

These notes explain the **why** behind every concept, not just the what. They include **analogies**, **real-life examples**, and explanations of **common mistakes**. Use these alongside your revision notes for full understanding.

4.4.1 Photosynthesis — How Plants Make Food From Light

Photosynthesis is one of the most important chemical reactions on Earth. Without it, there would be no food, no oxygen in the atmosphere, and no fossil fuels. Plants, algae and some bacteria use light energy to convert simple molecules — carbon dioxide and water — into glucose and oxygen.

Where and How Does Photosynthesis Happen?

Photosynthesis occurs in the chloroplasts, found mainly in the palisade cells of leaves. Chloroplasts contain chlorophyll — a green pigment that absorbs red and blue light but reflects green light (which is why plants look green). This absorbed light energy powers the chemical reactions that combine CO₂ and water to make glucose.

Word equation: carbon dioxide + water → glucose + oxygen (light energy required)

Symbol equation: $6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$

■ **Why does this happen?** Plants produce oxygen as a waste product of photosynthesis — not because they need it (they make it faster than they use it during the day). This oxygen was produced over billions of years by photosynthetic organisms, creating the oxygen-rich atmosphere that allowed animal life to evolve.

Limiting Factors — What Slows Photosynthesis Down?

In a reaction involving multiple inputs, the rate is limited by whichever input is in shortest supply. For photosynthesis the three main limiting factors are light intensity, CO₂ concentration, and temperature. At any moment, only one factor is limiting the rate.

■ **Think of it like this:** *Think of making a cake. If you have plenty of flour, sugar and eggs but only one oven, the oven is the limiting factor. Adding more flour will not make you bake faster. Only increasing oven capacity (the limiting factor) will help.*

- **Light intensity:** More light = more energy for photosynthesis = faster rate. But above a certain light intensity, another factor (usually CO₂) becomes limiting.
- **CO₂ concentration:** More CO₂ = more raw material = faster rate. But above a certain CO₂ level, light or temperature becomes limiting.
- **Temperature:** Higher temperature increases enzyme reaction rates — up to the optimum (~25°C for most plants). Above this, photosynthesis enzymes begin to denature and rate drops sharply.

■ **Real-life example:** Commercial greenhouses use artificial lighting, CO₂ generators, and temperature control to maximise all three factors simultaneously, producing crops year-round at much higher yields than outdoor farming.

4.4.2 Respiration — Releasing Energy From Glucose

Every living cell — plant, animal, fungus or bacterium — needs a continuous supply of energy to stay alive. This energy comes from respiration: the controlled release of energy from glucose. Respiration is NOT the same as breathing — breathing gets oxygen in; respiration uses that oxygen to release energy.

✓ **Actually:**
Respiration
breathes per

"Respiration means breathing."

Aerobic Respiration — The Efficient Option

Aerobic respiration uses oxygen to completely break down glucose, releasing a large amount of energy as ATP (adenosine triphosphate — the cell's energy currency). It occurs in the mitochondria.

Word equation: glucose + oxygen → carbon dioxide + water (+energy as ATP)

■ **Why does this happen?** ATP is used rather than glucose directly because ATP releases exactly the right amount of energy for cellular processes. Using glucose directly would be like trying to power a USB device by connecting it directly to a power station — too much energy at once would cause damage.

Anaerobic Respiration — When Oxygen Runs Out

During intense exercise, muscles use oxygen faster than the blood can deliver it. Cells switch to anaerobic respiration — respiration without oxygen. This is much less efficient, producing only a tiny fraction of the ATP that aerobic respiration produces. In animals, the product is lactic acid.

In animals and some bacteria: glucose → lactic acid (+small amount of energy)

In yeast and plant cells: glucose → ethanol + carbon dioxide (+small amount of energy) [fermentation]

■ **Why does this happen?** Why does lactic acid cause muscle pain and fatigue? As lactic acid accumulates, it lowers the pH in muscle cells, interfering with enzyme function and causing the burning sensation you feel during intense exercise. After exercise, you breathe deeply to take in extra oxygen — this oxygen debt repays the anaerobic respiration by converting lactic acid back to glucose in the liver.

■ **Real-life example:** Yeast's anaerobic respiration is fermentation — used for thousands of years in bread-making (CO₂ makes dough rise) and brewing (ethanol is the alcohol in beer and wine). Beer is essentially yeast waste!

Photosynthesis	The process by which plants convert CO ₂ and water into glucose using light energy — occurs in chloroplasts
Chlorophyll	The green pigment in chloroplasts that absorbs light energy
Limiting factor	The factor in shortest supply that controls the rate of a reaction
Aerobic respiration	Releases energy from glucose using oxygen — occurs in mitochondria — produces CO ₂ and water
Anaerobic respiration	Releases energy from glucose WITHOUT oxygen — much less efficient — produces lactic acid (animals) or ethanol + CO ₂ (yeast)
ATP	The energy-carrying molecule produced by respiration and used to power all cellular processes
Oxygen debt	The extra oxygen needed after anaerobic exercise to break down accumulated lactic acid

Fermentation

Anaerobic respiration in yeast — produces ethanol and CO_2 — used in brewing and baking