DP IB Environmental Systems & Societies (ESS): SL

Your notes

Communities & Ecosystems

Contents

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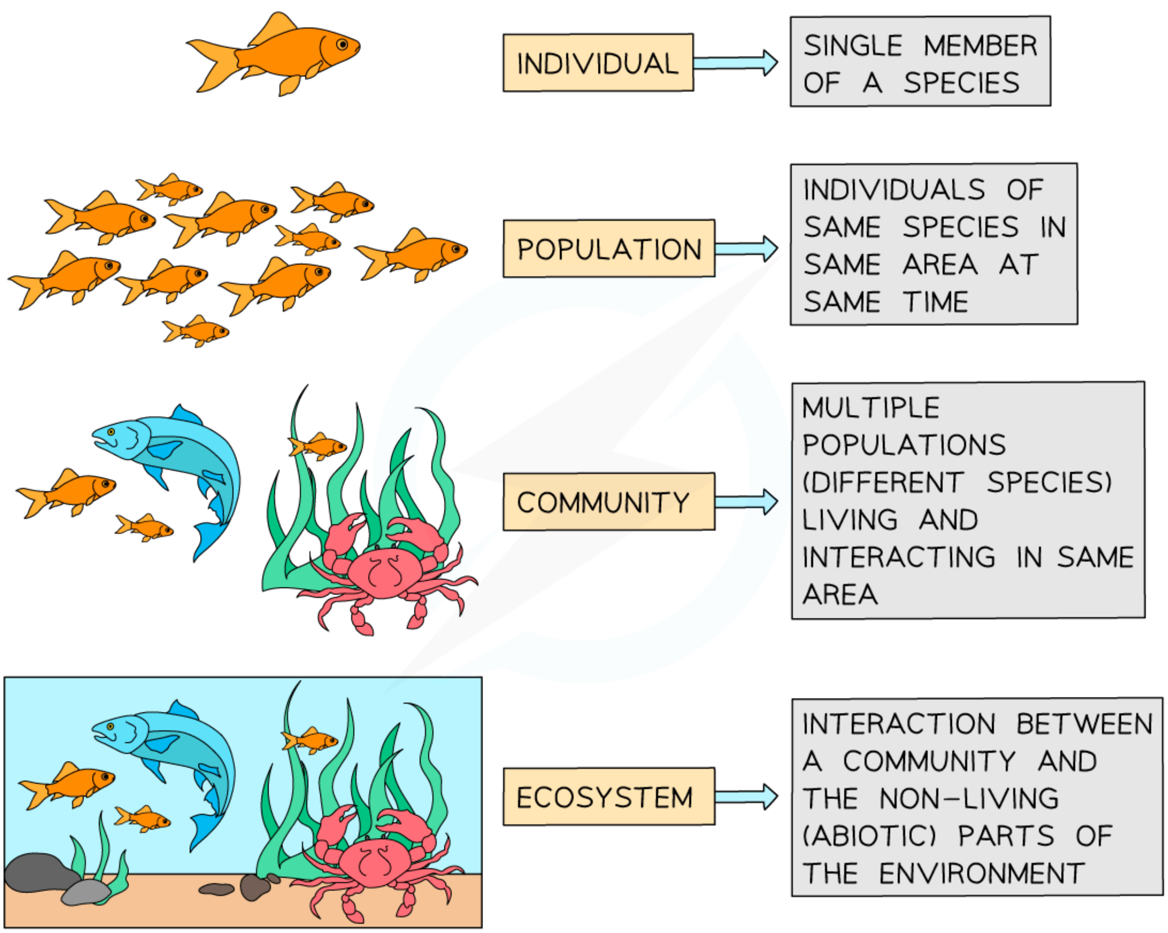
Communities & Ecosystems

- A community is a group of **populations** living and interacting with each other in a **common habitat**
- An ecosystem is a community (the living, biotic part) and the physical environment (the non-living, abiotic part) it interacts with



Levels of organisation in an ecosystem

Worked Example

Give an example of how a community interacts with its physical environment to create a unique ecosystem.

Answer

An example of an ecological community is a coral reef ecosystem. The coral reef ecosystem consists of various populations of living organisms such as coral polyps, fish, crustaceans, mollusks, algae, and other marine creatures that interact with each other and their non-living environment.

These organisms form a complex community that is adapted to the specific conditions of the coral reef ecosystem, including the temperature, light, water chemistry, and physical structure of the reef. Coral reefs require specific abiotic factors such as warm water temperatures, clear and shallow water, and high levels of sunlight to survive.

The interactions among the different species in the community help to maintain the health and stability of the ecosystem. For example, the corals provide a habitat for fish and other organisms, while the fish help to keep the reef healthy and clean by grazing on algae that grows on the corals and by removing dead or decaying matter. In these ways, the coral reef community and its physical environment are intricately connected and interact with each other to create a diverse and productive ecosystem.

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Photosynthesis

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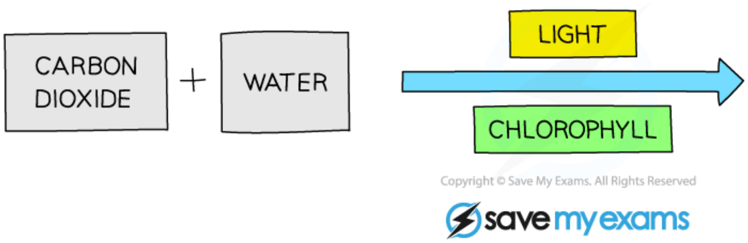
Photosynthesis

What is photosynthesis?

- Primary producers in the majority of ecosystems convert light energy into chemical energy in the process of photosynthesis
- The photosynthesis reaction is:



Photosynthesis Equation

Where does photosynthesis take place?

- The inputs and outputs are:
- Inputs: sunlight as 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 organic matter e.g. carbohydrates, fats and proteins)
- 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)
- The process of photosynthesis transfers light energy to chemical energy in biological molecules
- In ecosystems where sunlight and water is available, the process of photosynthesis enables plants to synthesise organic compounds (glucose and other sugars) from carbon dioxide

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- 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
- The remaining sugars (not used in respiration) are used to make other groups of biological molecules, such as:
  - Starch - a complex carbohydrate molecule (formed from many glucose molecules) that acts as a short-term energy storage molecule
  - Cellulose - another complex carbohydrate molecule (also formed from many glucose molecules) that acts as a structural component of plant cell walls
  - Lipids - plant cells can convert the sugars produced during photosynthesis into lipids, which act as another type of (longer-term) energy storage molecule
  - Proteins - plant cells can also combine the sugars produced during photosynthesis with nitrates to make amino acids, which can then be used to produce proteins
- These different groups of biological molecules (all formed from the sugars synthesised by plants during photosynthesis) make up the biomass of the plants
  - The biomass is the mass of living material
  - The biomass can also be thought of as the chemical energy that is stored within the plant

The sugars synthesised during photosynthesis can be used in respiration or the creation of other biological molecules needed by plants

Respiration

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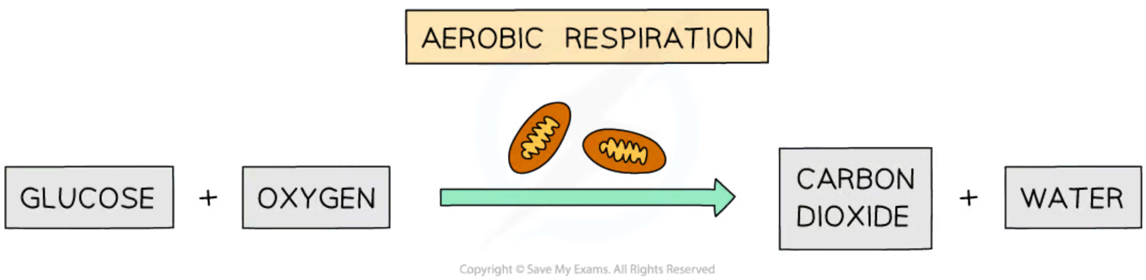
Respiration

What is respiration?

- Respiration and photosynthesis can be described as **processes** with inputs, outputs, and transformations of energy and matter
- Respiration is the conversion of organic matter into carbon dioxide and water in all living organisms, releasing energy
- **Aerobic respiration** can be simply described as: glucose + oxygen → carbon dioxide + water



Aerobic respiration

- **Inputs**: organic matter (glucose) and oxygen
- **Processes**: oxidation processes inside cells
- **Outputs**: release of energy for work and heat
- **Transformations**: stored chemical energy is transformed into kinetic energy and heat
- During respiration, large amounts of energy are dissipated as heat, increasing the **entropy** in the ecosystem while enabling the organisms to maintain relatively low entropy/high organisation

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Trophic Levels

Trophic Levels & Feeding Relationships

What are trophic levels?

- The trophic level is the position that an organism occupies in a food chain, or a group of organisms in a community that occupy the same positions in a food chain

Trophic Levels

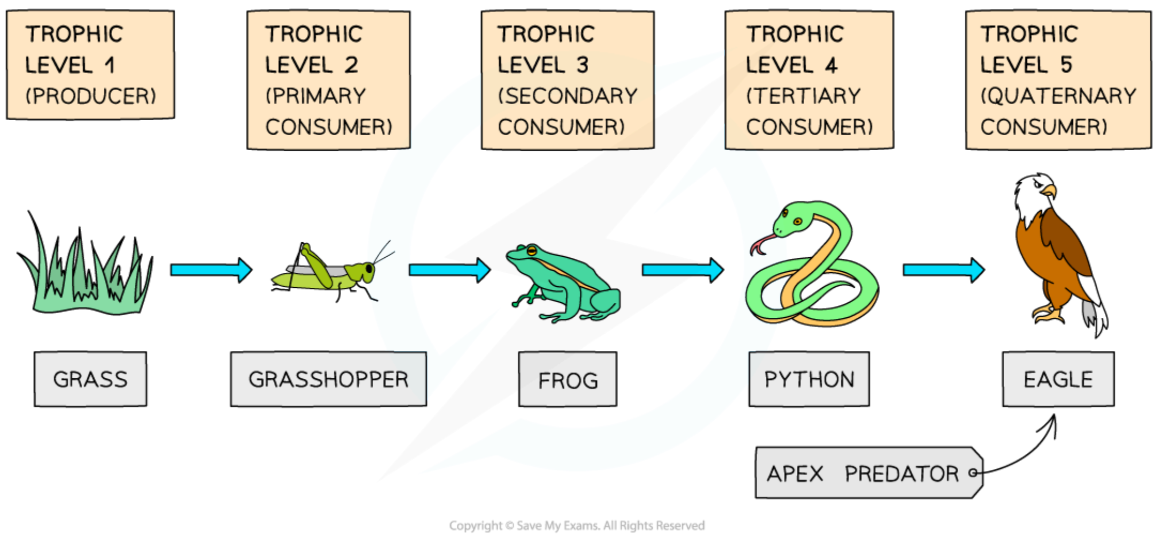
Trophic Level	Name of Trophic Level	Description of Organisms in Trophic Level
1	Producers	Plants and algae – produce their own biomass using energy from sunlight
2	Primary consumers	Herbivores – feed on producers
3	Secondary consumers	Predators – feed on primary consumers
4	Tertiary consumers	Predators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

- Producers (**autotrophs**) are typically plants or algae and produce their own food using photosynthesis and form the first trophic level in a food chain
  - Exceptions include **chemosynthetic** organisms that produce food **without sunlight**
  - For example, bacteria living inside the giant tube worm (*Riftia pachyptila*), found near hydrothermal vents on the ocean floor (where there in no light), use hydrogen sulfide from the vents to produce organic compounds through chemosynthesis, providing a source of energy for the tube worm
- 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
- Apex predators are at the very top of the food chain – they are carnivores with no predators

- The chemical energy stored within apex predators can be passed on to **decomposers** when apex predators die and are decomposed

Feeding Relationships

- Feeding relationships involve producers, consumers and decomposers
- These can be modelled using food chains, food webs and ecological pyramids



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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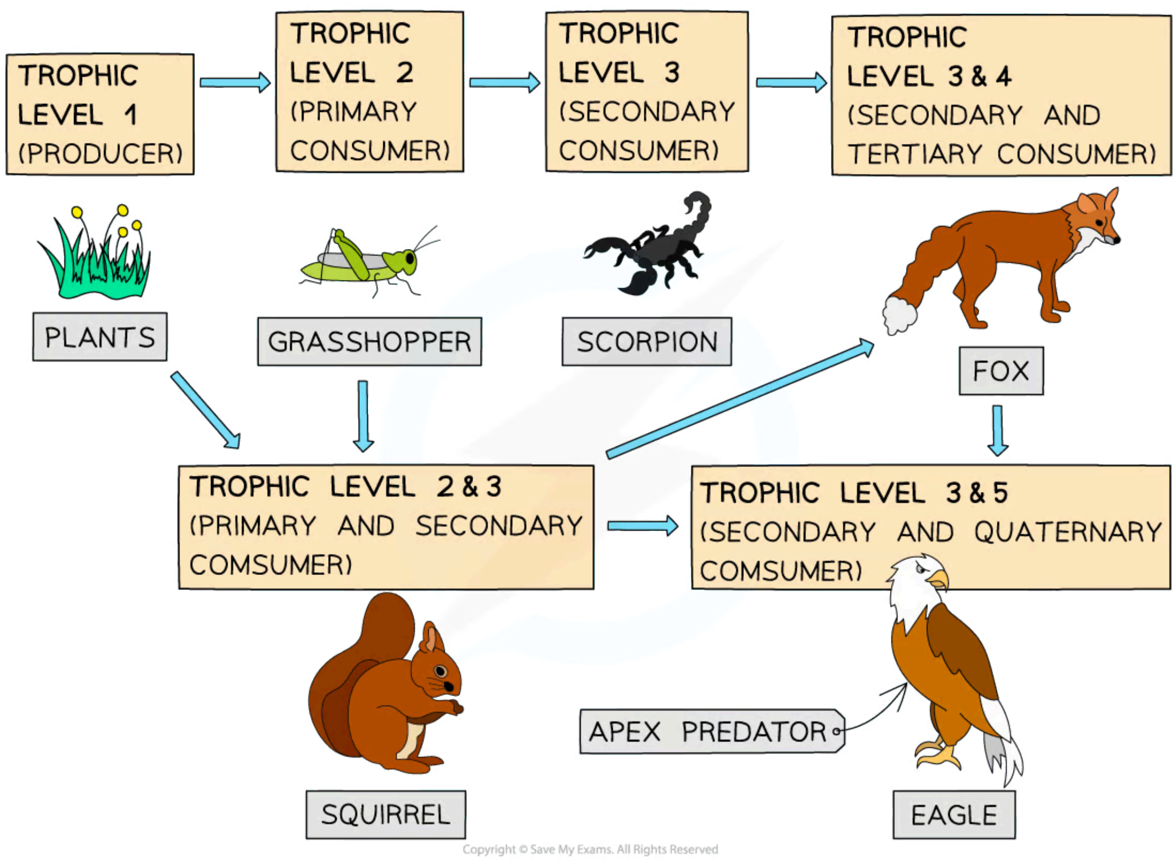

Trophic levels for a simple food web – note that some organisms can belong to more than one trophic level (such as the squirrel, fox and eagle in this food web)

Decomposers

- The net primary production (i.e. the chemical energy) of producers is also available to another group of organisms known as decomposers
- The two main groups of decomposers are bacteria and fungi
- Decomposers carry out a very important function in ecosystems - they break down dead plant and animal material (in the process gaining the chemical energy still stored in the dead matter)
- They do this by:
  - Secreting **digestive enzymes** onto the surface of the dead organism
  - These enzymes break down the dead matter into small soluble food molecules
  - These molecules are then absorbed by the decomposers

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- This process of decomposition also helps to **release organic nutrients** back into the environment (e.g. the soil), which are essential for the growth of plants and other producers

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Examiner Tips and Tricks

Don't forget - animals (known as consumers) can be at different levels within the same food web as they could be omnivores (animals that can eat both plants and animals) or could be predators that eat both primary, secondary and/or tertiary consumers!

Pyramid of Numbers

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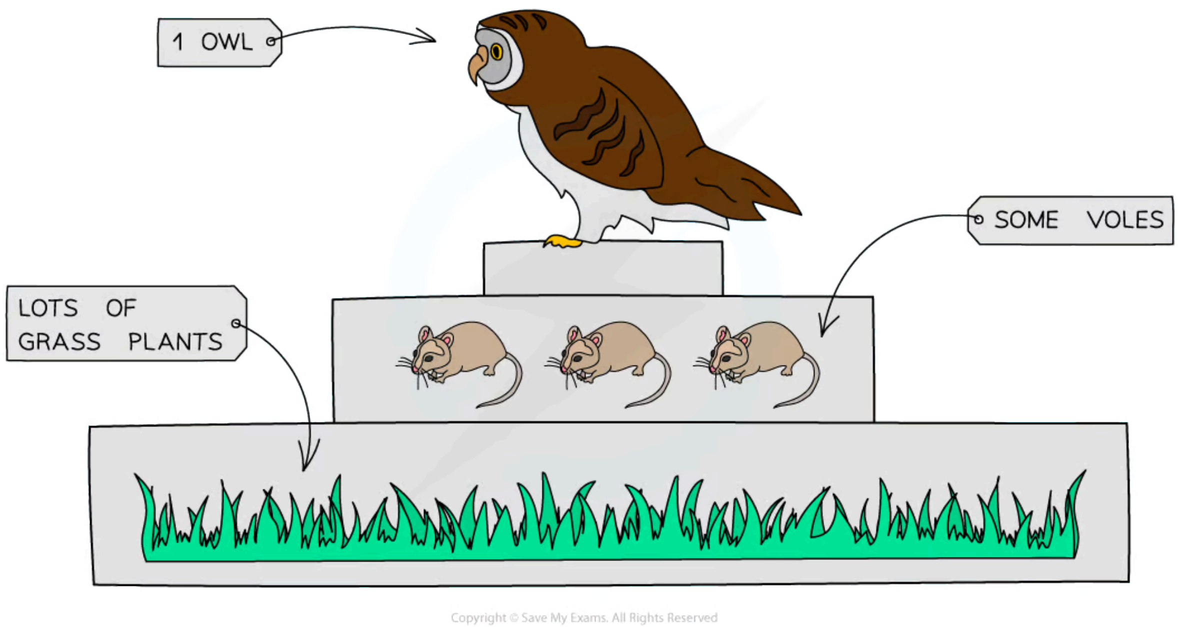
Pyramids of Numbers

- Ecological pyramids include:
  - Pyramids of numbers
  - Pyramids of biomass
  - Pyramids of productivity
- They are quantitative models usually measured for a given **time** and **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

- Ask yourself the following questions:
  - Is it likely that there would be more voles in an area than grass plants?
  - How many voles might one barn owl need to eat per day? If it's more than one, is it likely that there are more barn owls in an area than voles?
- A pyramid of numbers for this food chain would look like the one shown below
  - In accordance with the **second law of thermodynamics**, there is a tendency for number of organisms to **decrease** along food chains, as there is a decrease in available (chemical potential) energy, since some energy is lost to the surroundings at each trophic level
  - Therefore the pyramids become narrower towards the apex



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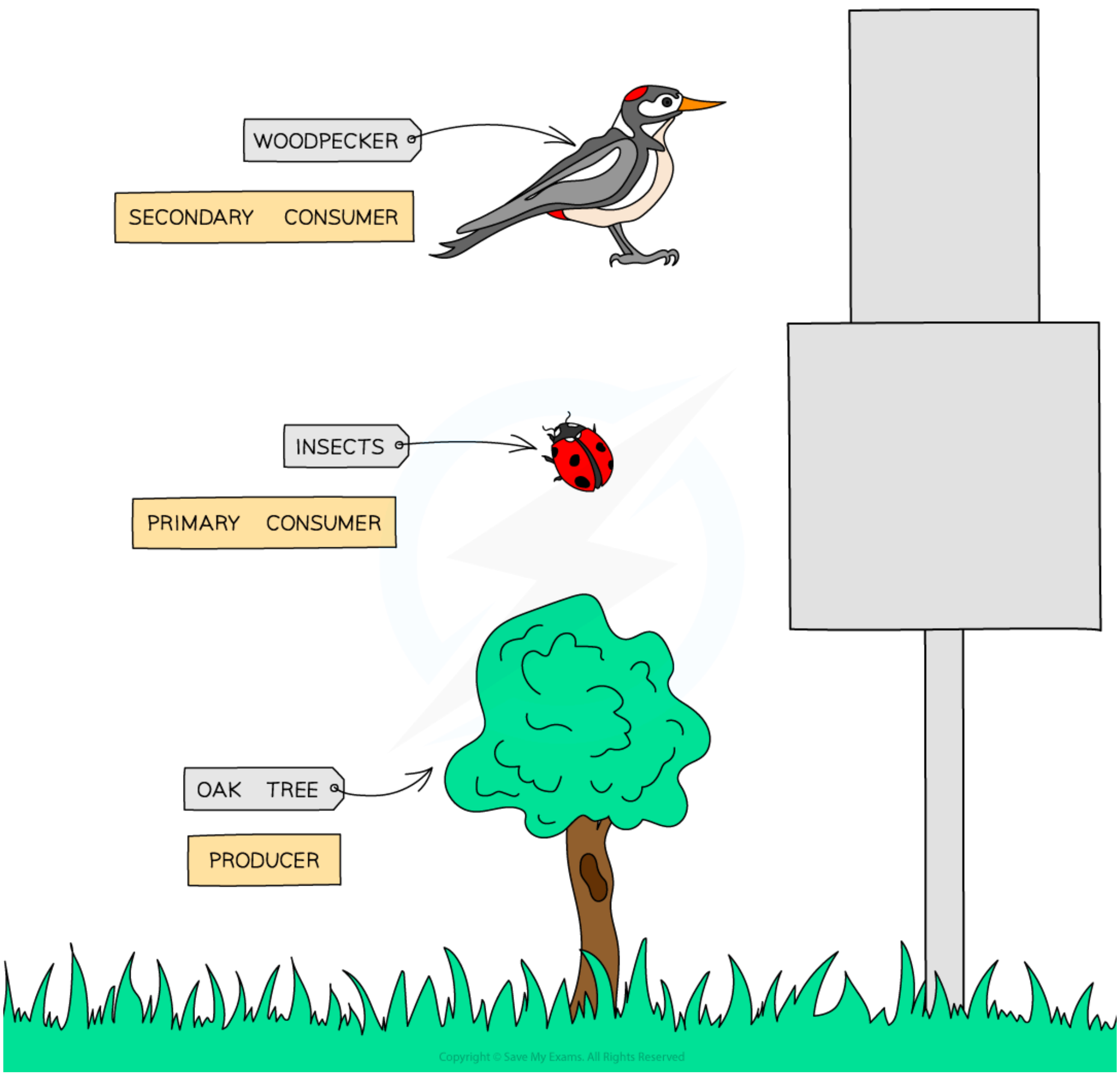
A pyramid of numbers

- 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**



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

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Pyramid of Biomass

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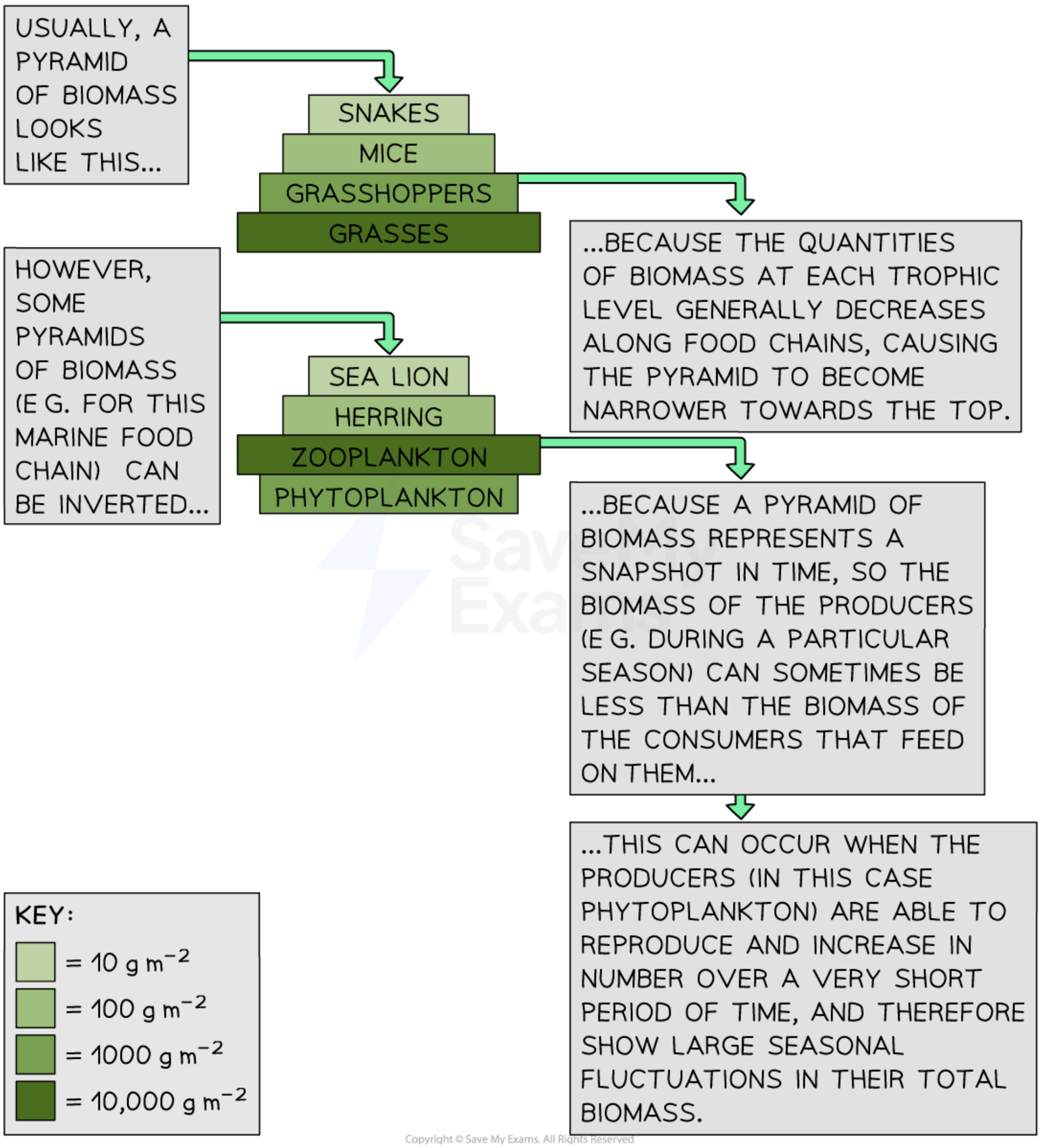
Pyramids of Biomass

- A pyramid of biomass measures the amount of biomass present at **each trophic level** at a specific point in time and represents the **standing stock** of each trophic level
  - Biomass can be measured in grams of biomass per square metre (g m^{-2}) or units of energy, such as joules per square metre (J m^{-2})
- As per the **second law of thermodynamics**, the quantities of biomass generally **decrease** along food chains, so the pyramids become **narrower** towards the top
- This means that pyramids of biomass are usually pyramid-shaped but can occasionally be **inverted** and show higher quantities at higher trophic levels
  - Pyramids of biomass are **snapshots** of the ecosystem and may not indicate productivity **over time**
  - A fertile intensively grazed pasture may have a lower standing crop biomass of grass but higher productivity than a less fertile ungrazed pasture because biomass is constantly removed by herbivores, resulting in an inverted pyramid of biomass
- 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



Constructing a Pyramid of Biomass

- Being able to construct accurate pyramids of biomass from appropriate data is an important skill

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Worked Example

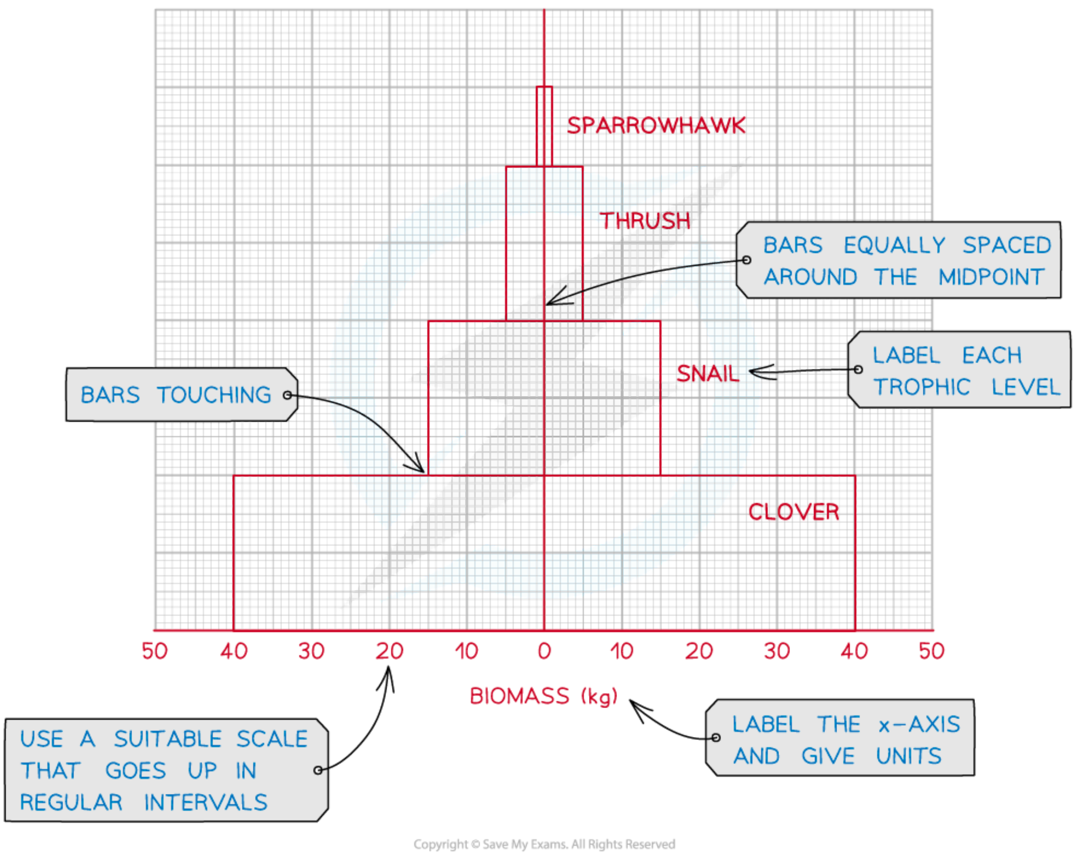
Figure 1 shows:

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

Figure 1

	Clover →	Snail →	Thrush →	Sparrowhawk
Biomass in kg	80	30	10	2

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



Pyramid of Productivity

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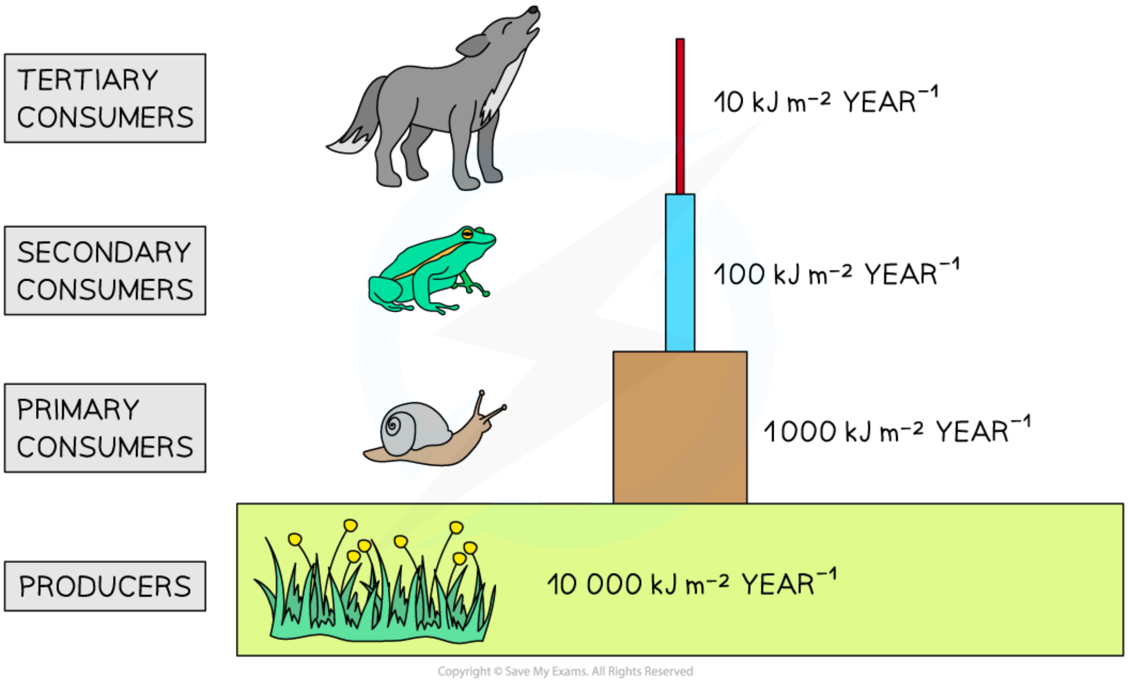
Pyramids of Productivity

- Pyramids of productivity show the flow of **energy** through trophic levels, indicating the **rate** at which that energy is being generated
- 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

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What is Bioaccumulation & Biomagnification?

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Bioaccumulation & Biomagnification

- **Bioaccumulation** is the build-up of **persistent** or **non-biodegradable** pollutants within an organism or trophic level because they cannot be broken down
  - This means that organisms at higher trophic levels (such as top predators) may accumulate higher concentrations of pollutants than those at lower trophic levels
- **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 can become more concentrated due to the decrease in total biomass of organisms at higher trophic levels
- Toxins such as **DDT** (dichlorodiphenyltrichloroethane) are persistent pollutants that can accumulate along food chains
  - 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, leading to harmful effects such as thinning of eggshells and reduced reproductive success

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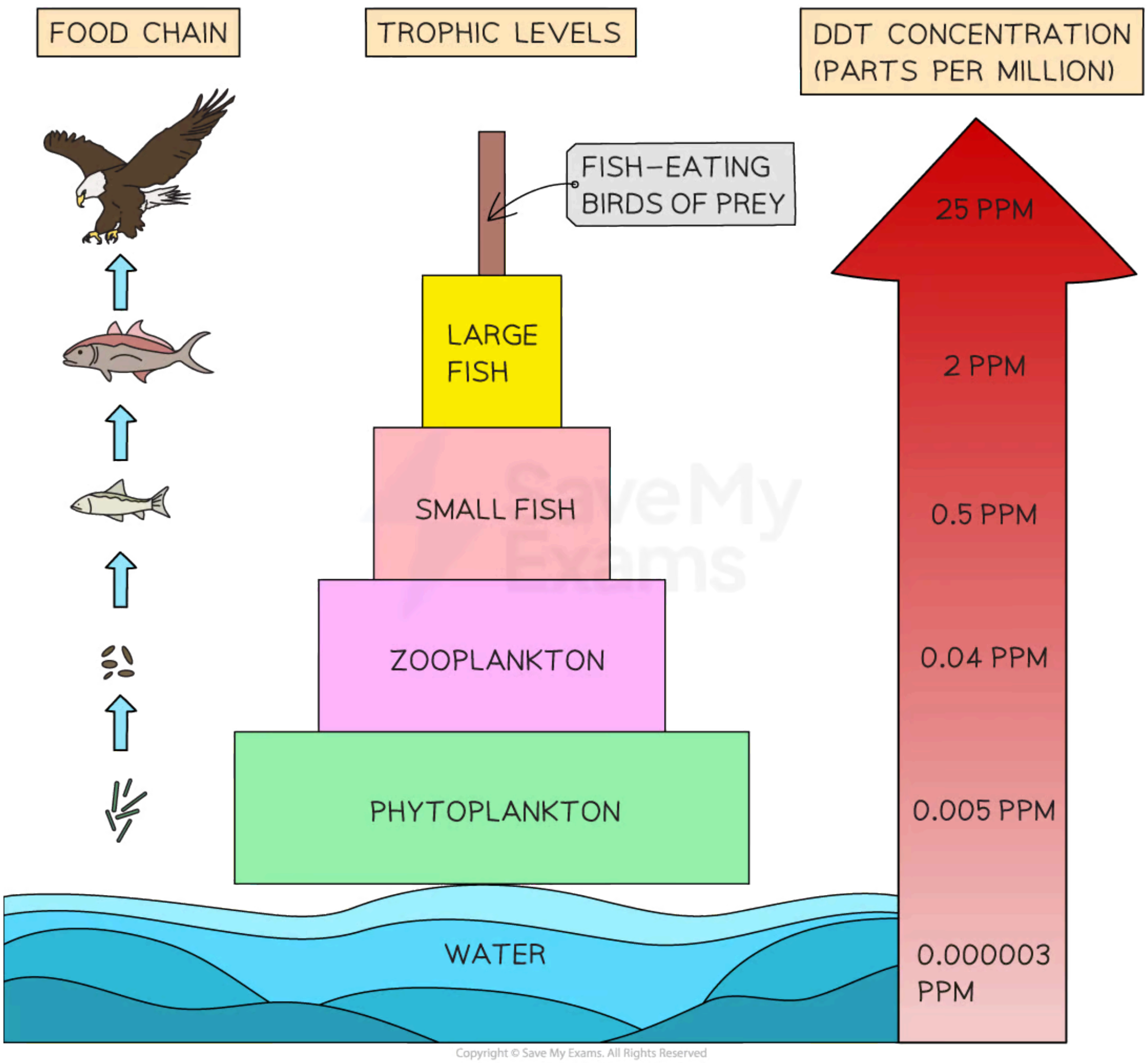
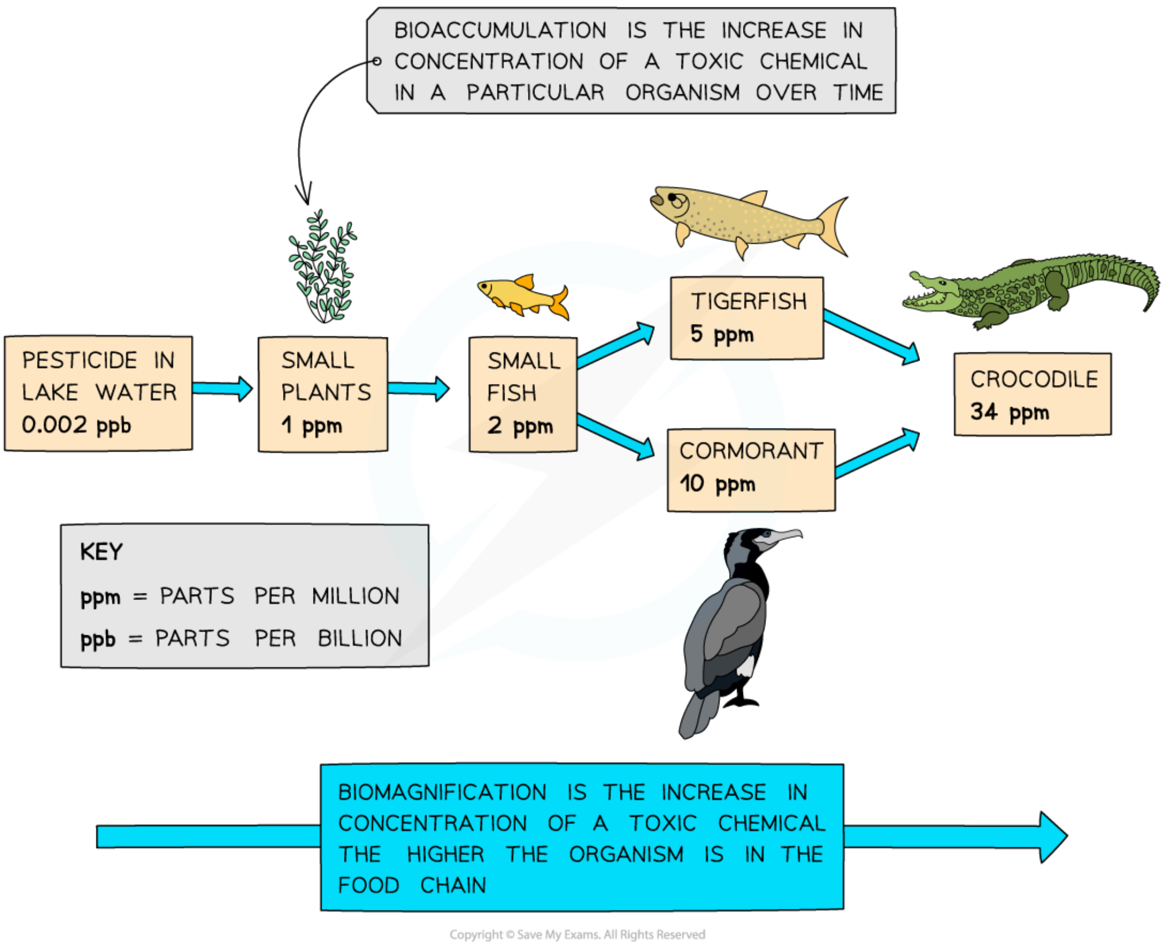


Through the process of biomagnification, the concentration of DDT in the tissues of organisms increases at successively higher trophic levels in a food chain

- **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**, which can accumulate 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