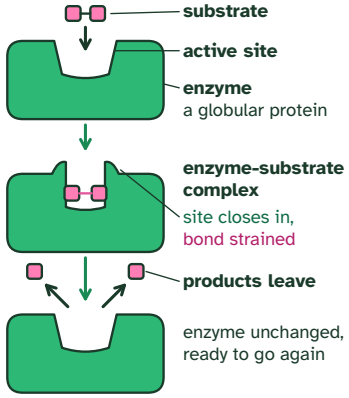
How *enzymes* work

What to know, what to draw and what to say. Nothing else.

THE ONE IDEA

An enzyme works because of its shape. Change the active site and you change, slow or stop the reaction.



Draw it like this. The site changes shape as the substrate binds; the enzyme comes out unchanged.

C1.1.4, C1.1.5 START HERE

The *active site* and induced fit

- Enzymes are **globular proteins**: chains folded into a compact, roughly round shape that dissolves in water.
- The **active site** is the small region where the substrate binds. It is made of **only a few amino acids**.
- Interactions between amino acids **all through the folded chain** hold the site in shape and give it the right charges for catalysis.
- **Induced fit**: as the substrate binds, **both substrate and enzyme change shape**. The site closes in and strains the substrate's bonds.

WHAT HAPPENS AT THE ACTIVE SITE

Bind, Bend, Break, Bye

B Bind	substrate enters the active site
B Bend	both change shape, bonds strained
B Break	bonds break and form: products
B Bye	products leave, enzyme free

C1.1.1

Enzymes as *catalysts*

- A catalyst **speeds up a reaction without being used up**, so one enzyme works again and again.
- Many cell reactions are possible but **far too slow** at body temperature. Heating would denature the cell's proteins.
- **Speed matters** for digestion, growth and fast responses.

5 million years for half the bonds in starch to break in water alone

1 ms about, for each bond, with amylase

C1.1.2, C1.1.3

Metabolism: build and break

- **Metabolism**: the web of linked reactions in an organism. The product of one is the substrate of the next.
- Enzymes are **specific**, so a cell needs **many different enzymes**, and it controls metabolism through them.

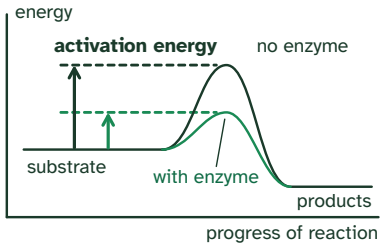
Anabolic *Add*: builds, takes in energy
Condensation of monomers: **protein synthesis**, **glycogen formation**. Also **photosynthesis**.

Catabolic *Cut*: breaks, releases energy
Hydrolysis of macromolecules in digestion; **oxidation** of substrates in respiration.

C1.1.10

A lower *activation energy*

- **Breaking bonds** in the substrate **takes in energy**; **making bonds** in the products **releases energy**.
- An enzyme **lowers the activation energy**, so many more molecules react at 37 °C. The energy released overall does not change.

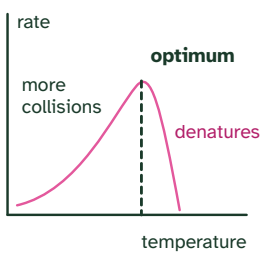


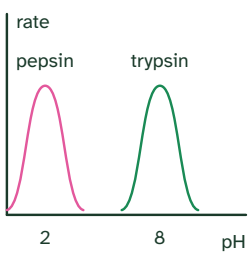
C1.1.6, C1.1.8

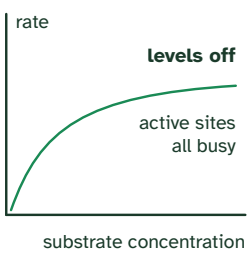
Collisions, and the *three graphs*

- Random **molecular motion** brings substrate and active site together. They react only after a **collision**, the right way round.
- **One partner can be still:** an enzyme **embedded in a membrane**, or a **large substrate held still**.
- **Temperature: more collisions** up to the optimum, then **denaturation**: a steep fall.
- **pH:** each enzyme has **its own optimum**. **Substrate:** the rate **levels off**.

NATURE OF SCIENCE
Sketch graphs are models
They show the general pattern, and are tested against results from enzyme experiments.







T Tigers	**P** Prefer	**S** Steak
Temperature: collisions, then denaturation	pH: charges in the active site	Substrate: collisions, then saturation

Measuring enzymes, and how cells *control* them

C1.1.7

A good fit, or *denatured*

- The site's shape and charges fit its substrate: **enzyme-substrate specificity**. **Weak interactions** hold that shape.
- Heat or extreme pH break them, so the **active site changes shape** and stops working: **denaturation**.

C1.1.9

Measuring a rate

- Rate: a **change per unit time** (catalase: O_2 in a gas syringe), from experiments or **secondary data**.
- **Initial rate:** the **gradient of a tangent** at time zero. **End point: rate = 1 ÷ time**.

C1.1.12 HIGHER LEVEL

Metabolism makes *heat*

- No transfer is **100% efficient** (about a third of glucose's energy reaches ATP), so **heat is inevitable**.
- **Mammals and birds** use it to keep a **constant body temperature**; a bumblebee shivers to warm up.

C1.1.11, C1.1.13 HIGHER LEVEL

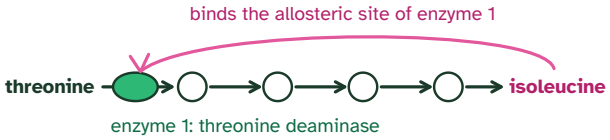
Inside or out, *chain* or cycle

PATHWAY	WHERE	KIND
Glycolysis glucose to pyruvate	**Intracellular:** cytoplasm	**Linear**
Krebs cycle	**Intracellular:** mitochondrial matrix	**Cyclical**
Calvin cycle	**Intracellular:** chloroplast	**Cyclical**
Digestion	**Extracellular:** gut, by secreted enzymes	Hydrolysis

C1.1.16 HIGHER LEVEL

Feedback inhibition

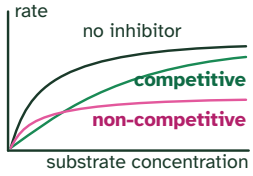
- The **end product** of a pathway inhibits **the first enzyme** at its allosteric site.
- More product slows the pathway; using it up speeds it again, so **production matches use**.



C1.1.14, C1.1.15, C1.1.17 HIGHER LEVEL

Three ways to *stop* an enzyme

	COMPETITIVE	NON-COMPETITIVE	MECHANISM-BASED
Binds	The **active site**: a substrate look-alike. Reversible.	An **allosteric site**: a **conformational change** alters the active site, reversibly.	The active site, by a **covalent bond**. **Irreversible**.
Add substrate	**Rate climbs back** to the same maximum	The **lower maximum** stays	No help: the site stays blocked
Example	**Statins** on HMG-CoA reductase: less cholesterol	Isoleucine on its first enzyme (below)	**Penicillin** on transpeptidase, which cross-links walls



Penicillin: without cross-links a bacterial wall is weak and the cell bursts. **Resistance:** a changed transpeptidase binds penicillin poorly but still cross-links.

WATCH OUT

Five mistakes that *cost marks*

- ✕ **Enzymes are not used up.** The substrate changes; the enzyme comes out as it went in.
- ✕ **Heat denatures; it does not kill.** Cold does not denature: it only slows collisions.
- ✕ **A level curve is not "substrate used up".** The active sites are all busy.
- ✕ **An enzyme does not give energy.** It only lowers the activation energy.
- ✕ **A non-competitive inhibitor never touches the active site.** More substrate cannot undo it.

COVER THE SHEET

Can you *answer these?*

1. Explain how enzymes benefit a cell by lowering activation energy.
2. Distinguish anabolic from catabolic reactions.
3. Describe induced-fit binding, and how denaturation stops it.
4. Explain the shapes of the temperature and substrate graphs.
5. Outline how to find an initial rate from a graph.
6. Compare glycolysis and the Krebs cycle. HL
7. Explain why metabolism generates heat. HL
8. Distinguish competitive from non-competitive inhibition. HL
9. Explain how isoleucine controls its own production. HL
10. Explain how penicillin kills bacteria. HL

IN THE EXAM

Explain a graph with two ideas: collisions for the rise, **denaturation** for the fall. Quote numbers from its axes.

GO FURTHER

Animated figures, a dry lab and a marked Check are in the full guide online.