of energy**, in the form of stored chemical energy in carbon compounds, from one trophic level to the next, by the process of **feeding**
- Food chains also show the transfer of biomass between trophic levels

Food chain diagram

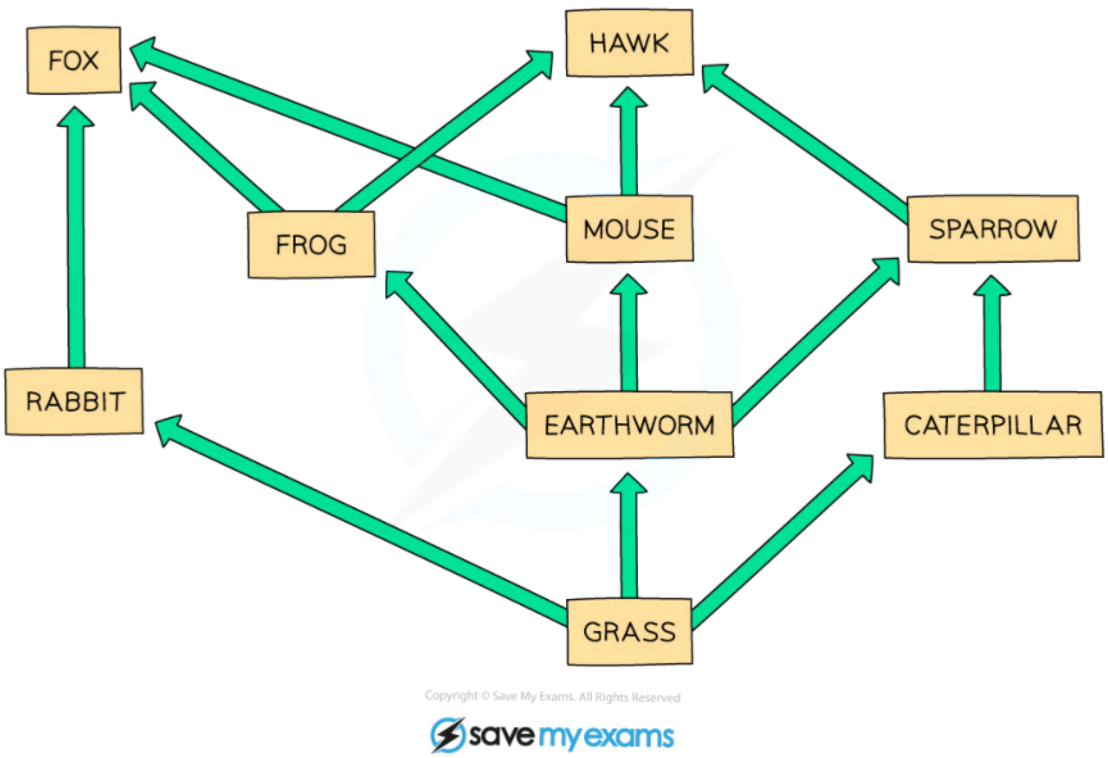


The arrows in a food chain represent the transfer of energy

Food webs

- Food webs show how **several food chains within an ecosystem are connected**
- In a real ecosystem, most species will have **more than one food source**, and will become **food for more than one consumer species**

Food web diagram



Food webs show the connections between food chains in an ecosystem

Your notes

Exam Tip

Don't forget that the arrows in a food chain or food web represent the **transfer of chemical energy** and **biomass** from one trophic level to the next through feeding.

Obtaining Carbon Compounds in Ecosystems

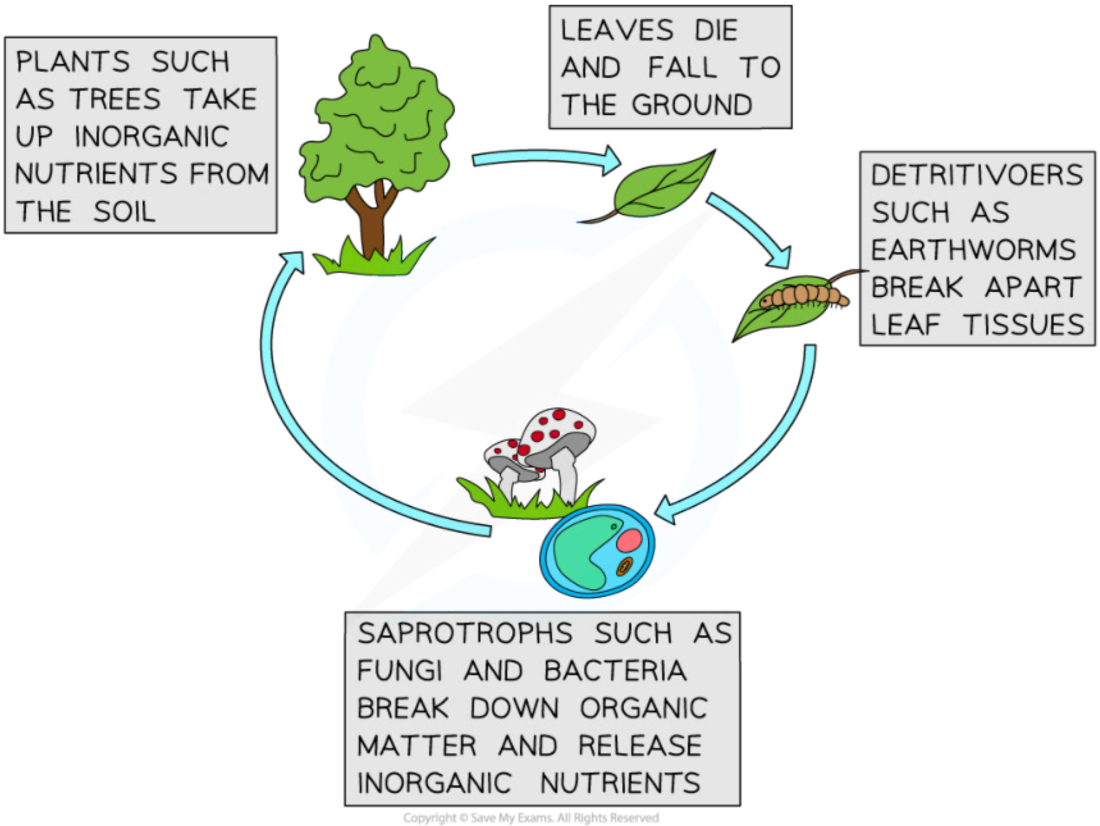
Your notes

Decomposers & Carbon Compounds

- When inorganic nutrients enter the food chain, they are converted into carbon compounds, e.g. carbohydrates and proteins, and are **locked up inside the tissues of living plants and animals**
- Because the **supply of inorganic nutrients is finite**, it is essential that when these organisms die the **nutrients locked up in their tissues are released**
  - The carbon compounds need to be converted back into inorganic nutrients that can be used by producers
- The process of breaking down the bodies of **dead organisms** and the **waste products** of living organisms is known as **decomposition,** and it enables the **cycling of nutrients**
  - Decomposition allows the breakdown of molecules in the **bodies of dead organisms**, **dead parts of organisms**, e.g. a fallen tree branch, and animal **faeces**
- The cycling of nutrients is carried out by **decomposers**, e.g.
  - **Detritivores** often begin the process of decomposition by breaking apart tissues
  - **Saprotrophs** release enzymes that break down the organic molecules in the tissues, **releasing inorganic nutrients**
- Saprotrophs absorb some of the nutrients themselves, and what is left in the soil becomes available for other organisms, e.g. producers

Nutrient cycling diagram

Your notes



Decomposers release carbon compounds from dead tissues and waste, making them available for themselves and for other organisms

Autotrophs & Carbon Compounds

Your notes

- Organisms need **energy in the form of** ATP to survive
- The energy stored in ATP comes from other **organic molecules, such as carbohydrates,** and is transferred during the process of **respiration**
- The method by which an organism gains organic molecules to fuel respiration is known as its **mode of nutrition**
- There are two main modes of nutrition; **autotrophy** and **heterotrophy**

Autotrophs

- An **autotroph synthesises**, or produces, **its own organic molecules** from simple inorganic substances in its environment, e.g.
  - Photosynthetic organisms use **light energy** to **fix carbon dioxide** from the air **into organic molecules** such as carbohydrates; these are **photoautotrophs**
  - Some autotrophs use **energy from the oxidation of inorganic compounds** instead of light energy; organisms that use energy from oxidation of chemicals in this way are known as **chemoautotrophs**
- The organic molecules produced can be built up into a range of macromolecules needed to produce cells and tissues, e.g. proteins and lipids
  - Chemical reactions that build larger molecules from smaller molecules are described as **anabolic**
- Because autotrophs make their own organic molecules without relying on other organisms, they are known as **producers**
- Most green plants are autotrophs, along with algae such as seaweeds, and photosynthetic bacteria such as cyanobacteria

Photoautotrophs & Chemoautotrophs

Your notes

- The energy transferred to ATP during ATP synthesis comes from **oxidation reactions**
  - Oxidation reactions involve the **loss of electrons**; you may be familiar with the acronym OIL = oxidation is loss
  - The donated electrons can be used in the production of ATP
- Different types of autotroph harvest electrons in different ways:

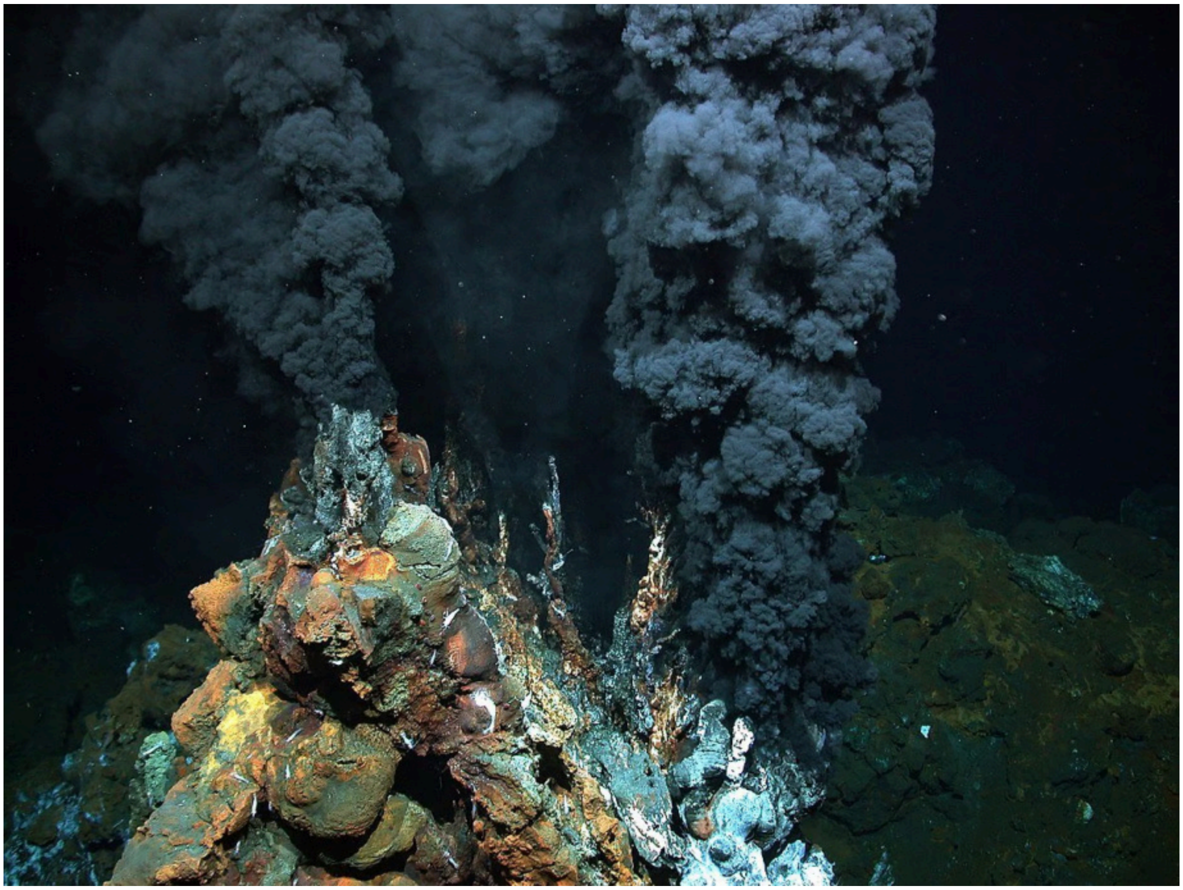
Photoautotrophs

- **Light energy** is used to release electrons:
  - Light energy **splits water in the process of photolysis**, releasing electrons, hydrogen ions and oxygen
  - Light energy **excites electrons in photosynthetic pigments**, causing them to be released
- The resulting electrons and hydrogen ions can be used in the production of ATP and reduced coenzymes
- ATP and reduced coenzymes are then involved in the **production of carbon compounds**, such as glucose, during the light independent reactions of photosynthesis

Chemoautotrophs

- Chemoautotrophs **oxidise inorganic chemicals** in the environment to provide electrons for ATP production
- E.g. some bacteria produce ATP by **oxidising iron**
  - Iron(II), or Fe^{2+} is oxidised to iron(III), or Fe^{3+}
  - The donated electrons are used in the production of ATP
- These chemoautotrophs take the role of **producers** in habitats where **light energy is not available**, e.g. in deep sea vents or caves

Your notes



Chemoautotrophs are the producers in ecosystems found around deep sea volcanic vents

Oxidation of Carbon Compounds

Your notes

- Autotrophs produce their own carbon compounds, and heterotrophs gain carbon compounds from other organisms
- The chemical energy stored in these carbon compounds can be **released by the process of** respiration
  - The carbon compound **glucose** is the fuel for respiration
  - Other carbon compounds such as lipids **can be converted into glucose** before being respired
- Respiration releases energy by the **oxidation of carbon compounds**
- The energy released during respiration can be used by by autotrophs and heterotrophs to carry out the **functions of life**
  - **M**etabolism - the enzyme-catalysed reactions taking place inside cells
  - **R**eproduction - the sexual or asexual production of offspring
  - **H**omeostasis - the maintenance of internal conditions within tolerable limits
  - **G**rowth - increasing in size
    - Note that during growth some of the chemical energy in the **carbon compounds** ingested by an organism is **incorporated into the tissues** of the organism as it grows; this **stored chemical energy can be passed to the next trophic level** in the food chain
  - **R**esponse - sensing and responding to the environment
  - **E**xcretion - disposal of metabolic waste
  - **N**utrition - gaining energy and nutrients
- The process of respiration also **releases heat as a by-product**

Exam Tip

Remember that **cellular respiration** occurs in **both heterotrophs and autotrophs**. The carbon compounds that fuel respiration are supplied in different ways, but respiration is common to both groups of organisms.

Heterotrophs & Carbon Compounds

Heterotrophs

- Heterotrophic organisms **gain their carbon compounds by ingesting the tissues** of other organisms
  - This may be through eating plants, killing and consuming other animals, consuming the bodies of dead organisms, or consuming biological waste
- Heterotrophs **ingest biological material** from other organisms, **breaking tissues down in the process of digestion** before **building the molecules back up** into, e.g. new proteins and nucleic acids
  - Note that the process of digestion can occur either inside or outside the body of the heterotroph
- The new carbon compounds can then be **assimilated into the bodies** of heterotrophs, where they become available to the next trophic level
- There are several types of heterotroph, including **consumers**, **detritivores**, and **saprotrophs**

Trophic Levels

Your notes

Trophic Levels

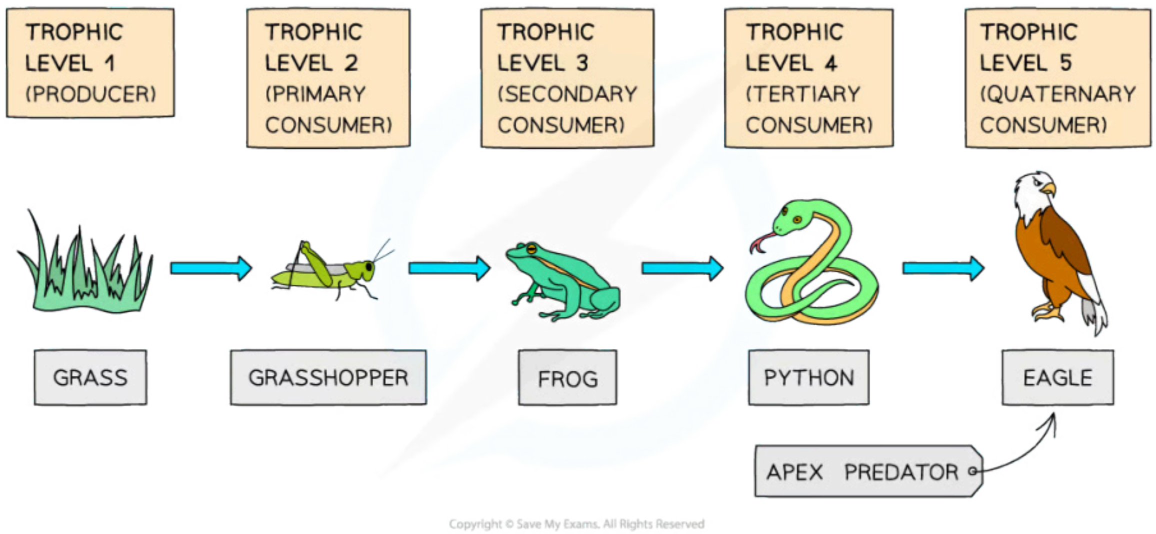
- Trophic levels are the **position of an organism in a food chain,** and indicate **how many organisms energy has passed through**
- Trophic levels can be represented by **numbers**, beginning with producers at the **first trophic level**, and progressing to consumers at the **second** and **third trophic levels**, etc.

Trophic levels table

Trophic level	Name of trophic level	Description of trophic level
1	Producers	Organisms that produce their own carbon compounds using, e.g. light energy
2	Primary consumers	Herbivores that feed on plant tissue
3	Secondary consumers	Carnivores that are predators of primary consumers
4	Tertiary consumers	Carnivores that are predators of secondary consumers
5	Quaternary consumers	Carnivores that are predators of tertiary consumers

- Energy from **sunlight** enters the food chain at the **first trophic level**
  - **Producers** convert **light energy** into **chemical energy**
  - This occurs during **photosynthesis**
- This **chemical energy** is then **transferred** to **primary consumers** as they consume producers
- The **chemical energy** is then **transferred** from **one consumer to the next** as each organism is ingested by organisms higher up the food chain
  - Primary consumers transfer energy to **secondary consumers**
  - Secondary consumers transfer energy to **tertiary consumers**
  - Tertiary consumers transfer energy to **quaternary consumers**
- **Apex predators** are at the very **top** of the food chain; these top predators have no predators that prey on them
- The chemical energy stored within apex predators can be passed on to **decomposers** when apex predators die and are decomposed

Your notes



Trophic levels are the levels at which organisms feed in a food chain, and indicate the number of organisms through which energy has been transferred

- Trophic levels can also be identified within **food webs**, which give a clearer representation of the **complex feeding relationships** present in an ecosystem
- Note that **some organisms have a varied diet**, meaning that a species may be present at **more than one trophic level** in an ecosystem
  - Species may be at different trophic levels **in different food chains** within a food web, e.g. in the food web below:
    - Sparrowhawks are at the **third, fourth and fifth trophic levels** in the food chains:

Grass → mouse → **sparrowhawk**

Tree → butterfly → robin → **sparrowhawk**

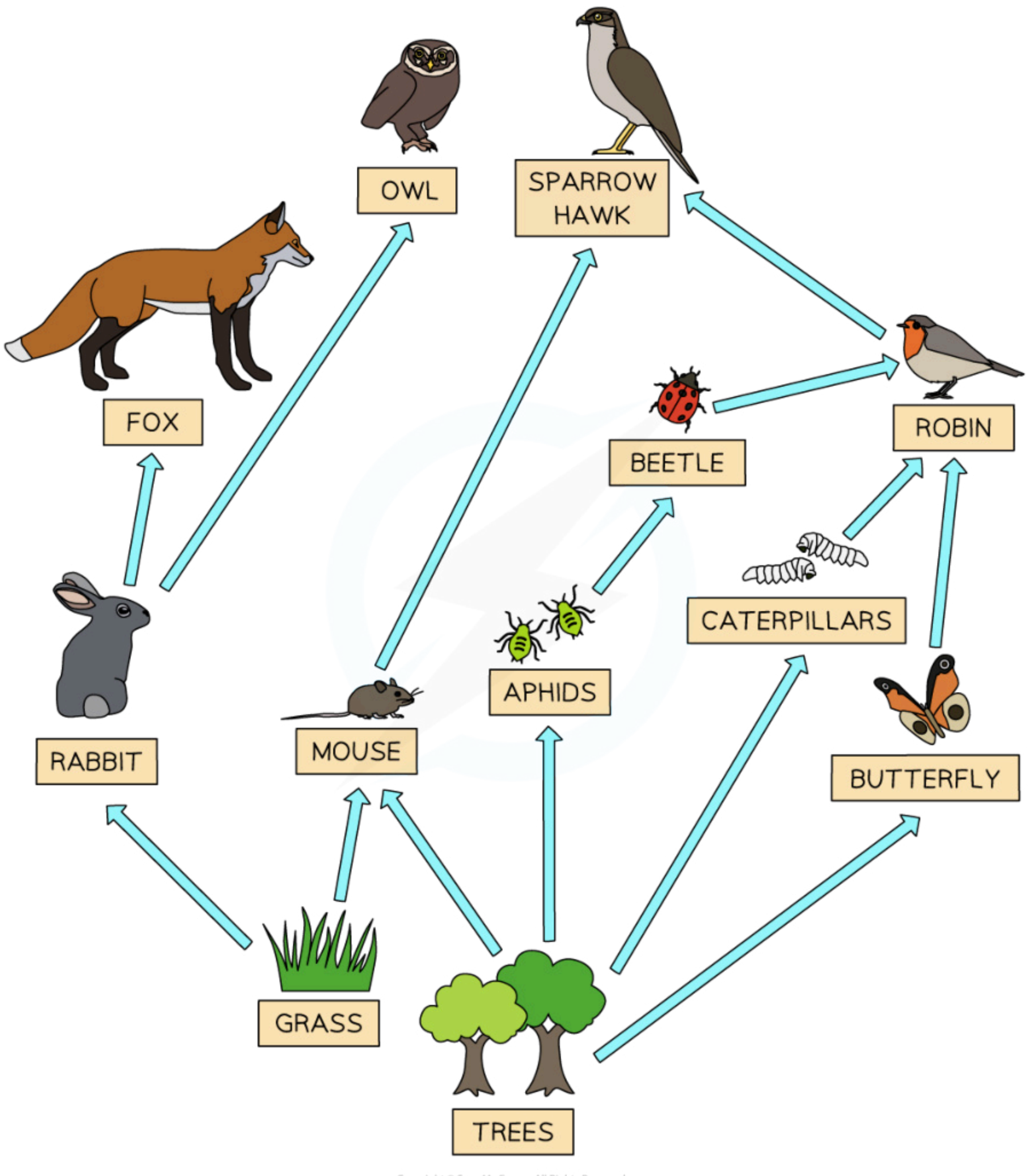
Tree → aphid → beetle → robin → **sparrowhawk**

    - Robins are at the **third and fourth trophic levels** in the food chains:

Tree → caterpillar → **robin** → sparowhawk

Tree → aphid → beetle → **robin** → sparrowhawk

Your notes



Food webs also contain trophic levels. Note that it is possible for an organism to be at different trophic levels in different food chains within a food web.

Pyramids of Energy: Skills

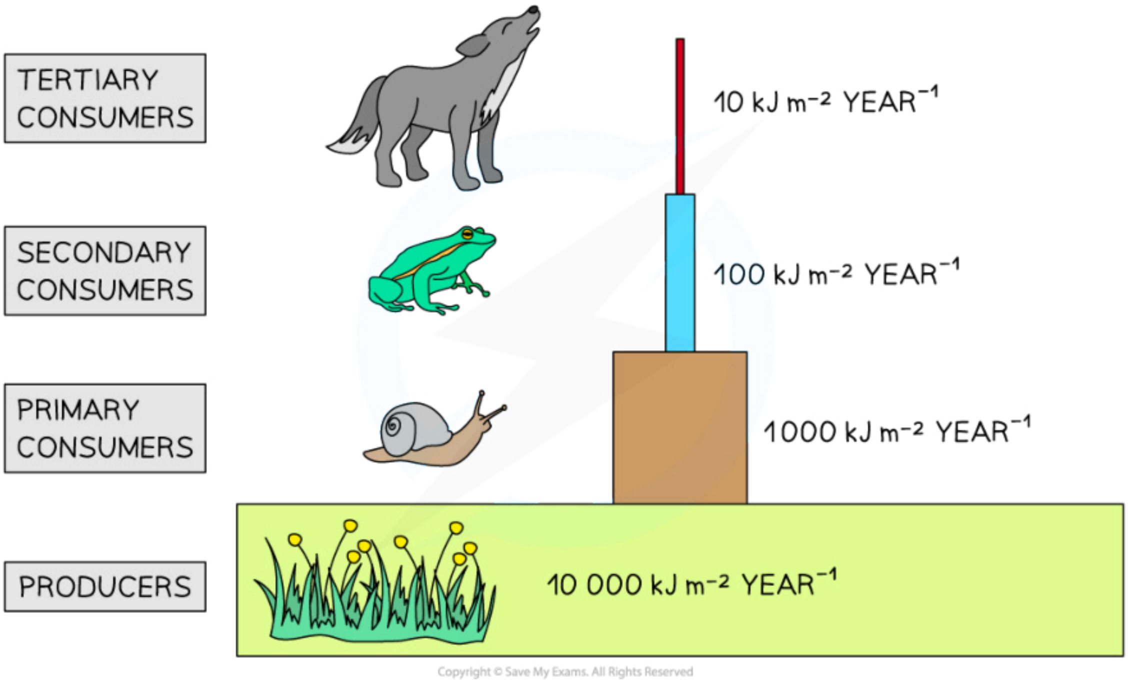
Your notes

Pyramids of Energy: Skills

- Pyramids of energy illustrate the **energy contained** within the biomass of organisms at each trophic level
- The **length** of each box, or bar, represents the energy present
  - Pyramids of energy **should be drawn to scale** so that each bar is **proportional** in size to the energy that it represents
  - In some situations, however, a pyramid of energy may be an approximate sketch where each bar is a rough representation of the energy contained
- These pyramids are always **widest at the base** and decrease in size as they go up
  - The base is wide due to there being more energy contained within the biomass of producers
- Pyramids of energy show a **stepped decrease** in the energy contained at each level of the food chain, rather than appearing as a pyramid with smooth sides
- The levels of a pyramid of energy should be labelled **producer**, **primary consumer**, **secondary consumer**, and so on
- The units used should be the **energy, per unit area, per year** e.g. kJ m^{-2} $year^{-1}$
- As you move up the pyramid to higher trophic levels, the energy available decreases as **not all energy is transferred** to the biomass of the next trophic level
  - Roughly 10 % of the energy is passed on at each trophic level
- Energy is lost at each trophic level due to
  - Incomplete consumption
  - Incomplete digestion
  - Loss of heat energy to the environment during respiration
  - Excretion of the waste products of metabolism e.g. carbon dioxide, water, and urea
- As a result of this the **biomass** at each trophic level will also decrease as energy availability decreases

Pyramid of energy diagram

Your notes



The energy stored in the biomass of organisms can be represented by a pyramid of energy

Exam Tip

Remember that pyramids of energy should be **drawn to scale** and the units used should be **energy, per unit area, per year** e.g. kJ m^{-2} $year^{-1}$

Energy Losses

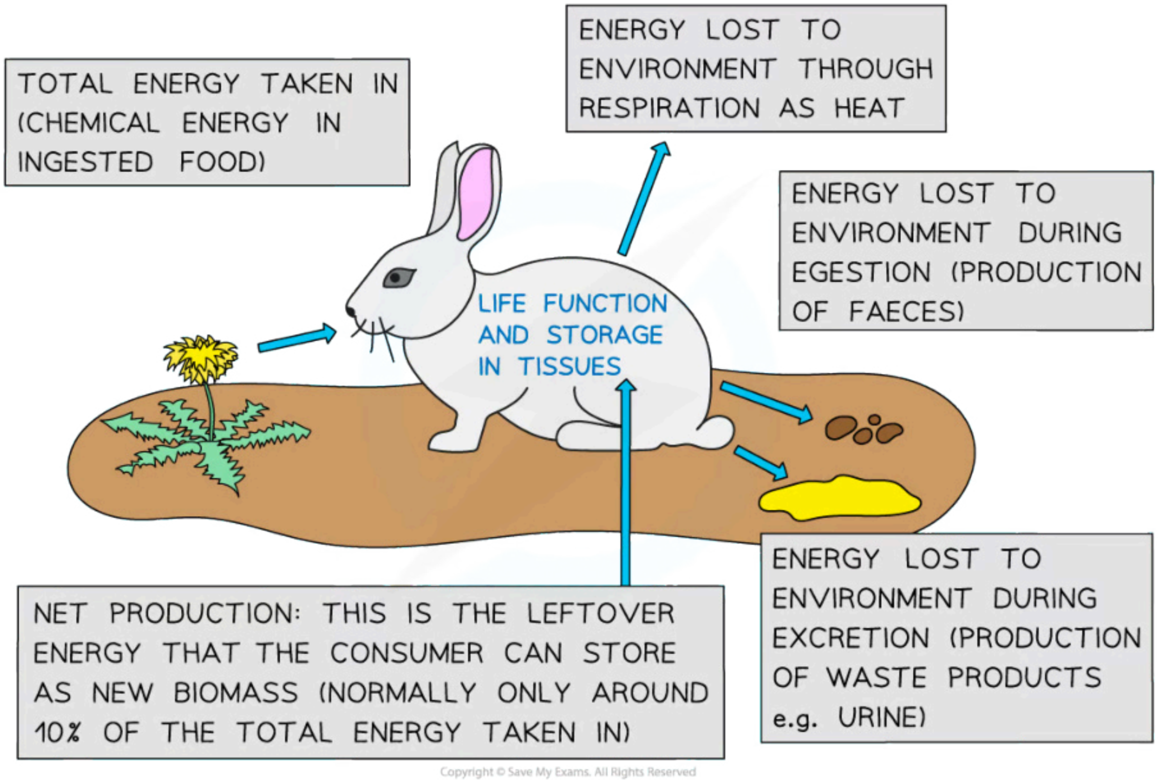
Your notes

Energy Losses between Trophic Levels

- When a consumer ingests another organism **not all the chemical energy in the consumer's food is transferred to the consumer's tissues**
  - **Only around 10 %** of the energy is available to the consumer to store in their tissues
  - This is because **around 90 %** of the energy is **lost to the environment**
- Around 90 % of the energy is lost to the environment because
  - **Not every part of the food organism is eaten**
    - E.g. the roots and woody parts of plants or the bones of animals, meaning that the chemical energy these uneaten tissues contain is **lost** to the **environment**
  - Consumers are **not able to digest** all of the food they ingest
    - E.g. cellulose in plants, or the fur of animals, so some is **egested** as **faeces**; the chemical energy in this undigested food is also lost to the environment
  - Energy is lost to the environment in the form of **heat** when consumers **respire**
  - Energy is lost to the environment when organisms **excrete** the waste products of metabolism
    - E.g. urea in urine
  - **Not all individual organisms are consumed**; some die without being consumed, and their bodies decompose
- The energy that is left after these losses **is available to the consumer** to fuel their **life functions,** including being stored in **carbon compounds in their tissues during growth**

Energy losses diagram

Your notes



Energy is lost from the food chain as heat during respiration, due to incomplete digestion, and through excretion of the waste products of metabolism. Remaining energy fuels the organism's life processes or is stored in carbon compounds in the tissues.

The role of decay organisms in energy loss

- Note that while **detritivores and saprotrophs are not considered to be part of a food chain**, they have a role to play in the **loss of energy from food chains**:
  - They decompose the parts of organisms that are not eaten, e.g. the bones and teeth of dead prey animals
  - They break down undigested waste material
  - They decompose the bodies of any organisms that die and are not consumed

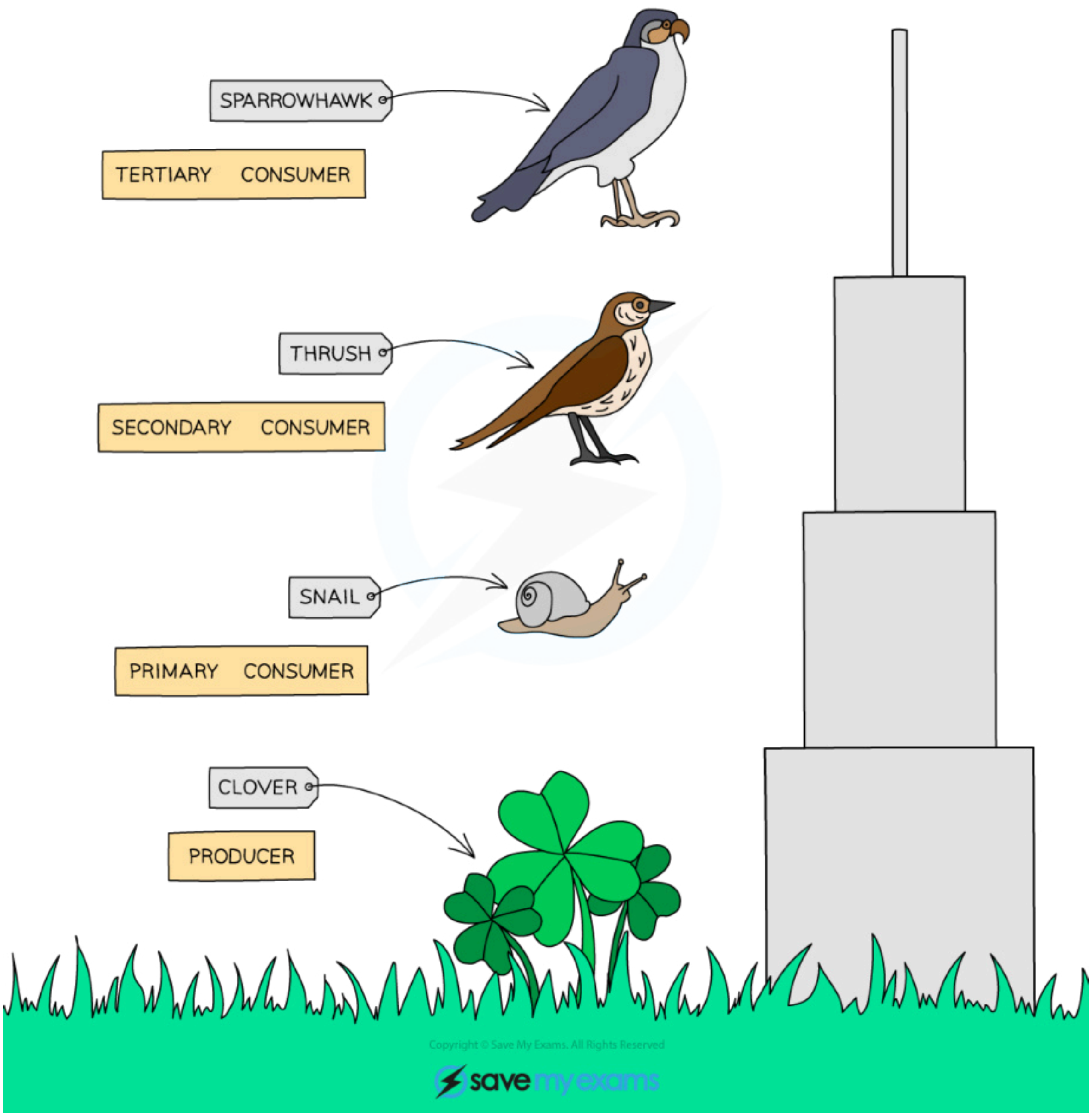
Number of Trophic Levels & Energy Loss

Your notes

- **Food chains are limited in length**
  - Food chains rarely have more than around four or five trophic levels; this is because with energy losses at each trophic level, there is **less and less energy available to the consumer** as you go up the food chain
  - When a food chain gets longer than four or five trophic levels it becomes too difficult for a predator to hunt enough prey to gain the energy to survive
- Biomass **decreases with each trophic level**, e.g. due to **fewer individuals** being present, or due to **individuals being smaller**
  - Because only around 10 % of the energy stored in a producer's tissues is available to a primary consumer, **primary consumers needs to consume a lot of plant biomass to gain enough energy to survive**
  - Again, only around 10 % of the energy stored in a primary consumer's tissues is available to a secondary consumer, meaning that **secondary consumers need to consume a lot of prey biomass to gain enough energy to survive**
- This leads to a **large reduction in biomass** at each trophic level and means that when represented in terms of biomass, food chains have a **pyramid** structure
  - Note that while the biomass decreases at each trophic level of a food chain, the energy stored in that biomass per unit of mass does not change

Pyramid of biomass diagram

Your notes



The biomass at each trophic level of a food chain can be represented as a pyramid of biomass. The pyramid shape results from the energy losses at each trophic level.

Your notes

Exam Tip

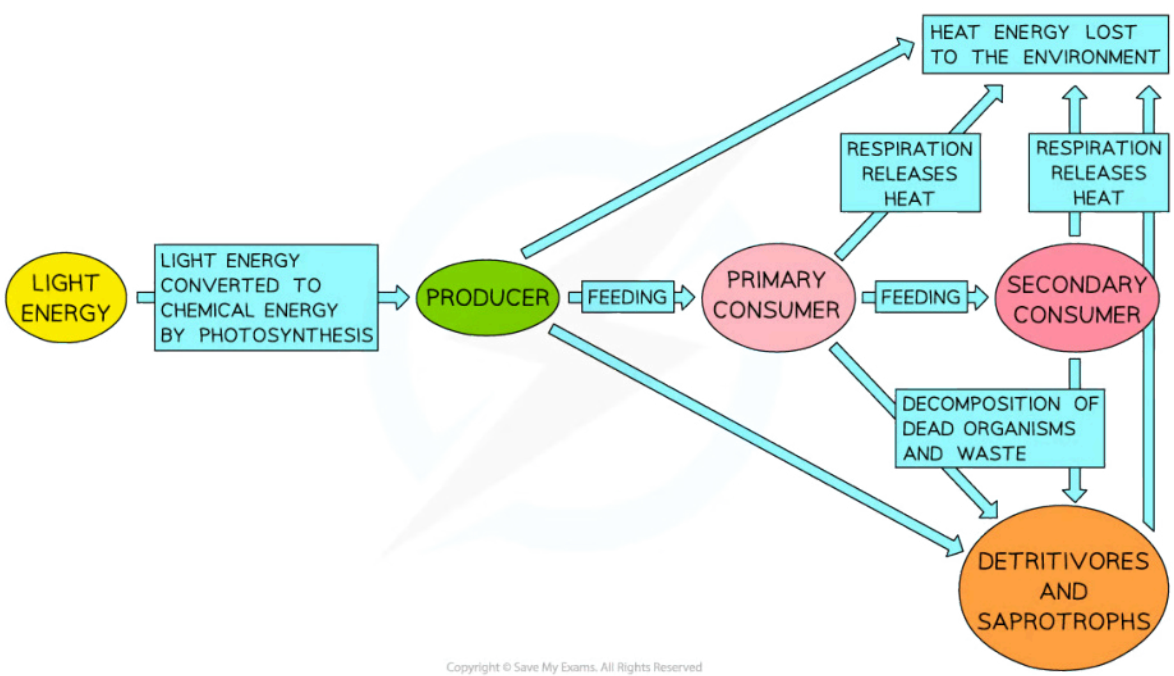
Make sure that you know the different **ways that energy can be lost** from a food chain and that you can explain the effects that these losses have on food chain structure.

Be careful not to mix up **pyramids of biomass** (above) with **pyramids of energy**.

Heat Loss to the Environment

- The transfer of energy in food chains is **not 100 % efficient**
- **Heat** is lost to the environment **during cellular respiration** and **when ATP is used** in other cellular processes
    - This applies in **producers, consumers, detritivores**, and **saprotrophs**
- This **heat energy is lost to the environment** at every trophic level, and during decomposition
    - Heat loss occurs by the process of **radiation**

Energy lost as heat diagram



Heat energy released during respiration and other cellular processes is lost to the environment at every stage of the food chain

Primary & Secondary Production

Your notes

Secondary Production

- Organisms that gain carbon compounds by ingesting **other organisms** are known as **heterotrophs**
- When heterotrophs ingest other organisms, the **chemical energy** in the **biomass** of these organisms is **transferred** to the heterotrophs and stored in their own biomass
- This process by which **biomass is stored in the tissues of heterotrophs** is known as **secondary production**
- However, **not all** the energy stored in the carbon compounds consumed by heterotrophs is transferred to new biomass
  - Carbon is lost in the form of carbon dioxide as a waste product of respiration
  - Energy is lost during the excretion of other metabolic waste, such as water and urea
- Due to the subtraction of respiratory losses, the **rate of secondary production is always lower than the rate of primary production** in an ecosystem
  - The rate of secondary production is therefore calculated by **subtracting respiratory losses** from the **stored energy ingested** by a heterotroph

Exam Tip

The terminology here can be confusing, so be sure that you are happy with the following main ideas:

- **Primary production** is the accumulation of biomass in autotrophs while **secondary production** is the accumulation of biomass in heterotrophs
- The **rate** of production, i.e. how quickly or slowly production is taking place, is usually measured in **$g\ m^{-2}\ yr^{-1}$**
- **Secondary production is lower** than primary production due to **energy losses** at each trophic level

Primary Production

Your notes

- During photosynthesis, autotrophs can convert **light energy** into **chemical energy** stored in biological molecules
  - Organisms that do this are known as **producers**
- The accumulation of carbon compounds in the biomass of autotrophs is known as **primary production**
  - **Biomass accumulates** when organisms **grow and reproduce**
- Primary production occurs more quickly in some biomes than in others
  - Biomes that have **more hours of sunlight**, **optimum temperatures** and **higher levels of rainfall** will allow **photosynthesis to occur at a higher rate**, leading to faster primary production
- E.g. tropical forest biomes have high levels of sunlight, rainfall, and ideal temperatures, so primary production occurs very quickly

Tropical forest biomes have very high rates of primary production due to the high rate at which photosynthesis can occur

Measuring the rate of primary production

- The **rate** at which producers convert light energy into chemical energy is expressed in **units of biomass, per unit area (or volume), per unit time**, e.g.
  - Using area: $g\ m^{-2}\ yr^{-1}$ (biomass, per *square* metre, per year)
  - Using volume: $g\ m^{-3}\ yr^{-1}$ (biomass, per *cubic* metre, per year)
    - Volume would be used when calculating rate of production in aquatic habitats

Your notes

The Carbon Cycle

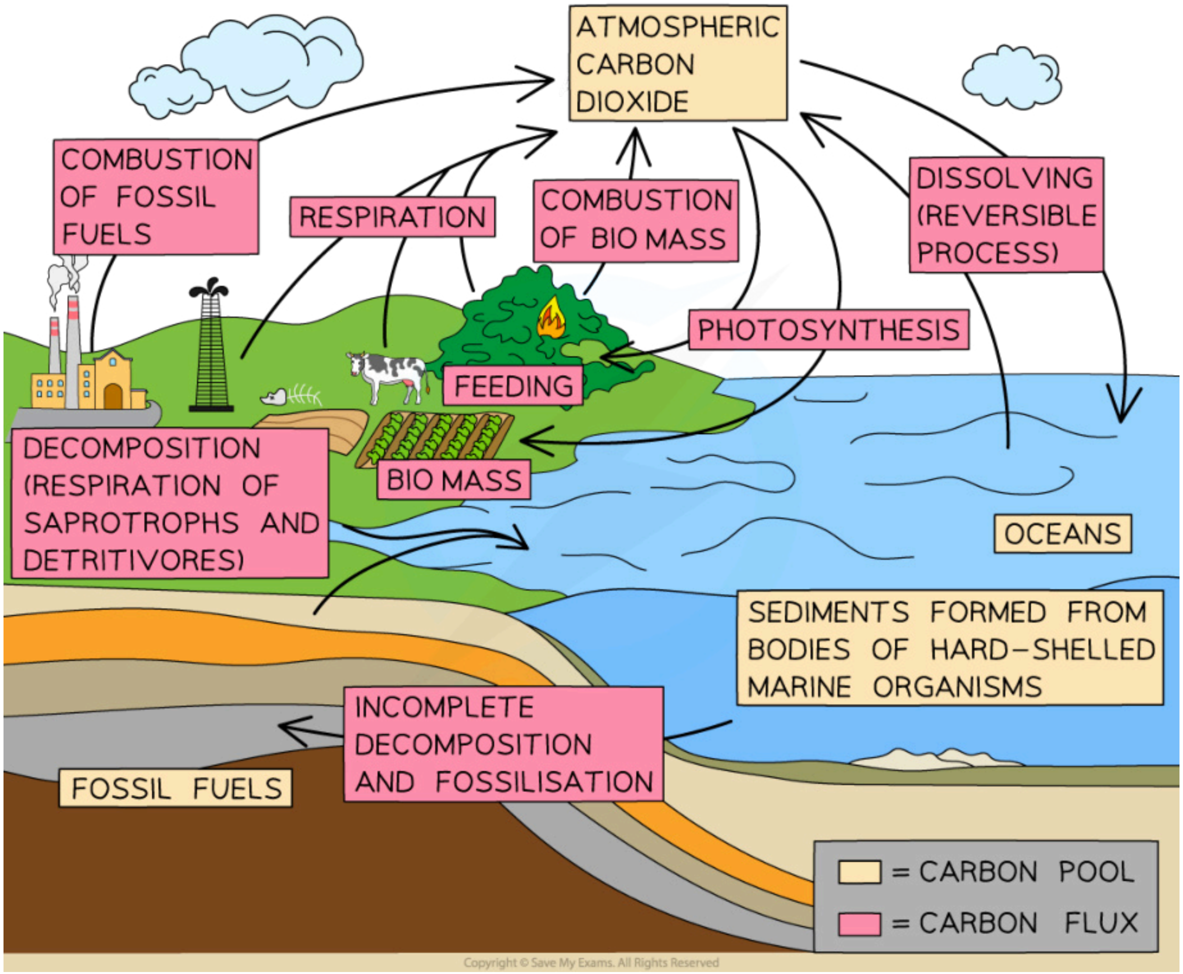
Your notes

Carbon Cycle Diagrams

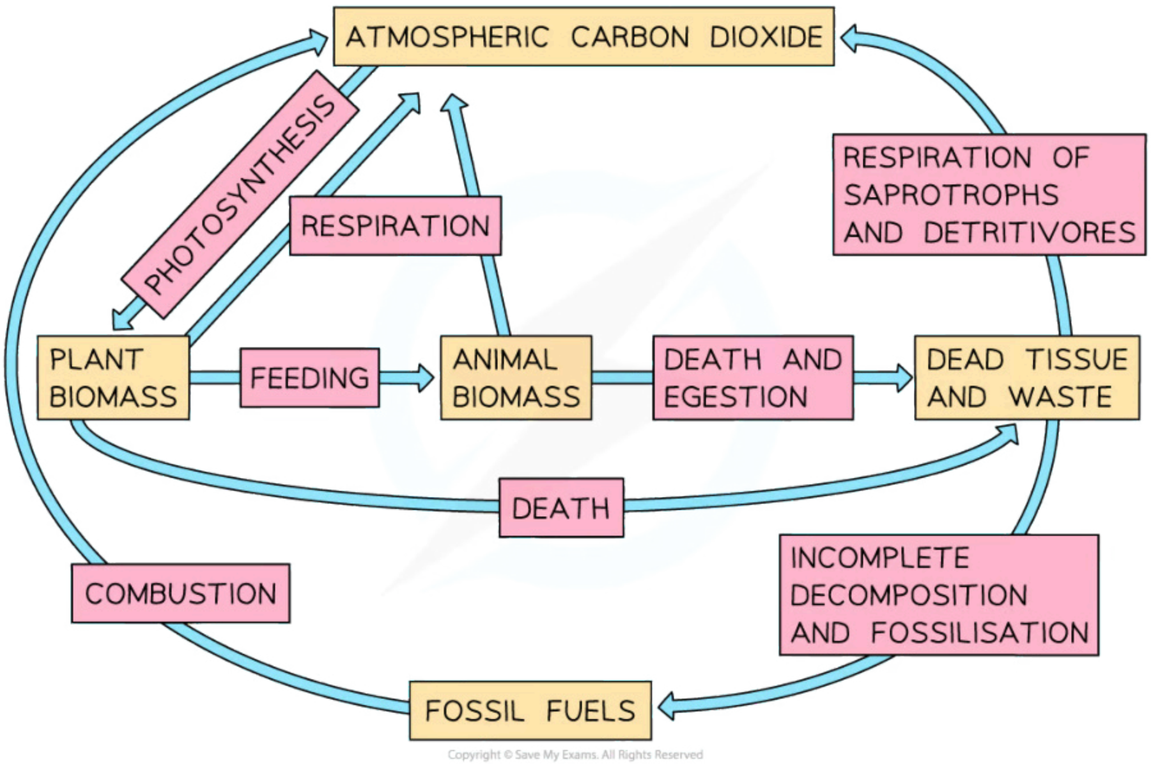
- The many processes by which carbon is transferred from one store to another are collectively known as the **carbon cycle**
  - During the carbon cycle, carbon is present in both **organic** and **inorganic** forms
    - Organic carbon is found in the biomass of living organisms, e.g. in **carbohydrates** and **proteins**
    - Inorganic carbon is found in the **atmosphere** as **carbon dioxide** and in the **oceans** as, e.g. **hydrogen carbonate ions**
- The carbon cycle can be represented using a **diagram**
  - Carbon cycle diagrams show:
    - Carbon stores, known as **pools** or **sinks**, e.g. the ocean, fossil fuels, or living organisms
    - Processes of carbon transfer, known as **fluxes**, e.g. dissolving, combustion, or photosynthesis
- Diagrams can be illustrated, or can be simple, containing just text boxes and arrows
- Diagrams can show **terrestrial** carbon cycling, **marine** carbon cycling, or **both combined** in one diagram

Carbon cycle diagrams

Your notes



Carbon cycle diagrams can be illustrated, and can show both terrestrial and marine cycling



Carbon cycle diagrams can be simple, and may show only terrestrial carbon cycling

Your notes

Carbon Sinks & Sources

- A **carbon sink** is a part of the carbon cycle that **takes up and stores carbon**, e.g.
  - Plants take up carbon dioxide when they photosynthesise and convert it into carbon compounds which they store in their tissues; plants therefore act as carbon sinks
  - Plant material sometimes fails to decompose and forms fossil fuels or peat; these substances act as carbon sinks over very long time periods
  - Carbon dioxide dissolves in the oceans, which form a large carbon sink
- A **carbon source** is a part of the carbon cycle that releases carbon, e.g.
  - If plant material is burned then the carbon stored within the tissues is released back into the atmosphere
  - The decay of dead or waste material leads to the release of carbon

Net uptake and release of carbon dioxide

- If an organism carries out **photosynthesis at a higher rate than respiration**, e.g. plants, then there can be said to be a **net uptake of carbon dioxide** and that organism will function as a carbon sink within its ecosystem
  - The term 'net' refers to the **overall direction of movement**
- If an organism carries out **respiration at a higher rate than photosynthesis**, e.g. animals, then there will be a **net release of carbon dioxide** and that organism will function as a carbon source within its ecosystem

Your notes

Release of Carbon Dioxide

Your notes

- Carbon can be returned to the atmosphere by the burning of **fossil fuels** and **organic material**; a process known as **combustion**
  - Complete combustion releases **carbon dioxide** and water as by-products
- Carbon is released during the combustion of:
  - Coal
  - Oil
  - Natural gas
    - Coal, oil and gas are **fossil fuels**; these have formed over millions of years from the bodies of dead plants and animals; burning them releases carbon that has been locked up for very long time periods
  - Peat
    - This is a material that forms when plant matter does not fully decompose due to waterlogged and acidic conditions; it releases carbon when it is burned, and when it is allowed to dry out and decompose
  - Biomass
    - This refers to plant matter, e.g. wood
- **Organic material**, or biomass, burns when fires occur in, e.g. forests or grasslands; **human activities have increased the burning of biomass**
  - Such fires can have natural causes, e.g. **lightning** hitting hot, dry ground, but can be set by humans, e.g. when **clearing land** for the purpose of farming
    - **Climate change** has increased the occurrence of wildfires
  - Biomass can also be **burned as a fuel** in e.g. wood fires or biomass boilers
- The burning of biomass is considered to have a less significant impact on atmospheric carbon dioxide than the burning of peat and fossil fuels; this is because the carbon contained in plant tissues has been removed from the atmosphere **relatively recently** (i.e. within the lifetime of the plant), whereas the carbon locked up in peat has been in that form for potentially **thousands of years**, and the carbon in fossil fuels for **millions of years**

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Carbon is released during combustion of peat (left) and combustion of biomass, e.g. during forest fires (right)

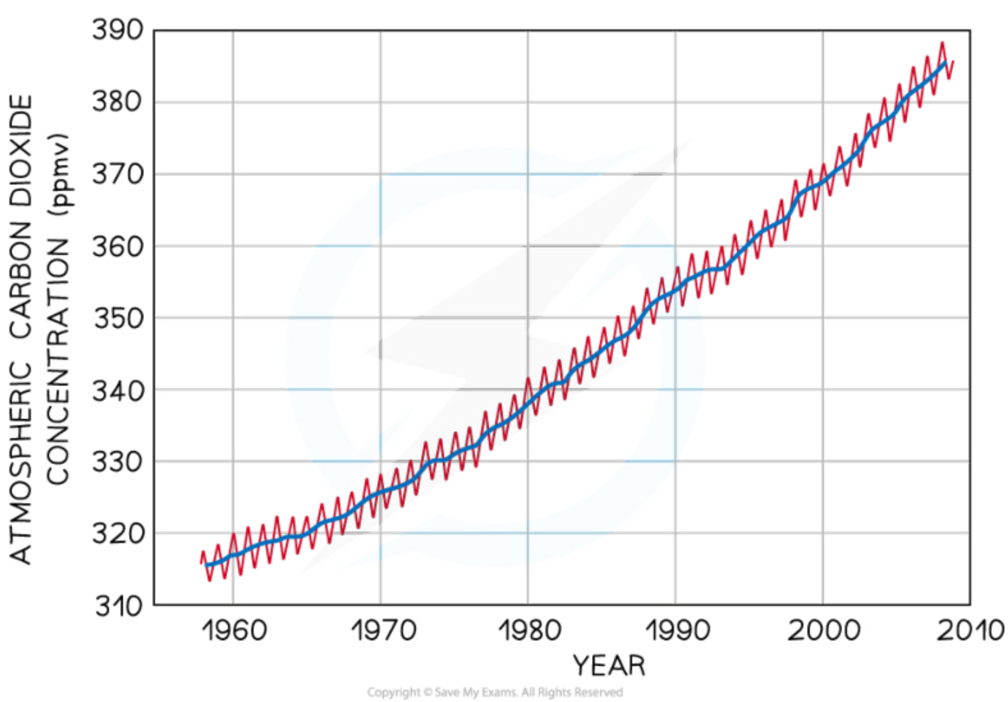
Your notes

Keeling Curve Analysis

Your notes

- Scientists from the World Meteorological Organisation and research stations have been taking quantitative measurements of the **atmospheric carbon dioxide** for many years
- The **Mauna Loa Observatory**, Hawaii, has been recording carbon dioxide levels since 1958
  - The data collection was initially carried out by American scientist **Charles Keeling**, and the dataset from Mauna Loa is now named after him
- The concentration of **carbon** in the atmosphere is constantly changing **due to seasonal fluctuations in rates of** photosynthesis; this is shown on the **Keeling curve** graph below in red
  - **Photosynthesis** removes carbon dioxide from the atmosphere, meaning that **atmospheric carbon dioxide levels decrease** in whichever hemisphere is experiencing **spring and summer**
  - This **seasonal decrease** is reversed during autumn and winter when **photosynthesis rates decrease** and are overtaken by processes such as **respiration**, **decomposition**, and **combustion**
- The overall trend in atmospheric carbon dioxide levels is the result of human activities; the **combustion** of fossil fuels by humans **releases carbon dioxide** into the atmosphere faster than photosynthesis is able to remove it, meaning that **carbon dioxide levels are slightly higher every year**
  - The overall trend is shown on the Keeling curve below in blue

Keeling curve graph



The Keeling curve shows changes in atmospheric carbon dioxide levels measured at the Mauna Loa Observatory (ppmv = parts per million by volume)

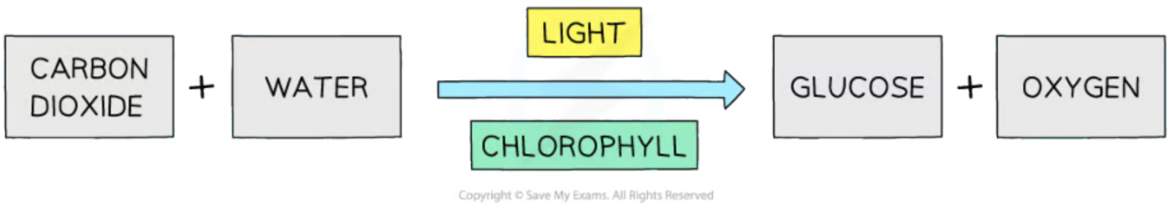
The yearly fluctuations shown in red are due to seasonal changes in photosynthesis rates, while the overall trend shown in blue is due to human combustion of fossil fuels

Nutrient Cycling

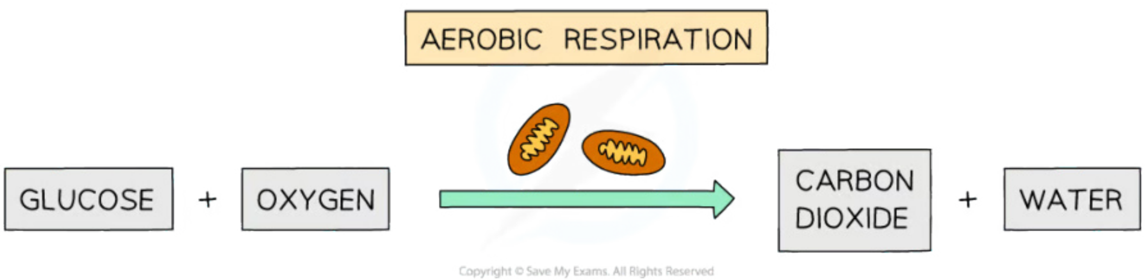
Your notes

Interaction Between Autotrophs & Heterotrophs

- The process of **photosynthesis**, carried out by most autotrophs, takes in carbon dioxide from the atmosphere and converts it into carbon compounds and **oxygen**
  - This process is the source of **atmospheric oxygen** on Earth



- **Aerobic respiration** depends on oxygen, so organisms that respire aerobically can **make use of the oxygen produced during photosynthesis** when they respire, in turn **producing carbon dioxide as a waste product**, which can be used in photosynthesis
  - Note that **both autotrophs and heterotrophs** make use of oxygen in respiration



- The combined photosynthesis of all photosynthetic organisms on earth **removes a huge volume of carbon dioxide and releases a huge volume of oxygen** into the atmosphere, while the combined respiration of all aerobically respiring organisms **removes a huge volume of oxygen and releases a huge volume of carbon dioxide**
  - This is a major **interaction** between autotrophs and heterotrophs
- The process that transfer carbon are known as **fluxes**; huge carbon fluxes take place on Earth every year due to photosynthesis and respiration

Recycling of Chemical Elements in Ecosystems

Your notes

- In a functioning ecosystem the elements that living organisms need are **constantly recycled**
  - Producers access inorganic nutrients **from the abiotic environment** and **convert them** into **carbon compounds**
  - Consumers gain organic nutrients from **ingesting** the tissues of producers and other consumers
  - Decomposers **break down the organic molecules** in dead tissues and waste matter, **making them available again** to producers
- This cycling of nutrients applies to **carbon**, which is taken in from the atmosphere by producers and then returned to the atmosphere by decomposers
- **Many other mineral elements** are also cycled through ecosystems, e.g.
  - Nitrogen
  - Calcium
  - Phosphorus
  - Sulfur
  - Potassium
- These elements are **incorporated into biological molecules** within the tissues of living organisms, and then **released back into the environment** when **decomposers break down tissues** after death

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Carbon is returned to the atmosphere and other mineral elements are returned to the soil by the action of decomposers, such as fungi and bacteria, on dead matter