

Enzymes and cellular energy

Three one-hour lesson plans

Three one-hour lessons, following the guide's chapters. Each lesson has a practical or a model to handle; the guide's figures go on the board for the explanations, and students can run [the dry lab](#) on phones or laptops.

LESSON	COVERS	FOCUS	CHAPTERS
1 What an enzyme does	3.1.A	Specificity from shape and charge, and lowering the activation energy, with a clay model and a gas demo	1, 2
2 What changes the rate	3.2.A, 3.2.B	Temperature, pH and substrate concentration, tested in a circus of practicals and explained with the figures	3, 4, 5
3 Inhibitors, pathways and energy	3.2.B, 3.3.A, 3.3.B	Competitive and noncompetitive inhibition, feedback in pathways, and coupling with ATP, ending on a timed free response	6, 7, 8, lab

The guide, for the class to read and play: biologybybradford.com/guides/ap-biology-unit-3-enzymes

What an enzyme does

60 minutes • 3.1.A • Chapters 1, 2

Specificity from shape and charge, and lowering the activation energy, with a clay model and a gas demo

BY THE END, STUDENTS CAN

- ☐ Explain how the shape and charge of an active site make an enzyme specific to its substrate 3.1.A
- ☐ Explain how an enzyme speeds up a reaction by lowering its activation energy, and why it leaves ΔG unchanged 3.1.A

TIMING

0-5	5 min	Do now: sugar in a bowl	
5-15	10 min	The active site	
15-30	15 min	Modeling clay enzymes	
30-42	12 min	Activation energy	
42-54	12 min	Demo: catch the oxygen	
54-60	6 min	Exit	
	60 min	One lesson	

STARTER

5 min Do now: sugar in a bowl

A spoonful of sugar can sit in a bowl for a year, burns in a flame in seconds, and your cells use it in minutes. Pairs write what each case needs. Keep the answers for the end of the lesson.

ON THE BOARD, FROM THE GUIDE

Open the guide on the projector at each chapter (the links work in this PDF). Every figure plays from its own buttons, and the lesson's slides have the same figures, step by step, in the order of this plan.

01 The active site fits one substrate

CHAPTER 01 IN THE SLIDES

Switch the figure through Substrate, Look-alike and Wrong shape, and have the class say what will change before each.

Predict box: A molecule has exactly the substrate's shape, but its two charges are the other way round. What happens at the active site? Hands up or mini whiteboards first.

Answer C: It is pushed away, because like charges repel

02 Enzymes lower the activation energy

CHAPTER 02 IN THE SLIDES

Step through the figure (5 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

1. The reactant must pass over a **hump** before it can become products. Here the products end up lower: this reaction releases energy.
2. At the top of the hump the bond is stretched and about to break. Getting there takes the **activation energy**, and at 37 °C few collisions have that much.
3. With the enzyme the route is **lower**: the active site holds the substrate in place and strains its bond, so less energy is needed.
4. The start and the finish have not moved, so **ΔG is the same** with or without the enzyme. The enzyme changes the route, never the destination.
5. A lower peak means **many more** molecules have enough energy to cross it each second, so the reaction runs far faster.

Predict box: An enzyme is added to a reaction with $\Delta G = -20$ kJ/mol. What is ΔG now? Hands up or mini whiteboards first.

Answer B: -20 kJ/mol: the enzyme does not change it

THE LESSON

10 min The active site

Chapter 1's figure on the board. Offer the enzyme each molecule and have students say, before you click, whether it binds and why. Draw out the double check: shape and charge. Name the parts with the tap labels.

15 min Modeling clay enzymes

Pairs build an enzyme and its substrate, first as a rigid lock and key, then remodeled to show induced fit (activity below). Ask which model explains the evidence that the site changes shape as the substrate binds.

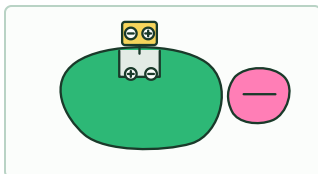
12 min Activation energy

Play chapter 2's figure a step at a time. Students sketch it, labeling the activation energy with and without the enzyme and ΔG . Push on the predict box: what does the enzyme not change?

12 min Demo: catch the oxygen

Catalase and hydrogen peroxide, the gas collected two ways (activity below). Students list every way the first method loses gas, then judge which method they would trust for the circus next lesson.

ACTIVITIES

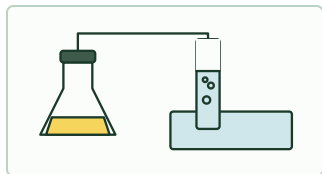


MODEL

Modeling clay enzymes

Pairs shape an enzyme with a pocket and a substrate to fit it, then add a + and a - sticker to each so the charges line up. First the site is rigid (lock and key). Then they rebuild it with soft walls that close around the substrate (induced fit). Last, one partner makes a look-alike with the stickers swapped, and the other explains why it is not held.

Needs: modeling clay in two colors per pair, small + and - stickers, [chapter 1's](#) figure on the board.



DEMO

Catch the oxygen

Add yeast suspension to 3% hydrogen peroxide in a flask, bung it, and collect the gas over water in an upturned measuring cylinder. Repeat with a gas syringe. Students list what the first method misses: gas lost before the bung goes in, bubbles that stick in the tube, oxygen dissolving, a meniscus that is hard to read.

Needs: 3% hydrogen peroxide, yeast suspension (or potato or liver), conical flask with bung and delivery tube, measuring cylinder and trough of water, 100 cm³ gas syringe, stopwatch, eye protection.

PLENARY

6

min

Exit

Chapter 1's predict box on paper before you reveal it (a molecule with the substrate's shape but its charges the other way round), then back to the sugar: the flame supplies activation energy, the cell supplies an enzyme.

WHAT STUDENTS GET WRONG

"An enzyme makes a reaction happen that otherwise would not." It only lowers the activation energy; ΔG and the end point are unchanged, and an uphill reaction still needs coupling.

"The substrate is the same shape as the active site." Complementary, not the same, and charge matters as much as shape.

"Exergonic means fast." Sugar in the bowl is exergonic and lasts a year: activation energy decides speed.

STRETCH AND SUPPORT

Support: a printed, pre-drawn energy diagram to annotate during chapter 2, and the free-response table with the rows to compare already highlighted.

IN THE GUIDE

- 1 The active site fits one substrate
- 2 Enzymes lower the activation energy
- All The whole guide, with the figures that play
- PPTX This lesson's slides, in the order of this plan

PRACTISE AND REVISE

BUILD FOR YOUR CLASS

- Tarsia puzzle, dominoes and picture reveal on Unit 3, built from its key terms and ready to print
- A pub quiz with rounds on Unit 3, to present or run with no projector
- The Kelp Light Habitat escape room, or an escape room built from the question bank on Unit 3

ALREADY ON THE SITE FOR UNIT 3

- Lesson: Enzymes
- Lesson: Environmental Impacts on Enzyme Function
- Lesson: Cellular Energy
- Quiz: Enzymes
- Quiz: Environmental Impacts on Enzyme Function
- Quiz: Cellular Energy
- Exam questions: Unit 3 in the exam maker, a paper with scoring guidelines

CARD SETS ON SPLYCR

Open a set to host it as a class game, or make a copy to edit.

- Unit 3: Cellular Energetics (part 1)
- Unit 3: Cellular Energetics (part 2)
- Unit 3: Cellular Energetics (part 3)

EXAM PRACTICE

Check yourself

Set it for homework: a fresh paper of exam-bank questions on 3.1 to 3.3 each time, marked as students go and saved to their Exam practice when they are signed in.

biologybybradford.com/exam-maker/sit?program=ap&units=U3&ced=3.1,3.2,3.3&paper=quiz&marks=15&src=ep



What changes the rate

60 minutes • 3.2.A, 3.2.B • Chapters 3, 4, 5

Temperature, pH and substrate concentration, tested in a circus of practicals and explained with the figures

BY THE END, STUDENTS CAN

- ☐ Explain how heat and extreme pH change an enzyme's structure, and when that change can be undone 3.2.A
- ☐ Predict how temperature, pH, substrate and product concentrations and inhibitors change the rate of a reaction 3.2.B

TIMING

0-5	5 min	Retrieval: SPITE	
5-35	30 min	Circus of enzyme labs	
35-47	12 min	Share and explain	
47-55	8 min	Data: two enzymes, one graph	
55-60	5 min	Exit	
60 min		One lesson	

STARTER

- 5 min** **Retrieval: SPITE**
- The Remember it tiles in [chapter 3](#), then sketch from memory the shape of rate against substrate concentration, temperature and pH. Leave the sketches up; they are tested by the circus.

ON THE BOARD, FROM THE GUIDE

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03 More substrate, more collisions, up to a limit

CHAPTER 03 IN THE SLIDES

Switch the figure through 3 enzymes and 6 enzymes, and have the class say what will change before each.

Predict box: A reaction has reached its plateau: more substrate no longer speeds it up. Which change would raise the rate? Hands up or mini whiteboards first.

Answer B: Adding more of the enzyme

Remember it: Spicy Peppers Irritate Tired Eyes (Substrate, pH, Inhibitors, Temperature, Enzyme).

04 Heat makes it faster, then breaks it

CHAPTER 04 IN THE SLIDES

Slide the figure through Temperature 10, Temperature 37, Temperature 49 and Temperature 68, and have the class say what will change before each.

Play the animation, Watch it happen: collisions, heat and inhibitors. It loops; pause it on each moment below and ask what is happening (in the lesson slides it is a video).

1. Molecules move at **random**, and most collisions miss the active site.
2. A **successful collision**: it binds and reacts, and the enzyme is unchanged.
3. Too hot: enzymes **denature**. Active sites lose their shape, and the rate falls.

Predict box: Salivary amylase is held at 70 °C for ten minutes, then cooled back to 37 °C. What is its rate now? Hands up or mini whiteboards first.

Answer C: Far lower than normal: it stays unfolded

05 pH changes the charges in the site

CHAPTER 05 IN THE SLIDES

Slide the figure through pH 2, pH 4, pH 7, pH 10 and pH 13, and have the class say what will change before each.

Predict box: Amylase is put in a buffer at pH 5 for a minute, then moved back to pH 7. What is its rate now? Hands up or mini whiteboards first.

Answer A: About normal: its site's charges come back

THE LESSON

30
min

Circus of enzyme labs

Everyone first times one disc in 3% peroxide to learn the end point (5 minutes). Then two of three stations, about 12 minutes each: pH, temperature, peroxide concentration. At each, read the method twice, draw a results table, run three trials.

12
min

Share and explain

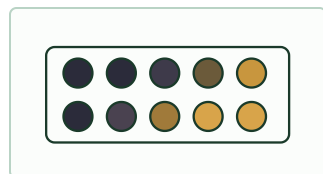
Each station's groups put their result on the board. Explain each shape with the figures from chapters 3 to 5, dragging the sliders live: collisions and saturation; collisions then unfolding; charges in the site.

8
min

Data: two enzymes, one graph

Plot pepsin and salivary amylase against pH from the table in the activity below, and explain both peaks with charges in the active site. Finish for homework if needed.

ACTIVITIES

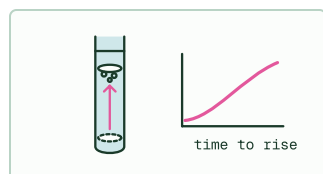


PRACTICAL

The enzyme in your spit

Salivary amylase digests starch. Students mix 2 cm³ of 1% starch with 1 cm³ of their own saliva at three temperatures, and every 30 seconds put a drop on a spotting tile with iodine. Iodine stays **blue-black** while starch is left; the end point is the first drop that stays yellow-brown. The guided version is the [amylase home lab](#) (written for IB, works as it is for AP).

Needs: 1% starch, dilute iodine solution, spotting tiles, droppers, stopwatches, iced water, room-temperature water and water at about 40 °C. Each student uses only their own saliva; where saliva practicals are not allowed, use 0.5% amylase solution instead.

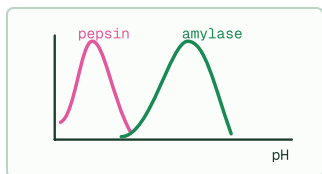


PRACTICAL

Circus of enzyme labs

A filter paper disc soaked in catalase sinks in hydrogen peroxide, then floats up as oxygen collects on it: the time to rise measures the rate. Three stations change one variable each: pH (buffers at 4, 7 and 10), temperature (water baths from ice to 60 °C) and peroxide concentration (0.5% to 3%).

Needs: hole punch, filter paper, yeast suspension, forceps, hydrogen peroxide at four concentrations, three buffers, water baths, stopwatches, eye protection.



DATA

Two enzymes, one graph

Plot both on one pair of axes, then explain why each peaks where it does and why each falls away on both sides.

pH	Pepsin	Amylase
1	62	0
2	100	0
3	71	2
4	34	9
5	11	38
6	3	83
7	0	100
8	0	58
9	0	17

Activity as a percentage of each enzyme's highest. Needs: graph paper or a spreadsheet.

PLENARY

5
min

Exit

Chapter 4's predict box on paper before you reveal it: salivary amylase held at 70 °C, then cooled back to 37 °C.

WHAT STUDENTS GET WRONG

"The plateau is the enzyme being used up." Every active site is busy and every enzyme molecule is still working. Ask what adding more enzyme would do, then show it in [chapter 3's](#) figure.

"Cold denatures enzymes." Cold slows them; they are intact and recover when warmed. Keep "denatured" for heat and extreme pH.

Errors that turn up in published slides. Iodine with starch is blue-black, not purple; a positive biuret test is purple (blue means no protein); zanamivir stops neuraminidase cutting sialic acid, not hemagglutinin; cyanide binds the metal center of cytochrome c oxidase and is not an allosteric inhibitor.

STRETCH AND SUPPORT

Stretch: explain why the temperature curve is not symmetrical: two effects with different sensitivity to heat, collisions rising steadily and unfolding switching on sharply.

Stretch: from two saturation curves with the same maximum, decide which enzyme holds its substrate more tightly, and what that means at low substrate concentration.

Stretch: in [the dry lab](#), compare full runs at 50 °C and 65 °C and explain why the 65 °C curve levels off far below the line where all the peroxide is used.

Support: one sentence frame for every graph: "As ____ increases from ____ to ____, the rate ____ because ____."

Support: drag a figure's slider and describe what moves before explaining why; the SPITE and Exits / Enters tiles as a checklist.

IN THE GUIDE

- 3** [More substrate, more collisions, up to a limit](#)
- 4** [Heat makes it faster, then breaks it](#)
- 5** [pH changes the charges in the site](#)
- All** [The whole guide, with the figures that play](#)
- PPTX** [This lesson's slides, in the order of this plan](#)

PRACTISE AND REVISE

BUILD FOR YOUR CLASS

- [Tarsia puzzle, dominoes and picture reveal](#) on Unit 3, built from its key terms and ready to print
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ALREADY ON THE SITE FOR UNIT 3

- Lesson: [Enzymes](#)
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- [Unit 3: Cellular Energetics \(part 1\)](#)
- [Unit 3: Cellular Energetics \(part 2\)](#)
- [Unit 3: Cellular Energetics \(part 3\)](#)

EXAM PRACTICE

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[biologybybradford.com/exam-maker/sit?](https://biologybybradford.com/exam-maker/sit?program=ap&units=U3&ced=3.1,3.2,3.3&paper=quiz&marks=15&src=ep)

[program=ap&units=U3&ced=3.1,3.2,3.3&paper=quiz&marks=15&src=ep](https://biologybybradford.com/exam-maker/sit?program=ap&units=U3&ced=3.1,3.2,3.3&paper=quiz&marks=15&src=ep)



Inhibitors, pathways and energy

60 minutes • 3.2.B, 3.3.A, 3.3.B • Chapters 6, 7, 8 • The dry lab

Competitive and noncompetitive inhibition, feedback in pathways, and coupling with ATP, ending on a timed free response

BY THE END, STUDENTS CAN

- ☐ Predict how temperature, pH, substrate and product concentrations and inhibitors change the rate of a reaction 3.2.B
- ☐ Describe why a living cell needs a constant input of energy, and how ATP couples an uphill reaction to a downhill one 3.3.A
- ☐ Explain why energy pathways run in small steps, and what the same pathways in every domain of life tell us 3.3.B

TIMING

0-5	5 min	Do now: two extra lines	
5-15	10 min	Block it or bend it	
15-25	10 min	Dry lab, Task 3	
25-37	12 min	Pathways and feedback	
37-49	12 min	Paying for uphill reactions	
49-60	11 min	Free response, timed	
	60 min	One lesson	

STARTER

- 5 min** **Do now: two extra lines**
- Sketch rate against substrate concentration. Add a line for something that competes for the active site, and one for something that changes the site's shape from elsewhere.

ON THE BOARD, FROM THE GUIDE

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06 Inhibitors block the site, or bend it

CHAPTER 06 IN THE SLIDES

Switch the figure through None, Competitive and Noncompetitive, and have the class say what will change before each.

Predict box: Two reactions are slowed by inhibitors. You add a large excess of substrate to both. One gets back almost its full rate; the other does not. What does the one that recovered contain? Hands up or mini whiteboards first.

Answer B: A competitive inhibitor, outnumbered by substrate

Remember it: Copycat Nope Another (Competitive, Noncompetitive, Allosteric site).

07 Staying alive takes a constant supply of energy

CHAPTER 07 IN THE SLIDES

Switch the figure through Energy flowing in and Energy cut off, and have the class say what will change before each.

Step through the figure (4 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

1. Making glutamine from glutamate and ammonia is **uphill**: $\Delta G = +14$ kJ/mol. On its own it hardly happens.
2. Splitting ATP into ADP and phosphate is **downhill**: $\Delta G = -31$ kJ/mol. The products are more stable than ATP was.
3. The enzyme glutamine synthetase **couples** them: ATP hands its end phosphate to glutamate. Glutamyl phosphate is unstable, ready to react.
4. Ammonia takes the phosphate's place, making glutamine. Overall $+14 - 31 = -17$ kJ/mol: downhill, so it runs. Respiration then rebuilds the ATP.

Predict box: Reaction X has $\Delta G = +20$ kJ/mol. Which of these would make it run in a cell? Hands up or mini whiteboards first.

Answer C: Coupling X to ATP hydrolysis (-31)

Remember it: Exits Enters (Exergonic, Endergonic).

08 Pathways go in small steps, shared by all life

CHAPTER 08 IN THE SLIDES

Step through the figure (4 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

1. A pathway: **each product is the next enzyme's substrate**, so threonine is turned into isoleucine step by step (three steps here; the real pathway has five).
2. The cell makes more isoleucine than it is using, and it **builds up**.
3. Isoleucine binds an **allosteric site** on enzyme 1 and bends its active site. The first step stops, so the whole pathway stops.
4. As the cell uses isoleucine to build proteins, the level falls, isoleucine **lets go**, and the pathway runs again: negative feedback.

Step through the figure (3 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

1. Bacteria, archaea and eukaryotes all **run on ATP**, and all break glucose down by versions of **glycolysis**, several of whose enzymes have closely similar sequences in all three.
2. All three groups trace back to **one common ancestor**. Archaea and eukaryotes share a more recent one as well.
3. The simplest explanation: the ancestor **already had** ATP and glycolysis, and every line of descent kept them. Shared, conserved pathways are evidence of common ancestry.

Predict box: The end product of a pathway builds up in a cell. What happens to the first enzyme of that pathway? Hands up or mini whiteboards first.

Answer D: It is slowed: the product binds it elsewhere

THE LESSON

10
min

Block it or bend it

Chapter 6's figure: compare the do-now sketches with the curves, then drag the substrate up with each inhibitor and count the molecules. Zanamivir and penicillin as the real cases; flag the cyanide trap.

10
min

Dry lab, Task 3

Pairs run the substrate series with no inhibitor, then competitive, then noncompetitive, and report each rate at 10% peroxide as a percentage of the uninhibited one. Or run it on the board and have the class predict each point.

12
min

Pathways and feedback

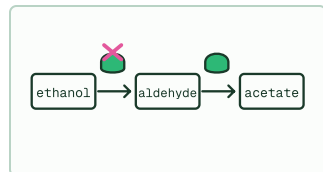
The alcohol pathway reading (activity below), then chapter 8's feedback figure, stopped at step 3 for students to predict step 4. Close with the tree: why the same pathway in every domain?

12
min

Paying for uphill reactions

Chapter 7: energy on and off for the cell, then the glutamine coupling a step at a time. Students add the ΔG values themselves before step 4 shows the total.

ACTIVITIES



READING

A pathway in the liver

Ethanol is turned into acetaldehyde by alcohol dehydrogenase, acetaldehyde into acetate by aldehyde dehydrogenase, and acetate into acetyl CoA, which enters the Krebs cycle. Ask: which enzyme has acetaldehyde as its product, and which as its substrate? What builds up if the second enzyme is slow? Methanol poisoning is treated with fomepizole, which binds the active site of alcohol dehydrogenase: why does that help, and what kind of inhibitor is it?

Needs: nothing but the guide. Fomepizole stops methanol being turned into formaldehyde and formic acid, the toxic products, while the methanol is excreted.

PLENARY

11
min

Free response, timed

Two parts of a free-response question on inhibitors or coupling, from the Unit 3 exam maker (in Practise and revise, below), in 6 minutes, then swap and mark against the scoring guide. For homework, the Check step: a fresh paper on 3.1 to 3.3 from the exam bank, marked as students go.

WHAT STUDENTS GET WRONG

"Breaking ATP's bond releases energy." Breaking any bond takes energy. ATP hydrolysis is exergonic because the products are more stable. Make students write the corrected sentence.

"A competitive inhibitor lowers the maximum rate." It raises the substrate needed to reach the same maximum. The graphs in chapter 6 and Task 3 of the dry lab settle it.

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STRETCH AND SUPPORT

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IN THE GUIDE

- 6** [Inhibitors block the site, or bend it](#)
- 7** [Staying alive takes a constant supply of energy](#)
- 8** [Pathways go in small steps, shared by all life](#)
- Lab** [Dry lab: Catalase and hydrogen peroxide](#)
- A11** [The whole guide, with the figures that play](#)
- PPTX** [This lesson's slides, in the order of this plan](#)

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How this was made. The course structure, the activities and the teaching choices come from my own classroom, my presentations and my years of teaching IB and AP Biology. I use Claude, an AI, to help write and build the interactive guides, lesson plans, slides and practice questions, and to draw the diagrams and code the interactives. I direct the work and review it against the IB and AP specifications before it goes live.