

The Calvin cycle, and the whole system HL

60 minutes • C1.3.15 to C1.3.19 • Chapters 12, 13, 14, 15

Rubisco and carbon fixation, GP to TP, RuBP remade, every compound from the Calvin cycle, and why each half needs the other

BY THE END, STUDENTS CAN

- ☐ Explain how Rubisco fixes carbon dioxide onto RuBP, and why the stroma needs so much of it C1.3.15
- ☐ Follow the carbon through the Calvin cycle: GP reduced to TP, and five TP in six remade into RuBP C1.3.16, C1.3.17
- ☐ Explain how every carbon compound in a plant is made from the Calvin cycle's products with mineral nutrients C1.3.18
- ☐ Explain why the light-dependent and light-independent reactions stop without each other C1.3.19

TIMING

0-5	5 min	Do now: true or false?	
5-17	12 min	Rubisco	
17-29	12 min	Count the carbons	
29-35	6 min	Where the carbon goes	
35-45	10 min	Each half needs the other	
45-55	10 min	Hexagons	
55-60	5 min	Exit	
	60 min	One lesson	

STARTER

5
min

Do now: true or false?

True or false, with a reason: "The light-independent reactions happen at night."

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.

12 Fixing carbon, slowly

CHAPTER 12 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. **RuBP**, a five-carbon sugar, waits in **Rubisco's** active site.
2. **Carbon dioxide** joins it: **carbon fixation**.
3. The six carbons split into two **GP**.
4. Rubisco is slow, so a leaf makes **a lot** of it.

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 Rubisco cannot keep up.
2. Eleven keep pace with bright light.
3. With little carbon dioxide, each does less and fumbles more.
4. More Rubisco helps until light is the limit.

Predict box: A leaf cell could save a lot of protein by making less Rubisco. Why doesn't it? Hands up or mini whiteboards first.

Answer D: Each Rubisco fixes only a few CO₂ a second

13 GP to TP, and RuBP made again

CHAPTER 13 IN THE SLIDES

Step through the figure (6 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

1. Three **RuBP** wait for three **carbon dioxide**.
2. **Rubisco** fixes them: six **GP**.
3. **Reduced NADP** and **ATP** turn GP into **TP**.
4. One TP in six leaves the cycle.
5. Five **TP** are remade into three **RuBP**, using ATP.
6. Six turns, six carbon dioxide: one **glucose**.

Predict box: Of every six TP the Calvin cycle makes, how many must be used to remake RuBP? Hands up or mini whiteboards first.

Answer C: Five

Remember it: Fresh Rolls Rise (Fix, Reduce, Regenerate).

14 Every carbon came this way

CHAPTER 14 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. From TP: **sugars, starch** and **cellulose**.
2. **Lipids**.
3. **Amino acids**, with nitrogen from **nitrate**.
4. **Nucleotides**, with nitrogen and **phosphate**.

Play the animation, Follow one carbon atom. It loops; pause it on each moment below and ask what is happening (in the lesson slides it is a video).

1. One **carbon atom**, in a molecule of **carbon dioxide** in the air.
2. It **diffuses** in through a stoma and into a chloroplast.
3. **Rubisco** joins the CO₂ to **RuBP**; the product splits into two molecules of **GP**.
4. GP is reduced to **TP** with ATP and reduced NADP. One TP in six leaves the cycle; the rest remake RuBP.
5. Every carbon compound in the plant is made from the **Calvin cycle's** products. Here, with nitrogen from **nitrate** in the soil, an **amino acid**.
6. Joined into a **protein**, the atom stays in the plant until the plant, or whatever eats it, respires it.

Predict box: A plant has plenty of light, water and carbon dioxide, but its soil has no nitrate. Which will it fail to make? Hands up or mini whiteboards first.

Answer A: Proteins

15 Each half needs the other

CHAPTER 15 IN THE SLIDES

Switch the figure through Light and carbon dioxide, Lights off and No carbon dioxide, and have the class say what will change before each.

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

1. Into a leaf, a palisade cell, a **chloroplast**, and one **thylakoid** membrane.
2. Light energy passes through an **array of pigments** to the **reaction centre**, which emits an **excited electron**.
3. **Photolysis**: water is split. Its electrons refill photosystem II, its **protons** stay in the lumen, and its **oxygen** is a waste product.
4. Electrons passing along the chain pump protons into the lumen; protons flowing back through **ATP synthase** make **ATP**.
5. At **photosystem I** the electrons are lifted again and **reduce NADP**, with a proton from the stroma.
6. Sometimes the electron from photosystem I goes **back round** the chain (**cyclic**): more ATP, and no NADP reduced.
7. **Rubisco** fixes 3 **CO₂** onto 3 **RuBP**: 6 **GP**.
8. **ATP** and **reduced NADP** turn 6 GP into 6 **TP**; ADP and NADP go back to the thylakoid.
9. 1 **TP** leaves the cycle; the other 5 are remade into 3 **RuBP**, using ATP.
10. Two halves, each running on what the other makes: **ATP** and **reduced NADP** one way, **ADP** and **NADP** the other.

Play the animation, Respiration and photosynthesis on one map. It loops; pause it on each moment below and ask what is happening (in the lesson slides it is a video).

1. **The link reaction**, in the matrix: each pyruvate loses carbon dioxide and is oxidised, making reduced NAD, and coenzyme A carries the acetyl group on.
2. Reduced NAD from glycolysis, the link reaction and the Krebs cycle hands its electrons to the **electron transport chain**, and goes back as NAD.
3. ATP and reduced NADP from the thylakoid reduce GP to TP. One TP in six leaves; the other five, with more ATP, remake RuBP.
4. Follow **ATP**: made in glycolysis, the Krebs cycle, at the electron transport chain and in the thylakoid; used in glycolysis, the Calvin cycle and all over the cell.

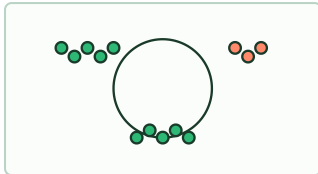
Predict box: A leaf in bright light is suddenly given no carbon dioxide. What happens to photosystem II? Hands up or mini whiteboards first.

Answer C: It stops, as NADP runs out further on

THE LESSON

12 min	Rubisco <u>Chapter 12</u> : the predict, the figure, then rounds 1 and 2 of the Rubisco race in pairs.
12 min	Count the carbons <u>Chapter 13</u> : the predict, then Count the carbons (below) in plasticine alongside the figure. Then the Fresh Rolls Rise tiles.
6 min	Where the carbon goes <u>Chapter 14</u> : the predict, then the carbon trail on its Built into the plant route.
10 min	Each half needs the other <u>Chapter 15</u> : the predict, the figure's three states, then the photosynthesis film, HL, with the light off and then the carbon dioxide off. The metabolism map's Follow a molecule, on ATP.
10 min	Hexagons Hexagons (below), in groups, telling the whole story.

ACTIVITIES

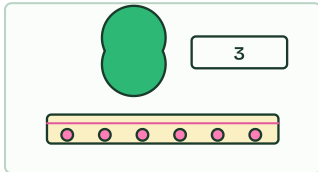


MODEL

Count the carbons

Plasticine balls as carbon atoms ([chapter 13](#)). Three RuBP of five balls each and three carbon dioxide of one: fix them into six GP of three; turn them into TP (an ATP card and a reduced NADP card each); take one TP out; remake three RuBP from the five left. Count the balls at every stage: fifteen plus three in, fifteen plus three out.

Needs: plasticine in two colours, and ATP and reduced NADP cards.

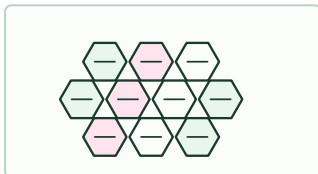


GAME

The Rubisco race

Pairs play rounds 1 and 2 on one device ([chapter 12](#)): how many Rubisco to keep up, and how many on the hot day?

Needs: a device per pair.

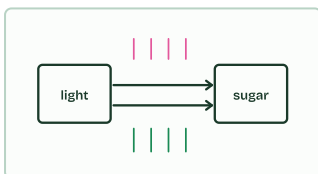


CARD SORT

Hexagons

Our own set of 24 hexagon cards (terms from both stages: photon, photosystem II, photolysis, oxygen, chain of carriers, proton gradient, ATP synthase, photosystem I, NADP, reduced NADP, stroma, lumen, Rubisco, RuBP, GP, TP, carbon dioxide, ATP, ADP, Calvin cycle, glucose, nitrate, starch, light). Groups join hexagons edge to edge only where they can say the link aloud, then tell the whole story in order.

Needs: printed hexagons for each group.



DIAGRAM

Improve the diagram

If there is time. A deliberately thin diagram of photosynthesis (two boxes, "light" in, "sugar" out). Students add every detail they now know, in two colours: one for SL and one for HL.

Needs: the printed diagram.

PLENARY

5
min

Exit

With no carbon dioxide, why does photosystem II stop?

WHAT STUDENTS GET WRONG

The light-independent reactions happen in the dark.

They need the light reactions' products, so they run in the light.

The light-dependent reactions make glucose. The Calvin cycle does.

Glyceraldehyde 3-phosphate is reduced in the Calvin cycle. GP (glycerate 3-phosphate) is reduced to TP.

Rubisco is abundant because it is used up. It is abundant because it is slow.

No carbon dioxide only stops the Calvin cycle. It stops photosystem II too ([chapter 15](#)).

STRETCH AND SUPPORT

Stretch: in the 1950s Calvin's group switched the light off on algae and measured the cycle's molecules: GP rose and RuBP fell. Explain both from the cycle.

Support: leave the Count the carbons balls on the bench while students write; use the Fresh Rolls Rise tiles as a frame.

Stretch: make a respiration and photosynthesis Tarsia puzzle in the Tarsia builder, ticking C1.2 and C1.3 together.

IN THE GUIDE

- 12** [Fixing carbon, slowly](#)
- 13** [GP to TP, and RuBP made again](#)
- 14** [Every carbon came this way](#)
- 15** [Each half needs the other](#)
- A11** [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 C1.3, built from its key terms and ready to print
- A [pub quiz](#) with rounds on C1.3, to present or run with no projector
- An [escape room built from the question bank](#) on C1.3

ALREADY ON THE SITE FOR C1.3

- Quiz: [Photosynthesis](#)
- Quiz: [Photosynthesis \(HL\)](#)
- Revision map: [C1.3 Photosynthesis](#), to fill in
- Exam questions: [C1.3 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.

- [C1.3 Photosynthesis \(SL\)](#)
- [C1.3 Photosynthesis \(HL\)](#)

EXAM PRACTICE

Check yourself

Set it for homework: a fresh paper of exam-bank questions on C1.3 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=C1.3&level=HL&paper=quiz&marks=15&src=ep



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.