6.5 Ecosystems

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6.5.1 ECOSYSTEMS

Ecosystems

Ecosystems

- **Species** do not exist by themselves in their own isolated environment, they interact with other species forming **communities**
- These communities interact with each other and the **environment** they live in, forming ecosystems
- An **ecosystem** is a relatively self-contained community of interacting organisms and the environment they live in, and interact with
- There is a **flow of energy** within an ecosystem and nutrients within it are recycled
- There are both **living** (biotic) **components** and **non-living** (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
  - An individual human being could also be described as an ecosystem; there are thousands of species of bacteria living on and in every person
- Ecosystems **vary in complexity**:
  - A desert is a relatively simple ecosystem
  - A tropical rainforest is a very complex ecosystem
- No ecosystem is completely self-contained as organisms from one ecosystem are often linked to organisms from another
  - For example, birds are able to fly long distances to feed from multiple ecosystems

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Example of an ecosystem

- A forest is a perfect example of a complex ecosystem
  - There is a large community of organisms including trees, birds, small and large mammals, insects, bacteria, and fungi
  - The non-living components of the ecosystem include the soil, dead leaves, water from the rain and streams, the rocks, and any other physical or chemical factors
  - The non-living components of the ecosystem influence the community of organisms

Biotic Factors

- A biotic factor is anything that influences the populations within a community that is a result of another organism's activity

Examples of Biotic Factors

- Predation
- Competition (inter-specific) for space, food, water, light etc.
- Cooperation between organisms (can be between the same species or different species)
- Parasitism
- Disease
  - Pathogenic disease caused by microorganisms e.g. cholera, or carried by vectors e.g. malaria
- Camouflage
  - A well-camouflaged prey animal will escape capture and not benefit the potential predator species
- Mimicry
  - A hoverfly is harmless, yet it has evolved body colouring like that of a wasp. This deters potential predators into thinking that it is a wasp and could deliver a harmful sting
- Mankind
  - Arguably the largest biotic factor of all, in terms of habitat loss, hunting, farming etc

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Abiotic factors

- An abiotic factor is any physical or chemical factor (non-living) that influences the populations within a community
- The environmental conditions can majorly impact the spread of a species

Examples of Abiotic factors

- Availability of water
- Light
- Radiation
- Temperature
- Turbidity (‘cloudiness’) of water
- Humidity
- Atmospheric composition
- pH
- Salinity
- Soil composition

Exam Tip

When describing abiotic factors, be as precise as possible. For example, there are aspects of water that affect aquatic organisms: salinity, flow rate, mineral content, turbidity, depth, and dissolved oxygen concentration. It is a good idea to specify which aspect of ‘water’ that you mean.

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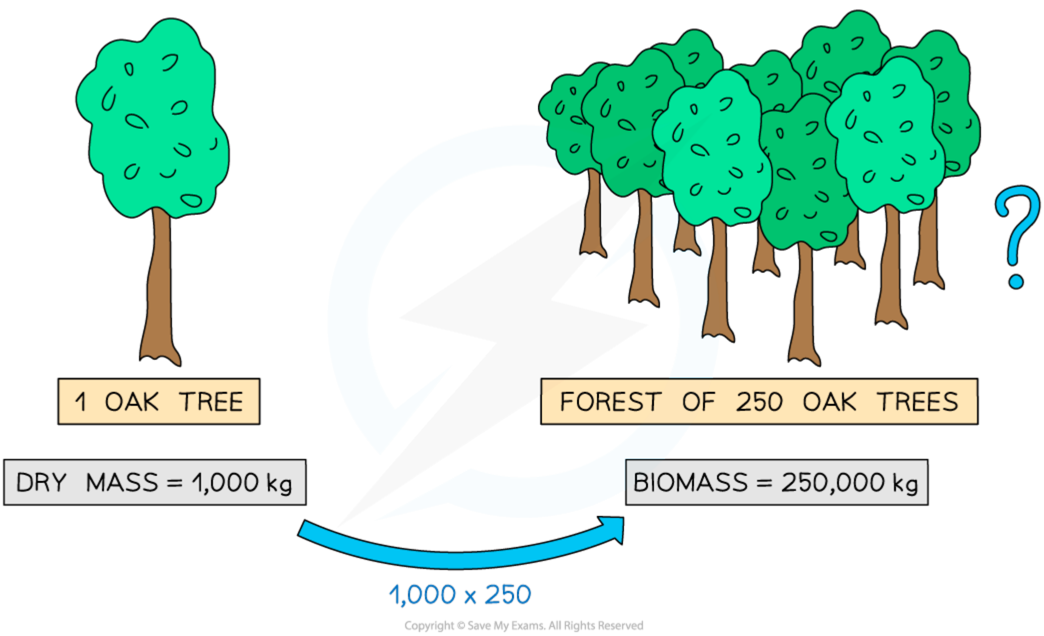
6.5.2 THE TRANSFER OF BIOMASS

The Transfer of Biomass

- The **biomass** of an organism (or of a sample of tissue from an organism) is:
  - The mass of **living material** of the organism or tissue
  - The **chemical energy** that is **stored** within the organism or tissue
- Biomass can be measured in terms of:
  - The **dry mass** of an organism or tissue (in a **given area**)
  - The mass of **carbon** that an organism or tissue contains
  - The **mass of carbon** that a sample (i.e. an organism or tissue) contains is generally taken to be **50% of the dry mass** of the sample
  - The **chemical energy content** of the organism when burned in pure oxygen

Dry mass

- The dry mass is the mass of the organism or tissue **after all the water has been removed**
- The dry mass of a sample can be used to **calculate** the biomass of a **total population** of organisms or of a **particular area**. 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)



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

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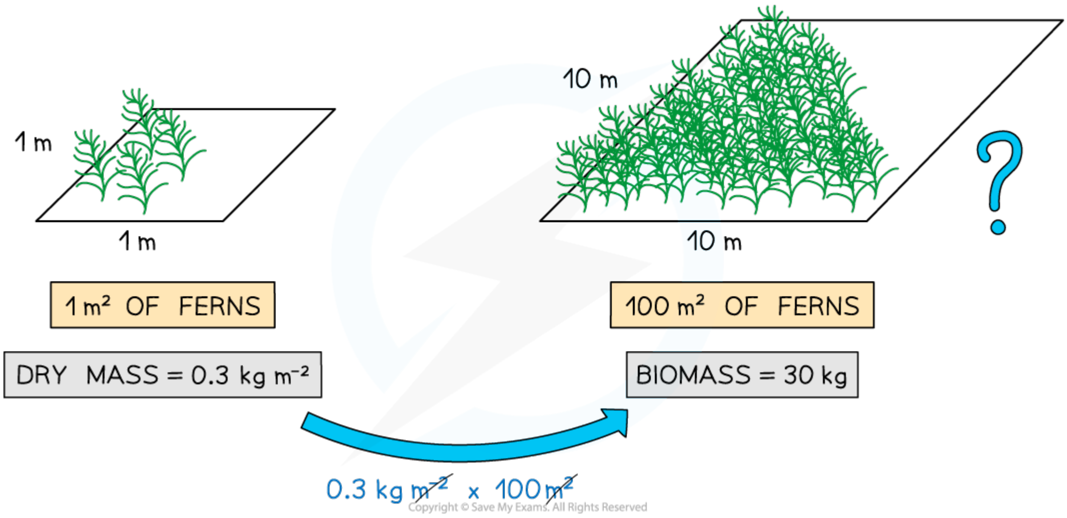
of a single organism

- If the dry mass of the grass from **1 m²** 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 m²** in size, then the biomass of the whole field must be **40 kg** (0.2 x 200 = 40)



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

Biomass can change over time

- For example, the biomass of deciduous trees decreases over autumn and winter as they lose their leaves
- This means that biomass is sometimes given with **units of time** as well
- This shows the average biomass of an organism within a given area over that time period
- For example, if the average biomass of a group of oak trees over the course of a **year** is found to be **13,000 kg**, the biomass may be given as **13,000 kg y⁻¹** (this means 13,000 kg per year)
- If the average biomass of **1 m²** of a grass field over the course of a year is found to be **0.15 kg m⁻²**, the biomass may be given as **0.15 kg m⁻² yr⁻¹** (this means 0.15 kg per square metre per year)

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Calorimetry

- Calorimetry can be used to **estimate** the **chemical energy** stored in dry biomass
- **Energy** is a vital consideration in ecology because every trophic level transfers energy to the subsequent level.
- **Energy transfer** is the main goal of feeding relationships
    - Calorimetry involves **burning** the sample of dry biomass in a piece of equipment known as a **calorimeter**
    - 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

Apparatus & Techniques: Finding the Dry Mass and Energy Value of Plant Biomass

- **Dry mass** is used to measure the mass of living material in a plant sample
    - The dry mass is the mass of the organism or tissue after **all** the **water** has been **removed**
    - To find the dry mass, the sample must first be **dehydrated** (dried out until it contains no more water)
- A **calorimeter** can then be used to **estimate** the **chemical energy** stored within the dried plant sample

Apparatus

- A heat-proof, open-topped container
    - This is often referred to as a **crucible**
    - It needs to be able to withstand the temperatures inside the oven
    - It is open-topped to allow any moisture leaving the sample can evaporate and escape
- Oven
    - To dry the sample slowly
- Digital balance
    - For monitoring the mass of the plant sample as it dries out
    - Needs to have a **high level of precision** to detect **small changes** in the mass of the sample
- Calorimeter
    - These can be **simple and inexpensive** (easy for students to set up using classroom equipment) or very **precise**, **expensive** pieces of apparatus known as **bomb calorimeters** (more commonly found in professional scientific laboratories)

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Method

Finding the dry mass of a plant sample:

- Weigh the crucible (heat-proof container) **without** the sample first
- Place the sample in the crucible
- Place the crucible in the oven
- Set the oven to a **low** temperature (if the temperature is too high the sample may burn, which would cause it to lose biomass)
- Remove and weigh the crucible (containing the sample) at **regular intervals** during the drying process
- Once the mass of the crucible (and sample) **stops decreasing** and becomes **constant**, the sample is **fully dehydrated** (all the water has been removed)
- From this final constant mass, **subtract the original mass of the crucible** (without the sample in it) to find the **dry mass** of the sample

Finding the energy released by a sample of plant biomass:

- To estimate the chemical energy stored in the dried sample, use a **calorimeter**
- A calorimeter burns the dried sample and uses the energy released to heat a **known volume** of **water**
- Measure the change in **temperature** of the water
- This temperature change can be used to estimate the chemical energy stored within the sample
- This energy is measured in **joules** (J) or **kilojoules** (kJ)
- 1 joule is the amount of heat needed to raise the temperature of **24 g** or **0.24 cm^3** or **0.24 ml** of water by **1 °C**
- 1 kilojoule (kJ) is the amount of heat needed to raise the temperature of **240 g** or **240 cm^3** or **240 ml** of water by **1 °C** (or to raise the temperature of 24 g of water by 10 °C)

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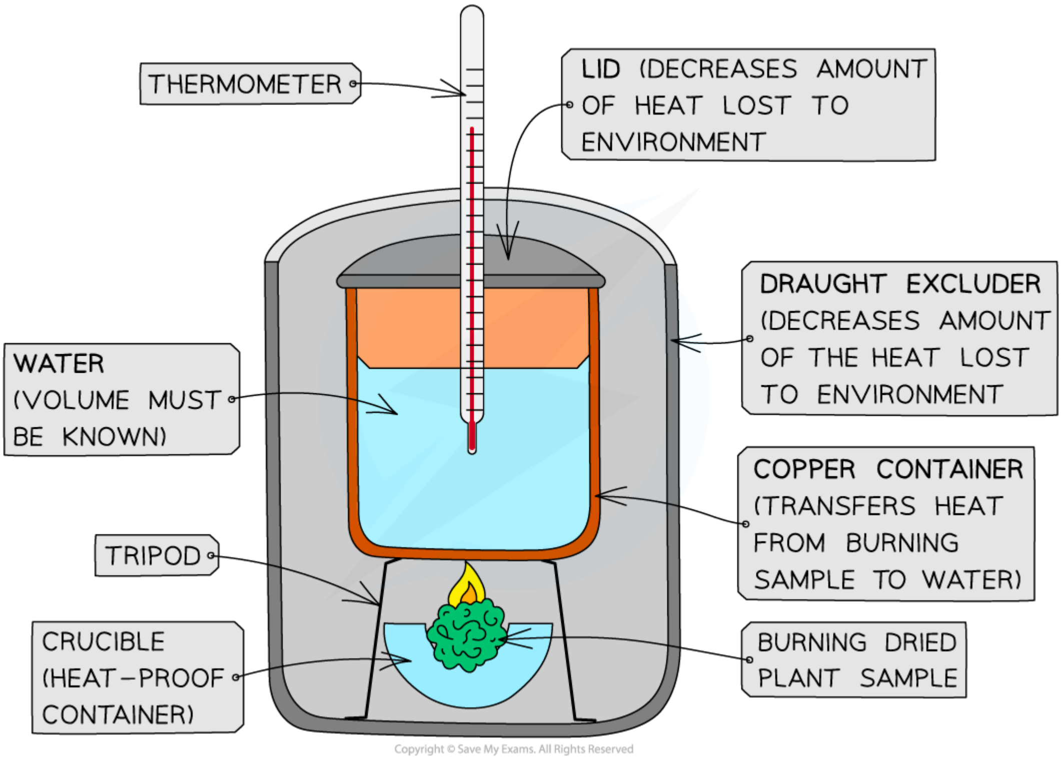

A simple, inexpensive version of a calorimeter that can be set up using classroom equipment

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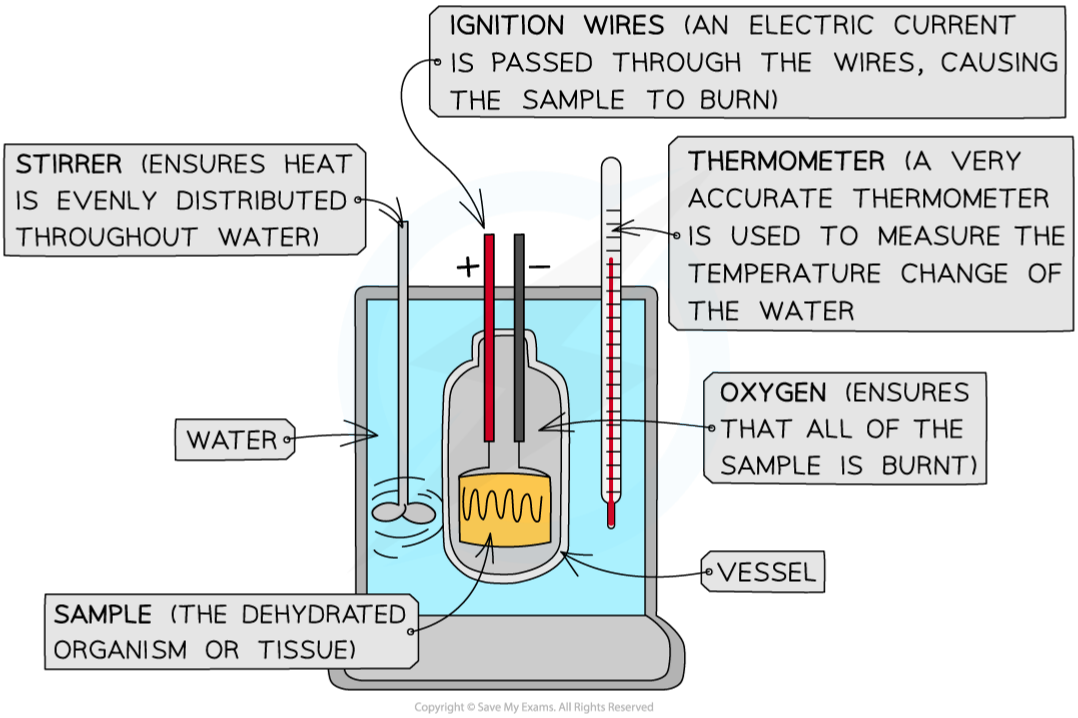

An example of a more precise (and much more expensive) version of a calorimeter known as a bomb calorimeter – this type is used in professional scientific laboratories

Limitations

- It can take a **long time** to **fully** dehydrate (dry out) a plant 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**
  - A very precise digital balance should be used to measure the mass of the plant sample as it is drying (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 (again, 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 plant 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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6.5.3 EFFICIENCY OF ENERGY TRANSFERS

Efficiency of Energy Transfers

- A very large proportion of the Sun's energy is not made available to photosynthetic plants, because
  - **Light falls away** from plants
  - Light **passes through leaves** or is **reflected** away
  - Light is a mixture of wavelengths, and **only certain wavelengths** stimulate photosynthesis
- During photosynthesis, primary **producers** (such as plants and algae) convert **light** energy to **chemical** energy in **biological molecules**
- The **storing** of this chemical energy as plant **biomass** makes a certain amount of energy available to the next trophic level, the **primary consumers**
- Only a **small percentage** of plant biomass becomes biomass in the primary consumer because:
  - Not all the plant's biomass is eaten by the primary consumer
  - Not all the consumer's biomass intake is digested
    - Think about the energy content of cow dung, which can be dried and used as a heating/cooking fuel, as it contains a lot of undigested biomass e.g. cellulose
  - The primary consumer converts a lot of chemical energy to **movement** and **heat**, and only a small amount to new biomass in its own body
- The efficiency of biomass transfer from one trophic level to the next is **low**, typically around 10%

Calculating Efficiency of Biomass Transfers Between Trophic Levels

- Given the appropriate data, it is possible to calculate the **efficiency** of biomass transfer from one trophic level to the next, as a **percentage**

$$\text{Efficiency of energy transfer} = \frac{\text{biomass transferred}}{\text{biomass available to next trophic level}} \times 100$$

Worked Example

A blackberry bush with a mass of 35kg is fed upon by aphids, who have a collective mass of 4.1kg grammes. Calculate the percentage efficiency of energy transfer in this step of the food chain.

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Step 1: Ensure both units are the same

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

Step 2: Substitute the values into the formula

$$\text{Efficiency of energy transfer} = \frac{\text{biomass transferred}}{\text{biomass available to next trophic level}} \times 100$$

$$(4.1 \div 35) \times 100\ \% = 11.7\ \%$$

- The equation for the efficiency of energy transfer between trophic levels can be written in different ways
- Another common way of working out the efficiency is calculating the **net productivity** of one trophic level as a **percentage** of the net productivity of the preceding trophic level:

$$\text{Efficiency of energy transfer} = \frac{\text{net productivity of primary consumers}}{\text{net productivity of producers}} \times 100$$

$$\text{Efficiency of energy transfer} = \frac{\text{net productivity of secondary consumers}}{\text{net productivity of primary consumers}} \times 100$$

Net productivity of producers

- The net productivity of producers (also known as net primary productivity or NPP) can be calculated using the following equation:

NPP = GPP - R

- Where:
  - GPP = gross primary productivity
  - R = respiratory losses

Net productivity of consumers

- The net productivity of consumers can be calculated using the following equation:

N = I - (F + R)

- Where:
  - I = the chemical energy store in ingested food
  - F = the chemical energy lost to the environment in faeces and urine
  - R = the respiratory losses to the environment

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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 but lose 2,000 kJ m^{-2} yr^{-1} of this energy in faeces and urine. They lose a further 7,000 kJ m^{-2} yr^{-1} using energy for respiration. Calculate the percentage efficiency of energy transfer from the insects to the toads.

Step 1: Calculate the net productivity of the toads

$$N = I - (F + R)$$

$$N = 10{,}000 - (2{,}000 + 7{,}000)$$

$$N = 10{,}000 - 9{,}000$$

$$N = 1{,}000 \text{ kJ m}^{-2} \text{ yr}^{-1}$$

Step 2: Write out the equation for % efficiency and substitute in the known values

$$\text{Efficiency of energy transfer} = \frac{\text{net productivity of secondary consumers}}{\text{net productivity of primary consumers}} \times 100$$

$$\% \text{ Efficiency} = (1{,}000 \div 10{,}000) \times 100$$

Step 3: Calculate the efficiency

$$\% \text{ Efficiency} = (0.1) \times 100$$

$$\% \text{ Efficiency} = 10\%$$

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How human activities can manipulate the transfer of biomass through ecosystems

- **Human activity** can adjust the efficiency of transfer of biomass between trophic levels, usually to maximise it in the context of **maximising agricultural productivity**
- For producers, **arable** farmers can adopt these methods
  - Providing artificial light in greenhouses on overcast days
  - Optimising planting distances between crops
  - Irrigation to maximise growth in dry weather
  - Use of fertilisers
  - Selective breeding for fast growth
  - Use of fungicides/pesticides
  - Fencing to exclude grazers
  - Ploughing and herbicides to kill weeds
  - Plant crops that store energy in edible form e.g. seeds, fruit, tubers
- **Livestock** farmers can adopt these methods for primary consumers (grazers)
  - Use of good quality feeds / food supplements
  - Use antibiotics and vaccines to reduce disease
  - Control predation with fencing or with indoor animal husbandry
  - Reduce competition for grazing e.g. rabbits, deer
  - Indoor husbandry to reduce energy loss from movement or from getting cold outside

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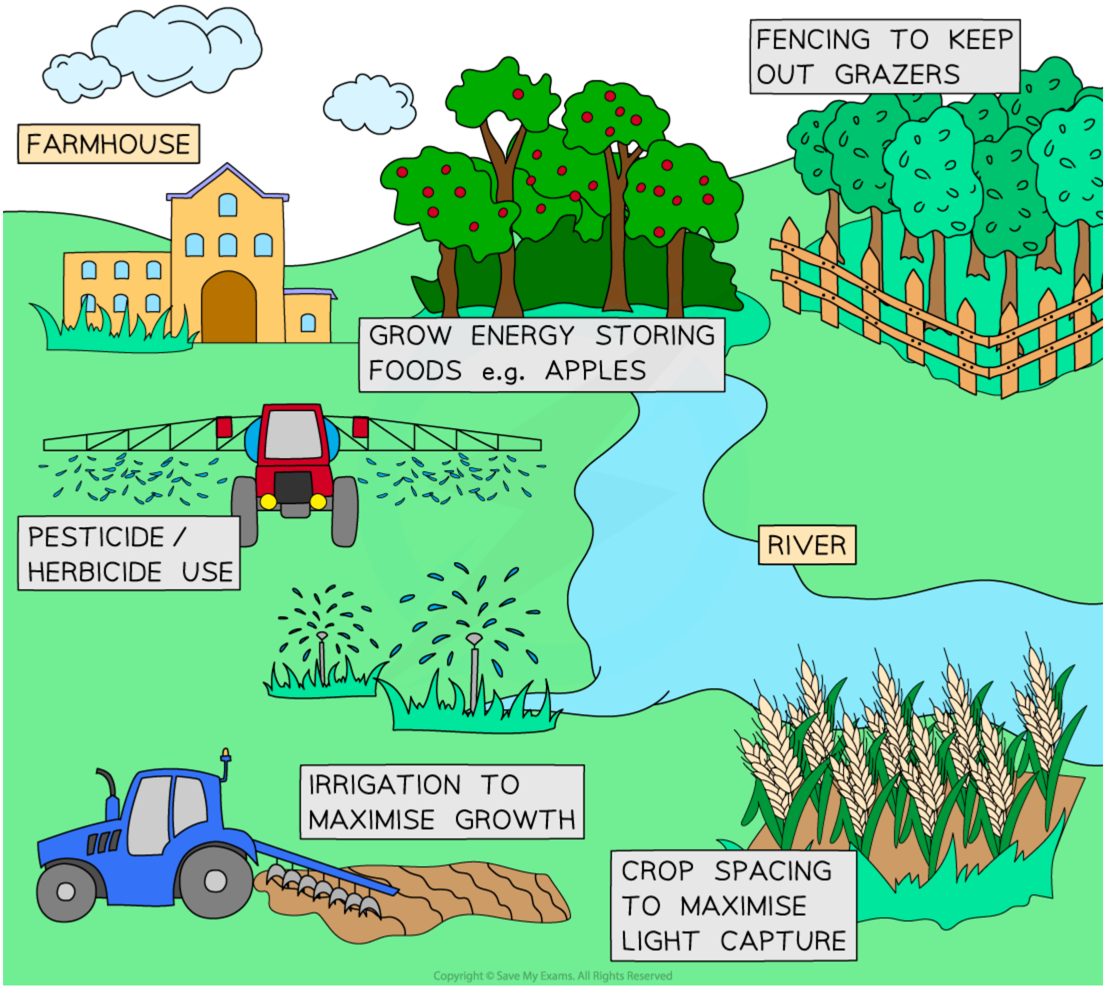

Human activity can increase the efficiency of biomass transfer in an arable farm setting

Exam Tip

Exam questions refer to biomass and energy interchangeably. Remember, the biomass of an organism is effectively a measure of how much chemical energy is stored within it!

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6.5.4 THE NITROGEN CYCLE

The Nitrogen Cycle

- In natural ecosystems, **nutrients** (such as nitrogen and phosphorus) are **recycled** through food webs
- For example, these nutrients get passed on from **producers** to **primary consumers** when they feed on the producers and from **primary consumers** to **secondary consumes** when they feed on primary consumers
- **Microorganisms** are very important in ensuring that the nutrients that are stored within **dead organisms** and in the **waste products** of organisms (i.e. faeces and urine) are **recycled** and made **available** to **producers** once again
    - This process is known as **decomposition**

Saprobionts

- True decomposers are known as **saprobionts**
- Saprobionts mainly come from the **fungi** and **bacteria** kingdoms
- Saprobionts **secrete enzymes** onto their food (dead organisms and waste material), which then digest the material externally
    - This process is also known as **extracellular digestion**
    - The **products** of this external digestion are then **absorbed** by the saprobionts
- This method of obtaining nutrients from dead or waste organic matter via extracellular digestion is known as **saprobiotic nutrition**
- Saprobionts secrete a wide range of digestive enzymes that allow them to hydrolyse (break down) a large variety of biological molecules, releasing a large range of products (**nutrients**) as a result
    - For example, mineral ions such as **ammonium** and **phosphate ions** that are important for the growth and function of producers (e.g. plants) may be released as products during saprobiotic nutrition
- Importantly, **not all** of the products of extracellular digestion get absorbed by saprobionts and many **remain** in the surrounding environment (e.g. the **soil**) and are available to be absorbed by **other organisms** (e.g. plants)
    - This is why saprobionts are such an essential component of ecosystems and food webs
    - Without them, the nutrients locked up in dead and waste matter would never be made available again and producers such as plants would not have access to sufficient nutrients
    - In addition, some saprobionts even **excrete** important **nutrient mineral ions** as **waste products** from their own metabolism

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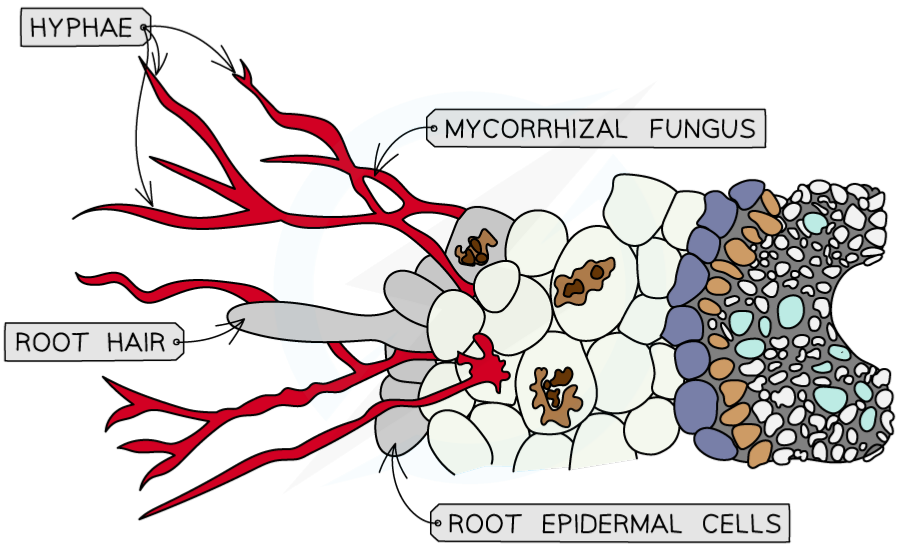
Mycorrhizae

- Many plants have evolved **symbiotic** (mutually beneficial) relationships with **fungi**
  - The fungi are composed of long, thin filaments known as **hyphae**, which **interact** with the **roots** of the plants
  - These hyphae **greatly increase** the **surface area** of the root systems of the plants, increasing the amount of **water** and **mineral ions** (e.g. nitrates and phosphates) that can be absorbed by the plants' roots
  - In return, the fungi receive **organic compounds** (e.g. glucose) from the plant
- These relationships between plant roots and fungi are known as **mycorrhizae**



An example of a mycorrhiza (plural = mycorrhizae) – the mutual, symbiotic relationship between a fungus and the roots of a plant

The Nitrogen Cycle

- Nitrogen is the most abundant gas in the atmosphere, though is relatively inert. It does have a role in biology thanks to its ability to be converted (fixed) into biomass
- Bacteria and other microorganisms play a vital role in the nitrogen cycle
- **Nitrogen-fixing bacteria** (*Azotobacter* and *Rhizobium* species) are able to convert gaseous nitrogen into ammonium ions (NH_4^+)
- Ammonium ions are nitrified by **nitrifying bacteria** (*Nitrosomonas* and *Nitrobacter* species) into nitrite (NO_2^-) and nitrate (NO_3^-), which are highly soluble and can be absorbed by roots
- **Denitrifying bacteria** (e.g. *Thiobacillus denitrificans)* use nitrates for respiration and return gaseous nitrogen to the atmosphere
- Other bacteria and fungi are involved in **saprobiotic** decomposition e.g. decay of dead biomass or excreta

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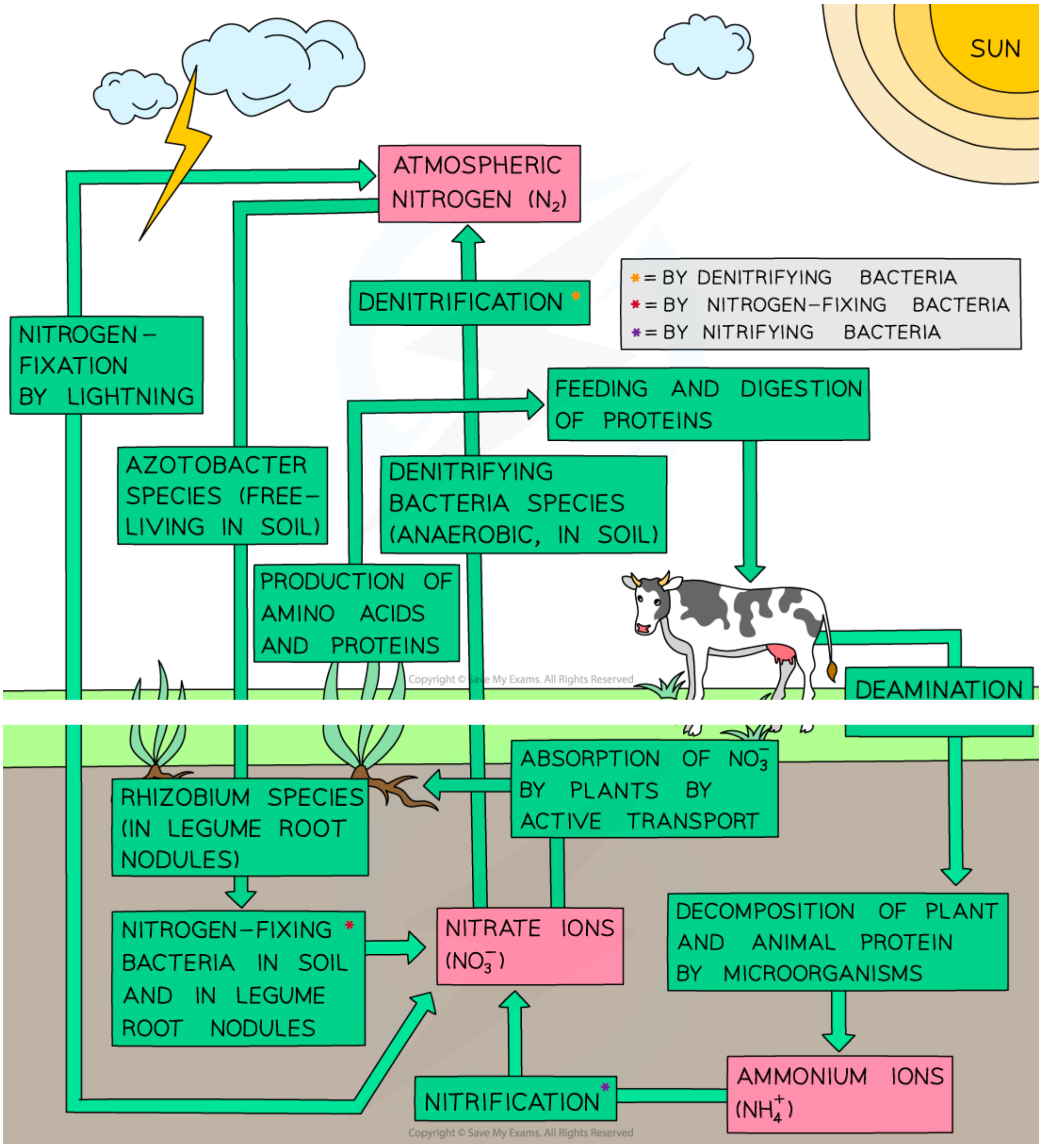

The roles of various bacteria in the recycling of nitrogen

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Summary of the Role of Microorganisms in Recycling Minerals Table

Microorganism	Role in recycling minerals
Saprobionts	• **Decompose** waste and dead matter via **extracellular digestion**, making inorganic (mineral) ions available to other organisms • Carry out process of **ammonification** (convert nitrogen compounds in waste and dead matter into ammonia, which then forms ammonium ions in soil)
Nitrogen-fixing bacteria	• Convert atmospheric **nitrogen gas** into nitrogen-containing compounds, such as **ammonia**, which then forms ammonium ions in soil that can be used by plants
Nitrifying bacteria	• Convert ammonium ions in soil into nitrogen compounds that can be used by **plants**, known as **nitrates** • Some nitrifying bacteria convert ammonium ions into **nitrites**, different nitrifying bacteria then convert nitrites into **nitrates**
Denitrifying bacteria	• Use **nitrates** during **respiration**, releasing **nitrogen gas** in the process
Mycorrhizal fungi	• Increase surface area of root systems, helping plants to absorb water and **scarce mineral ions** from soil

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6.5.5 THE CARBON CYCLE

The Carbon Cycle

The role of organisms in the Carbon Cycle

- Carbon is constantly being **recycled** around the biosphere so that the number of carbon atoms in the biosphere is essentially **constant**; carbon atoms merely swap from one compound to another by the various processes in the carbon cycle
- Carbon is stored in various forms:
  - In the **atmosphere** (as CO_2)
  - In **sedimentary rocks**
  - In **fossil fuels** like coal, oil, and gas; coal is almost pure carbon
  - In **soil** and other organic matter
  - In **vegetation** (e.g. as cellulose)
  - **Dissolved** in the oceans (as CO_2)

Photosynthesis

- **Autotrophs** use the energy of sunlight to 'fix' carbon dioxide, turning its carbon into sugars and other organic molecules
- This **removes carbon** from the atmosphere
- The Calvin cycle is where CO_2 is fixed, by the enzyme Rubisco, which **carboxylates RuBP**
- Terrestrial plants use **gaseous CO_2** directly from the air
- Aquatic organisms use **CO_2 dissolved in water**
- As much CO_2 is fixed from ocean microorganisms, as from terrestrial plants

Sedimentation

- Plants that die are not fully decomposed by saprobionts; their bodies form layers of sediment that can accumulate over millions of years, locking carbon into the ground
- This sediment is a store of energy and can form fossil fuels like **peat** and **coal**
- Aquatic organisms that die also form sediments on the sea bed; these can go on to form other **fossil fuels** like oil and gas
- **Shells** and other calcium-containing body parts can form sedimentary rocks such as limestone
- The existence of life forms over billions of years has shaped the biosphere, in that their remains are still being recycled

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Respiration

- All life forms respire, including autotrophs
- Heterotrophs rely on respiration for **all their energy needs**
- Respiration puts CO_2 into the atmosphere, in the opposite direction to photosynthesis
- CO_2 is released in the **Link Reaction** and the **Krebs Cycle** of aerobic respiration
- **Anaerobic respiration** also releases CO_2 into the atmosphere, via **fermentation** by yeast, moulds and bacteria

Feeding

- Carbon is passed from **autotroph** to **heterotroph** during feeding
- Carbon is also passed from primary consumer to secondary consumer
- Biomass transfer always includes the transfer of carbon, the main element in biomass

Decay & Decomposition

- Dead plants and animals are fed upon by detritivores and decayed by saprophytes
    - Releasing carbon into the surroundings
    - Supplying carbon to the detritivores
    - Supplying carbon to the saprophytes
- Waste matter such as faeces and urine is used by decaying saprobionts
- Such processes can release CO_2 back into the air

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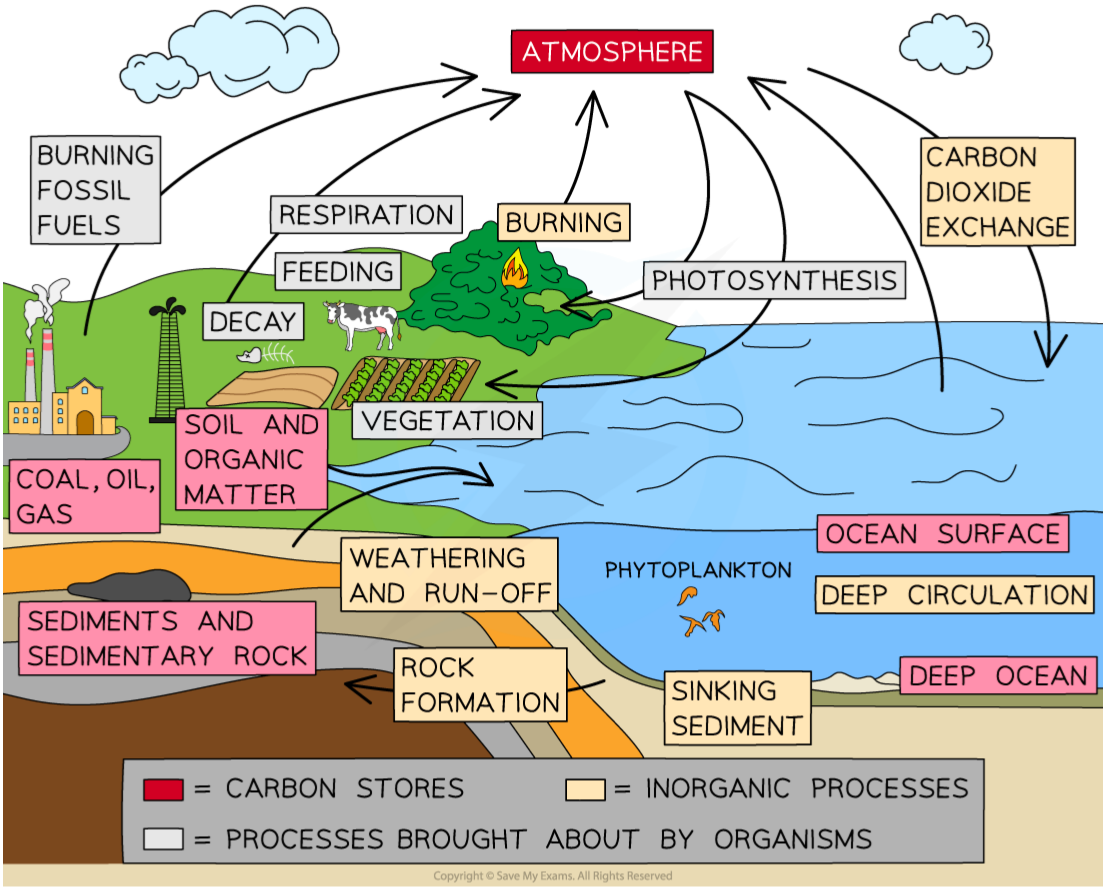

The roles of organisms in the carbon cycle

Burning fossil fuels

- Since the mid 19th century, humans have **extracted** and **burned** increasing amounts of fossil fuels from the Earth
- CO_2 is being returned to the atmosphere **faster** than it can be absorbed by plants and aquatic producers
- The CO_2 level in the atmosphere is approximately **double** that of 800,000 years ago
- Warmer temperatures mean that **less CO_2 can be dissolved in the oceans**, so is released into the air
- This has caused dramatic **climate change** and affected many other species, mainly through changing habitats

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6.5.6 SUCCESSION

Succession

- Ecosystems are **dynamic**, meaning that they are constantly **changing**
- Sometimes, ecosystems change from being very **simple** to being relatively **complex**
    - This process is known as **succession**
    - During succession, the **biotic** conditions (i.e. the living factors) and the **abiotic** conditions (i.e. the non-living factors) **change over time**
- **Primary** succession is the process that occurs when **newly formed** or **newly exposed** land (with no species present) is gradually **colonised** (inhabited) by an increasing number of species
- This new uninhabited land can be created in several ways. For example:
    - The magma from erupting **volcanoes** cools and often leads to the formation of **new rock** surfaces or even new rocky **islands** in the sea
    - Another way new land can be exposed is by sea-level dropping or the drying up of a lake, leaving areas of **bare rock**
- Primary succession does not only occur on bare rock. Any **barren terrain** that is slowly being colonised by living species is undergoing primary succession. For example:
    - **Sand dunes** in coastal areas (**marram grasses** are the pioneer species in these environments as they have **deep roots** to access water that other plants can't reach and are able to **tolerate the salty environment** i.e. the high concentrations of sodium and calcium ions caused by sea spray)

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Primary succession occurs in a series of stages

- Firstly, **seeds** and **spores** that are carried by the **wind** land on the exposed rock and begin to grow
  - These first species to colonise the new land (often **moss** and **lichens**) are known as **pioneer species**
  - As these pioneer species die and decompose, the dead **organic** matter (**humus**) forms a **basic soil**
- Seeds of **small plants and grasses**, sometimes also carried in the wind or sometimes transported other ways (e.g. in bird faeces) land on this basic soil and begin to grow (these smaller plants are adapted to survive in **shallow**, relatively **nutrient-poor** soils)
  - As these small plants and shrubs die and decompose, the new soil becomes **deeper** and more **nutrient-rich**
  - The **roots** of these small plants and shrubs also form a network that helps to **hold the soil in place** and prevent it from being washed away
- **Larger plants and shrubs**, as well as **small trees**, that require deeper, more nutrient-rich soil, can now begin to grow
  - These larger plants and small trees also require **more water**, which can be stored in **deeper soils**
- Finally, the soil is sufficiently deep, contains enough nutrients and can hold enough water to support the growth of **large trees**
  - These final species to colonise the new land become the **dominant species** of the now relatively **complex ecosystem**
  - The **final community** formed, containing all the different plant and animal species that have now colonised the new land, is known as the **climax community**

6.5 Ecosystems

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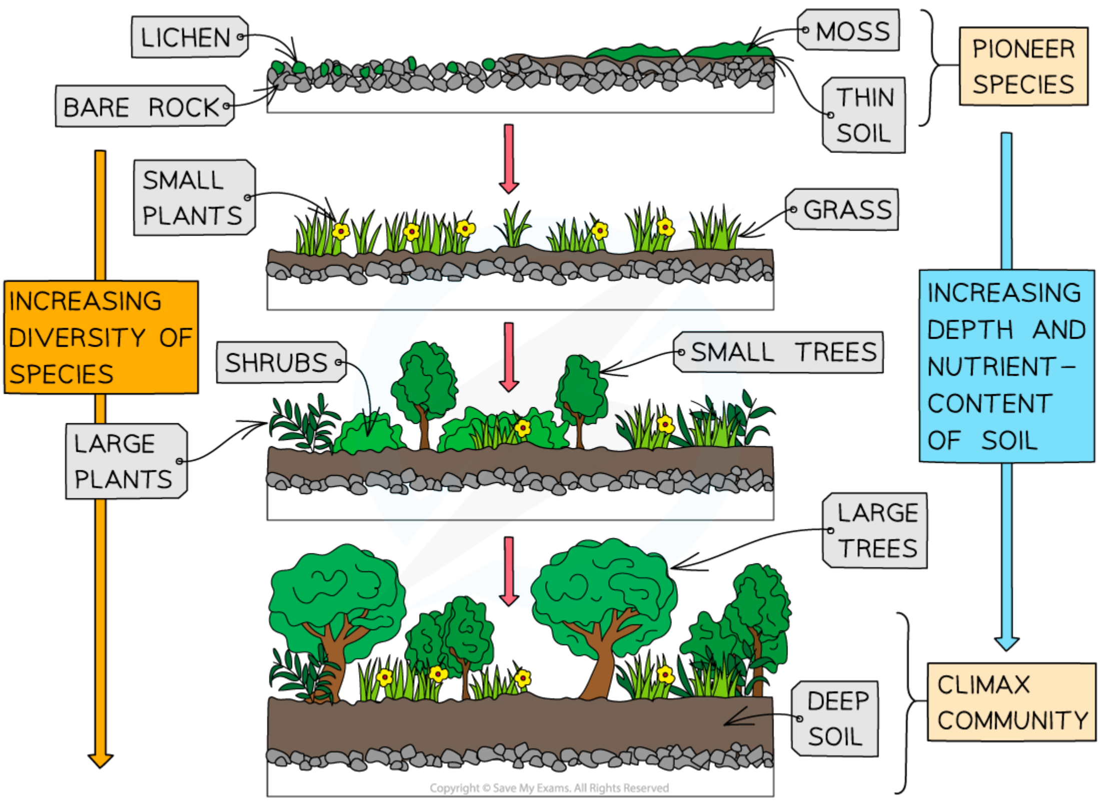

An example of primary succession occurring on a newly formed rock surface

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Changes In the Environment During Succession

- At each **stage** in **succession**, there are certain species that gradually **change** the **local environment** so that it becomes **more suitable** for **other species** (with different adaptations) that have not yet colonised the new land
    - For example, pioneer species change the abiotic conditions so that they are less hostile to new colonising species
- Often, these new colonising species then change the environment in such a way that it becomes **less suitable** for the **previous species**

Examples of a changing environment during succession

- The processes described above are demonstrated in the example of primary succession occurring on a newly formed rock surface. For example:
    - Pioneer species that first colonise and grow on the bare rock, such as **lichens**, help to slowly **break apart** the top surface of the rock. This fragmented rock, along with the dead organic matter (**humus**) left behind when the lichens die and are broken down, forms a **basic soil**. In this way, the lichens gradually **change** the **local environment** so that it becomes **more suitable** for other species, such as **mosses**
    - As mosses grow, the basic soil continues to build up until small plants and grasses can colonise the new land. Eventually, these species result in the formation of a **thin soil layer** that **covers** the newly formed rock surface completely. As lichens cannot grow on soil, they now **disappear** from the **ecosystem**. In this way, the new species that arrived after the lichens have changed the environment in such a way that it becomes **less suitable** for the lichens
        - This is why the term ‘succession’ is used. Rather like one king succeeding (following on from) his predecessor on the throne, one species is effectively replaced by a new, more suitable one
    - Finally, as the soil deepens further and **trees** are able to grow, they may then **out-compete** certain shrubs and other smaller plant species, which may no longer be able to grow beneath the trees due to a **lack of light**

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Management of Succession in Conservation

- **Human activities** often **prevent** or **interrupt** the process of succession. This is called **deflected succession**
- As a result, this stops a climax community from developing. For example:
  - If **left alone**, a grassy field would eventually develop into an area of **shrubs** and **trees** due to the process of succession. However, regular **mowing** prevents these larger, more woody plants from **establishing** themselves, so succession can't occur (only the small grasses can **survive** being regularly mowed)
  - Similarly, in areas where **livestock** such as sheep, horses or cattle are kept, succession is halted by the **grazing** activity of these animals, which eat any **new plant shoots** trying to grow. Again, grasses are the main plant species that can remain established in these areas

Managing Succession

- **Conservation** involves the **protection** and **management** of **ecosystems**
- In conservation terms, preventing an area from reaching its climax community can sometimes be a **good thing**
  - This is because ecosystems at the **intermediate** stages of succession, where small plants, grasses, ferns or shrubs are present, often hold a **distinct diversity** of plant species (some of which may be of **conservation importance**) that would no longer exist if the climax community was reached
  - These diverse plant species also provide food and habitat for a **high diversity of animal species**, some of which may also be of conservation importance (e.g. species that are **rare** or **threatened**, or species that have important **ecosystem functions**, such as **pollinators** like bees, which are also of great importance to humans due to their role in pollinating the crops we consume)
- As a result, some conservation projects require the **deliberate**, **artificial** prevention of succession in order to **preserve** an ecosystem in its current stage of succession. For example:
  - Scottish **moorlands** provide habitats for many species of plants and animals
  - If succession was allowed to occur, this valuable moorland would be replaced by a climax community dominated by spruce forest, which **cannot support the same species** as the moorlands
  - This would mean **losing** these important species
  - By having some areas where the climax community is allowed to develop and other areas where succession is prevented so that the moorland remains **intact**, both ecosystems can be **maintained**, giving a **higher overall species diversity**

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Preventing Succession

- There are a few different ways that succession can be deliberately prevented for conservation purposes. For example:
    - **Grazing animals** can be **introduced** temporarily. As they eat the growing shoots of shrubs and trees, this stops these plants from establishing themselves and prevents succession
    - **Managed burning** can be used, during which **controlled fires** are deliberately lit and allowed to **burn away** the shrubs and trees. Species such as heather (a key moorland plant) grow back quickly in their place. This **resets** the process of succession, meaning the larger, woody plants will take a long time to grow back, at which point the burning can be repeated

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6.5.7 TESTING FOR DISTRIBUTION & ABUNDANCE

Testing for Distribution & Abundance

- Measuring all the different levels of biodiversity within an ecosystem could be very **time-consuming**
- Finding out which species live in an ecosystem and the size of the populations requires the **identification and cataloguing** of all organisms present to build a **species list**
- This is possible for areas that are **very small** or where the species are **very large** like trees
- However, for larger and more complex ecosystems like rainforests, it is simply **impossible** to find, identify and count every organism that exists there
- When this is the case different **samples** of the area can be taken and used to make an **estimate for the total** species numbers in the area

Sampling

- Sampling is a method of investigating the **abundance** and **distribution of species and populations**
- There are two different types of sampling:
  - **Random**
  - **Systematic**
- In random sampling the positions of the **sampling points** are completely random or **due to chance**
  - This method is beneficial because it means there will be no **sampling bias** by the person that is carrying out the sampling that may affect the results
- In systematic sampling the positions of the **sampling points are chosen** by the person carrying out the sampling
  - There is a possibility that the person choosing could show bias towards or against certain areas
  - Individuals may deliberately place the quadrats in areas with the least species as these will be easier and quicker to count
  - This is unrepresentative of the whole area
- When a sampling area is **reasonably uniform** or has **no clear pattern** to the way the species are distributed then **random sampling** is the best choice

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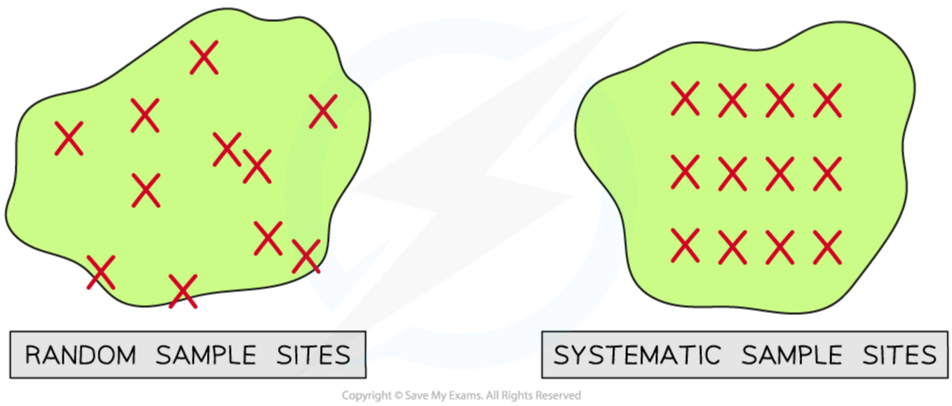

Random sampling differs from systematic sampling when choosing sample sites on an island

Sampling methods

- There are **three** main **sampling methods** used when trying the **estimate** the **size** of a **population**:
  - **Quadrats** (for non-motile or slow-moving species)
  - **Transects** (for non-motile or slow-moving species)
  - **Mark-release-recapture** (for motile species)

Apparatus & Techniques: Investigating the Distribution of Organisms

- The **distribution** of a species describes how it is spread throughout the ecosystem
- The **abundance** of a species is the number of individuals of that species
- The distribution and abundance of non-motile or slow-moving species in an area can be assessed using two different practical methods:
  - Frame **Quadrats**
  - Belt **Transects**

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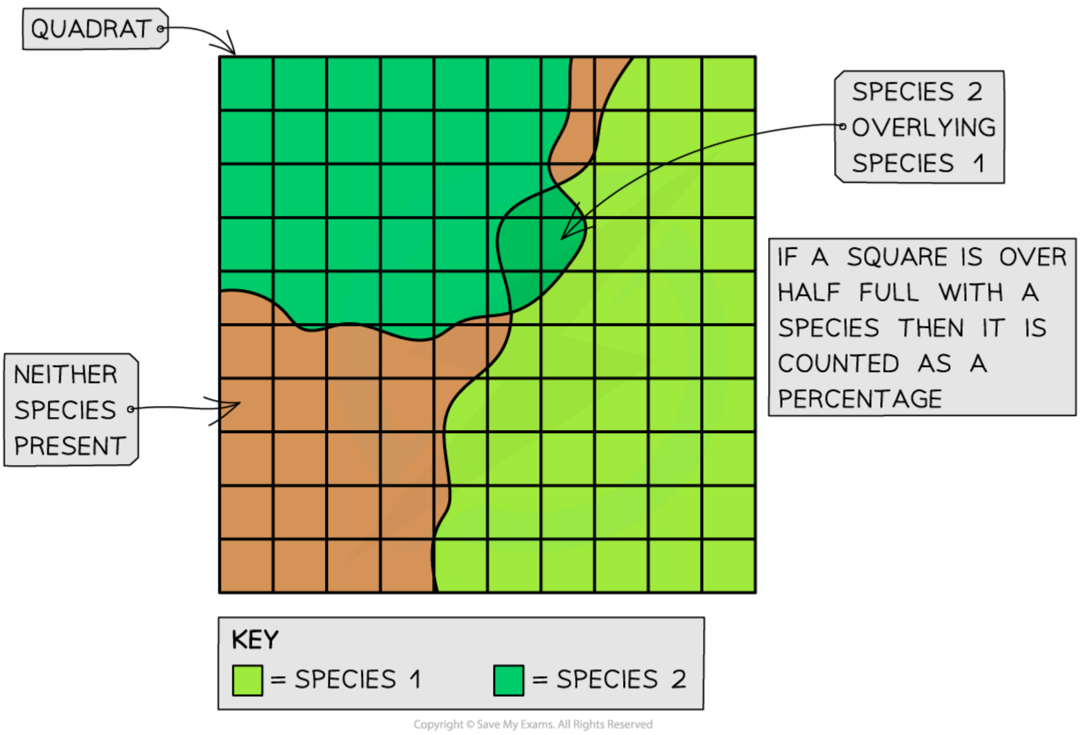
Frame quadrats

- Some ecosystems are very complex with large numbers of different species of different sizes
- For the sake of logistics, **sampling** is often used to estimate the **distribution** and **abundance** of species
- When carrying out sampling, square frames called **quadrats** can be used to mark off the area being sampled
- Quadrats of **different sizes** can be used depending on what is being measured and what is most suitable in the space the samples are being made in
- Quadrats must be laid **randomly** in the area to **avoid sampling bias**
    - This random sampling can be done by converting the sampling area into a **grid format** and labeling each square on the grid with a number
    - Then a random number generator is used to pick the sample points
- Once the quadrat has been laid on the chosen sample point the **abundance** of all the **different species** present can be recorded



Using a quadrat to investigate percentage cover of two species of grass. There may be some squares lacking any species and other squares with multiple species – this means the total percentage cover of a single quadrat can sometimes be over or under 100%

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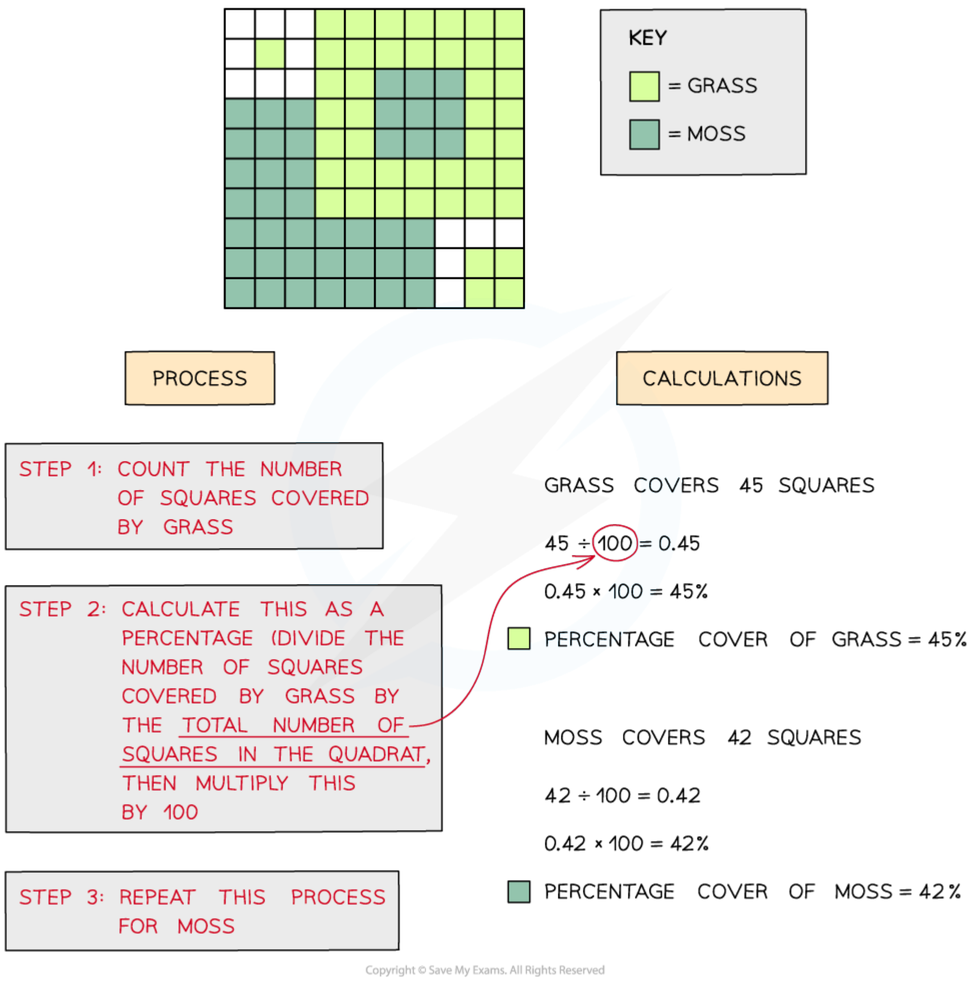
Results from quadrats

- The results from the quadrats can be used to calculate the predicted frequency and density of a species within an area
- **Species frequency** is the probability that the species will be found within any quadrat in the sample area
  - The number of **quadrats** that the species was present in is divided by the total number of quadrats and then multiplied by 100
  - For example, if bluebells were found in 18 out of 50 quadrats the species frequency would be (18/50) x 100 = 36%
- It can sometimes be difficult to count individual plants or organisms. When this is the case **percentage cover** of the species within the quadrat can be estimated instead
  - The quadrat is divided into 100 smaller squares. The number of squares the species is found in is equivalent to its percentage cover in that quadrat
  - For example, if grass is found in 89 out of 100 squares in the quadrat then it has a percentage cover of 89%



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How to estimate percentage cover of one or more species using a quadrat

Belt transects

- Throughout some areas, there can be **changes in the physical conditions** (i.e. abiotic factors)
  - For example, there may be changes in altitude, soil pH or light intensity
- When investigating the species distribution in these kinds of areas **systematic sampling** is more appropriate
- Methods using **transects** can help show how the distribution or abundance of a species changes with the different physical conditions in the area
  - A transect is a line represented by a measuring tape, along which samples are taken
- For a **belt transec**t:
  - Place quadrats at **regular intervals** along the tape and **record the abundance of each species within each quadrat**
  - This produces quantitative data

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Mark-release-recapture

- The two sampling methods described above are only useful for **non-motile** (sessile) organisms
- Different methods are required for estimating the number of individuals in a population of **motile animals**
    - The **mark-release-recapture** method is used
- For a single species in the area:
    - The **first large sample is taken**. As many individuals as possible are caught, counted and **marked** in a way that won't affect their survival e.g. if studying a species of beetle, a small amount of brightly coloured non-toxic paint can be applied to their carapace (shell)
    - The marked individuals are **returned to their habitat** and allowed to randomly mix with the rest of the population
    - When a sufficient amount of time has passed **another large sample is captured**
    - The number of marked and unmarked individuals within the sample are **counted**
    - The proportion of marked to unmarked individuals is used to calculate an **estimate of the population size**
    - The formula for the calculation is:

$$N = (n_1 \times n_2) \div m_2$$

    - Where:
        - **N** = population estimate
        - n_1 = number of marked individuals released
        - n_2 = number of individuals in the second sample (marked and unmarked)
        - m_2 = number of marked individuals in the second sample

Worked Example

Scientists wanted to investigate the abundance of leafhoppers in a small grassy meadow. They used sweep nets to catch a large sample of leafhoppers from the meadow. Each insect was marked on its underside with non-toxic waterproof paint and then released back into the meadow. The following day another large sample was caught using sweep nets. Use the figures below to estimate the size of the leafhopper population in this meadow.

• No. caught and marked in first sample (n_1) = 236

• No. caught in second sample (n_2) = 244

• No. of marked individuals in the second sample (m_2) = 71

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Step One: Write out the equation and substitute in the known values

$$N = (n_1 \times n_2) \div m_2$$

$$N = (236 \times 244) \div 71$$

Step Two: Calculate the population size estimate (N)

$$N = 57{,}584 \div 71$$

$$N = 811$$

Results from mark-release-recapture

Assumptions

- When using the mark-release-capture method, there are a few **assumptions** that have to be made:
  - The marked individuals are given **sufficient time** to **disperse** and **mix** back in fully with the **main population**
  - The marking doesn't affect the **survival rates** of the marked individuals (e.g. doesn't make them more visible and therefore more likely to be predated)
  - The marking remains **visible** throughout the sampling and doesn't rub off
  - The **population** stays the **same size** during the study period
    - there are no significant changes in population size due to births and deaths
    - there are no migrations into or out of the main population

Measuring Abundance and Distribution in Difficult Habitats

- The methods of quadrats, transects and mark-release-recapture work well for estimating the abundance and distribution of a large number of **land-based** species
- However, certain species in their habitats are **not so easy** to estimate, for example:
  - The abundance of lichen species growing on **tree branches and twigs**
  - The abundance of **aquatic species** on the sea bed
- The **ACFOR** scale is used by biologists to estimate abundance:
  - ACFOR = **A**bundant, **C**ommon, **F**requent, **O**ccasional, **R**are
  - This is a suitable (though less quantitative) method that can be used for the lichen example above
  - For seabed analysis, the use of quadrats is carried out, using specialist diving equipment and expertise to analyse and identify the contents of the quadrats