CAIE Biology IGCSE

19: Organisms and Their Environment

Notes

(Content in **bold** is for Extended students only)

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Energy Flow

Energy is introduced into biological systems as light energy which is absorbed by plants, where the Sun is the principal source of energy. This energy is then transferred to chemical energy and can pass to other organisms through feeding**.** When these animals die, they are broken down by decomposers which return their nutrients to the soil.

Food chains and Food webs

Key words:

- Producer - an organism which converts light energy to chemical energy through photosynthesis in order to produce its own organic nutrients.
- Consumer - an organism which gets energy from feeding on other animals or plants.
- Food chain - a diagram which shows the order of energy transfer through feeding in an ecosystem, beginning with a producer.
- Food web - a diagram showing how different food chains interact with each other.
- Trophic level **-** the trophic level of an organism refers to its position in the food chain, food web, pyramid of numbers or pyramid of biomass. Examples are producers, primary consumers, secondary consumers, tertiary consumers and quaternary consumers.
- Pyramid of numbers - shows the number of organisms in each trophic level of a food chain.
- Pyramid of biomass **-** shows the total mass of organisms in each trophic level of a food chain.
- Biomass - the total mass of living material.
- Herbivore - An animal that gets its energy by eating plants.
- Carnivore - An animal that gets its energy by eating other animals.
- Decomposer - An organism that get its energy from dead or waste organic material

A food chain shows the order of energy transfer between organisms. Food chains start with producers, which are plants which convert light energy from the Sun to chemical energy. Organisms which feed on plants, or other animals, are known as consumers. Plants are eaten by herbivores, which gain nutrients from the plants for growth. This consumer is then eaten by another animal which gains nutrients from it. Each of these organisms has its own trophic level. Consumers are classed as primary, secondary, tertiary or quaternary, depending on their position in the food chain.

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How to construct a food chain:

1. Identify the **producers** first - this is usually a plant. This should be on the left of your diagram.
2. Add the **primary consumer** next (the organisms which eat the **producers**).
3. Add the **secondary consumer** (organisms which eat the **primary consumer**) and then the **tertiary consumers**.

Grass (Producer) → **Grasshopper** (Primary consumer) → **Frog** (Secondary consumer) → **Owl** (Tertiary consumer)

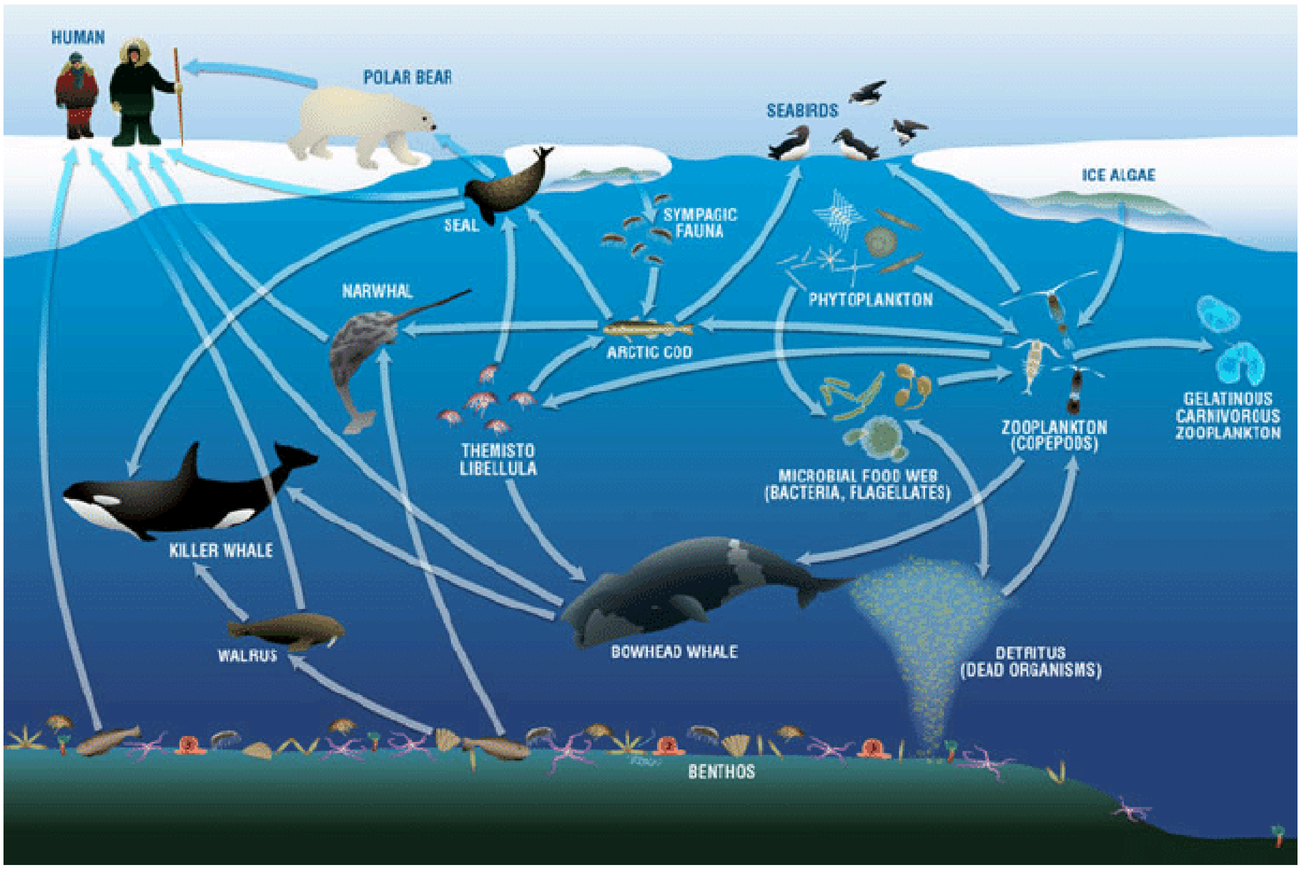
Energy is passed between trophic levels, although this process is highly inefficient due to a variety of reasons:

- **Not all animal and plant material can be digested to gain energy, e.g. fur and bones.**
- **Energy is lost through excretion and decay.**
- **Energy is used in other processes, e.g. movement and keeping warm.**

This means that organisms later on in the food chain gain less energy from their food than organisms earlier on, as energy is lost at each level. Consequently, organisms later in the food chain must eat a larger amount to gain enough energy for survival. For this reason, there are usually not more than five trophic levels as too much energy would be lost to sustain another. This is also why it is more efficient for humans to eat plants rather than animals, as there are more stages in the food chain if animals are present.

Food webs:

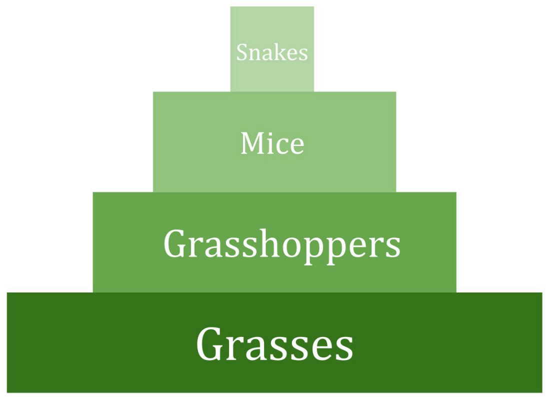
Food webs are used to illustrate how different food chains interact with each other. The diagram below is an example of an Arctic marine food web.



From the food web, we can see that ice algae is the producer and zooplankton is the primary consumer. We can also count how many secondary or tertiary consumers are in the food web. There can also be more than one producer in a food web.

Pyramids of numbers:

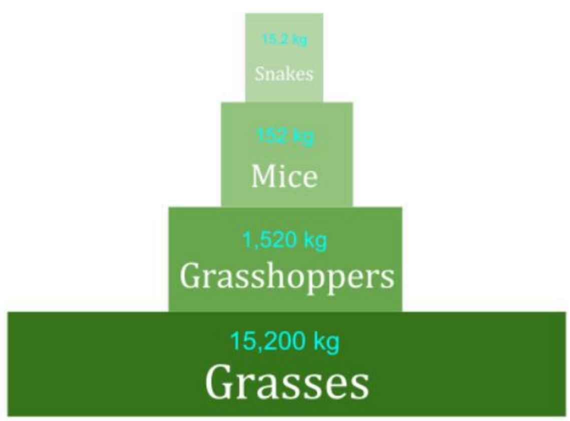
A **pyramid of numbers** can be used to show the number of organisms in each trophic level.



The number of organisms decline as you go up the pyramid due to the **energy loss** between each **trophic level**. This means there is less energy available for organisms at higher trophic levels at the top of the pyramid. However, a pyramid of numbers does not take size and mass of organisms into account.

Pyramid of biomass:

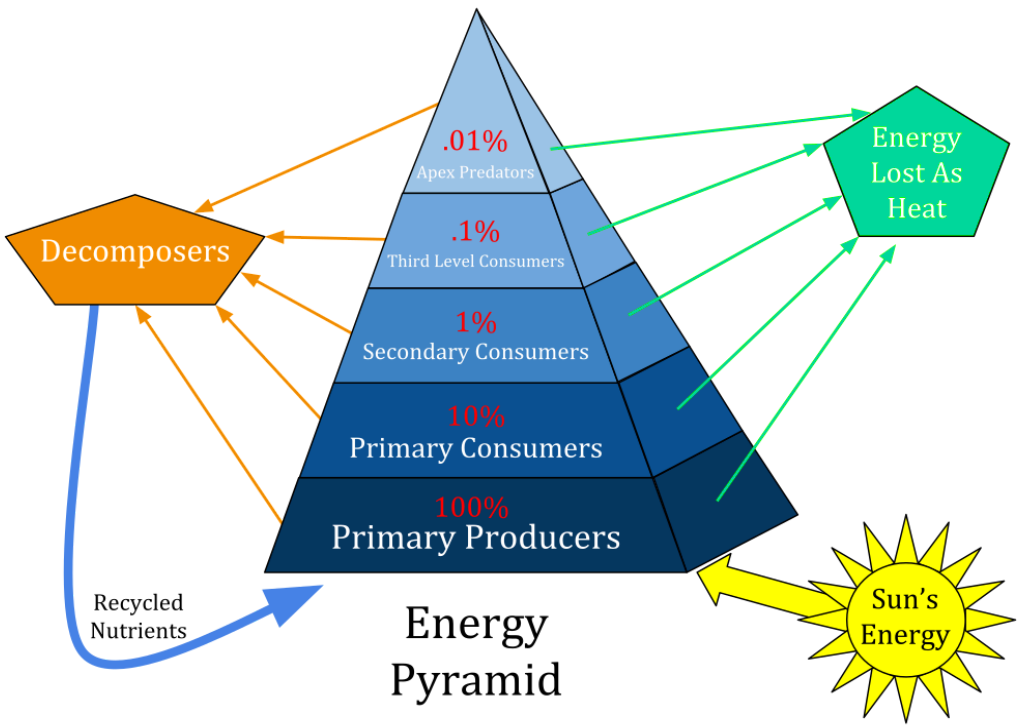
A **pyramid of biomass** measures the total biomass of all the organisms at each level.



The wider the bar for each trophic level, the greater the **biomass**. The **producers** usually have the greatest biomass. The width of the bar reduces at each **trophic level** which shows there is a decrease in the mass of organisms.

A pyramid of biomass tends to have a true pyramid shape as biomass is lost in each level which corresponds to the energy lost. A pyramid of biomass therefore is more useful as it gives an indication of the amount of energy being passed on at each stage of the food chain.

Pyramids of energy:



Pyramids of energy show the amount of energy within the biomass of organisms at each trophic level. There is a decrease in energy as it moves up the trophic levels. In most energy pyramids, the producers have the highest amount of energy. This energy is captured by the sun during photosynthesis. There is significantly less energy available for the primary consumers and even less energy for the secondary consumers. This is due to energy losses via respiration of the animals and heat.

Pyramids of energy provide the most accurate representation of energy flow in ecosystems compared to pyramids of numbers and biomass. They are the most effective in illustrating the efficiency of energy transfer.

<u>Human impact on food chains:</u>

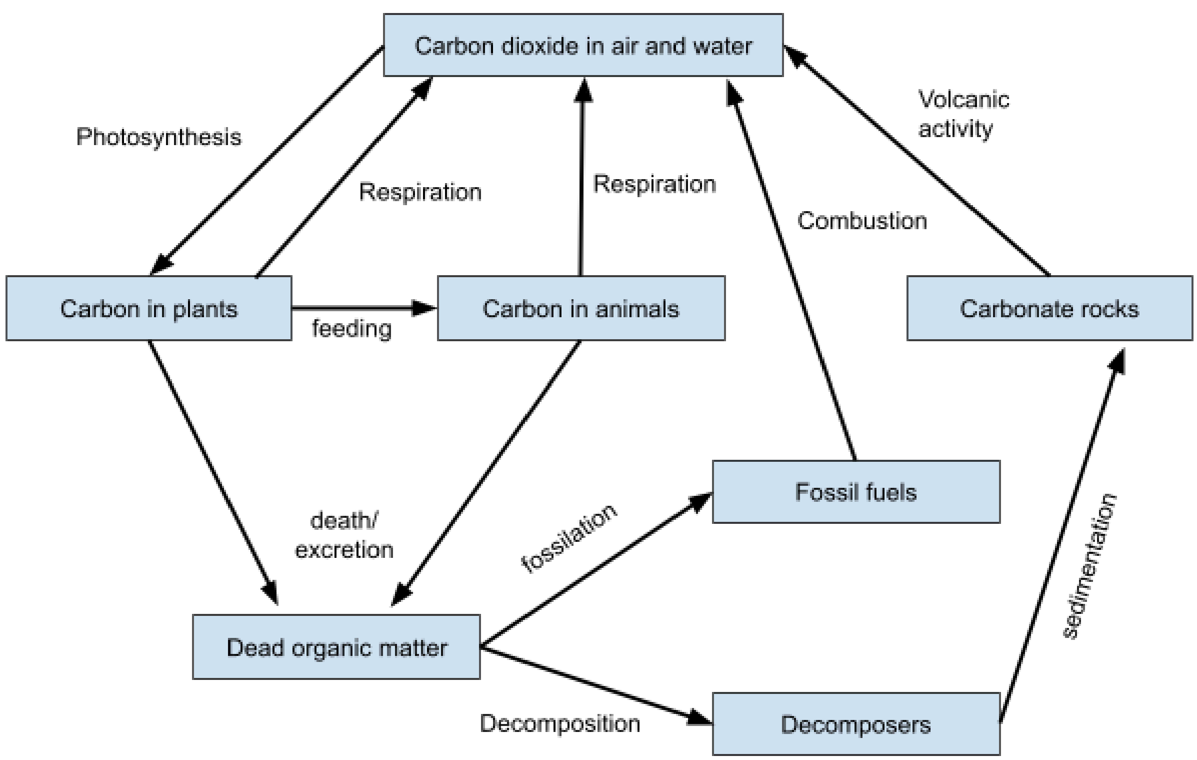
Humans alter food webs through **over-harvesting food** species and **introducing foreign species** to habitats. Over-harvesting will damage food chains as other organisms which consume these organisms will **not have enough food to survive**, meaning that many of them will die. Introducing foreign species may have the same effect as there is now **competition for resources**, which could damage existing species by interfering with the food chain.

An example of this is **cane toads**, which were introduced to Australia to eat pests. Due to their toxic skin, they have **destroyed many native species** and **damaged habitats**, especially water habitats, where the **biodiversity has been reduced**. This has had a negative effect on the bird population which preyed on animals living in these areas. This shows that when one trophic level is damaged, all that follow are also impacted as the amount of food for them decreases.

Nutrient cycles

The carbon cycle:

Carbon is an essential **element** which makes up the majority of molecules in living organisms. The carbon cycle is used to show how carbon atoms move between the **atmosphere and living organisms**:



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1. Carbon is present in the atmosphere in the form of carbon dioxide, which makes up about 0.04% of the air.
2. Carbon dioxide is taken in by plants during photosynthesis. Here, the carbon is transferred from carbon dioxide to other molecules such as proteins and carbohydrates.
3. These molecules are passed through the food chain when feeding occurs, hence carbon is also passed between the trophic levels.
4. Carbon is returned to the atmosphere during respiration, which releases carbon dioxide, and during decomposition.

Carbon can be trapped in dead organisms when decomposition does not occur. These organisms become fossilised over thousands of years to form fossil fuel. When this fossil fuel is burned, large amounts of carbon dioxide is released back into the atmosphere. This, along with the effect of deforestation, leads to the amount of carbon dioxide in the atmosphere increasing, which causes global warming.

The nitrogen cycle:

Nitrogen is another element which is key to biological lifeforms. Nitrogen is used to make amino acids, DNA and ATP, which is a molecule that releases energy. Microorganisms are key to the nitrogen cycle as they help to convert nitrogen to different forms so that it can be used.

1. **Decomposers, such as bacteria and fungi, break down protein in dead organisms and their waste, producing ammonium ions.**
2. **Nitrifying bacteria converts ammonium ions into nitrites, and then nitrates.**
3. **Nitrogen gas is present in the air. This nitrogen is fixed (converted to usable nitrate ions) by nitrogen-fixing bacteria which live on the root nodules of some plants, or by lightning.**
4. **Plants absorb these nitrate ions and use them to make other molecules, such as amino acids and proteins.**
5. **These molecules are passed through the food chain via feeding.**
6. **Nitrogen is returned to the soil in the form of ammonia when decomposition occurs, or in the form of urea, which is excreted from organisms after deamination occurs. If this decomposition occurs in anaerobic conditions (without oxygen) then denitrifying bacteria can break down nitrates and return nitrogen gas to the atmosphere.**

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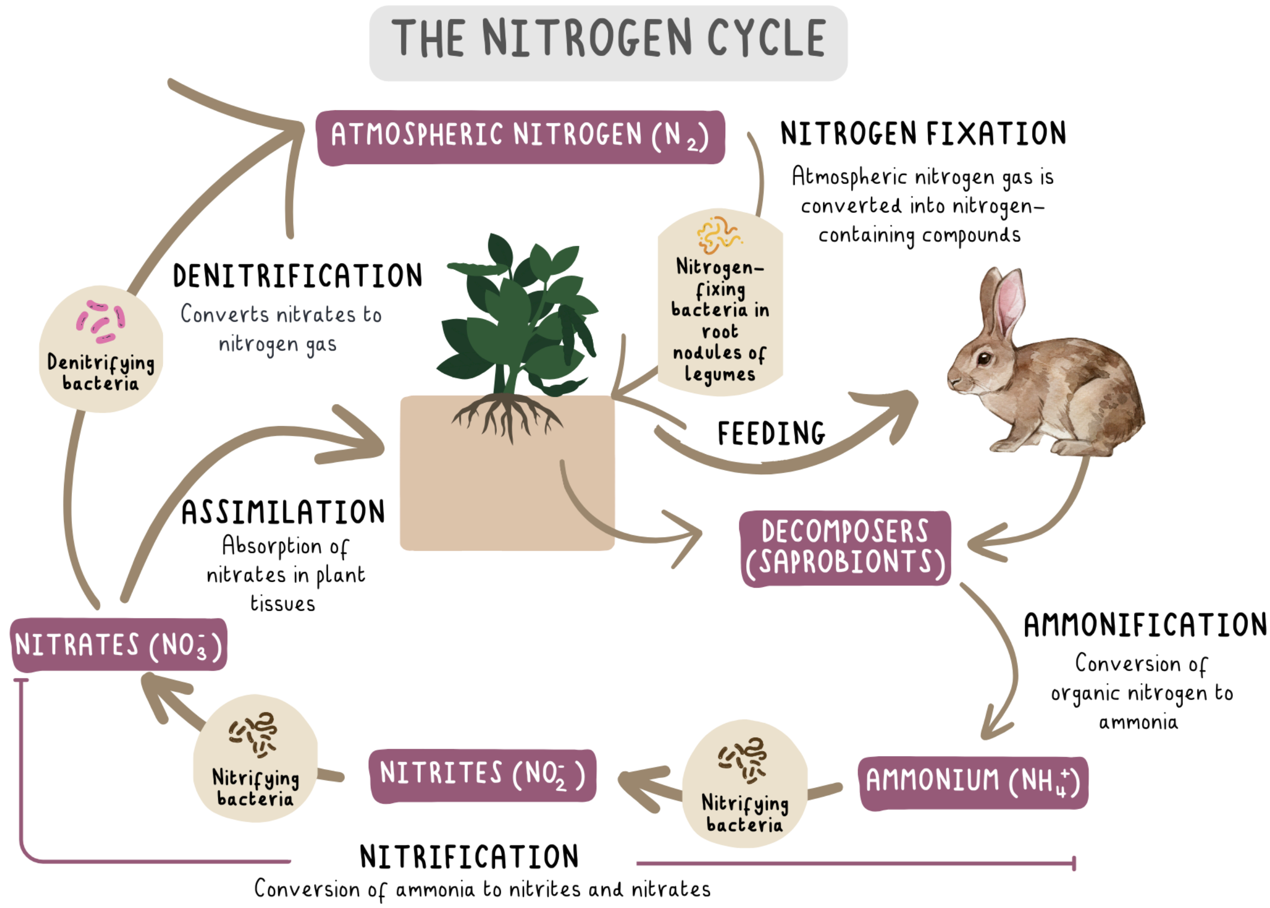
THE NITROGEN CYCLE
ATMOSPHERIC NITROGEN (N_2)
NITROGEN FIXATION
Atmospheric nitrogen gas is converted into nitrogen-containing compounds
Nitrogen-fixing bacteria in root nodules of legumes
DENITRIFICATION
Converts nitrates to nitrogen gas
Denitrifying bacteria
FEEDING
ASSIMILATION
Absorption of nitrates in plant tissues
DECOMPOSERS (SAPROBIONTS)
AMMONIFICATION
Conversion of organic nitrogen to ammonia
NITRATES (NO_3^-)
Nitrifying bacteria
NITRITES (NO_2^-)
Nitrifying bacteria
AMMONIUM (NH_4^+)
NITRIFICATION
Conversion of ammonia to nitrites and nitrates

Populations

Key words:

- **Population** - A group of organisms of the same species living in the same area, at the same time.
- **Community** - All of the populations of different species in an ecosystem.
- **Ecosystem** - A system in a specific area which contains the community of organisms and their environment, interacting together.

Factors affecting rate of population growth:

- **Food supply** - if there is a large amount of food, organisms can breed more successfully. If there is a food shortage, there is a higher death rate which results in a slow or negative population growth.
- **Predation** - organisms which have lots of predators will have a slower rate of population growth as more will be killed by predators.
- **Disease** - disease can reduce the population by killing organisms. In densely populated areas, disease can spread quickly, thus a large proportion of the population may be wiped out.

Human population growth:

Over the last 250 years, the human population has risen from just over **1 billion to 7.6 billion**. There are many **social and economic implications** of this. Due to the massive demand for resources and space, **deforestation** occurs, and a high amount of **fossil fuels** are burnt. This leads to **global warming** and also **damages habitats**. Rapid population growth also puts a **strain on services** such as healthcare and education, meaning that many people cannot access these services, which **lowers quality of life**.

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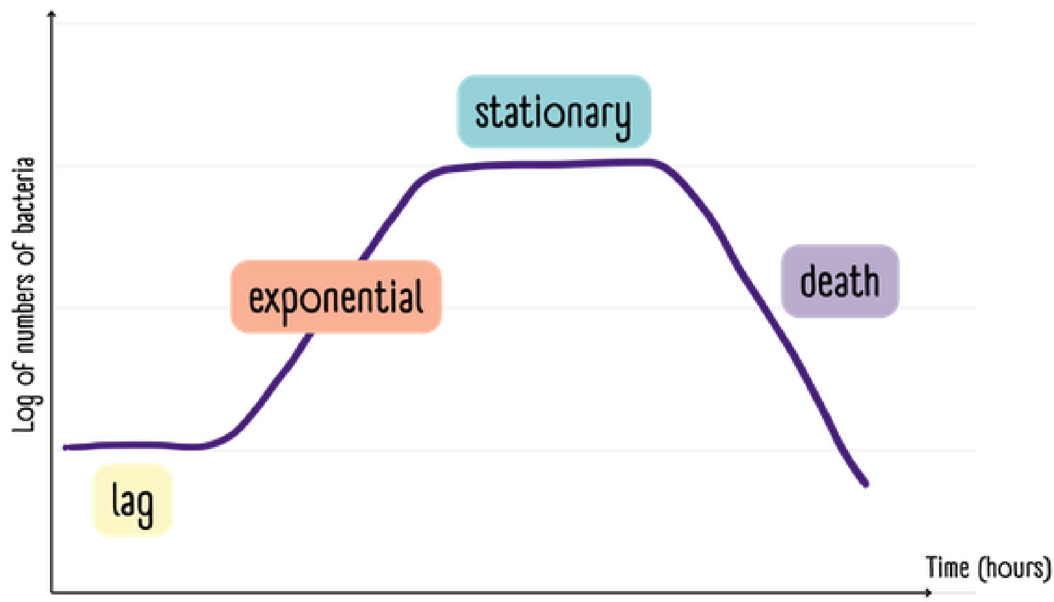
For a population growing in an environment with limited resources, we would usually see a **sigmoid curve** in its population growth. There are 4 main phases in a sigmoid curve of population growth which are the **lag phase**, **exponential phase**, **stationary phase** and **death phase.**



- **Lag phase** - Initially there is slow growth **as new populations are developing, or after populations recover from a decline. Organisms start adapting to their environment.**
- **Exponential growth phase** - the population growth increases rapidly in this phase**. Organisms grow under optimum conditions with plentiful resources. There are no limiting factors.**
- **Stationary phase** - The rate of population growth levels out and plateaus**: the birth rate and death rate become equal. The amount of resources becomes a limiting factor, causing the rate of reproduction to slow.**
- **Death Phase** - a decrease in population size**. The death rate becomes greater than the birth rate. This is due to overpopulation, increased competition and limited resources.**

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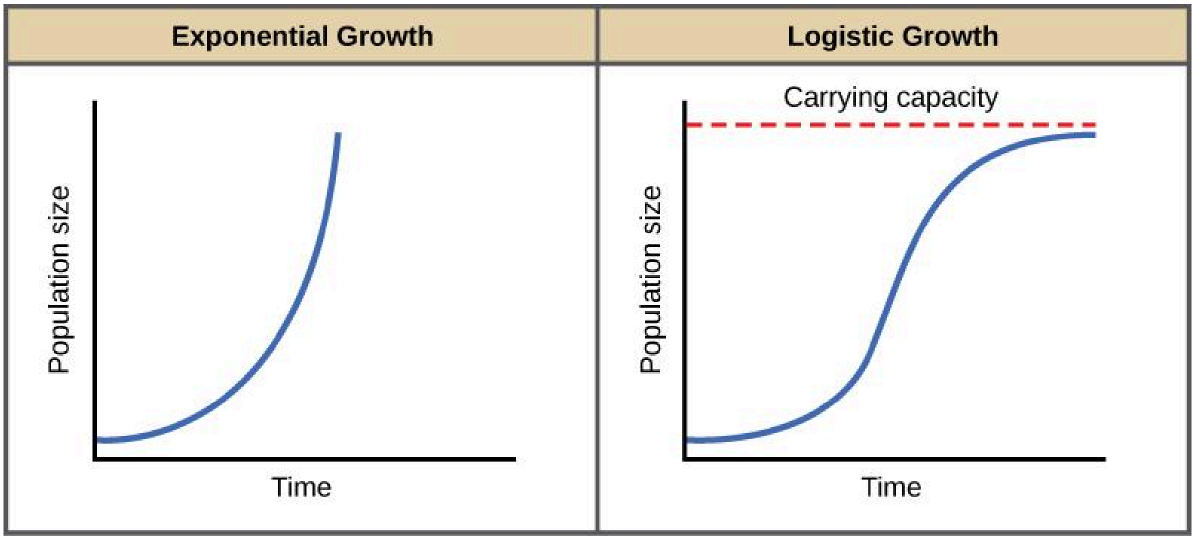
Interpreting Population Growth graphs:



The graph on the left shows exponential population growth without limitations to resources. The graph on the right shows that the population size plateaus at **carrying capacity**. **Carrying capacity** refers to the maximum population size that an environment can support. Any changes in the gradient of the curve are due to disease outbreaks, environmental changes or human interventions.