DP Biology – C1.3

Photosynthesis

- How does photosynthesis capture and use the energy in sunlight?
- How do non-living factors affect photosynthesis?

SL statements C1.3.1–8. Textbook pp. 425–438.
Image: light passing through a leaf. Jon Sullivan, public domain.



Objectives for each class

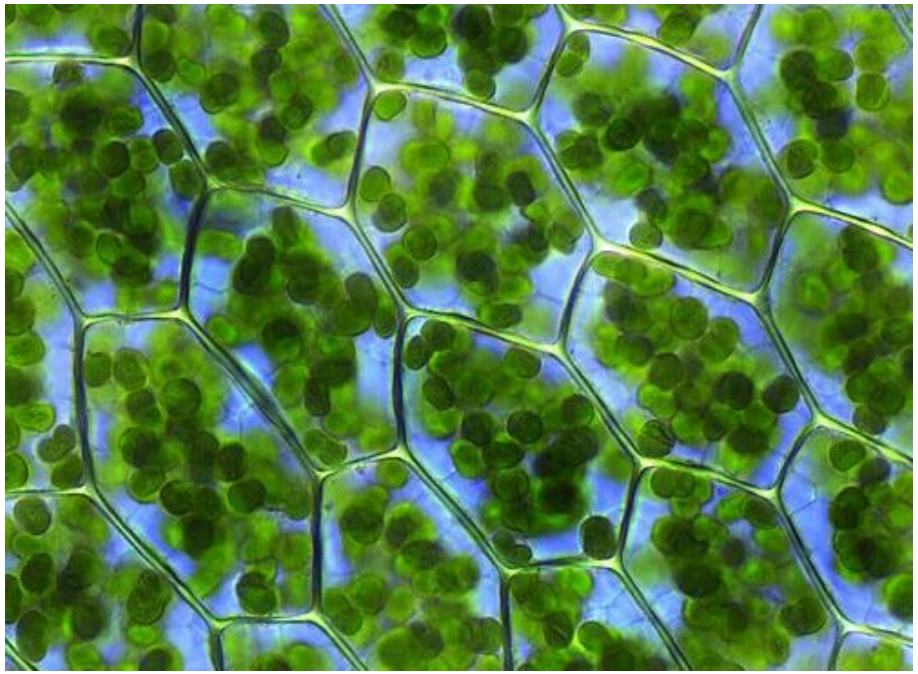
Class	Statements	By the end of the class, you can...
1	C1.3.1–3	Explain the energy change in photosynthesis, and write its word equation
2	C1.3.4–5	Separate pigments by chromatography, calculate Rf values, and explain how pigments absorb light
3	C1.3.6	Compare absorption and action spectra
4	C1.3.7–8	Investigate limiting factors, and explain what CO_2 enrichment experiments predict

Overview of this chapter

Part	Statements	What it covers
The process	C1.3.1–3	Energy, equation and oxygen
Pigments	C1.3.4–5	Chromatography and absorption of light
Spectra	C1.3.6	Absorption and action spectra
Limits	C1.3.7	Carbon dioxide, light and temperature
The future	C1.3.8	Greenhouse and FACE experiments

From light energy to chemical energy

C1.3.1



Chloroplasts in moss cells. Kristian Peters, CC BY-SA 3.0.

- Photosynthesis transforms **light energy** into **chemical energy**, stored in carbon compounds
- This happens in chloroplasts in plants and algae
- It supplies most of the chemical energy needed for life processes in ecosystems

Link

Nearly all food chains start with this. Organisms that make their own carbon compounds are autotrophs, and those that consume others are heterotrophs. Look ahead to C4.2 for how energy passes along food chains.

The word equation

carbon dioxide + water → glucose + oxygen

(using light energy)

- Water is split, in a reaction that needs light energy
- The hydrogen from water is used to reduce carbon dioxide
- This produces glucose, a carbon compound, which stores the energy
- Glucose can then be converted to starch and other compounds

Common mistake

The carbon in glucose comes from carbon dioxide, and the hydrogen comes from water. Do not say that a plant gets its mass from the soil.

Oxygen is a by-product



Stromatolites: living mats of cyanobacteria. Happy Little Nomad, CC BY-SA 2.0.

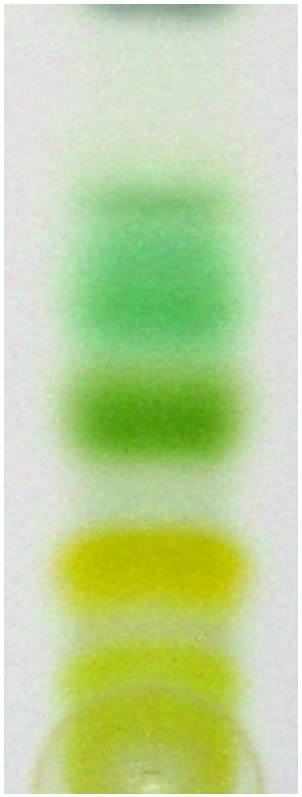
- Oxygen released comes from the **splitting of water**
- Plants, algae and cyanobacteria all do this
- It is a by-product: the organism does not need all of it, so it diffuses out
- Cyanobacteria first made oxygen build up in the atmosphere

Evidence

If plants are given water with a heavy isotope of oxygen, the oxygen gas that they release contains the heavy isotope. This shows that the oxygen comes from water, and not from carbon dioxide.

Separating pigments by chromatography

C1.3.4



Pigments on a strip. Flo, CC BY-SA 2.5.

1. Grind a leaf with a little solvent
2. Place a concentrated spot on a pencil line near one end of a strip
3. Dip the end in a solvent, keeping the spot above it
4. Pigments move at different speeds, as they differ in solubility
5. Mark the solvent front
6. Calculate **Rf** for each spot

Pigment	Colour
Carotene	Orange-yellow
Xanthophyll	Yellow
Chlorophyll a	Blue-green
Chlorophyll b	Yellow-green

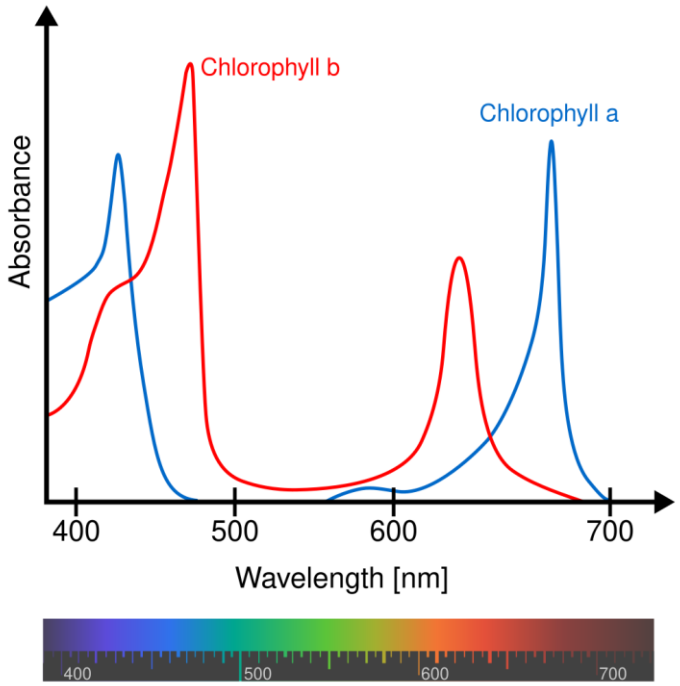
Formula

Rf = distance moved by pigment / distance moved by solvent

Worked example

A pigment moves 36 mm, and the solvent moves 80 mm. Rf = 36 / 80 = 0.45. Rf has no units. It depends on the solvent used, so identify the pigment by colour too.

How pigments absorb light



- When a pigment absorbs a photon, an **electron is excited** to a higher energy level
- Light energy has become chemical energy
- Only certain wavelengths have the right energy to do this
- Chlorophyll absorbs red and blue light best, and reflects green
- Other pigments widen the range of light used

Absorption spectra of chlorophyll a and b. Daniele Pugliesi, CC BY-SA 3.0.

Exam note

Be ready to label the horizontal axis of an absorption spectrum with both wavelengths (from about 400 to 700 nm) and colours.

Absorption and action spectra

	Absorption spectrum	Action spectrum
Vertical axis	Percentage of light absorbed	Rate of photosynthesis
Shows	What the pigments absorb	What the plant does with each wavelength
Peaks	Red and blue	Red and blue
Green	Very little absorbed	Lower rate, but not zero

Why do they differ slightly?

Both have similar shapes, as absorbed light drives photosynthesis. The action spectrum is higher in places, as a whole leaf has accessory pigments and light scatters around within it, so more of this light gets used.

Measuring the rate of photosynthesis

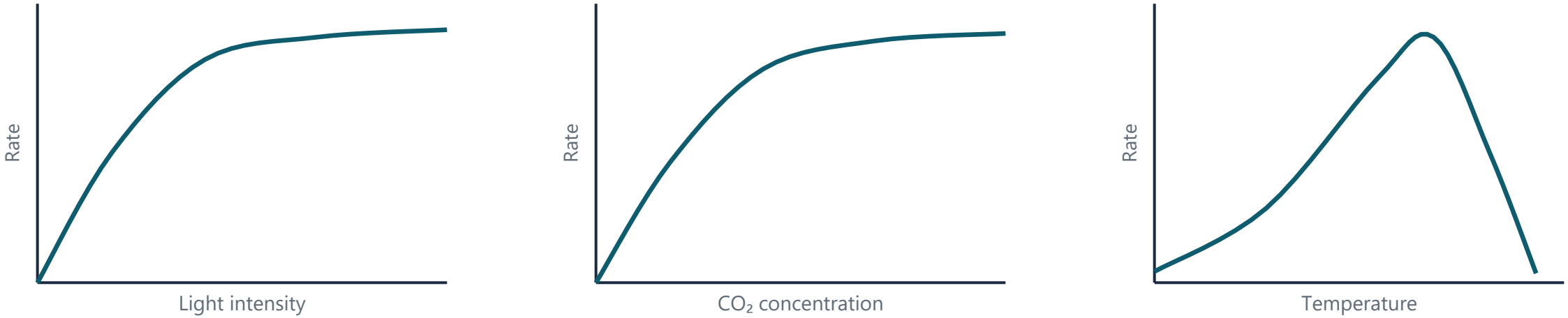
C1.3.7

Measure	How
Oxygen production	Count bubbles from pondweed, or collect the gas over a fixed time
Carbon dioxide use	Follow the pH of the water: it rises as CO_2 is used
Biomass	Find the dry mass of plants before and after a period of growth

Variable	How to change it
Light intensity	Move a lamp to measured distances
CO_2 concentration	Add different amounts of sodium hydrogencarbonate
Temperature	Stand the plant tube in water baths

Limiting factors

C1.3.7



General shapes only, with no numerical values.

- The rate is limited by whichever factor is furthest from its optimum
- Increasing that factor raises the rate, until another factor becomes limiting

Activity

For the graph of light intensity, say which factor limits the rate on the rising part, and which factors could limit it on the plateau. Then plan how you would test this.

CO_2 enrichment experiments



A greenhouse. Lolo425, CC BY-SA 3.0.



A FACE facility in Nevada. NNSA, public domain.

- CO_2 levels are rising
- So how will plants respond?
- Experiments raise CO_2 and measure growth

	Enclosed greenhouse	FACE (free-air enrichment)
Method	Add CO_2 to a closed space	Release CO_2 over open plots
Advantage	Easy to control other factors	Real conditions, with many species and soil

Most experiments find that growth rises at first, but less than expected, and it can level off when other factors become limiting. They help to predict future rates of photosynthesis.

Check that you can explain

1. The energy change in photosynthesis
2. The word equation
3. Where oxygen comes from
4. How to separate pigments, and calculate Rf
5. How pigments absorb light
6. Absorption and action spectra
7. How to measure rates and vary factors
8. Limiting factors, and CO_2 enrichment

Exit activity: 5 minutes

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

1. Write the word equation for photosynthesis.

2. A pigment moves 24 mm, and the solvent moves 60 mm. Calculate Rf.

3. State where the oxygen released in photosynthesis comes from.

Image credits

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Plagiomnium affine laminazellen.jpeg – Kristian Peters – Fabelfroh – CC BY-SA 3.0

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Chromatography of chlorophyll – Step 7.jpg – Flo~commonswiki – CC BY-SA 2.5

Chlorophyll ab spectra-en.svg – Original: Daniele Pugliesi Vector: M0tty – CC BY-SA 3.0

Greenhouse.jpg – Lolo425 – CC BY-SA 3.0

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