AP BIOLOGY | UNIT 3 | TOPICS 3.1 TO 3.3

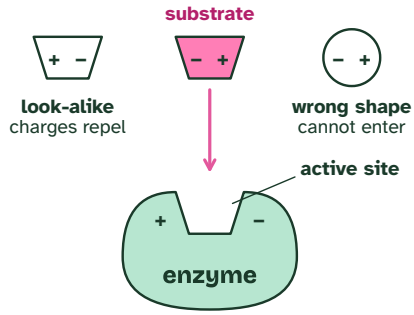
REVISION ON TWO PAGES

Enzymes and *energy*

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

THE ONE IDEA

An enzyme's shape lowers the activation energy of one reaction. Change the shape and the rate changes. ATP pays for order.



Draw it like this. Site and substrate are complementary, like a mold and what fills it: never "the same shape".

3.1.A START HERE

The active site fits *one substrate*

- An **enzyme** is a biological catalyst: a protein that speeds up one reaction and is **not used up**. It lets go of the products unchanged and binds the next substrate.
- The **active site** is a small pocket in the folded 3D shape, lined by a few R groups. The molecule the enzyme works on is its **substrate**.
- A substrate binds only if its **shape fits** the site and its **charges are compatible** with those R groups. That double check makes an enzyme **specific**: lactase splits lactose and leaves sucrose alone.
- **Induced fit**: as the substrate settles in, the site shifts to grip it more tightly.

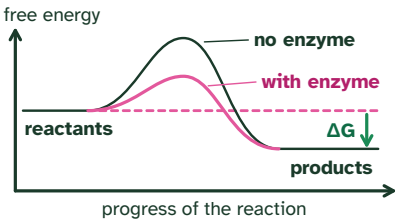
HOW THE SITE LOWERS THE ACTIVATION ENERGY

1. **Holds** the substrate in exactly the right position
2. **Strains** the bond that has to break
3. **Pulls** electrons, with charged R groups

3.1.A CATALYSIS

Lower *activation energy*, same ΔG

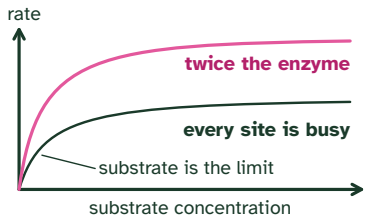
- Breaking a bond takes energy in. So even a reaction that releases energy must first be pushed over a hump: the **activation energy**.
- An enzyme **lowers the activation energy**, so far more molecules get over each second. It supplies no energy of its own.
- The free energy of the reactants and of the products, and so **ΔG, stays the same**. An enzyme cannot make an uphill reaction go, and it speeds the reverse reaction just as much.



3.2.B

Substrate: up to a limit

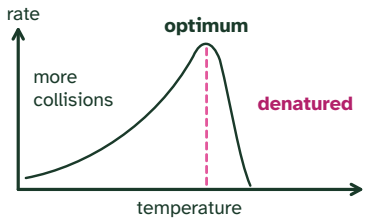
- More substrate means more collisions between substrate and free active sites, so the rate climbs.
- When every site is refilled the moment it empties, the enzyme is **saturated** and the rate levels off. Only **more enzyme** raises it.
- As substrate is used up and **product builds up**, the rate falls. An enzyme speeds a reversible reaction whichever way the concentrations favor.



3.2.A, 3.2.B

Temperature

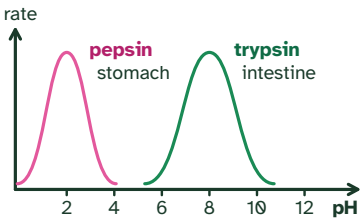
- **Rising side:** molecules move faster, so collisions are more frequent and carry more energy. Most human enzymes peak near 37 to 40 °C.
- **Falling side:** past the **optimum**, the weak bonds that hold the shape break. The active site changes shape and the substrate no longer fits: **denatured**.
- Denaturing breaks bonds between R groups, **not peptide bonds**. It can reverse, but after heat the chains tangle: usually permanent.



3.2.A, 3.2.B

pH

- The pH scale is logarithmic: **each step down is ten times more H^+**.
- **A little off the optimum:** R groups in the site gain or lose H^+, their charges change and the substrate is held less well. This reverses when the pH returns.
- **Far off it:** the ionic and hydrogen bonds that hold the fold break too, and the enzyme **denatures**.
- Each optimum suits the place: pepsin near pH 2 in the stomach, trypsin near pH 8 in the small intestine.

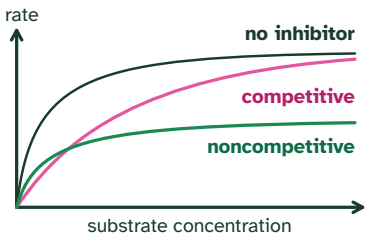


Five things change the rate, SPITE: Substrate, pH, Inhibitors, Temperature, Enzyme. *Spicy Peppers Irritate Tired Eyes.*

3.2.B

Inhibitors: block the site, or bend it

- An **inhibitor** binds to an enzyme and slows it down. A graph of rate against substrate concentration tells the two kinds apart.
- A **competitive inhibitor** fits the active site, so the substrate cannot bind. The two take turns: add enough substrate and the rate climbs back to nearly its normal maximum.
- A **noncompetitive inhibitor** binds an **allosteric site** (any site that is not the active site) and changes the enzyme's shape, active site included. No amount of substrate wins those enzymes back.
- Most inhibitors bind reversibly. Some bond for good: penicillin, on a bacterial cell wall enzyme.



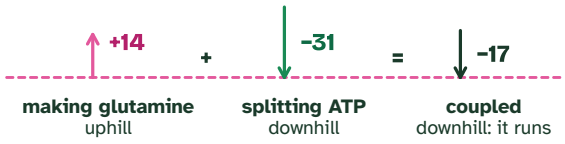
Competitive the active site
Same maximum rate, but more substrate is needed to reach it. Zanamivir, a flu drug, fills the active site of the virus's neuraminidase.

Noncompetitive an allosteric site
Lower maximum rate, whatever the substrate concentration. Isoleucine does this to the first enzyme of its own pathway.

3.3.A

Staying alive takes *constant energy*

- A cell is highly ordered. It keeps that order only by taking in energy, from food or light, **faster than it loses energy**. Cut off the flow, or lose the order, and the cell dies.
- **Second law of thermodynamics:** every energy transfer turns some energy into heat, and the disorder of the universe increases. A cell pays for its order with the heat and disorder it releases.
- A cell runs an endergonic reaction by **coupling** it to an exergonic one, usually the hydrolysis of **ATP**, its energy currency.
- **Exergonic** reactions release free energy (ΔG negative): breaking down glucose. **Endergonic** ones need it put in (ΔG positive): building a protein.

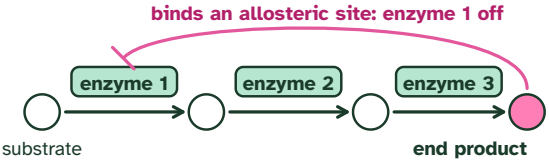


ΔG in kJ/mol. EXergonic: energy EXits. ENdergonic: energy ENters.

3.3.B

Pathways run in *small steps*

- A **metabolic pathway** is a chain of reactions, each with its own enzyme: the product of one step is the substrate of the next.
- Small steps release energy a little at a time, so the cell can capture it as ATP and control it. Burned, glucose gives it all up at once as heat and light.
- **Feedback inhibition**: the end product binds an allosteric site on the pathway's **first enzyme** and switches it off. It binds reversibly: as the product is used up it lets go and the enzyme works again. This is negative feedback, so nothing is wasted.
- Bacteria, archaea and eukaryotes all run on ATP and on versions of glycolysis. Pathways **conserved** in every domain are evidence of **common ancestry**.



WATCH OUT

Five mistakes that *cost points*

- ✕ **Breaking bonds takes energy in.** Energy is released when new, more stable bonds form.
- ✕ **An enzyme never changes ΔG.** It lowers the activation energy: the route, not the destination.
- ✕ **A plateau is not denaturing.** Every enzyme is still working, flat out. Add more and the rate climbs.
- ✕ **Cold does not denature.** At 5 °C an enzyme is slow but whole, and works normally once warmed.
- ✕ **ATP is not a spring.** Its hydrolysis releases energy because ADP and phosphate are more stable than ATP and water were.

COVER THE SHEET

Can you *answer these?*

1. Explain why lactase splits lactose but not sucrose.
2. Describe what an enzyme does to ΔG.
3. Explain why rate levels off at high substrate.
4. Explain why rate falls above the optimum temperature.
5. Predict the rate of pepsin once it reaches pH 8. Justify it.
6. Identify the inhibitor that excess substrate can overcome.
7. Calculate ΔG: a +20 kJ/mol step coupled to ATP hydrolysis.
8. Explain how an end product switches off its own pathway.

IN THE EXAM

Chain the cause: the condition, the bonds or charges it changes, the shape of the active site, whether the substrate binds, then the rate. "It denatures" alone explains nothing.

GO FURTHER

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