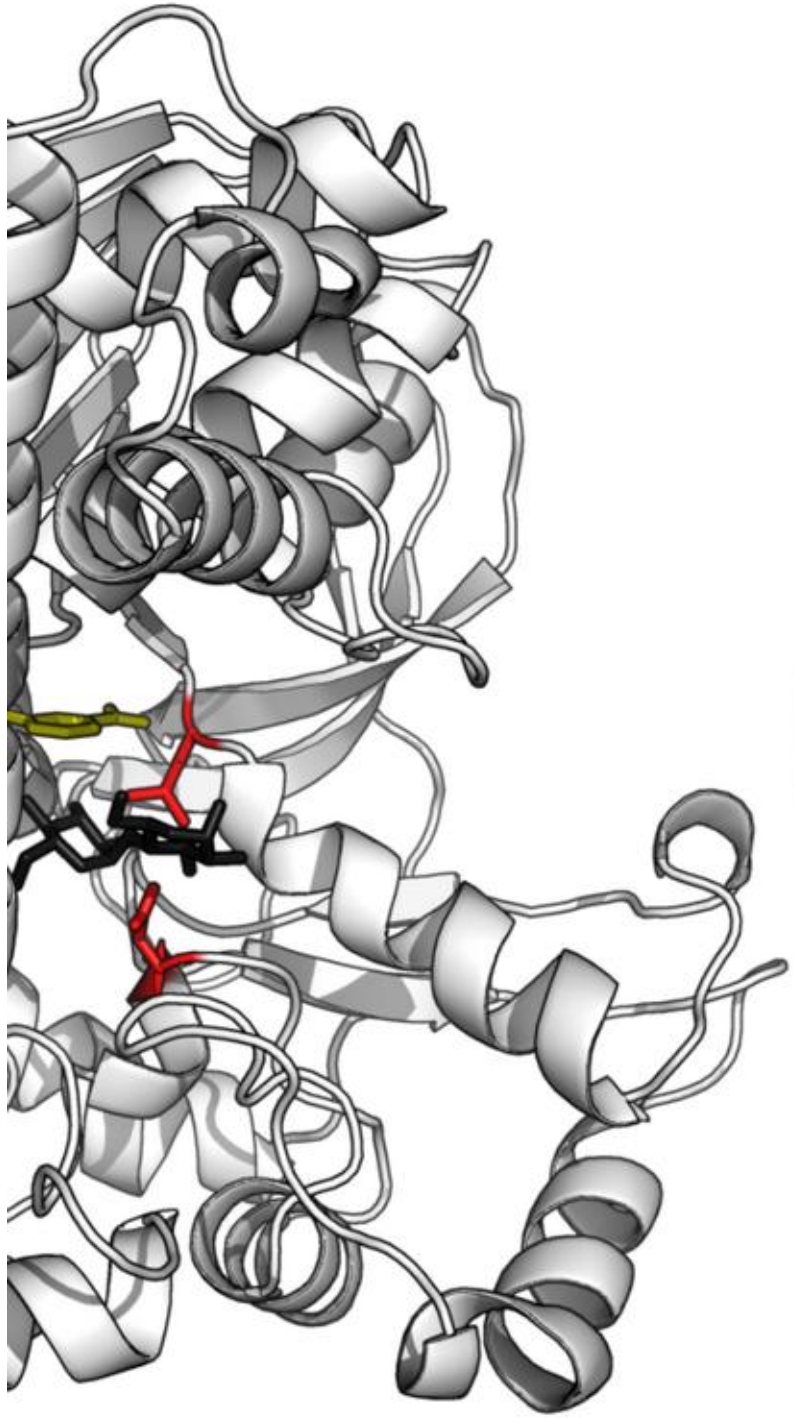
DP Biology – C1.1

Enzymes and metabolism

- How do enzymes act on, and respond to, other molecules?
- Which parts of metabolism depend on one another?



SL statements C1.1.1–10. Textbook pp. 380–395.
Image: model of an enzyme, a glucosidase. Thomas Shafee, CC BY 4.0.

Objectives for each class

Class	Statements	By the end of the class, you can...
1	C1.1.1–3	Explain why enzymes are needed, and distinguish anabolic and catabolic reactions
2	C1.1.4–7	Explain how structure, induced fit, collisions and denaturation affect catalysis
3	C1.1.8	Explain how temperature, pH and the amount of substrate change the rate of reaction
4	C1.1.9–10	Calculate reaction rates, and explain how enzymes lower activation energy

Overview of this chapter

Part	Statements	What it covers
Why enzymes matter	C1.1.1–3	Catalysis and metabolism
How enzymes work	C1.1.4–6	Active site, induced fit and collisions
Specificity and damage	C1.1.7	Shape, specificity and denaturation
Rates of reaction	C1.1.8–9	Three factors, and how to measure a rate
Energy	C1.1.10	Lowering activation energy

Enzymes are catalysts

- A **catalyst** speeds up a reaction, and it is not used up by the reaction
- An **enzyme** is a biological catalyst, which works in small amounts
- It can be used again and again

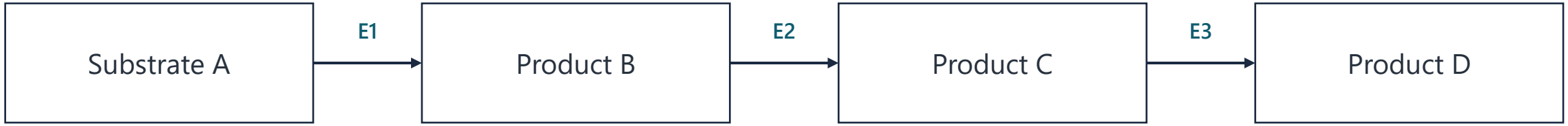
Why cells need faster reactions

Without enzymes, many reactions in a cell would be far too slow to sustain life. Heating up a cell would speed up reactions, but it would also damage its proteins. Enzymes let reactions proceed quickly at body temperature, and each cell controls which reactions proceed by choosing which enzymes it makes.

The role of enzymes in metabolism

C1.1.2

- **Metabolism** is the complex network of chemical reactions that occur in an organism
- Reactions are interdependent: products of one often become substrates of the next
- Enzymes are **specific**, so organisms need many different enzymes



Key idea

Every step needs its own enzyme, marked E1, E2 and E3 here. A cell can control a whole pathway by controlling one enzyme. This is why metabolism can be regulated with such precision, and why missing one enzyme can cause disease, as in phenylketonuria (D3.2).

Anabolic and catabolic reactions

C1.1.3

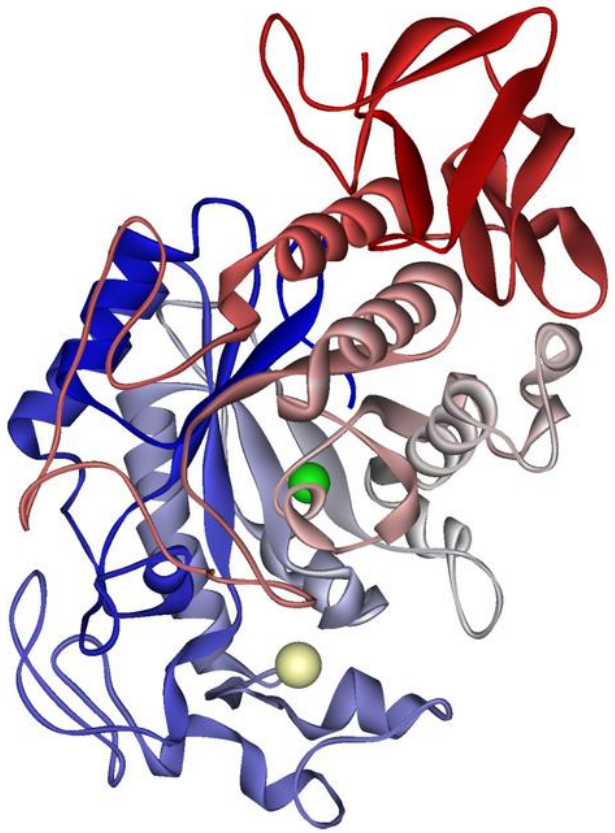
	Anabolic	Catabolic
What happens	Builds larger molecules from smaller ones	Breaks larger molecules into smaller ones
Example 1	Protein synthesis, by condensation	Digestion of macromolecules, by hydrolysis
Example 2	Glycogen formation	Oxidation of substrates in respiration
Example 3	Photosynthesis	Decomposition of dead organic matter

How to remember

Anabolic: to build. Catabolic: to break down. Anabolic reactions usually use energy from ATP, and catabolic reactions often release energy that is used to make it.

Enzymes are globular proteins

C1.1.4



Salivary amylase, a globular protein. Public domain.

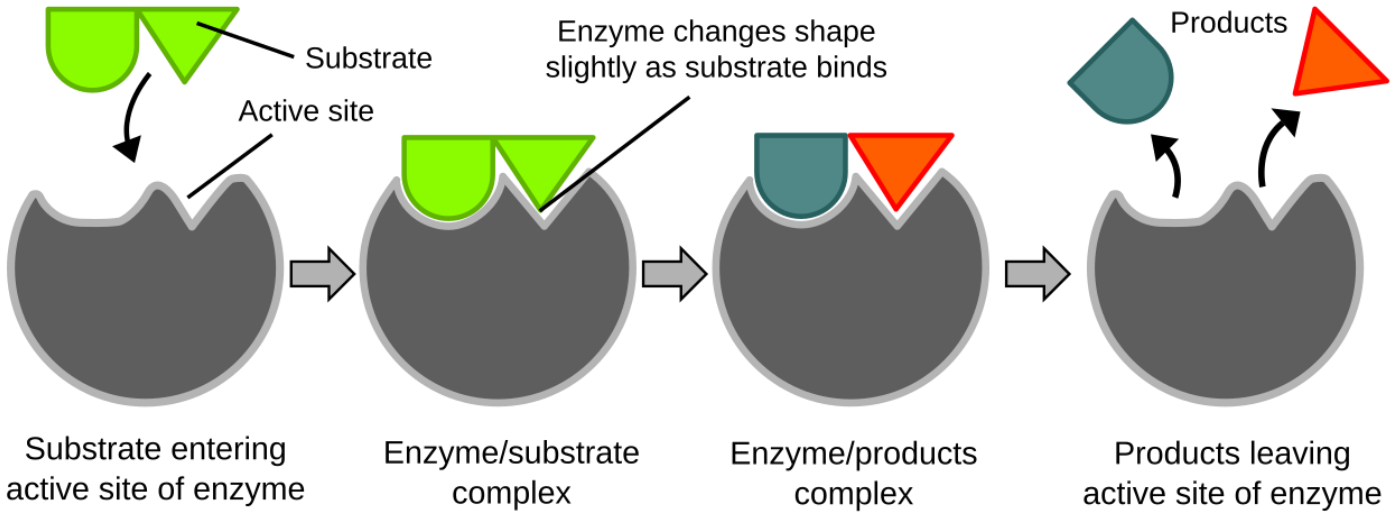
- Enzymes are **globular proteins**, with polypeptides folded into a compact shape
- The **active site** is where the substrate binds
- It contains only a few of the amino acids
- Others throughout the protein hold it in the right shape, so that it has the properties needed for catalysis

Common mistake

Do not say that an active site and its substrate are the same shape. Their shapes and chemical properties are complementary, and they fit together.

Induced-fit binding

C1.1.5



Induced fit. TimVickers, vectorized by Fvasconcellos, public domain.

- As the substrate binds, **both the substrate and the enzyme change shape**
- This places stress on bonds in the substrate, and helps the reaction to take place

Stages

The substrate binds to the active site. It is converted into products while bound. The products then leave, and the active site can be used again.

Molecular motion and collisions

C1.1.6

- Movement is needed for a substrate and an active site to meet
- Molecules in solution are in random motion, so they **collide**
- A collision only succeeds if the orientation is right

Situation	What moves
Both in solution	Both substrate and enzyme, with small substrates moving fastest
Enzyme in a membrane	Only the substrate moves
Large immobile substrate	Only the enzyme moves

Why it matters

Immobilizing an enzyme can be useful. For example, an enzyme fixed in a membrane stays in the right place within a cell, or can be used again in an industrial process.

Specificity and denaturation

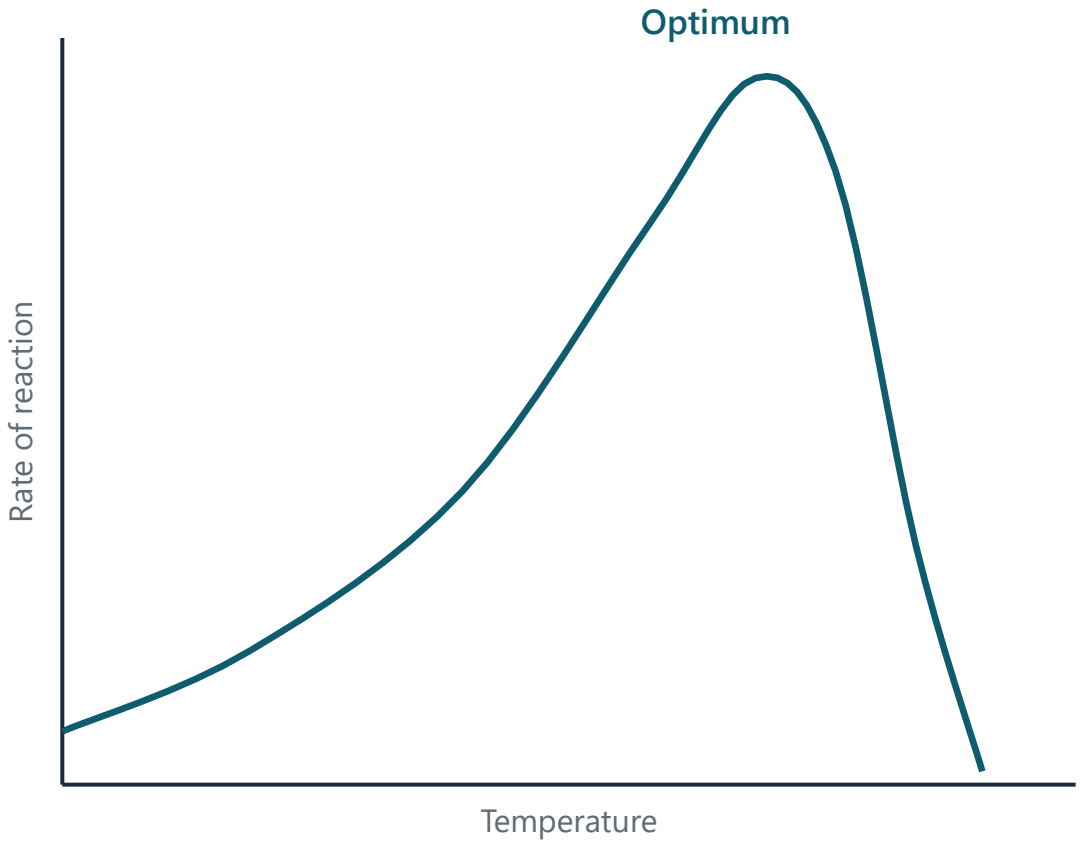
C1.1.7

Term	How it links to the active site
Specificity	Only substrates with a complementary shape and chemical properties can bind
Denaturation	Heat or extreme pH breaks bonds that hold the active site in shape
Result	The substrate can no longer bind, so catalysis stops

Explain the links

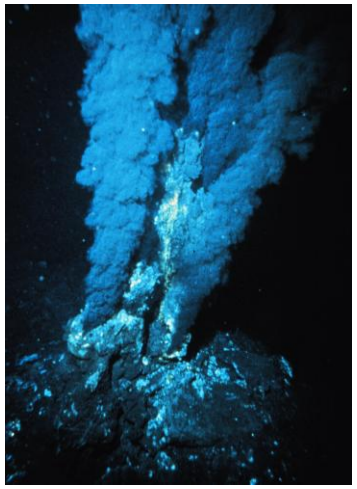
The sequence of amino acids decides the shape of the enzyme. This shape determines the active site, and that is what gives specificity. Change the shape of the active site, and both specificity and activity are lost.

Effect of temperature



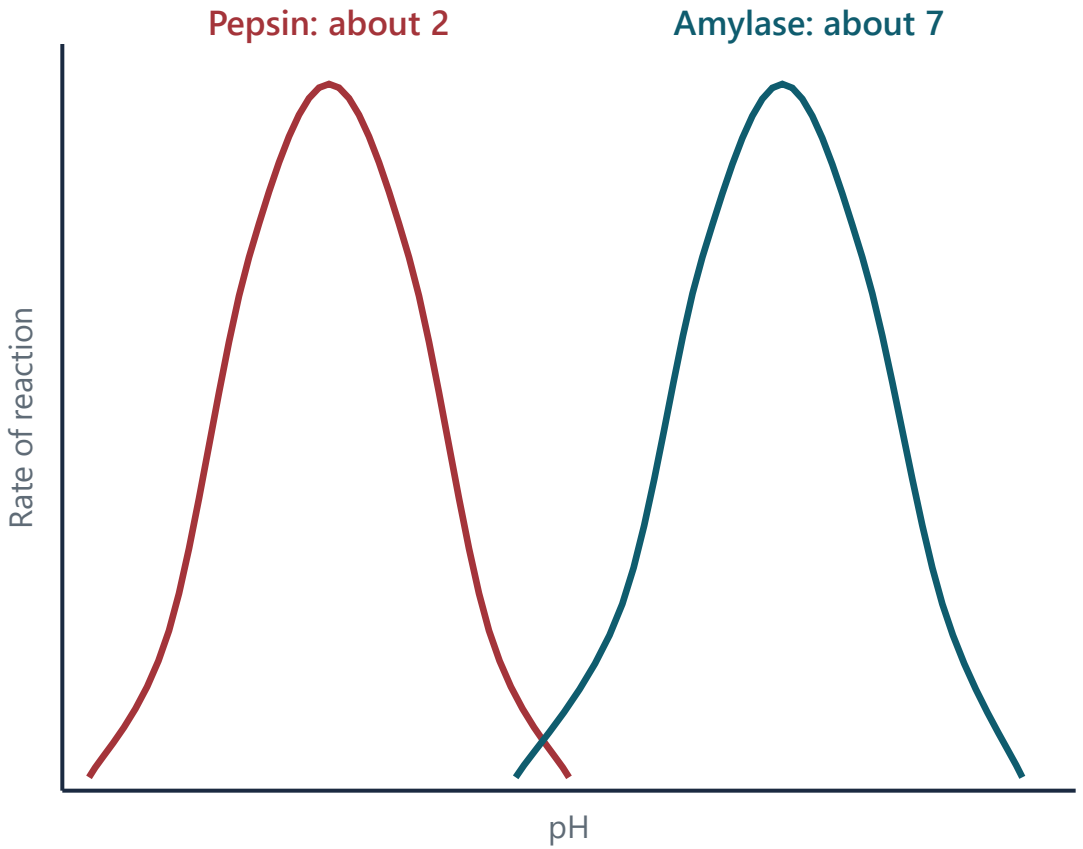
General shape only, without numerical values.

- **Rising temperature**: molecules move faster, so there are more collisions
- **Above the optimum**: bonds in the enzyme begin to break, so the active site changes
- **Well above**: the enzyme is fully denatured, and activity stops



Enzymes vary. Bacteria near deep-sea vents have enzymes with very high optimum temperatures. Image: P. Rona, NOAA, public domain.

Effect of pH



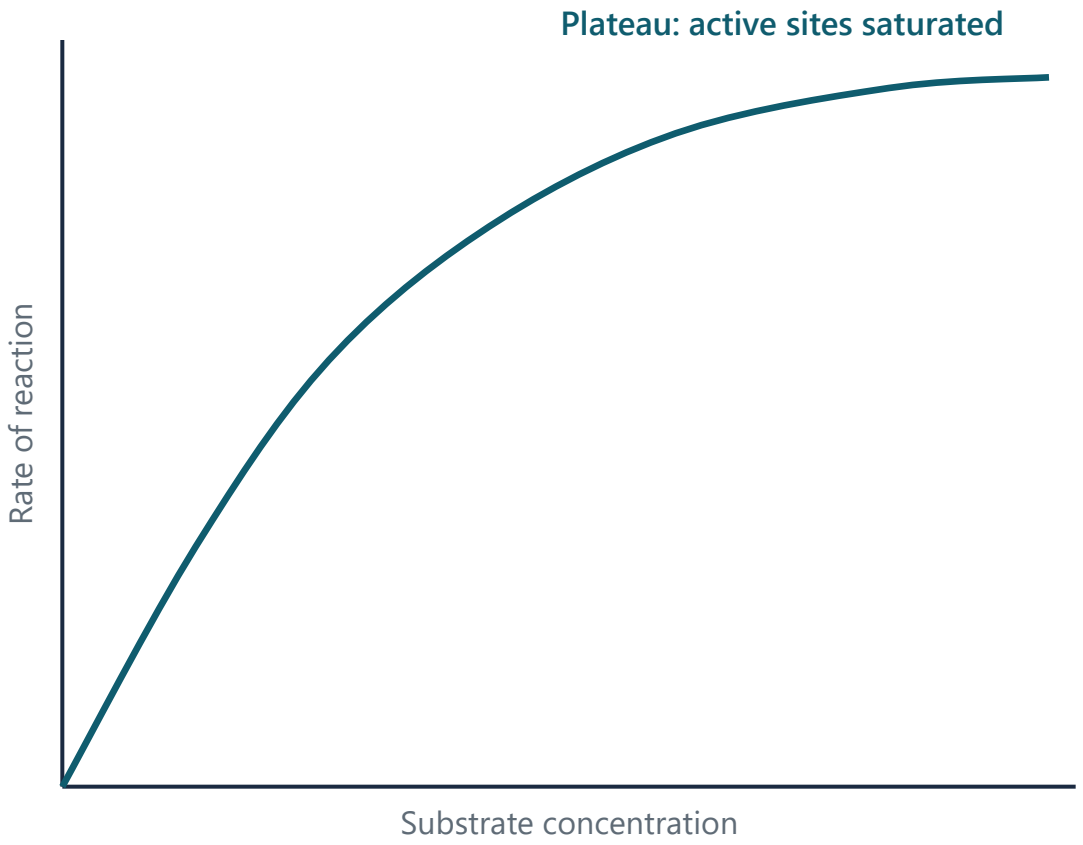
- pH measures hydrogen ion concentration, on a log scale
- Every enzyme has an **optimum pH**
- Away from it, charges on R-groups change, so the bonds that hold the active site are disrupted
- The optimum usually suits where the enzyme works

Activity

Explain why pepsin works in the stomach but stops working in the small intestine, in terms of the active site.

Effect of substrate concentration

C1.1.8

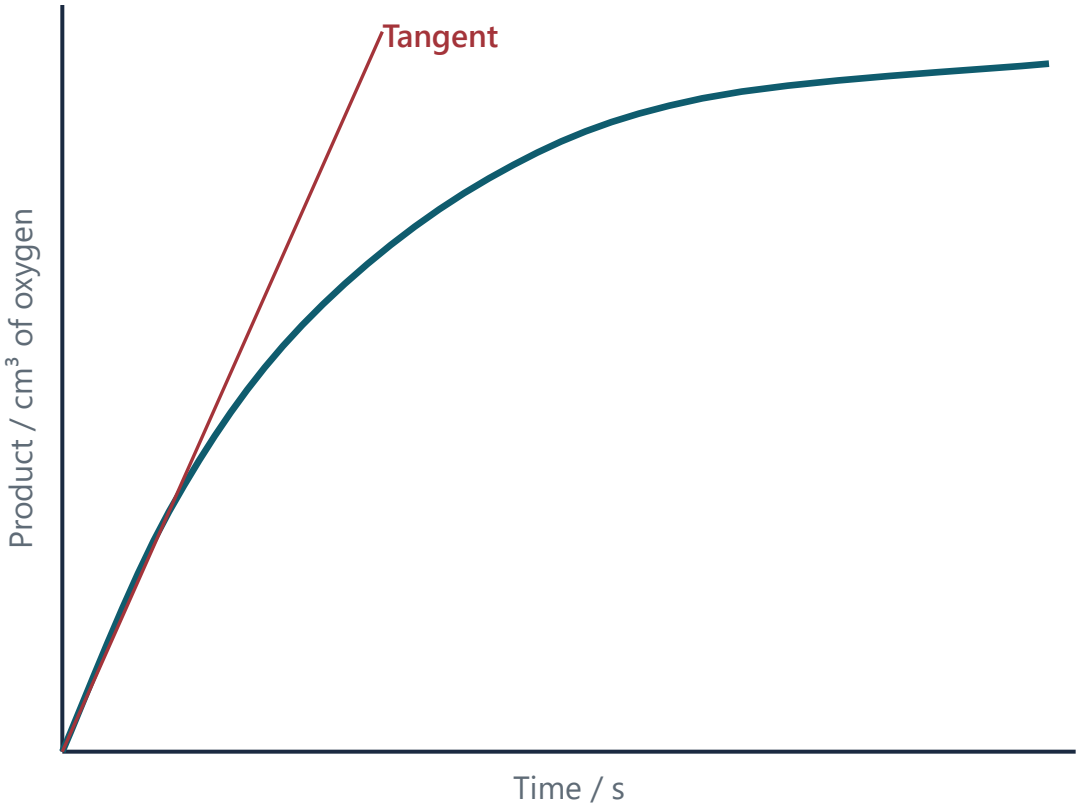


- **Low concentration**: few substrate molecules, so few collisions
- **Rising concentration**: more collisions with active sites
- **High concentration**: active sites are occupied almost all the time, so the rate levels off

Common mistake

No optimum exists here, and the enzyme is not denatured. The rate stays high, and the enzyme is working as fast as it can.

Measuring reaction rates



Invented values, for practice.

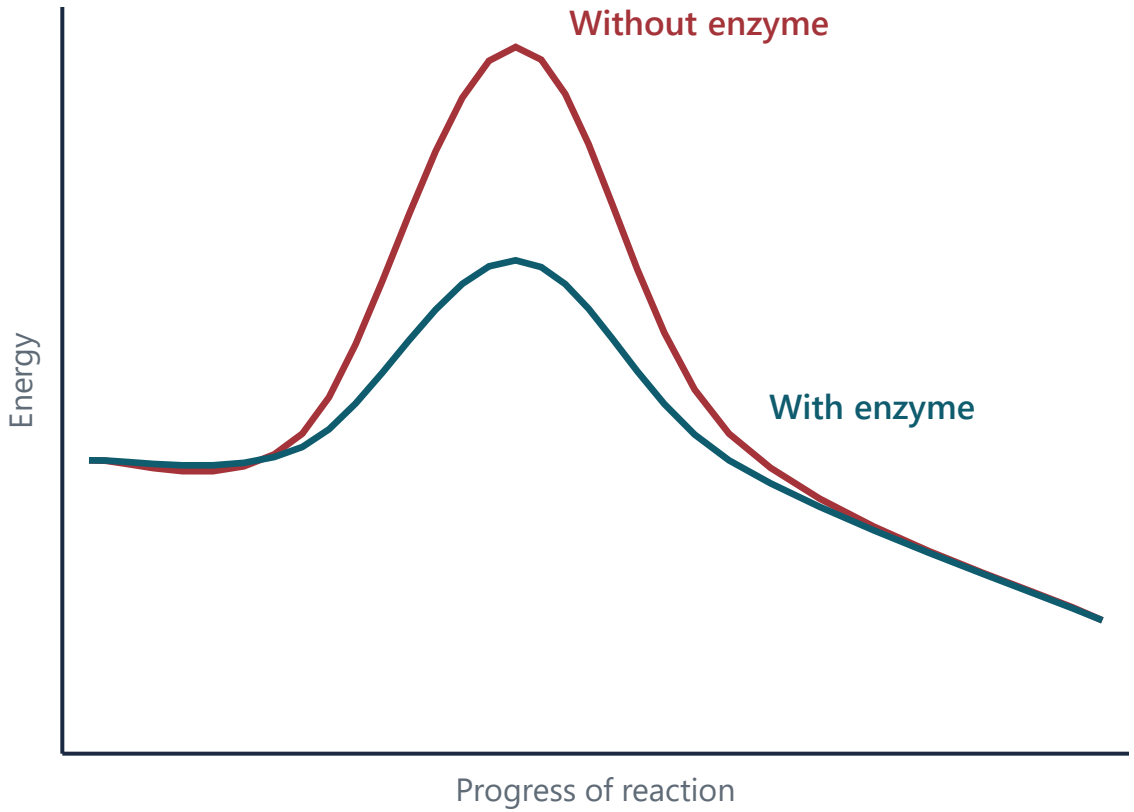
- Rate is the change in substrate or product per unit of time
- The curve is steepest at the start, when there is most substrate
- So use the **initial rate**: the gradient of a tangent at time 0

Worked example

Catalase produces 6 cm^3 of oxygen in the first 20 s, and this part of the graph is almost straight. Rate = 6 / 20 = 0.3 cm^3 per second. Compare this to other conditions.

Enzymes lower activation energy

C1.1.10



- **Activation energy** is the energy needed to start a reaction, by breaking or weakening bonds
- Energy is released when new bonds form in the products
- An enzyme lowers the activation energy
- It does not change the total energy released

Common mistake

Enzymes do not supply energy to a reaction. They lower the energy needed, so that more collisions result in a reaction.

Check that you can explain

1. Why cells need catalysts
2. What metabolism is, and how enzymes control it
3. Anabolic and catabolic reactions, with examples
4. The active site and induced fit
5. Molecular motion and collisions
6. Specificity and denaturation
7. How temperature, pH and substrate affect the rate
8. How to find an initial rate
9. How to read an activation energy graph

Exit activity: 5 minutes

On your own and without notes. Hand this in as you leave.

1. Classify each as anabolic or catabolic: digestion, protein synthesis, respiration.
2. Explain why the rate of an enzyme-catalysed reaction falls at very high temperatures.
3. Sketch a graph showing how substrate concentration affects the rate, and label the plateau.

Image credits

Glucosidase enzyme.png – Thomas Shafee – CC BY 4.0

Salivary alpha-amylase 1SMD.png – Own work. – Public domain

Induced fit diagram.svg – Created by TimVickers, vectorized by Fvasconcellos – Public domain

Blacksmoker in Atlantic Ocean.jpg – P. Rona / OAR/National Undersea Research Program (NURP); NOA – Public domain

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