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|------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|
| <p>Enzymes and metabolism</p> <p><b>Why do cells need enzymes?</b></p> | <p>Enzymes and metabolism</p> <p><b>Why do organisms need many different enzymes?</b></p>                         |
| <p>Enzymes and metabolism</p> <p><b>Anabolism vs catabolism</b></p>    | <p>Enzymes and metabolism</p> <p><b>Why is the whole enzyme structure needed for the active site to work?</b></p> |
| <p>Enzymes and metabolism</p> <p><b>Induced fit</b></p>                | <p>Enzymes and metabolism</p> <p><b>Why is molecular motion needed for catalysis?</b></p>                         |
| <p>Enzymes and metabolism</p> <p><b>Denaturation</b></p>               | <p>Enzymes and metabolism</p> <p><b>Why does rate rise with temperature below the optimum?</b></p>                |

Enzymes are specific, so each reaction in the network of metabolism needs its own enzyme; controlling enzymes controls metabolism.

Enzymes are catalysts that speed up reactions so they happen fast enough at body temperature, without being used up.

The active site is only a few amino acids, held in the right positions by interactions throughout the 3D structure.

Anabolism: building macromolecules by condensation (protein synthesis, glycogen, photosynthesis). Catabolism: hydrolysis in digestion, oxidation in respiration.

Substrate and active site must collide. Sometimes large substrates or membrane-embedded enzymes are immobilised, so only the other moves.

Both substrate and enzyme change shape when the substrate binds to the active site.

More kinetic energy, so more frequent substrate-active site collisions, and more with enough energy to react.

A change to the 3D structure of an enzyme (high temperature or extreme pH) so the active site no longer binds the substrate.

Enzymes and metabolism

**Why does rate level off at high substrate concentration?**

Enzymes and metabolism

**How do you find the initial rate from a curve?**

Enzymes and metabolism

**Activation energy**

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**Intracellular vs extracellular enzyme reactions: examples**

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**Why do metabolic reactions always release heat?**

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**Linear vs cyclical pathways: examples**

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**Non-competitive inhibition**

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**Competitive inhibition (example)**

Draw a tangent at time zero and calculate its gradient (change in product  $\div$  time).

All active sites are occupied; enzyme concentration becomes limiting.

Intracellular: glycolysis (cytoplasm), Krebs cycle (matrix). Extracellular: chemical digestion in the gut.

Energy needed to break bonds in the substrate to start a reaction. Enzymes lower it; the overall energy change is unchanged.

Linear: glycolysis. Cyclical (starting molecule regenerated): Krebs cycle (oxaloacetate) and Calvin cycle (RuBP).

They are not 100% efficient in energy transfer. Mammals and birds use this heat to keep a constant body temperature.

Inhibitor resembling the substrate binds reversibly to the active site; overcome by high substrate. Example: statins.

Inhibitor binds reversibly to an allosteric site, causing a conformational change that alters the active site; extra substrate does not help.

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**What do statins inhibit?**

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**Feedback inhibition (example)**

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**Mechanism-based inhibition  
(example)**

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**How are some bacteria resistant to  
penicillin?**

Cell respiration

**Structure of ATP**

Cell respiration

**Properties that suit ATP as energy  
currency**

Cell respiration

**Three uses of ATP in cells**

Cell respiration

**ATP ↔ ADP energy transfers**

End product inhibits an early enzyme at its allosteric site. Isoleucine inhibits threonine deaminase.

An enzyme in the liver (HMG-CoA reductase) in the pathway that synthesises cholesterol.

They have a changed transpeptidase whose active site penicillin cannot bind, but which still cross-links the cell wall.

Irreversible binding that chemically changes the active site. Penicillin inactivates bacterial transpeptidases.

Soluble, stable without enzymes, cannot cross membranes freely, releases a useful amount of energy, rapidly regenerated.

A nucleotide: adenine, ribose and three phosphate groups. Full name: adenosine triphosphate.

Hydrolysis of ATP to ADP + phosphate releases energy; making ATP from ADP + phosphate requires energy.

Active transport, synthesis of macromolecules (anabolism), movement of cells or chromosomes.

Cell respiration

## Cell respiration

Cell respiration

## Word equations for respiration in humans

Cell respiration

## Where do aerobic and anaerobic respiration happen?

Cell respiration

## How does a respirometer measure respiration rate?

Cell respiration

## Variables affecting respiration rate

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## Oxidation by dehydrogenation

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## Four stages of glycolysis and its net yield

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## Why do human cells make lactate?

Aerobic: glucose + oxygen → carbon dioxide + water. Anaerobic: glucose → lactate.

A system for producing ATP within the cell using energy released from carbon compounds, mainly glucose and fatty acids.

Alkali absorbs CO<sub>2</sub>, so oxygen uptake moves a liquid drop; distance × tube area ÷ time ÷ mass gives rate.

Anaerobic: cytoplasm only. Aerobic: starts in the cytoplasm, then mitochondria (which are required).

Removal of hydrogen (with its electron) from a substrate; the substrate is oxidised and NAD is reduced.

Temperature, oxygen concentration, substrate availability, type and activity of organism.

Pyruvate accepts hydrogen from reduced NAD, regenerating NAD so glycolysis continues (net 2 ATP per glucose).

Phosphorylation, lysis, oxidation, ATP formation. Net per glucose: 2 ATP, 2 reduced NAD, 2 pyruvate.

Cell respiration **HL only**

**Anaerobic respiration in yeast:  
products and uses**

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**The link reaction**

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**Krebs cycle summary**

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**Where does reduced NAD for the  
electron transport chain come from?**

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**How is the proton gradient generated  
in mitochondria?**

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**Chemiosmosis**

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**Oxygen as terminal electron acceptor**

Cell respiration **HL only**

**Why do lipids yield more energy per  
gram than carbohydrates?**

Pyruvate is oxidised and decarboxylated in the matrix; the 2C acetyl group is carried by coenzyme A to the Krebs cycle.

Ethanol and carbon dioxide. Brewing uses ethanol; baking uses CO<sub>2</sub> to make dough rise.

Glycolysis, the link reaction and the Krebs cycle.

Acetyl (2C) + oxaloacetate (4C) → citrate (6C); two decarboxylations, four oxidations, regenerate oxaloacetate; yields CO<sub>2</sub>, reduced NAD, ATP.

Protons diffuse down their gradient through ATP synthase, which couples the energy released to phosphorylation of ADP.

Energy from electrons flowing along the chain pumps protons from the matrix into the intermembrane space.

Less oxygen and more oxidisable hydrogen and carbon. Fatty acids enter as acetyl CoA, not via glycolysis.

Accepts electrons from the chain and protons from the matrix, forming metabolic water, so electron flow continues.

Photosynthesis

**What energy transformation happens in photosynthesis?**

Photosynthesis

**Word equation for photosynthesis**

Photosynthesis

**Where does the hydrogen in glucose come from?**

Photosynthesis

**Oxygen in photosynthesis**

Photosynthesis

**Rf value**

Photosynthesis

**Colours of photosynthetic pigments on a chromatogram**

Photosynthesis

**What happens when a pigment absorbs light?**

Photosynthesis

**Absorption spectrum vs action spectrum**

carbon dioxide + water → glucose + oxygen

Light energy is transformed to chemical energy in carbon compounds, supplying most energy for ecosystems.

A by-product from the splitting of water, released by plants, algae and cyanobacteria.

From splitting water molecules, using light energy.

Carotene orange-yellow, xanthophyll yellow, chlorophyll a blue-green, chlorophyll b yellow-green.

Distance moved by pigment ÷ distance moved by solvent front. No units; between 0 and 1.

Absorption: % light absorbed at each wavelength. Action: rate of photosynthesis at each wavelength. Both peak in blue and red.

An electron in the pigment molecule is excited to a higher energy level; only wavelengths matching the energy gap are absorbed.

Photosynthesis

**How can light intensity, CO<sub>2</sub> and temperature be varied?**

Photosynthesis

**Limiting factor**

Photosynthesis

**FACE vs greenhouse CO<sub>2</sub> enrichment**

Photosynthesis **HL only**

**Photosystem**

Photosynthesis **HL only**

**Advantages of a pigment array in a photosystem**

Photosynthesis **HL only**

**Photolysis of water**

Photosynthesis **HL only**

**Cyclic vs non-cyclic photophosphorylation**

Photosynthesis **HL only**

**How is NADP reduced?**

The factor furthest from its optimum, which limits the rate of photosynthesis.

Light: lamp distance or filters. CO<sub>2</sub>: sodium hydrogencarbonate concentrations.  
Temperature: water baths.

Molecular array of chlorophyll and accessory pigments in a membrane, with a special chlorophyll reaction centre that emits excited electrons.

FACE: CO<sub>2</sub> released over field plots, realistic but less controlled. Greenhouse: enclosed, controlled but less natural.

In photosystem II:  $2\text{H}_2\text{O} \rightarrow 4\text{H}^+ + 4\text{e}^- + \text{O}_2$ .  
Electrons and protons are used; oxygen is waste.

Wider range of wavelengths absorbed, more light captured, energy funnelled to one reaction centre beside an electron acceptor.

It accepts two electrons from photosystem I and a hydrogen ion from the stroma.

Non-cyclic: electrons from PSII; ATP, reduced NADP, O<sub>2</sub>. Cyclic: electrons from PSI return to carriers; ATP only.

Photosynthesis **HL only**

**Where in a thylakoid do photolysis, ATP synthesis and NADP reduction happen?**

Photosynthesis **HL only**

**Carbon fixation by Rubisco**

Photosynthesis **HL only**

**Synthesis of triose phosphate**

Photosynthesis **HL only**

**Regeneration of RuBP**

Photosynthesis **HL only**

**How are amino acids made in plants?**

Photosynthesis **HL only**

**Why does lack of CO<sub>2</sub> stop photosystem II?**

$\text{RuBP} + \text{CO}_2 \rightarrow 2 \text{ glycerate 3-phosphate.}$   
Rubisco is slow and ineffective at low  $\text{CO}_2$ ,  
so it is very abundant.

Photolysis: lumen side of PSII. ATP: ATP  
synthase, released to stroma. NADP  
reduced: stroma side of PSI.

Five triose phosphate  $\rightarrow$  three RuBP, using  
ATP. Five-sixths of TP is recycled if glucose  
is the product.

Glycerate 3-phosphate (GP) is converted to  
triose phosphate (TP) using reduced NADP  
and ATP.

No carbon fixation, so NADP is not  
regenerated; carriers stay reduced and PSII  
cannot pass electrons on.

From Calvin cycle intermediates plus  
mineral nutrients: nitrogen (nitrate or  
ammonium), and sulfur for some.