Your notes

HL IB Environmental Systems & Societies (ESS)

2.2 Energy & Biomass in Ecosystems

Contents

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Energy Flow in Ecosystems

Energy Flow in Ecosystems

- Ecosystems rely on a constant supply of **energy** and **matter** to maintain their structure and function
  - Energy is essential for driving biological processes, while matter cycles through the ecosystem, being reused and recycled
- Ecosystems are considered **open systems**, meaning they exchange both energy and matter with their surroundings
  - Energy enters ecosystems primarily from the sun, entering as sunlight and being converted into chemical energy by producers through photosynthesis
    - This energy is then **transferred between trophic levels** as organisms consume one another, with some energy lost as **heat** at each transfer
    - Decomposers break down organic matter, releasing energy and returning nutrients to the environment
  - Matter, such as nutrients and water, flows into and out of ecosystems through various processes like decomposition, nutrient cycling and precipitation

The first law of thermodynamics

- Energy exists in many different **forms**, including light energy, heat energy, chemical energy, electrical energy and kinetic energy
- The way in which energy behaves within systems can be explained by the laws of thermodynamics
  - There are **two laws of thermodynamics**
- The first law of thermodynamics is as follows:

Energy can neither be created nor destroyed, it can only be transformed from one form to another

- This is also known as the principle of conservation of energy
  - It means that the energy entering a system **equals** the energy leaving it
  - It means that as energy flows through **ecosystems**, it can only change from one form to another
- The transfer of energy in food chains within ecosystems demonstrates the principle of conservation of energy:
  - Energy enters the system (the food chain or food web) in the form of sunlight
  - Producers convert this light energy into biomass (stored chemical energy) via photosynthesis

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- This chemical energy is passed along the food chain, via consumers, as biomass
- All energy ultimately leaves the food chain, food web or ecosystem as heat energy

The second law of thermodynamics

- The second law of thermodynamics is as follows:

The entropy of a system increases over time

- **Entropy** is a measure of the amount of **disorder** in a system
- As entropy increases (through inefficiencies in energy transformations) the energy available to do **work** decreases
- This is because the transformation and transfer of energy in any system is never 100% efficient
  - In other words, in any energy conversion, the amount of useable energy at the end of the process is always **less** than the amount of energy available at the start
- The second law of thermodynamics states that energy transformations in ecosystems are **inefficient**
- In this way, it explains the decrease in available energy within ecosystems:
  - In a food chain, for example, energy is transformed from a more concentrated (ordered) form (e.g. light energy from the Sun), into a more dispersed or disordered form (heat energy)
  - Initially, light energy from the Sun is absorbed by producers
  - However, even at this initial stage, energy absorption and transfer by producers is **inefficient** due to reflection, transmission (light passing through leaves) and inefficient energy transfer during photosynthesis
  - The energy that is converted to plant biomass is then inefficiently transferred along the food chain through respiration and production of **waste** heat energy
    - In ecosystems, the biggest losses occur during cellular respiration
  - As a result of these inefficient energy transfers, food chains are often **short** (they rarely contain more than five trophic levels)

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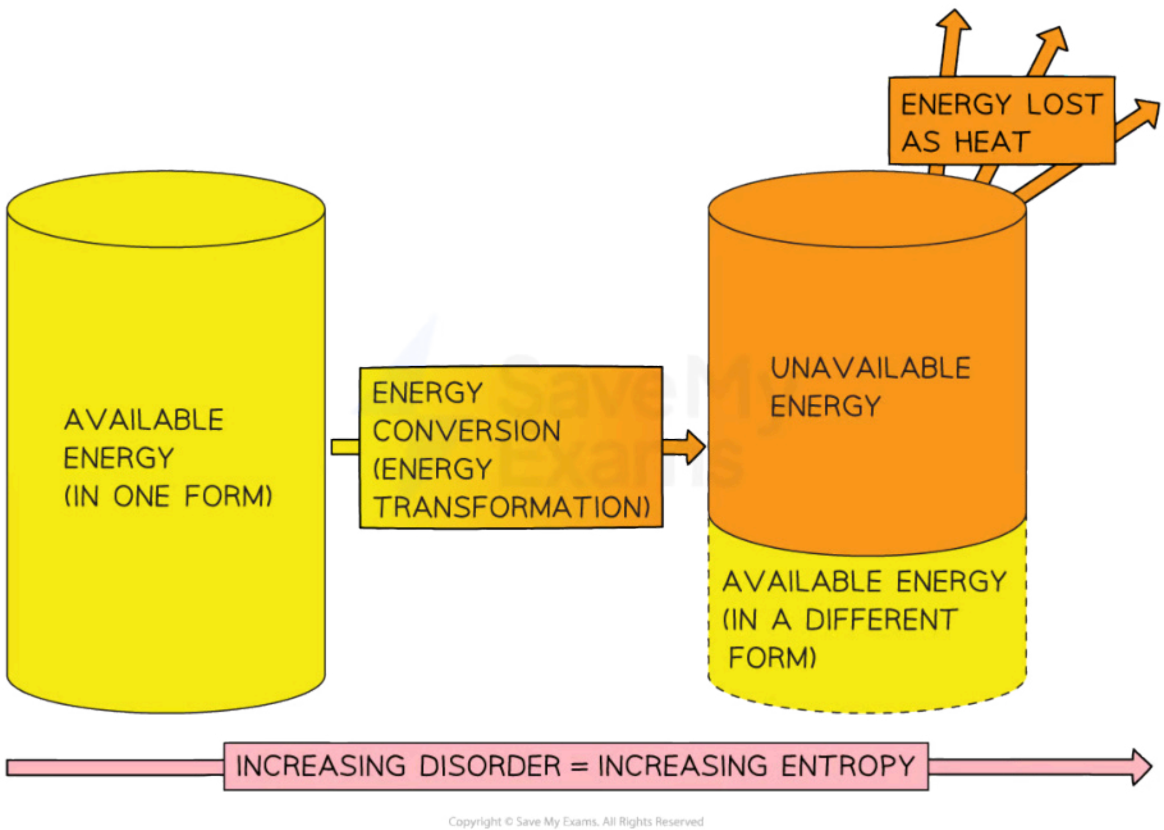

The laws of thermodynamics—energy cannot be created or destroyed (it can only be transformed) and energy is always lost from systems when work is done, bringing about disorder (increasing entropy)

Photosynthesis

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Photosynthesis

What is photosynthesis?

- Primary producers in the majority of ecosystems convert **light energy** into **chemical energy** in the process of photosynthesis
  - Producers are typically plants, algae and photosynthetic bacteria that produce their **own food** using photosynthesis
    - They are also known as autotrophs
  - Producers form the **first** trophic level in a food chain
  - The photosynthesis reaction is:

Photosynthesis word equation

- The inputs and outputs are:
  - **Inputs**: sunlight as an energy source, carbon dioxide, and water
  - **Processes**: inside chloroplasts, chlorophyll captures certain visible wavelengths of sunlight energy and stores this as chemical energy
  - **Outputs**: glucose and oxygen
  - **Transformations**: light energy is transformed into stored chemical energy (in the form of glucose)
- Photosynthesis produces the raw material for producing **biomass**
  - The glucose produced during photosynthesis is used as an energy source for the plant but also as the basic starting material for other organic molecules (e.g. cellulose and starch)
- In ecosystems where sunlight and water are available, the process of photosynthesis enables plants to synthesise these organic compounds (glucose and other sugars) from carbon dioxide

- Most of these sugars synthesised by plants are used by the plant as **respiratory substrates**
    - A respiratory substrate is a molecule (such as glucose) that can be used in **respiration**, to release **energy** for **growth**

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EXAM TIP

You are not required to know the biochemical details of photosynthesis, just remember that photosynthesis is the conversion of light energy to chemical energy in the form of glucose, some of which can be stored as biomass by producers.

Respiration

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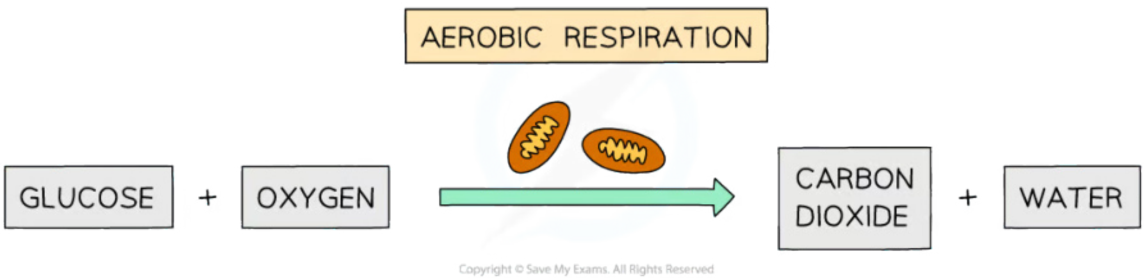
Respiration

- Respiration is the conversion of organic matter into carbon dioxide and water in all living organisms, releasing **energy**
  - Cellular respiration releases energy from **glucose** by converting it into a chemical form that can easily be used in carrying out **active processes** (such as growth and repair) within **living cells**
  - The **aerobic respiration** reaction is:



Aerobic respiration

- The inputs and outputs are:
  - **Inputs**: organic matter (glucose) and oxygen
  - **Processes**: oxidation processes inside cells
  - **Outputs**: release of energy for work (movement) and heat
  - **Transformations**: stored chemical energy is transformed into kinetic energy and heat
- Some of the chemical energy released during cellular respiration is transformed into **heat**
  - Heat is generated by cellular respiration because it is **not 100% efficient** at transferring energy from substrates, such as carbohydrates, into the chemical form of energy used in cells
  - Heat generated within an individual organism **cannot** be transformed back into chemical energy and is ultimately lost from the body
  - The heat energy released increases the **entropy** in the ecosystem, following the second law of thermodynamics, while enabling organisms to maintain relatively low entropy (high organisation)

EXAM TIP

Your notes

You are not required to know that adenosine triphosphate (ATP) is the readily usable energy currency of cells, just remember that the energy released by respiration is used in carrying out active processes within living cells.

Trophic Levels & Food Chains

Your notes

Trophic Levels & Food Chains

What are trophic levels?

- The trophic level is the **position** that an organism occupies in a food chain (or food web)
  - If multiple organisms occupy the same position in a food chain, they are in the same trophic level

Trophic Levels

Trophic Level	Name of Trophic Level	Description of Organisms in Trophic Level
1	Producers	Plants and algae—produce their own biomass using energy from sunlight
2	Primary consumers	Herbivores—feed on producers
3	Secondary consumers	Predators—feed on primary consumers
4	Tertiary consumers	Predators—feed on secondary consumers

- **Producers** are typically plants or algae and produce their own food using photosynthesis
  - They form the **first trophic level** in a food chain
- The chemical energy stored in producers is then transferred to **primary consumers** as they **consume** (eat) producers
- The chemical energy is then transferred from one consumer to the next as they eat one another
- Consumers have diverse strategies for obtaining energy-containing carbon compounds

Consumer Strategies

Type of Consumer	Description	Examples

Herbivores	Feed primarily on plants and plant-derived material	Deer: graze on grasses, leaves, and shrubs Rabbits: consume grasses, herbs, and vegetables
Detritivores	Consume decomposing organic matter (detritus) and help break it down further	Earthworms: feed on decaying plant material and enhance soil structure Dung beetles: consume animal dung, aiding in nutrient recycling
Predators	Hunt and consume other organisms (prey) for food	Lions: prey on various herbivores such as gazelles and zebras Wolves: hunt animals like deer and elk in packs
Parasites	Depend on a host organism for survival, often harming but not immediately killing it	Tapeworms: live in the intestines of mammals, absorbing nutrients from the host's food Mosquitoes: feed on the blood of animals, including humans, for nourishment
Saprotrophs and decomposers	Saprotrophs: decompose dead organic matter externally and absorb nutrients Decomposers: break down organic matter into simpler substances, playing a vital role in nutrient recycling	Fungi: break down dead plant material, such as fallen leaves and wood, into simpler compounds Bacteria: decompose organic matter, releasing nutrients for plant uptake
Scavengers	Consume dead animal carcasses, helping to clean up ecosystems	Vultures: feed on the remains of dead animals, scavenging carrion Hyenas: opportunistic scavengers known to consume a wide range of animal remains

Food chains

- Feeding relationships in ecosystems can be modelled using food chains

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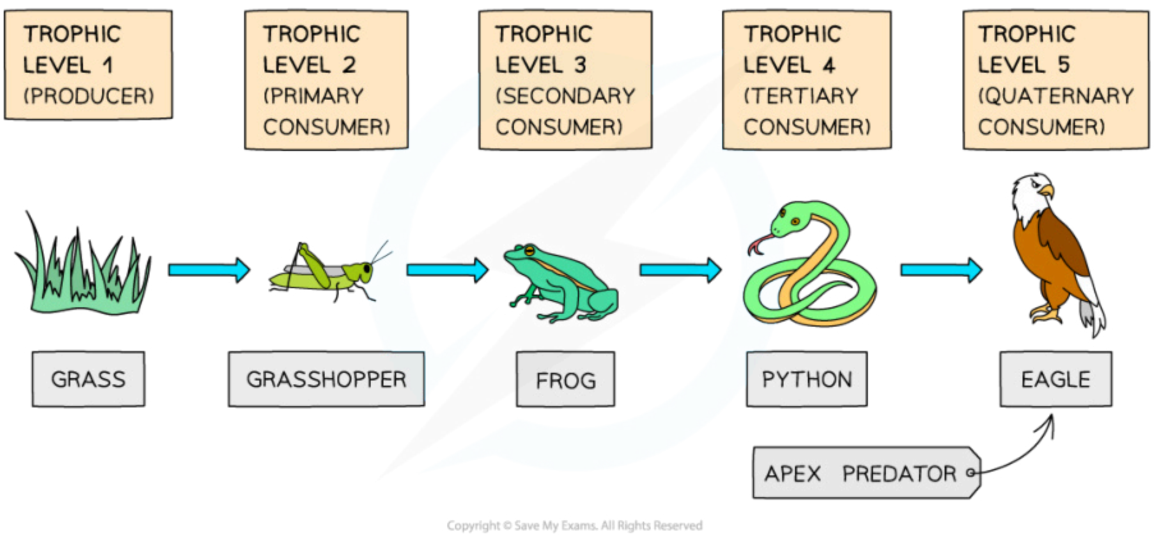
- Because producers in ecosystems make their own carbon compounds by photosynthesis, they are at the start of food chains
- Consumers obtain carbon compounds from producers or other consumers, so are placed in the higher trophic levels
- In a food chain, carbon compounds and the energy they contain are passed from primary producers to primary consumers to secondary consumers, and so on
- Apex predators are at the very top of the food chain—they are carnivores or omnivores with no predators
    - The chemical energy stored within apex predators can be passed on to **decomposers** when apex predators die and are decomposed
    - Traditionally, decomposers are not included in food chains as they gain carbon compounds from a variety of trophic levels



Trophic levels for a simple food chain—the blue arrows show how the chemical energy originally produced by the primary producer (grass) is transferred to other organisms in the community

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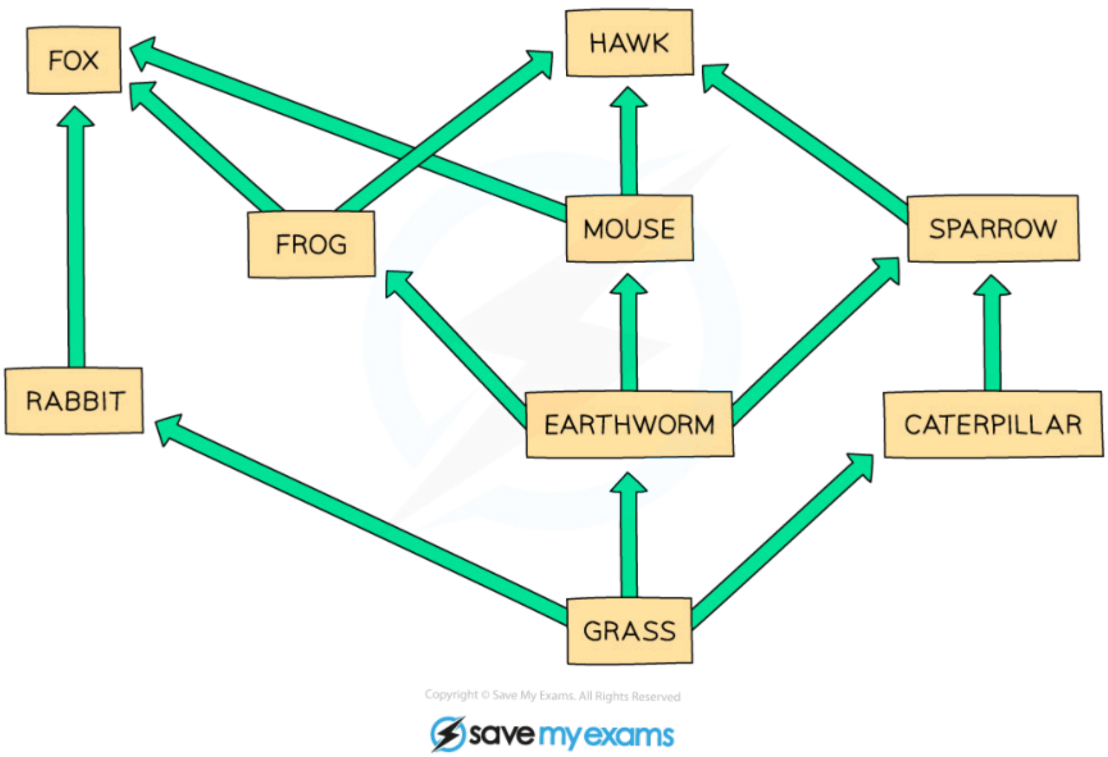
Food Webs

Food Webs

- A food web is a network of **interconnected food chains**
- Food webs are more realistic ways of showing connections between organisms within an ecosystem as **consumers rarely feed on just one type of food source**



A food web shows the interdependence of organisms

- Compared to food chains, food webs give us a lot more information about the transfer of energy in an ecosystem
- They also show **interdependence** (how a change in one population can affect others within the food web)
- For example, in the food web above, if the **population of earthworms decreased**:
  - The population of **grass plants would increase** as there are now fewer species feeding off them

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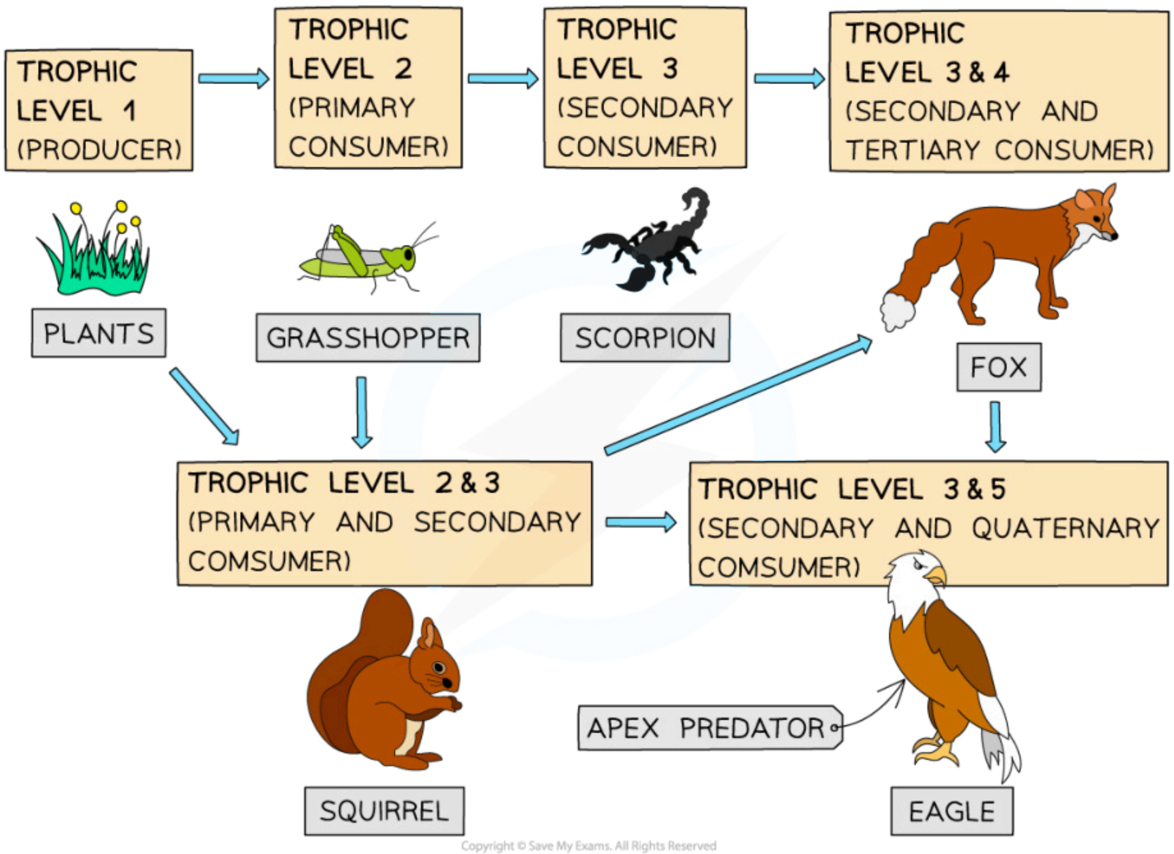
- The populations of **frogs and mice would decrease significantly** as earthworms are their only food source
- The population of **sparrows would decrease slightly** as they eat earthworms but also have another food source to rely on (caterpillars)



Trophic levels for a simple food web—note that some organisms can belong to more than one trophic level (such as the squirrel, fox and eagle in this food web)

EXAM TIP

Remember—the arrows in food chains and food webs indicate the direction of energy flow and transfer of biomass.

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Energy Losses in Food Chains

Energy Losses in Food Chains

- There are losses of energy and organic matter as food is transferred along a food chain
- The total **organic matter** transferred from one trophic level to the next is **never 100%** because:
    1. Not all the food available to a given trophic level is harvested
    2. Of what is harvested, not all is consumed
    3. Of what is consumed, not all is absorbed
    4. Of what is absorbed, not all is stored
- For example, if we take the example of caterpillars (the primary consumer) eating the leaves of an oak tree (the producer):
    1. The caterpillars do not eat every leaf available to them (there may simply be too many leaves, not enough caterpillars, or some leaves may be in locations that are difficult for the caterpillars to access)
    2. The caterpillars may not eat the entire leaf (they might eat only the softer, more nutritious parts and leave behind tougher portions or parts with toxins)
    3. Once the caterpillars eat the leaves, not all of the nutrients are absorbed by their bodies (some parts of the leaves may be indigestible or contain compounds that the caterpillars cannot process, which are then egested by the caterpillars)
    4. When the caterpillars digest the leaves and convert the nutrients into energy, not all of the energy from the leaves is stored for growth and development, as some of that energy is lost as heat during cellular respiration.
- The transfer of **energy** in a food chain is also **not 100 % efficient**
    - Energy is **lost** to the **environment** at every trophic level
- When a consumer ingests another organism, not all the chemical energy in the consumer's food is transferred to the consumer's **biomass**
    - 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**

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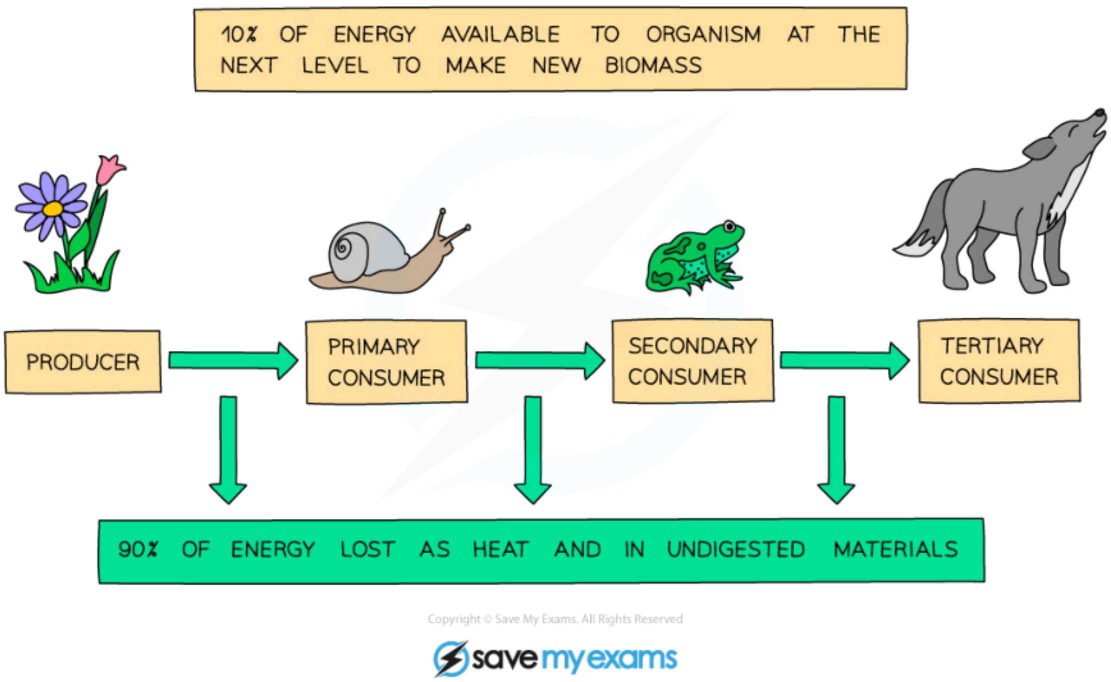

- So much energy is lost to the environment because:
  - Not every part of the food organism is eaten (e.g. the roots and woody parts of plants or the bones of animals, meaning that the stored energy in these uneaten tissues is lost to the environment)
  - Consumers are not able to digest all of the 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 then 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

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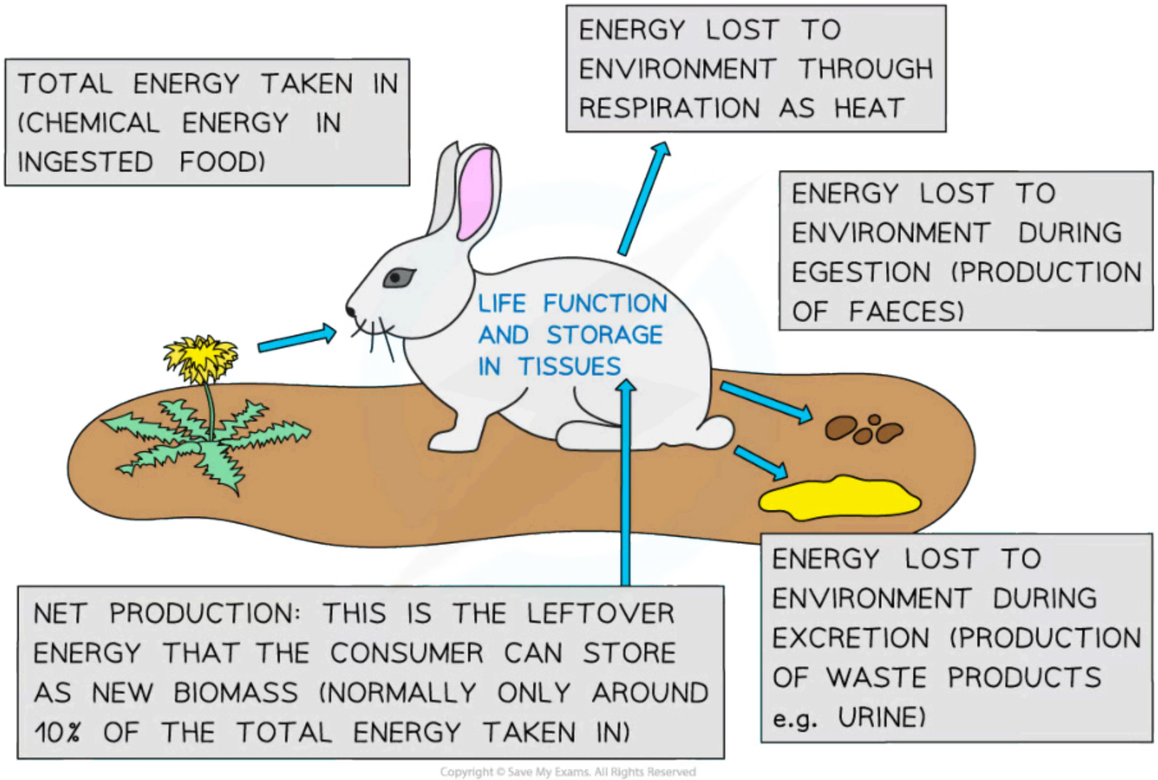

Energy losses by organisms at particular trophic level

- The energy that is left after these losses is available to the consumer to fuel their life functions, including being stored in biomass during **growth**
- These energy loss limits the number of trophic levels in ecosystems
  - Eventually, the amount of energy remaining becomes **insufficient** to support **further trophic levels**
  - This is why most terrestrial ecosystems are unable to support more than five trophic levels

Calculating ecological efficiency

- Given the appropriate data, it is possible to calculate the efficiency of **energy transfer** from one trophic level to the next as a percentage
- This value is known as the ecological efficiency
- The equation for calculating ecological efficiency is shown below:

Ecological efficiency = (energy used for new biomass ÷ energy supplied) × 100

WORKED EXAMPLE

Your notes

A butterfly lays an egg on a blackberry bush. In its first day, the caterpillar that hatches consumes blackberries containing a total of 35 J of energy. 4.1 J of this energy are used to form new caterpillar biomass. Calculate the ecological efficiency of this step of the food chain.

Answer

Step 1: Ensure both units are the same

In this case, both are expressed in joules so the units do not need to be converted

Step 2: Substitute the values into the equation

Ecological efficiency = (energy used for new biomass ÷ energy supplied) × 100

Ecological efficiency = (4.1 ÷ 35) × 100

Ecological efficiency = **11.7 %**

WORKED EXAMPLE

A wheat farmer decides to use biological control against insect pests that are eating her wheat crop. The farmer introduces a species of toad. By eating the insect pests the toads ingest 10 000 kJ m^{-2} yr^{-1} of energy. The toads lose 7 000 kJ m^{-2} yr^{-1} of this energy as heat from respiration and 2 000 kJ m^{-2} yr^{-1} of energy in faeces and urine. Calculate the ecological efficiency of energy transfer from the insects to the toads.

Answer

Step 1: Calculate the energy used for toad growth (new biomass)

Toad energy received = 10 000 kJ m^{-2} yr^{-1}

Toad energy losses = 7 000 + 2 000 = 9 000 kJ m^{-2} yr^{-1}

Energy for growth = 10 000 - 9 000 = 1 000 kJ m^{-2} yr^{-1}

Step 2: Substitute the values into the equation

Ecological efficiency = (energy used for new biomass ÷ energy supplied) × 100

Ecological efficiency = (1 000 ÷ 10 000) × 100

Ecological efficiency = **10 %**

Your notes

Productivity & Biomass

Productivity

- **Gross productivity** (GP) is the **total gain in biomass** by an organism or community in a given area or time period
  - It includes all the energy captured by organisms
  - E.g. by plants through photosynthesis or by consumers feeding on other organisms
    - For example, in a pond ecosystem, the total amount of energy captured by the aquatic plants and other species in the pond represents the gross productivity of that ecosystem
- **Net productivity** (NP) is the amount of energy or biomass remaining **after losses due to cellular respiration**
  - These energy losses are **subtracted** from the gross productivity
  - Net productivity reflects the energy available for **growth** and **reproduction**
    - For example, if a plant has captured 1 000 kJ of energy through photosynthesis (gross productivity) but has used 300 kJ for cellular respiration, its net productivity would be 700 kJ
- Losses due to cellular respiration are usually **greater in consumers** than in producers
  - This is due to the more energy-requiring activities of consumers
    - For example, herbivores need to spend energy on activities such as digestion and movement, resulting in higher respiratory losses compared to plants

Net productivity and sustainable yield

- The NP of any organism or trophic level represents the maximum sustainable yield that can be harvested without decreasing the availability of resources for the future
  - To maintain ecosystem stability and biodiversity, it is important to **avoid harvesting beyond the sustainable yield** of populations
    - For example, in fisheries management, the sustainable yield of fish populations is determined by considering the net productivity of the fishery
    - Harvesting beyond the sustainable yield can lead to overexploitation and depletion of fish stocks
    - This affects both the ecosystem itself and human livelihoods

Measuring Biomass

Your notes

- Estimating the biomass and energy of trophic levels in a community is an important step in understanding the structure and function of an ecosystem
- There are several methods for measuring the biomass of a particular trophic, including:
  - Measurement of dry mass
  - Controlled combustion
  - Extrapolation from samples

Measurement of dry mass

- One common method for estimating biomass is to measure the dry mass of organisms
- This involves collecting samples of organisms from a particular **trophic level** and drying them in an oven to **remove all water** within the tissues
- The dry weight of the sample is then measured
- This can then be used to estimate the **total biomass** of the populations that have been sampled
  - Dry mass of samples is approximately equal to the mass of organic matter (biomass) since water represents the majority of inorganic matter in most organisms
- For example:
  - If the dry mass of one daffodil plant is found to be 0.1 kg, then the dry mass (i.e. the biomass) of 200 daffodils would be 20 kg (0.1 x 200 = 20)
  - If the dry mass of the grass from 1 m^2 of a field is found to be 0.2 kg, we can say that the grass has a dry mass (i.e. biomass) of 0.2 kg m^{-2} (this means 0.2 kg per square metre)
  - If the grass field is 200 m^2 in size, then the biomass of the whole field must be 40 kg (0.2 x 200 = 40)

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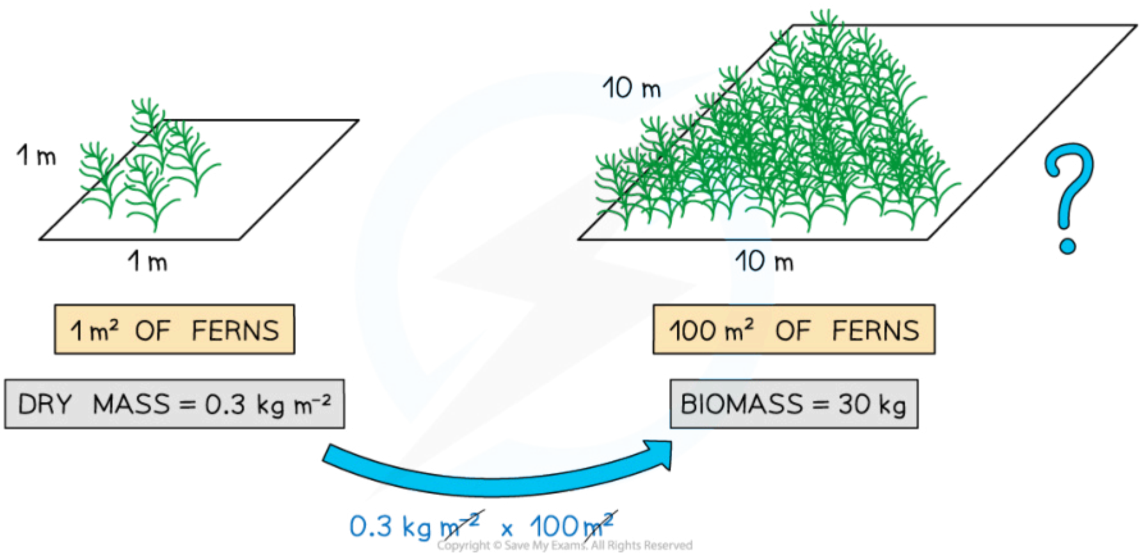

It is possible to estimate the biomass of organisms in a larger area if you know the dry mass of the organisms in a given (smaller) area

Controlled combustion

- Another method for estimating biomass is controlled combustion
- This involves burning a known quantity of biomass and measuring the **heat produced**
- By knowing the heat value of the biomass, it is possible to estimate the total biomass of a population or trophic level, based on the amount of heat produced
- A piece of equipment known as a **calorimeter** is required for this process
    - The burning sample heats a **known volume** of **water**
    - The **change in temperature** of the water provides an estimate of the chemical energy the sample contains

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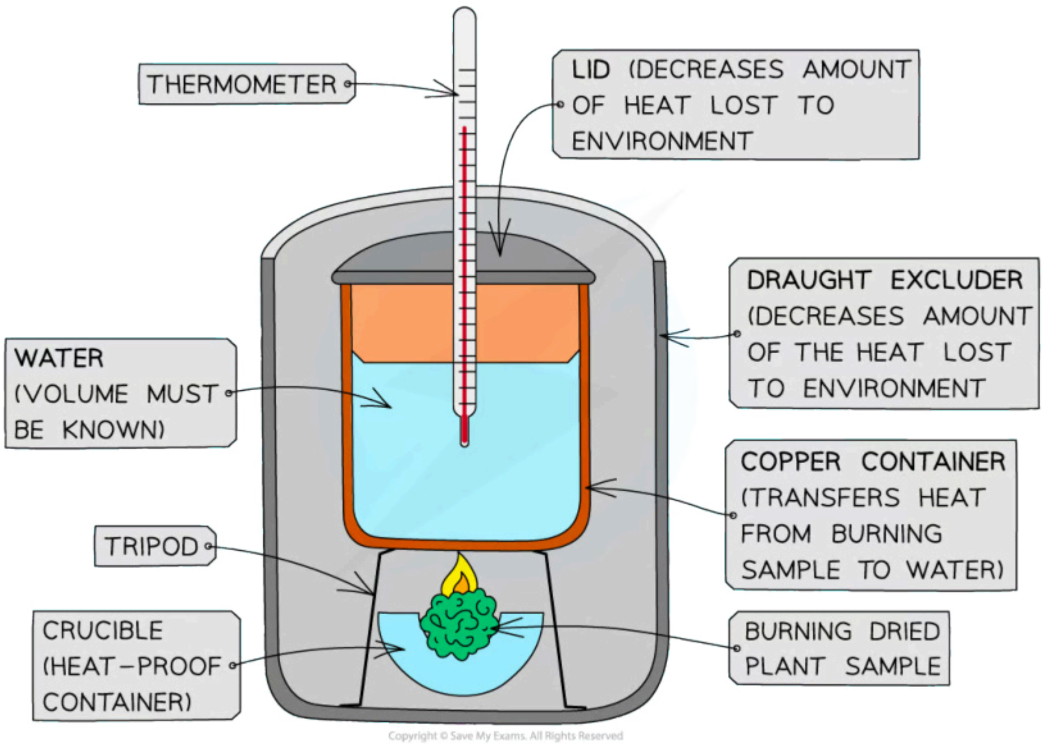
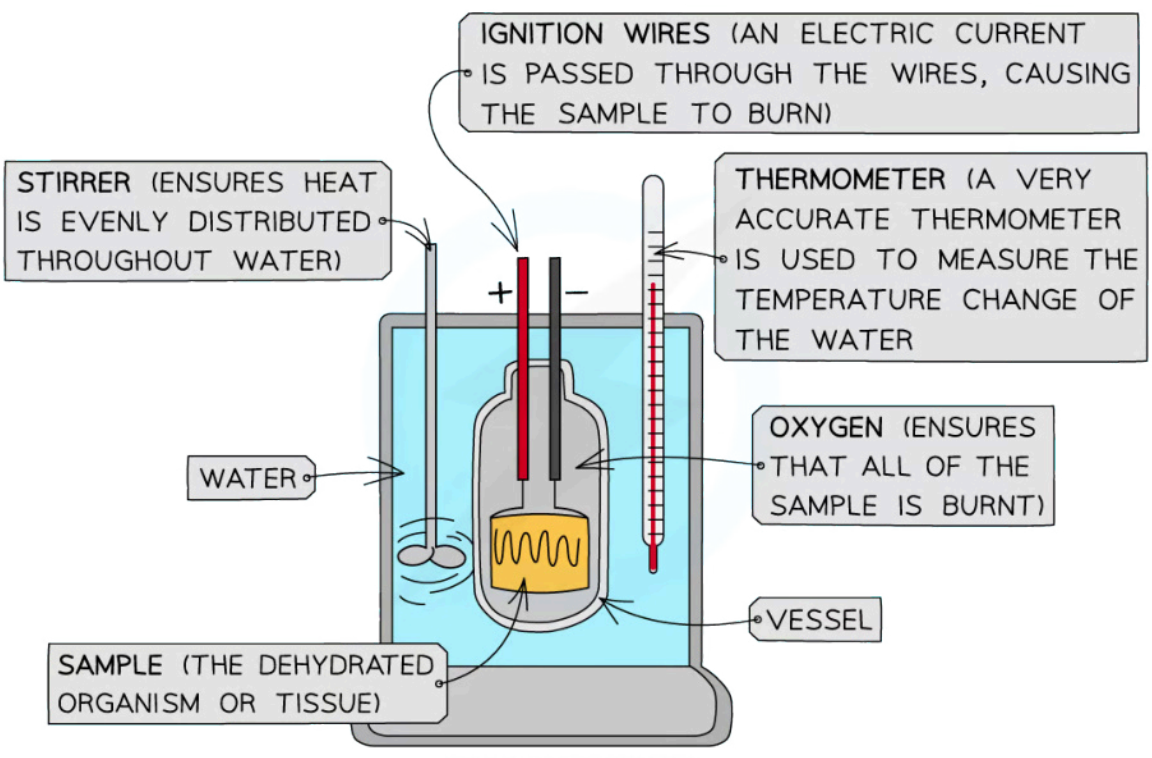


A simple, inexpensive version of a calorimeter that can be set up using classroom equipment



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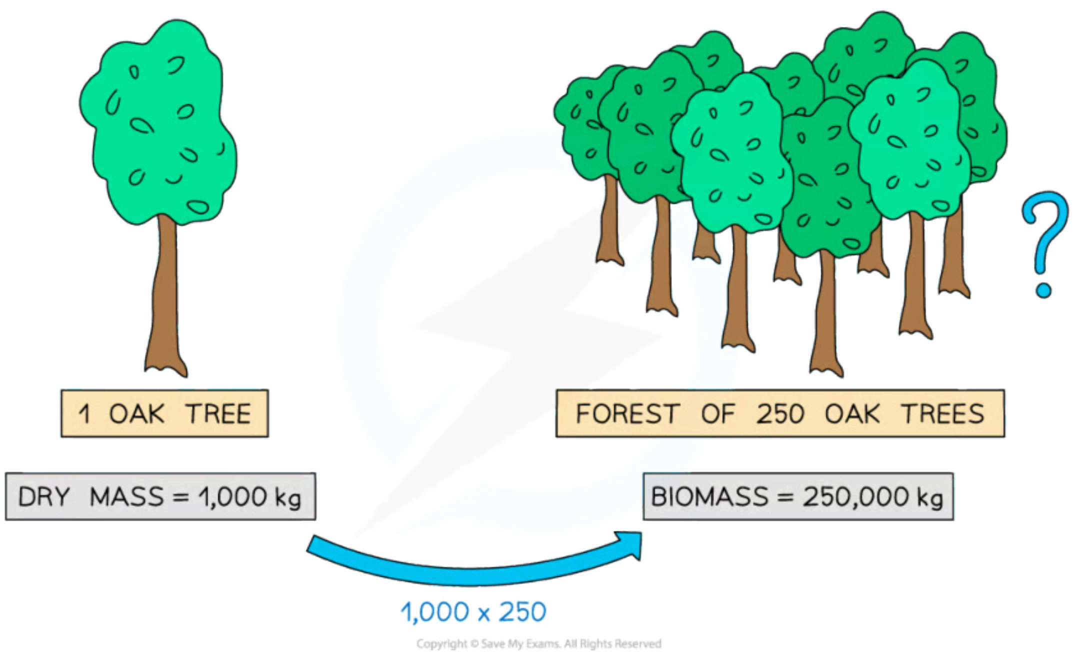
An example of a more precise (and much more expensive) version of a calorimeter known as a bomb calorimeter—this type is used in professional scientific laboratories

Extrapolation from samples

- A third method for estimating biomass is to take small samples of populations and extrapolate to estimate the total biomass of a population or trophic level
- This method can be particularly useful when dealing with **large** or **difficult-to-sample** populations



It is possible to estimate the biomass of a group of organisms if you know the dry mass of a single organism

- Data obtained from these methods can be used to construct ecological pyramids
  - Ecological pyramids (such as pyramids of biomass) are very useful in visually illustrating the relationships between different trophic levels in an ecosystem and how energy and biomass are transferred through the system

Limitations of calorimetry

- It can take a **long time** to fully dehydrate (dry out) a biological sample to find its dry mass
  - This is partly because the sample has to be heated at a relatively low temperature to ensure it doesn't burn

- Depending on the size of the sample, the drying process could take several days

- **Precise equipment** is needed, which may not be available and can be very expensive
  - A very precise digital balance should be used to measure the mass of the sample as it is drying
    - This is to detect even extremely small changes in mass
  - It is preferable to use a very precise digital thermometer when measuring the temperature change of the water in the calorimeter
    - This is to detect even very small temperature changes
- The more simple and basic the calorimeter, the less accurate the estimate will be for the chemical energy contained within the sample
  - This is due to heat energy from the burning sample being **lost** and not being **transferred efficiently** to the water
  - A bomb calorimeter ensures that almost all the heat energy from the burning sample is transferred to the water, giving a **highly accurate estimate**

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Ecological Pyramids

Ecological Pyramids

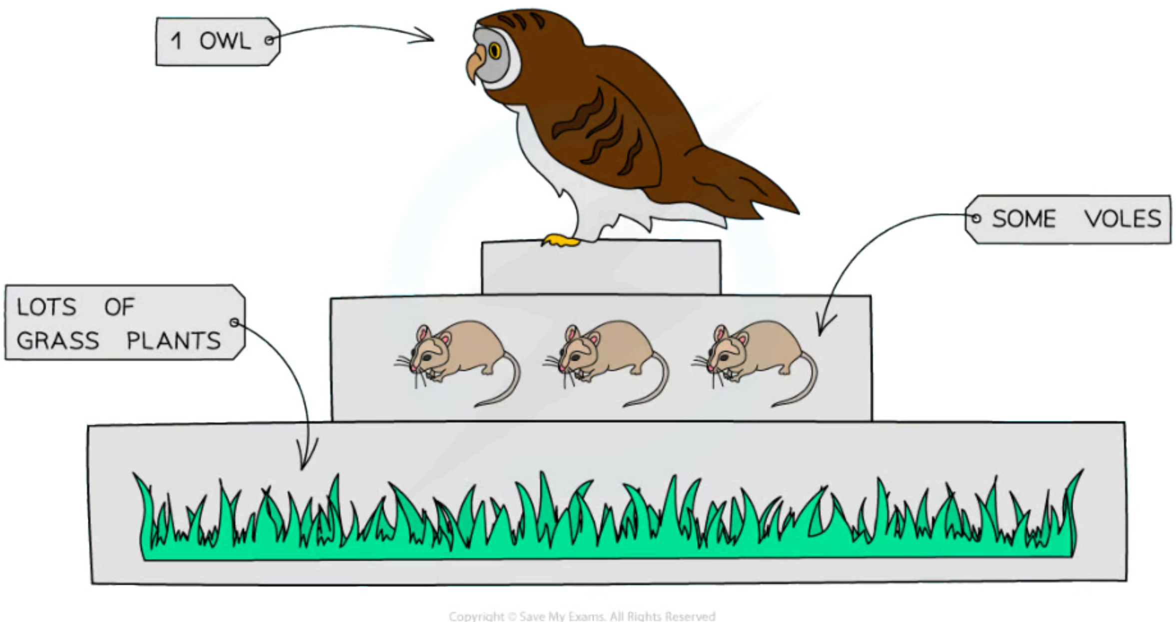
- Ecological pyramids include:
  - Pyramids of numbers
  - Pyramids of biomass
  - Pyramids of energy (also known as pyramids of productivity)
- They are quantitative models usually measured for a given **time** and **area**

Pyramids of numbers

- Ecological pyramids include:
  - Pyramids of numbers
  - Pyramids of biomass
  - Pyramids of energy
- They are quantitative models usually measured for a given **time** and given **area**
- A pyramid of **numbers** shows how many organisms we are talking about at each level of a food chain
- The **width** of the box indicates the **number of organisms** at that trophic level
- For example, consider the following food chain:

grass → vole → owl

- A pyramid of numbers for this food chain would look like the one shown below
  - Often, the number of organisms **decreases** along food chains, as there is a decrease in available energy since some energy is lost to the surrounding environment at each trophic level
  - Therefore pyramids of numbers usually become **narrower** towards the apex (the top)



Pyramid of numbers

Your notes

- Despite the name, a pyramid of numbers doesn't always have to be pyramid-shaped
- For example, consider the following food chain:

oak tree → insects → woodpecker

- The pyramids of numbers for this food chain will display a different pattern to the first food chain
- When individuals at lower trophic levels are relatively **large**, like the oak tree, the pyramid becomes **inverted**:
    - Only a single oak tree is needed to support large numbers of insects (which can then support large numbers of woodpeckers)

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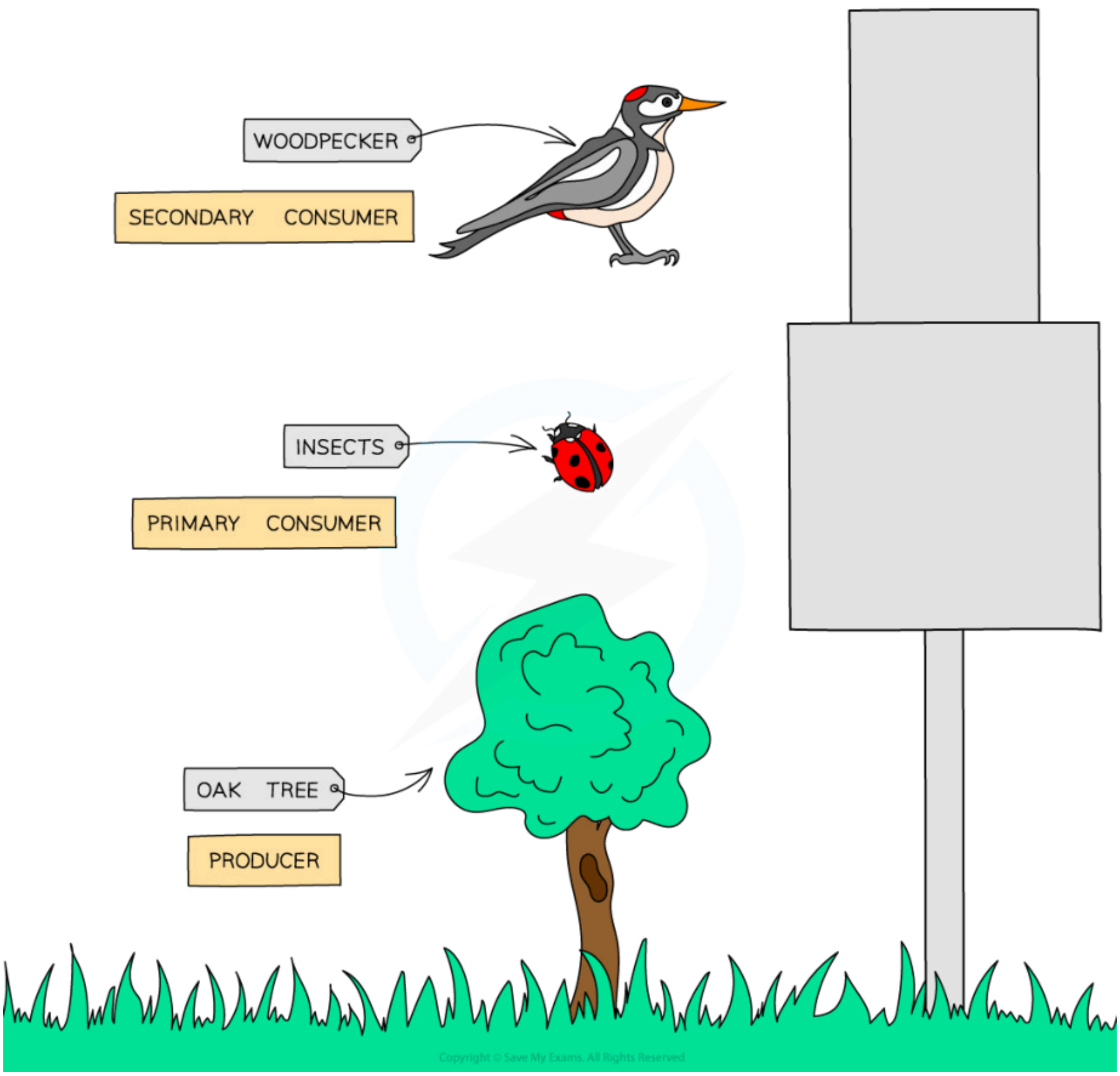


Pyramids of numbers are not always pyramid-shaped (they can be inverted, like the one shown above)

Pyramids of biomass

- A pyramid of biomass shows how much mass the organisms at each trophic level would have without including all the water that is in the organisms:
  - This is known as their '**dry mass**'
- As per the **second law of thermodynamics**, the quantities of biomass generally **decrease** along food chains, so the pyramids become **narrower** towards the top

- If we take our first food chain as an example, it would be impossible to have 10kg of grass feeding 50kg of voles feeding 100kg of barn owls
- Being able to **construct** accurate pyramids of biomass from appropriate data is an important skill

Your notes

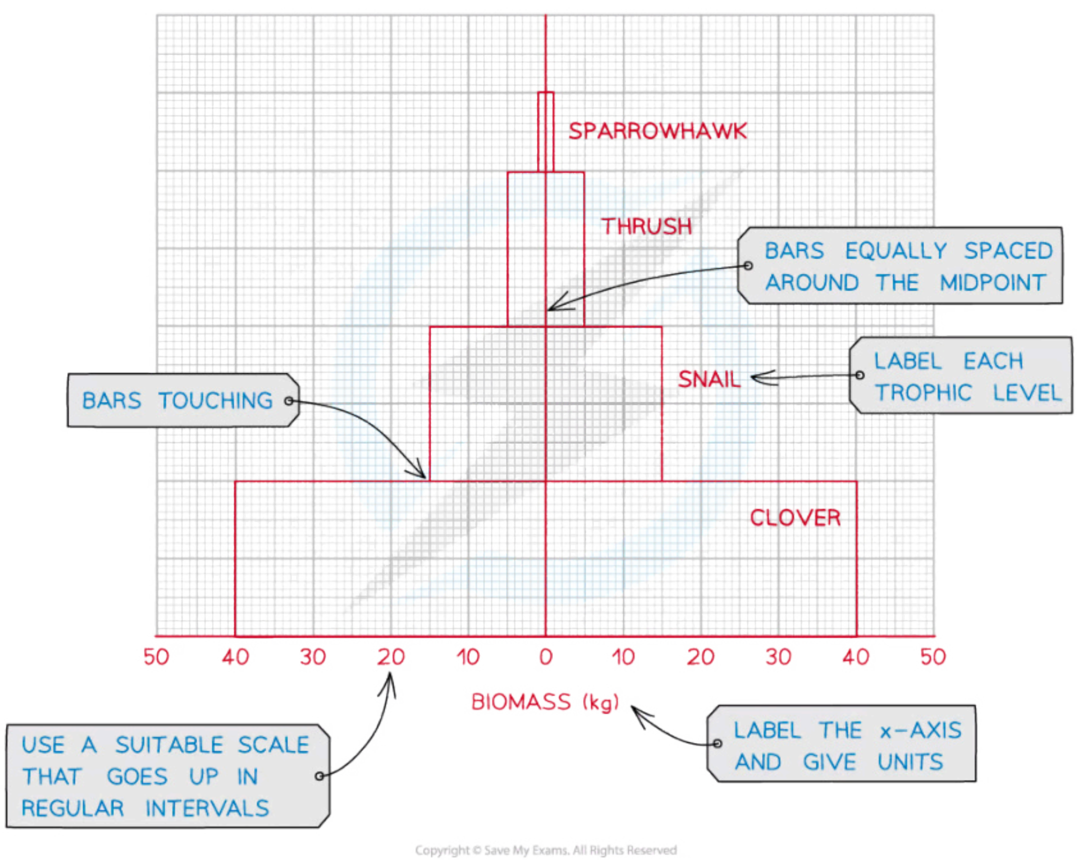
WORKED EXAMPLE

The table below shows:

- A food chain with four trophic levels
- The total mass of organisms at each trophic level

	Clover →	Snail →	Thrush →	Sparrowhawk
Biomass (kg)	80	30	10	2

Draw a pyramid of biomass for the food chain in Table 1.



- Pyramids of biomass are **usually pyramid-shaped**, regardless of what the pyramid of numbers for that food chain looks like
  - However, they can occasionally be **inverted** and show higher quantities at higher trophic levels
  - These inverted pyramids sometimes occur due to marked **seasonal variations**
    - For example, in some marine ecosystems, the standing crop of phytoplankton, the major producers, is lower than the mass of the primary consumers, such as zooplankton
    - This is because the phytoplankton **reproduce very quickly** and are constantly being consumed by the primary consumers, which leads to a lower standing crop but higher productivity
    - This can occur because phytoplankton can vary greatly in productivity (and therefore biomass) depending on sunlight intensity

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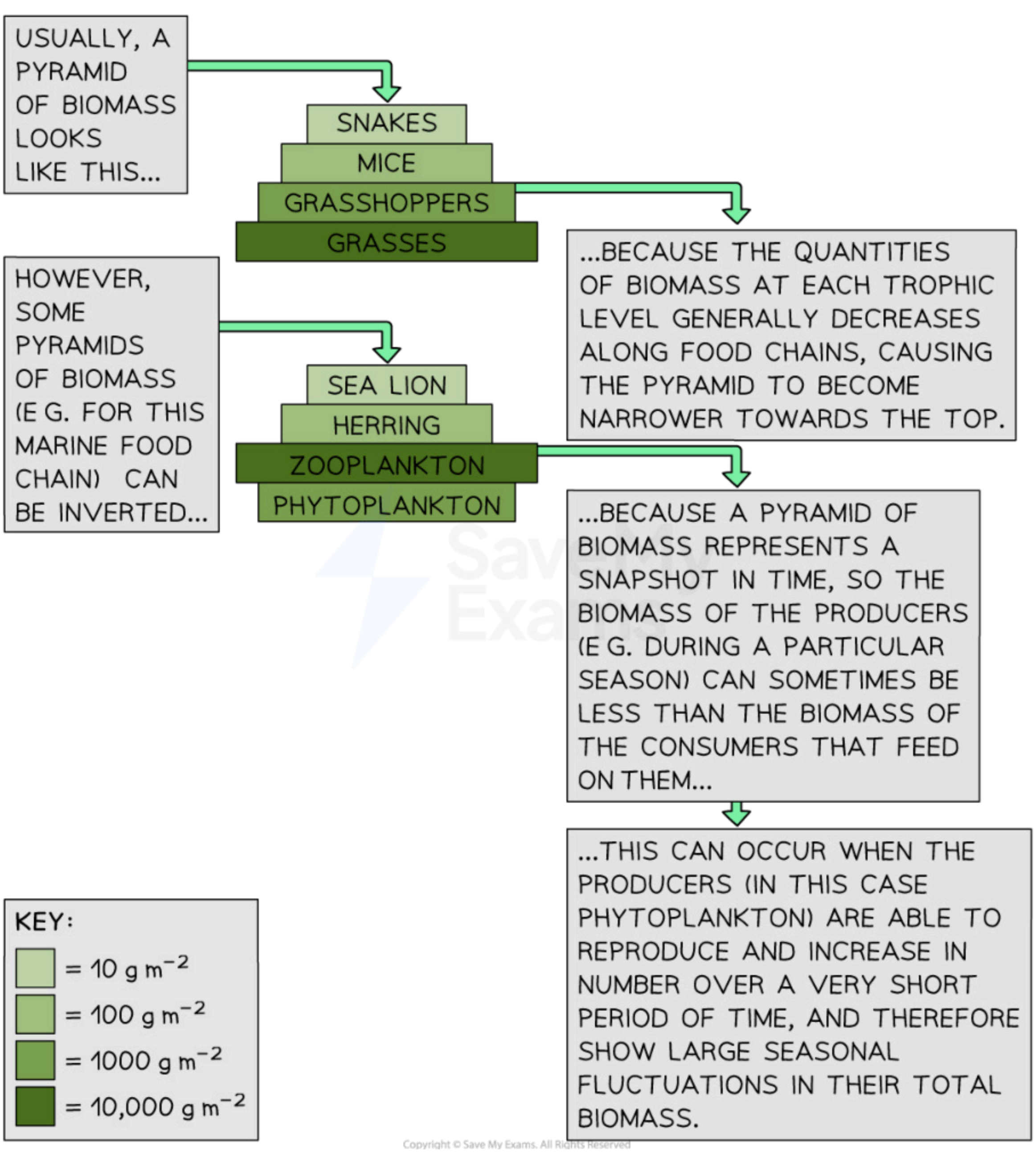


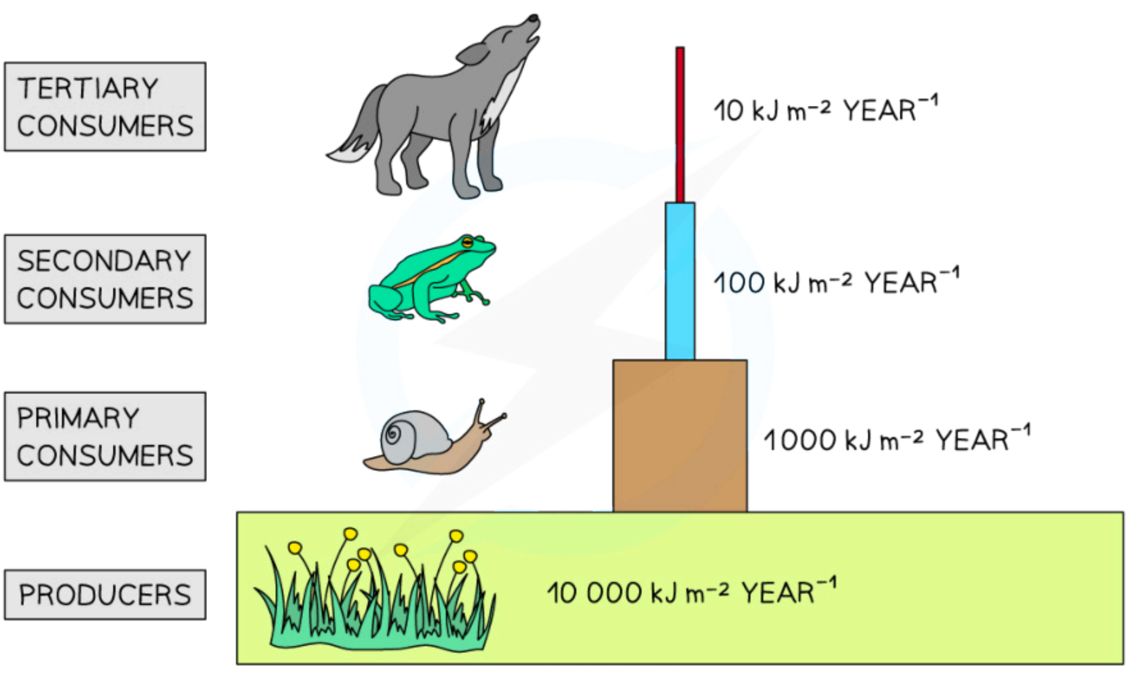
Pyramids of biomass

Pyramids of energy

- Pyramids of energy (also referred to as pyramids of productivity) show the flow of **energy** through trophic levels, indicating the **rate** at which that energy is being generated

Your notes

- Pyramids of productivity illustrate the amount of energy or biomass of organisms at each trophic level per unit **area** per unit **time**
  - Productivity is measured in units of **flow**
  - The units are mass or energy per metre squared per year (g/kg m^{-2} yr^{-1} or J/kJ m^{-2} yr^{-1})
- The length of each box, or bar, represents the quantity of energy present
- These pyramids are **always** widest at the base and decrease in size as they go up
  - This is because pyramids of productivity for entire ecosystems over a year always show a decrease along the food chain, following the **second law of thermodynamics**
- The base is wide due to the large amount of energy contained within the biomass of **producers**
- As you move up the pyramid to higher trophic levels, the quantity of energy decreases as not all energy is transferred to the biomass of the next trophic level (roughly 10 % of the energy is passed on)
- 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



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

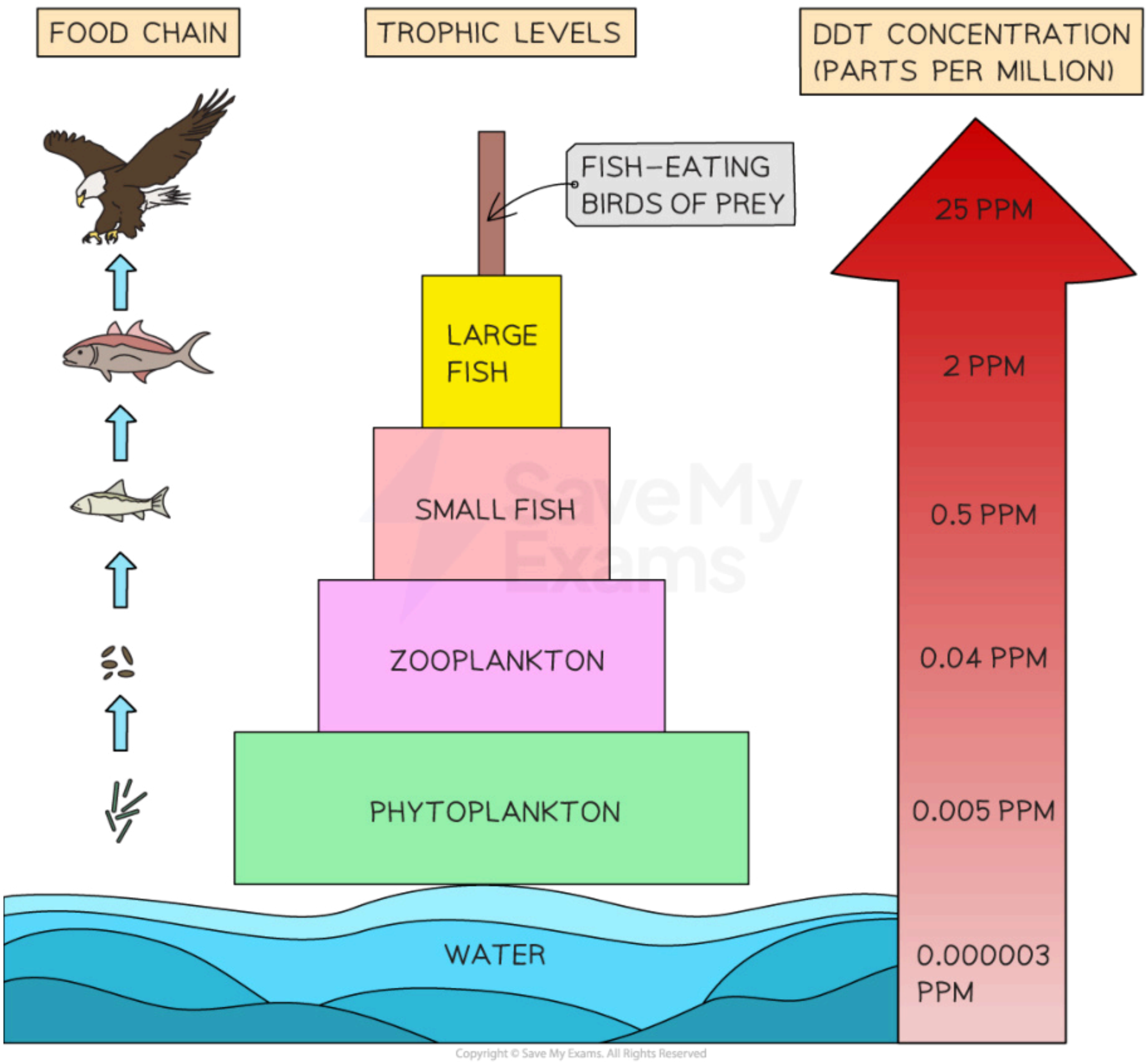
Your notes

Human Impacts on Energy & Matter Flows

Bioaccumulation and biomagnification

- **Bioaccumulation** is the build-up of **persistent** or **non-biodegradable pollutants** within an organism or trophic level because they cannot be broken down
- **Biomagnification** is the **increase in the concentration** of persistent or non-biodegradable pollutants along a food chain
  - As pollutants are passed up the food chain from one trophic level to the next, they become more concentrated
  - This means that organisms at higher trophic levels (such as top predators) accumulate higher concentrations of pollutants than those at lower trophic levels
  - This is due to the decrease in the total biodegradable biomass of organisms at higher trophic levels
- Pollutants that are persistent and non-biodegradable can accumulate along food chains
  - Examples include:
    - Polychlorinated biphenyl (PCB)
    - Dichlorodiphenyltrichloroethane (DDT)
    - Mercury
- They can cause changes to ecosystems through the processes of bioaccumulation and biomagnification
  - For example, **DDT** was a widely used **insecticide** in the mid-20th century that was found to have harmful effects on birds of prey such as eagles and falcons
  - When DDT was sprayed on crops, it would leach into waterways and eventually enter freshwater and marine ecosystems
  - DDT would then enter food chains (via plankton) and accumulate in the bodies of fish
  - These fish would then be eaten by birds, which would accumulate **higher concentrations** of DDT
  - Because DDT is persistent and does not break down easily, it can continue to **accumulate** in the bodies of animals at **higher trophic levels** (such as birds of prey), leading to harmful effects such as thinning of eggshells and reduced reproductive success

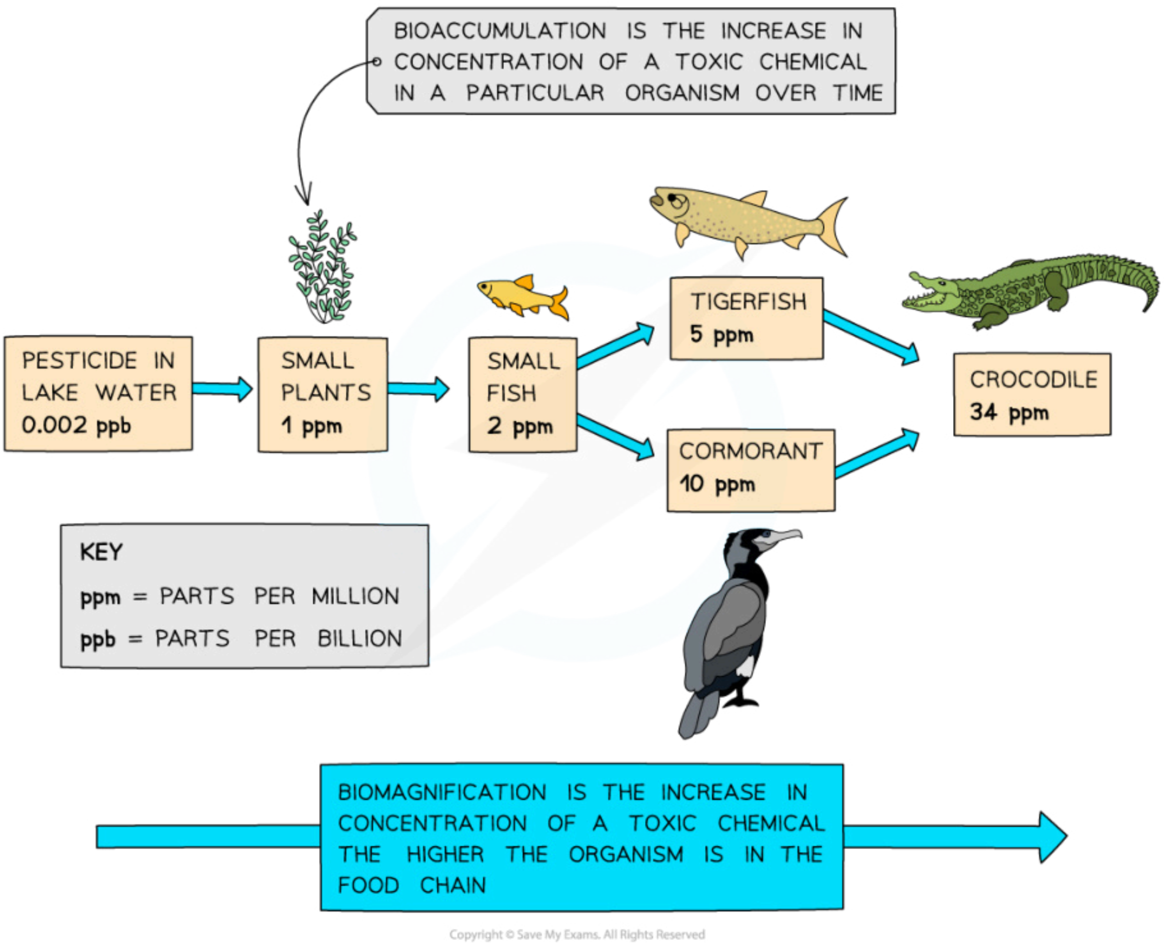
Your notes



Through the process of biomagnification, the concentration of DDT in the tissues of organisms increases at successively higher trophic levels in a food chain

- **Mercury** is another example of a pollutant that can accumulate along food chains
  - Mercury is released into the environment through activities such as coal-fired power plants and gold mining
  - Once in the environment, mercury can be converted into a highly toxic form called **methylmercury**
  - This accumulates in the bodies of fish

- As larger fish eat smaller fish, the concentration of methylmercury within the tissues of these fish increases, leading to potential harm for **humans** who eat large predatory fish such as tuna or swordfish
  - In 1956, for example, a chemical factory released toxic methylmercury into waste water entering Minamata Bay in Japan
  - Mercury accumulation in fish and shellfish caused mercury poisoning in local people (who ate the fish and shellfish) and resulted in severe symptoms (paralysis, death, or birth defects in newborns)



Biomagnification and bioaccumulation of a pesticide in an aquatic ecosystem

Non-biodegradable pollutants and microplastics

- One concerning aspect of many non-biodegradable pollutants is that they can be **absorbed** by **microplastics**

- This can increase the transmission of these pollutants within food chains (i.e. increase the level of biomagnification)
- Microplastics are tiny plastic particles, often less than 5mm in size
    - They come from various sources like plastic bottles, packaging and synthetic clothing
    - When in the environment, these microplastics act a bit like **sponges**, absorbing non-biodegradable pollutants such as polychlorinated biphenyls (PCBs), pesticides and heavy metals such as lead and mercury

Effect on the food chain

- Marine animals often **ingest** microplastics as they feed
- As smaller organisms consume microplastics containing pollutants, these toxins accumulate in their bodies
- Larger predators then consume these contaminated organisms, leading to biomagnification, where the concentration of toxins increases at higher trophic levels
- This can have negative consequences for organisms in food chains
    - For example, a study found that oysters exposed to microplastics containing pollutants experienced:
        - Lower feeding rates
        - Altered growth patterns
        - Reduced reproductive success
    - This was found to negatively impact the fitness of individual oysters and the success of the population as a whole

Human activities and ecosystem impacts

- Human activities can significantly change the natural flows of energy and matter within ecosystems
- **Burning fossil fuels**:
    - Releases carbon dioxide into the atmosphere, contributing to global warming
    - Increased CO_2 availability can increase photosynthesis rates
        - However, other pollutants and climate change effects (e.g. temperature rise and changing rainfall patterns) can outweigh this benefit, reducing primary productivity
    - For example, burning coal to generate electricity emits CO_2 but also releases sulfur dioxide (SO_2)
    - This pollutant contributes to acid rain and affects soil pH, which in turn impacts plant health and nutrient availability

Your notes

Your notes

- This further reduces photosynthesis rates
- **Deforestation**:
  - Clearing forests for agriculture, urbanisation, or logging disrupts ecosystems
    - As well as causing habitat loss and disruption of food webs, deforestation reduces the carbon sink capacity of forests
  - This contributes to climate change
- **Urbanisation**:
  - Urban development replaces natural habitats with impervious surfaces like concrete, leading to increased runoff and reduced infiltration
  - Urban areas generate "heat islands", increasing local temperatures
- **Agriculture**:
  - Intensive agriculture involves the use of fertilisers, pesticides and monoculture practices
  - This can lead to soil degradation, water pollution and loss of biodiversity