

OCR (B) Biology A-level

4.3 Photosynthesis, Food production and Populations

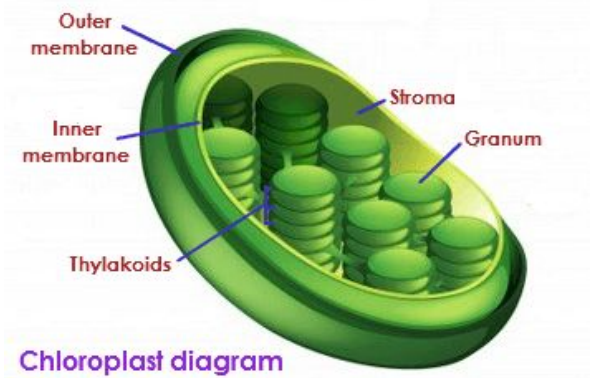
Notes



4.3.1 Photosynthesis, food production and management of the environment

Photosynthesis is a reaction in which **light energy** is converted to chemical energy in the form of glucose. **Oxygen** is a waste product of this reaction and is released into the atmosphere.

Photosynthesis occurs in the **chloroplasts**, which are adapted for photosynthesis in the following ways:



[Image source: factfile.org](https://www.factfile.org)

- They contain **stacks of thylakoid membranes called grana** which contain the photosynthetic pigments such as **chlorophyll**. These are arranged as **photosystems**.
- They contain **stroma** which is the fluid surrounding the grana, stroma contains all the **enzymes** required for the light independent stage of photosynthesis

The rate of photosynthesis is determined by **limiting factors**, such as carbon dioxide concentration, light intensity, light wavelength and temperature. **The rate of photosynthesis increases as these factors increase**, however at high light intensities and temperatures, the leaves can be damaged and enzymes denature, thus the rate is slowed. These factors can be controlled when growing crops to **maximise efficiency and yield**. This can be done by growing crops in a greenhouse.

Leaves of **C4 plants** such as maize and sorghum are **adapted to work at high temperatures**. The enzymes involved in photosynthesis have a **higher optimum temperature**, so are not damaged by the high temperatures. In addition, they fix carbon dioxide into a four carbon organic acid called **malate** in mesophyll cells which surround the photosynthetic cells, before transporting it to the photosynthetic cells where it is broken down into carbon dioxide. This ensures that there is a **high concentration of carbon dioxide** so rubisco fixes carbon dioxide and not oxygen*. This removes carbon dioxide as the limiting factor.

*At temperatures above 25°C (before denaturing), rubisco fixes oxygen and not carbon dioxide. This is a wasteful process.

Photosynthetic pigments



Photosynthetic pigments are involved in absorbing light required for photosynthesis and subsequently convert it to chemical energy. The colour of pigments is determined by the light they reflect.

Chlorophylls absorb red as well as blue-violet light, they only reflect green light, thus giving chlorophyll green colour. The two forms of chlorophyll are **chlorophyll a** with the highest abundance which absorbs light at 430nm and 663nm, and **chlorophyll b**, which absorbs at 453nm and 642nm.

Apart from chlorophyll, **carotenoids** are also involved in photosynthesis and serve to prevent damage of chlorophyll. Carotenoids are present in two forms, **beta carotene** which is orange in colour and **xanthophyll** which is yellow in colour.

An **absorption spectrum** can be used to determine the wavelengths absorbed by particular pigments by illustrating the percentage of light absorbed at a particular wavelength. Whereas an **action spectrum** illustrates the relationship between the rate of photosynthesis for a given wavelength.

Photosynthesis

There are two stages of photosynthesis:

- **Light-dependent reaction**
 1. Light energy **excites electrons** in the chlorophyll molecule in the thylakoid membrane, causing them to pass to an **electron acceptor** at the start of the **electron transport chain**. This is called **photo-ionisation**.
 2. Electrons pass down the chain from one electron carrier to the next in a **series of redox reactions**. This process generates **ATP from ADP and inorganic phosphate** in a process called **photophosphorylation**.
 3. Light splits water into protons (H⁺ ions), electrons and oxygen (waste). The electrons are used to replace the electrons lost from the chlorophyll in step 1. This process is called **photolysis of water**. The protons are pumped across the membrane using the ATP created in step 2 in a process called **chemiosmosis**. This creates a **chemical potential gradient**.
 4. **Reduced NADP** is generated as the electrons in the electron transport chain are transferred to NADP along with a proton.
 5. Protons pass back through the membrane through an **ATP synthase** enzyme which makes ATP. Approximately 4 protons make one ATP molecule. Both ATP and reduced NADP are used in the light-independent stage of photosynthesis.
- **Light-independent reaction**, also known as the **Calvin cycle**, is the final stage of photosynthesis which uses ATP and reduced NADP from the light dependent stage to produce glucose.



Light independent reaction occurs as follows:

- 1) **RuBP** is combined with **carbon dioxide** in a reaction called **carbon fixation**, catalysed by the enzyme **RUBISCO**.
- 2) **RuBP** is converted into **two glycerate 3-phosphate (GP)** molecules
- 3) Reduced NADP and ATP are used to **reduce each GP molecule to triose phosphate**. In this process, the reduced NADP becomes oxidised.
- 4) Some of triose phosphate molecules are used to make **glucose** (every 6 cycles) which is then converted to essential organic compounds such as **polysaccharides, lipids, amino acids and nucleic acids**.
- 5) Remaining triose phosphate molecules are used to **regenerate RuBP with the help of ATP**.

4.3.2 The impact of population increase

Population is dependent on the birth rate and death rate.

Birth rate: number of births per 1000 individuals

Death rate: number of deaths per 1000 individuals

Population growth rate = Birth rate – Death rate

Demographic Transition Model:

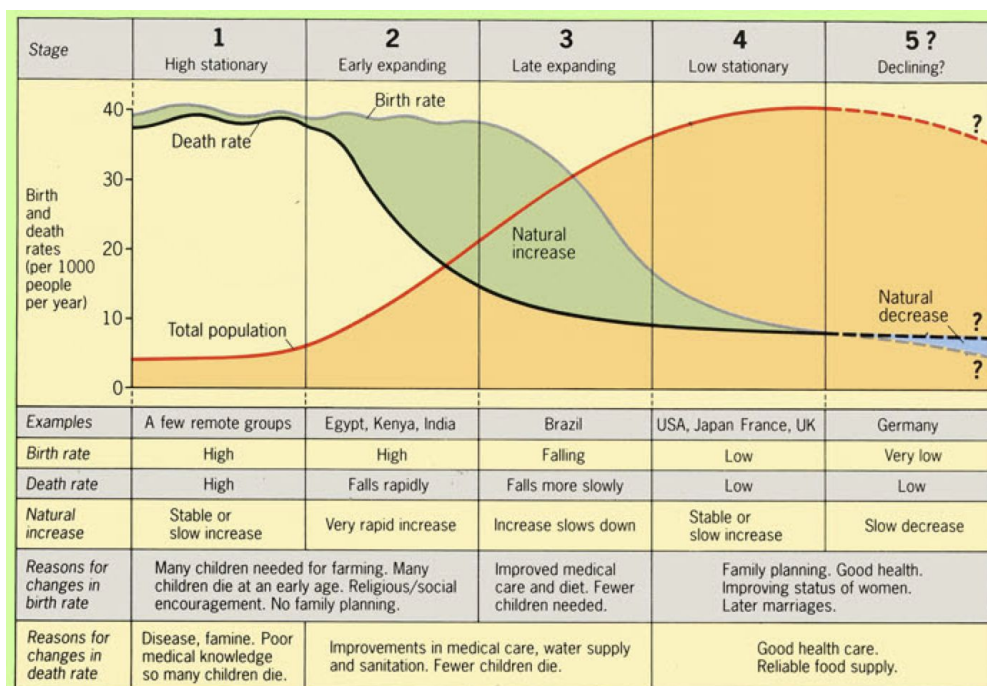


Image source: francedemographics.weebly.com



Competition

Interspecific: between members of **different** species for the same resources.

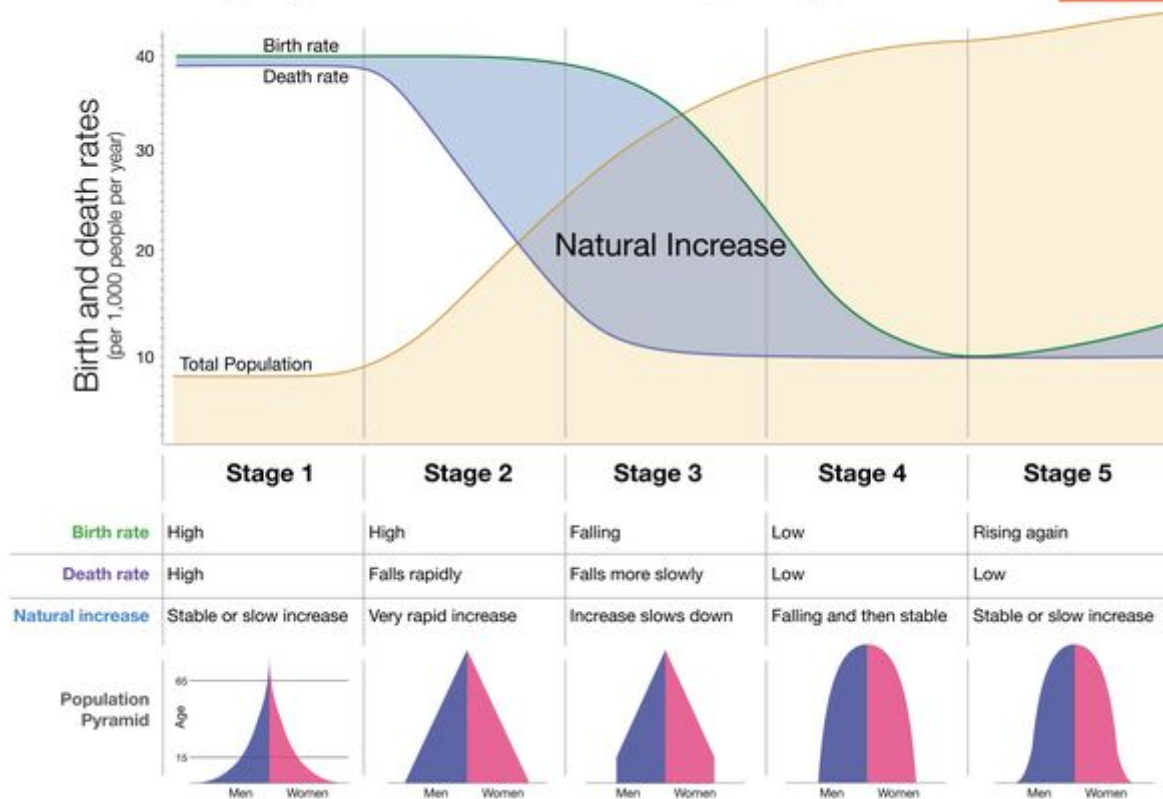
- New species in a habitat

Intraspecific: between members of the same species for the same resources.

Population pyramids

The demographic transition in 5 stages

Our World
in Data



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Image source: ourworldindata.org

The accelerating growth of human populations has had multiple impacts on ecosystems and biodiversity, both through **abiotic factors** and **biotic factors**.



Abiotic and biotic factors

Abiotic (non-living)	Biotic (living)
<p style="text-align: center;">Light intensity</p> <p>Light is required for photosynthesis and the rate of photosynthesis affects the rate at which the plant grows. Also, plants can be food sources or shelter for many organisms.</p>	<p style="text-align: center;">Food availability</p> <p>More food means organisms can breed more successfully and therefore the population can increase in numbers</p>
<p style="text-align: center;">Temperature</p> <p>Temperature affects the rate of photosynthesis.</p>	<p style="text-align: center;">New predators</p>
<p style="text-align: center;">Moisture levels</p> <p>Both plants and animals need water to survive</p>	<p style="text-align: center;">New pathogens</p> <p>When a new pathogen arises the population has no resistance to it so they can be wiped out quickly</p>
<p style="text-align: center;">Soil pH and mineral content</p> <p>Soil pH affects the rate of decay and therefore how fast mineral ions return to soil (which are then taken up by other plants). Different species of plants thrive in different nutrient concentration levels</p>	<p style="text-align: center;">Competition</p> <p>If one species is better adapted to the environment than another, then it will outcompete it until the numbers of the lesser adapted species are insufficient to breed</p>

