

The chain, the turbine and the whole journey HL

60 minutes • C1.2.13 to C1.2.16 • Chapters 10, 11

Reduced NAD and the electron transport chain, the proton gradient, ATP synthase and oxygen as the last acceptor

BY THE END, STUDENTS CAN

- ☐ Explain how electrons passed along the chain build a proton gradient across the inner membrane C1.2.13, C1.2.14
- ☐ Explain how ATP synthase uses the proton gradient to make ATP, and why oxygen is needed at the end of the chain C1.2.15, C1.2.16

TIMING

0-5	5 min	Do now: what does oxygen do?	
5-17	12 min	The chain	
17-30	13 min	The turbine	
30-38	8 min	The whole journey	
38-48	10 min	The loop game	
48-55	7 min	Plan an 8-mark answer	
55-60	5 min	Exit	
	60 min	One lesson	

STARTER

5 Do now: what does oxygen do?

min

In one sentence, what does oxygen do in respiration? Keep the answer for the exit.

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.

10 Down the chain

CHAPTER 10 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.

- Reduced NAD from all three stages arrives at the inner membrane.
- It hands a **pair of electrons** to the first carrier, and becomes NAD again.
- Each step down releases a little energy, used to **pump protons**.
- Protons pile up in the intermembrane space: a **proton gradient**.

Predict box: Electrons pass along the chain of carriers, releasing a little energy at each step. What is that energy used for? Hands up or mini whiteboards first.

Answer D: Pumping protons across the inner membrane

11 Protons through the turbine

CHAPTER 11 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. One way back for the protons: **ATP synthase**.
2. Protons flowing down the gradient turn it, and their energy joins **ADP and phosphate**: ATP.
3. **Oxygen** takes the electrons and protons at the end, making **water**.
4. **Chemiosmosis**: the gradient makes ATP, and oxygen keeps the chain flowing.

Play the animation, The chain and the turbine. It loops; pause it on each moment below and ask what is happening (in the lesson slides it is a video).

1. **Reduced NAD** from glycolysis, the link reaction and the Krebs cycle hands a **pair of electrons** to the first carrier, and becomes NAD again.
2. As the electrons pass along the chain they give up energy, which the carriers use to **pump protons** into the intermembrane space.
3. Protons pile up in the narrow space: a **proton gradient**. The membrane will not let them back through, except at one place.
4. Protons flow back down their gradient through **ATP synthase**, turning it. The energy joins **ADP and phosphate**: ATP.
5. **Oxygen** takes the electrons at the end of the chain, with protons from the matrix, making **water**. That keeps the electrons flowing.

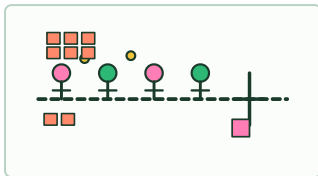
Predict box: A cell's mitochondria run out of oxygen. What happens to the electron transport chain? Hands up or mini whiteboards first.

Answer A: Electrons back up and the pumping stops

THE LESSON

12 min	The chain <u>Chapter 10</u> : the predict, then Be the chain (the role play below), then the figure, stopping on each caption.
13 min	The turbine <u>Chapter 11</u> : the predict, then the figure, then the chemiosmosis film: turn the oxygen off and watch what stops first.
8 min	The whole journey The HL respiration film from start to end. Switch the fuel to a fatty acid, then the cell to yeast. Grandma Likes Knitting Everything for the order: Glycolysis, Link reaction, Krebs cycle, Electron transport chain.
10 min	The loop game One card each (below), corrected: students read their answer and the next question until the loop is closed.
7 min	Plan an 8-mark answer Plan "Explain how ATP is made in the mitochondrion by chemiosmosis" in keywords (activity below). Write it for homework, then check it with <u>the Check step</u> .

ACTIVITIES

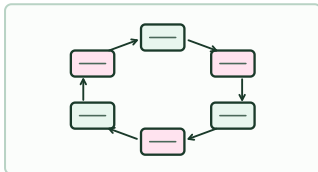


ROLE PLAY · HL

Be the chain

A rope on the floor is the inner membrane. Three students are pumps and two are carriers, standing on it; one is ATP synthase, a turnstile in the rope. "Reduced NAD" brings a pair of tennis balls (electrons) to the first pump; each time the balls are passed on, that pump moves one bean bag (a proton) across the rope into the "intermembrane space". When the space is crowded, bean bags may go back only through the turnstile, and each one that goes through hands an "ATP" card to the matrix. "Oxygen" at the end takes the balls and two bean bags. Then oxygen sits down: what happens?

Needs: a rope, two tennis balls, ten bean bags, ATP cards, labels on lanyards.

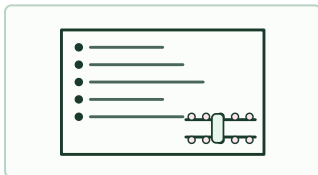


LOOP GAME · HL

The loop game

Eighteen cards, each an answer and a question, that loop back to the start. Each student reads their answer and the next question until the loop closes. The corrections to look for: aerobic respiration gives about 30 to 32 ATP (not 36 to 38); the Krebs cycle's main product is reduced NAD (no FADH_2 at IB); the product in humans is lactate (not "lactic acid"); and hydrolysis of ATP releases energy.

Needs: a printed set, one card per student.

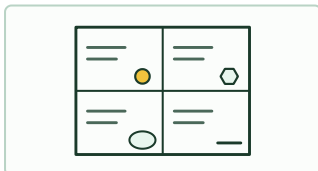


WRITING · HL

Plan an 8-mark answer

"Explain how ATP is made in the mitochondrion by chemiosmosis." Plan it in keywords first: reduced NAD from three stages, a pair of electrons to the first carrier, energy released along the chain, protons pumped into the intermembrane space, a gradient, ATP synthase, protons flow back, ADP and phosphate joined, oxygen as terminal acceptor, water, which keeps the chain flowing, and cristae for area. Then write it.

Needs: lined paper.



SUMMARY · HL (OPTIONAL)

Four corners

Divide a page into four: glycolysis, link reaction, Krebs cycle, and chain and chemiosmosis. In each corner, ten keywords and a small picture: where, what, why and how.

Needs: A3 paper.

PLENARY

5
min

Exit

Rewrite your Do now sentence so that it would earn two marks.

WHAT STUDENTS GET WRONG

The chain makes ATP. It makes a proton gradient; ATP synthase makes the ATP.

ATP synthase pumps protons. Protons flow down through it and turn it.

Oxygen turns into carbon dioxide. It ends up in water.

Aerobic respiration gives 36 to 38 ATP. About 30 to 32 is the figure now used. Many older sources and papers give 36 to 38.

STRETCH AND SUPPORT

Stretch: cyanide stops the last carrier passing electrons to oxygen. Predict, stage by stage, what stops in a cell, and why the blood leaving the tissues is still rich in oxygen while the cells run short of ATP (breathing and gas exchange are not respiration).

Stretch: make a Tarsia puzzle on C1.2 that is better than the site's own, in the Tarsia builder.

Consequences for ecosystems: respiration returns carbon dioxide to the air and releases heat at every transfer. Use both to start the energy flow of C4.2: where does the energy of a food chain go?

IN THE GUIDE

10 [Down the chain](#)

11 [Protons through the turbine](#)

A11 [The whole guide, with the figures that play](#)

PPTX [This lesson's slides, in the order of this plan](#)

EXAM PRACTICE

Check yourself

Set it for homework: a fresh paper of exam-bank questions on C1.2 at higher level each time, marked as students go and saved to their Exam practice when they are signed in.

biologybybradford.com/exam-maker/sit?topics=C1.2&level=HL&paper=quiz&marks=15&src=ep



PRACTISE AND REVISE

BUILD FOR YOUR CLASS

- [Tarsia puzzle, dominoes and picture reveal](#) on C1.2, built from its key terms and ready to print
- A [pub quiz](#) with rounds on C1.2, to present or run with no projector
- An [escape room](#) built from the [question bank](#) on C1.2

ALREADY ON THE SITE FOR C1.2

- Lesson: [Cell Respiration HL \(HL\)](#)
- Lesson: [Cell Respiration](#)
- Quiz: [Cell Respiration](#)
- Quiz: [Cell Respiration \(HL\)](#)
- Revision map: [C1.2 Cell respiration](#), to fill in
- Exam questions: [C1.2 in the exam maker](#), a paper with its markscheme

CARD SETS ON SPLYCR

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

- [C1.2 Cell Respiration](#)
- [B3.2–C2.2 Plant Transport, Respiration & Neural Signalling](#)

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.