Photosynthesis Introduction

A Level

Part A Photosynthesis definition

Photosynthesis is the process by which energy from [ ] is used to produce glucose (and other organic molecules) from water and [ ].

Photosynthesis consists of two main stages.

- The [ ] stage: water is split into hydrogen ions (protons), electrons, and [ ]. The electrons and protons are used to produce ATP and NADPH.
- The [ ] stage: carbon dioxide goes through a series of reactions to produce [ ] molecules, which can then be used to produce glucose and other organic molecules (e.g. lipids and amino acids). This series of reactions uses the ATP and NADPH produced in the other stage.

Items:

triose phosphate **oxygen** **light-dependent** **carbon dioxide** **sunlight** **light-independent**

Part B Photosynthesis equation

Complete the equation to give the correct (and balanced) general equation for photosynthesis, with glucose produced as the end product.

$$6 + 6\,H_2O \longrightarrow \ + O_2$$

Part C Stages and locations

Match the stage of photosynthesis to the cell location in the table below.

Stage	Location
Light-dependent stage	
Light-independent stage	

Items:

cytoplasm **chloroplast thylakoid membrane** **mitochondrial inner membrane** **mitochondrial matrix**
chloroplast stroma **nucleus**

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The Light-dependent Stage

A Level

Part A Location

Where in a cell does the light-dependent stage take place?

- at the inner membrane of chloroplasts
- at the thylakoid membrane inside chloroplasts
- at the inner mitochondrial membrane
- at the outer mitochondrial membrane
- at the outer membrane of chloroplasts
- in the cytoplasm
- in the chloroplast stroma
- in the mitochondrial matrix

Which cell type is primarily responsible for photosynthesis in a plant?

- phloem companion cells
- root epidermal cells
- leaf epidermal cells
- xylem parenchyma cells
- leaf mesophyll cells

Part B Processes

Which of the following processes are part of the light-dependent stage of photosynthesis?

- [ ] photophosphorylation (can be non-cyclic or cyclic)
- [ ] oxidative phosphorylation
- [ ] photolysis of water
- [ ] the Calvin cycle
- [ ] Krebs cycle

Part C Reactants and products

Which of the following are **reactants** in the light-dependent stage? Select all that apply.

- [ ] water
- [ ] oxygen
- [ ] ATP
- [ ] ADP
- [ ] $NADP^+$
- [ ] NADPH (reduced NADP)
- [ ] CO_2
- [ ] triose phosphate

Which of the following are **products** in the light-dependent stage? Select all that apply.

- [ ] water
- [ ] oxygen
- [ ] ATP
- [ ] ADP
- [ ] $NADP^+$
- [ ] NADPH (reduced NADP)
- [ ] CO_2
- [ ] triose phosphate

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Gameboard:
STEM SMART Biology Week 32

Photophosphorylation

A Level

Photophosphorylation is the process by which light energy is used to phosphorylate ADP, producing ATP. The light-dependent stage of photosynthesis is comprised of this process and the photolysis of water.

Photophosphorylation can occur in two different ways: non-cyclic or cyclic.

Part A Non-cyclic photophosphorylation

Both non-cyclic and cyclic photophosphorylation depend on the ability of photosystems (transmembrane complexes of proteins and pigment molecules) to absorb light energy.

During non-cyclic photophosphorylation, light energy is absorbed by photosystem [ ]. Once this energy reaches the reaction centre of the photosystem (a region containing [ ] molecules), it excites an electron here to a higher energy level. This electron is then released and passes through a series of proteins embedded in the membrane called an [ ].

This process releases energy, which is used to actively pump protons ([ ] ions) [ ] the thylakoid lumen. These protons then move back through ATP synthase, providing the energy needed to produce ATP.

The electron lost by the photosystem is replaced by [ ].

Items:

I | oxygen | $NADP^+$ | NADPH | out of | II | the photolysis of water | hydrogen | electron transport chain | into | chlorophyll

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The electron from the [ ] is passed on to the reaction centre of photosystem [ ]. When this photosystem absorbs light energy, this electron is excited back to a higher energy level, and is again released and passed along another electron transport chain. The final electron acceptor of this electron transport chain is [ ], which is reduced to form [ ].

Items:

I | II | electron transport chain | hydrogen | oxygen | chlorophyll | $NADP^+$ | NADPH | the photolysis of water | into | out of

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Part B Cyclic photophosphorylation

Cyclic photophosphorylation, unlike non-cyclic photophosphorylation, only involves one photosystem (photosystem [ ]). Instead of the electron being passed to the electron transport chain that ends in producing [ ], the electron is passed to the first electron transport chain that is responsible for producing [ ]. This electron then returns back to photosystem [ ] through this electron transport chain, and so the process can keep cycling without requiring the [ ] or photosystem [ ].

Cyclic photophosphorylation produces ATP but not NADPH, both of which are required for the [ ]. Therefore, this form of photophosphorylation may be favoured by the cell if the ATP is needed for other processes.

Items:

I | **II** | **$NADP^+$** | **NADPH** | **ADP** | **ATP** | **photolysis of water** | **light-independent stage of photosynthesis**

Part C Non-cyclic vs cyclic

Which of the following statements are correct? Select all that apply.

- [ ] Non-cyclic photophosphorylation only involves the production of ATP, whereas cyclic photophosphorylation involves the production of both ATP and NADPH .
- [ ] Non-cyclic photophosphorylation involves the production of both ATP and NADPH, whereas cyclic photophosphorylation only involves the production of ATP.
- [ ] Non-cyclic photophosphorylation involves both photosystem **I** and photosystem **II**, whereas cyclic photophosphorylation only involves photosystem **I**.
- [ ] Non-cyclic photophosphorylation only involves photosystem **I**, whereas cyclic photophosphorylation involves both photosystem **I** and photosystem **II**.
- [ ] Cyclic photophosphorylation requires the photolysis of water, whereas non-cyclic photophosphorylation does not.
- [ ] Non-cyclic photophosphorylation requires the photolysis of water, whereas cyclic photophosphorylation does not.

Pondweed Bubbles

A Level

Pondweed, in a solution of sodium hydrogen carbonate, was placed in front of a light source to investigate the relationship between light intensity and the rate of photosynthesis. The number of bubbles of gas produced during a period of two minutes was recorded. The experiment was repeated with the light source at different distances from the pondweed.

The relationship between light intensity and distance (d) from a light source can be described as:

$$\text{light intensity} \propto \frac{1}{d^2}$$

Note that $\propto$ means "directly proportional to".

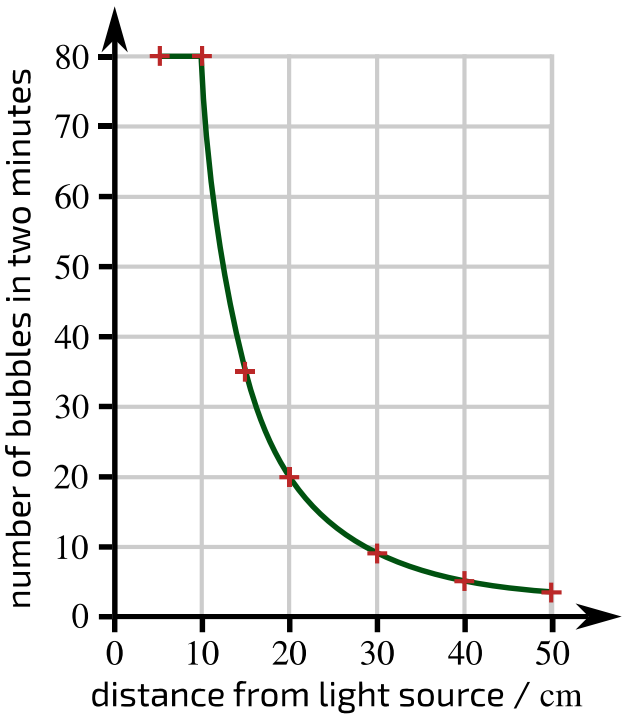

Figure 1: The number of bubbles produced by pondweed at different distances from a light source.

Part A Statements

Which of the following statements are correct? Select all that apply.

- [ ] The bubbles produced were composed mostly of carbon dioxide
- [ ] The bubbles produced were composed mostly of oxygen
- [ ] Between $5\,\mathrm{cm}$ and $10\,\mathrm{cm}$ the rate of photosynthesis is directly proportional to **the distance from the light source.**
- [ ] Between $5\,\mathrm{cm}$ and $10\,\mathrm{cm}$ the rate of photosynthesis is directly proportional to **light intensity.**
- [ ] Between $10\,\mathrm{cm}$ and $50\,\mathrm{cm}$ the rate of photosynthesis is directly proportional to **the distance from the light source.**
- [ ] Between $10\,\mathrm{cm}$ and $50\,\mathrm{cm}$ the rate of photosynthesis is directly proportional to **light intensity.**
- [ ] Light intensity was the limiting factor for photosynthesis at a distance of $5\,\mathrm{cm}$ from the pondweed.
- [ ] Light intensity was the limiting factor for photosynthesis at a distance of $30\,\mathrm{cm}$ from the pondweed.

Part B Volume of gas

The bubbles released by the pondweed went into a capillary tube of water that contained a gas bubble. The capillary tube had a diameter of $2.5\,\mathrm{mm}$.

In one experiment, the gas bubble expanded in length by $10\,\mathrm{mm}$ over the course of 2 minutes.

Calculate the rate of gas production. Give your answer to 2 significant figures.

Adapted with permission from NSAA 2022 Specimen Paper Section 2 Q29 and NSAA 2020 Section 1 Q73

Gameboard:
STEM SMART Biology Week 32

Photophosphorylation vs Oxidative Phosphorylation

A Level

Part A Overview

Fill in the blanks in the table below.

	Non-cyclic photophosphorylation	Oxidative phosphorylation
Part of the process of...		
Organelle		
Initial electron donor(s)		
Protons are pumped into the...		
Final electron acceptor		

Items:

photosynthesis | cytoplasm | chloroplasts | glucose | intermembrane space | matrix | stroma | $NADP^+$ | oxygen | aerobic respiration | thylakoid lumen | NADH and $FADH_2$ | water | mitochondria | anaerobic respiration

Part B Reactants

Which of the following are reactants in non-cyclic photophosphorylation? Select all that apply.

- [ ] oxygen
- [ ] water
- [ ] NAD^+
- [ ] NADH (reduced NAD)
- [ ] FAD
- [ ] $FADH_2$ (reduced FAD)
- [ ] $NADP^+$
- [ ] NADPH (reduced NADP)
- [ ] ADP
- [ ] ATP

Which of the following are reactants in oxidative phosphorylation? Select all that apply.

- [ ] oxygen
- [ ] water
- [ ] NAD^+
- [ ] NADH (reduced NAD)
- [ ] FAD
- [ ] $FADH_2$ (reduced FAD)
- [ ] $NADP^+$
- [ ] NADPH (reduced NADP)
- [ ] ADP
- [ ] ATP

Part C Products

Which of the following are products of non-cyclic photophosphorylation? Select all that apply.

- [ ] oxygen
- [ ] water
- [ ] NAD^+
- [ ] NADH (reduced NAD)
- [ ] FAD
- [ ] $FADH_2$ (reduced FAD)
- [ ] $NADP^+$
- [ ] NADPH (reduced NADP)
- [ ] ADP
- [ ] ATP

Which of the following are products of oxidative phosphorylation? Select all that apply.

- [ ] oxygen
- [ ] water
- [ ] NAD^+
- [ ] NADH (reduced NAD)
- [ ] FAD
- [ ] $FADH_2$ (reduced FAD)
- [ ] $NADP^+$
- [ ] NADPH (reduced NADP)
- [ ] ADP
- [ ] ATP

Light-dependent Labelling

A Level

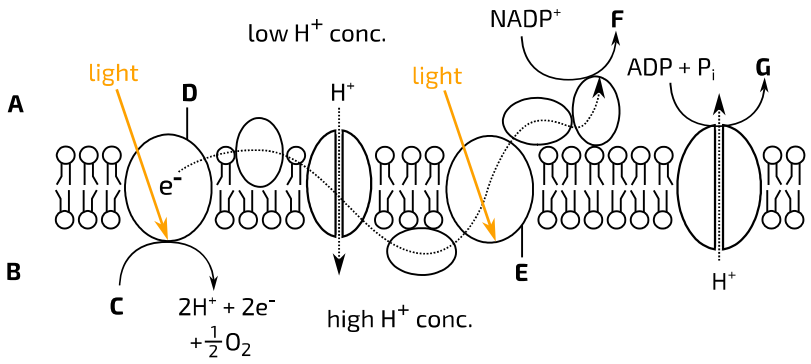

Figure 1: The light-dependent stage of photosynthesis. The diagram shows a region of a thylakoid membrane, and the process of non-cyclic photophosphorylation. "A" and "B" label different sides of the membrane. P_i = inorganic phosphate.

Part A Label the diagram

Match the descriptions to the labels in the table below.

Label	Description
A	
B	
C	
D	
E	
F	
G	

Items:

oxygen | NADH (reduced NAD) | NAD^+ | ATP | NADPH (reduced NADP) | photosystem I | photosystem II | water | inside the thylakoid (thylakoid lumen) | outside the thylakoid (chloroplast stroma)

Part B Name the process

In **Figure 1**, molecule C is split by light energy into hydrogen ions, electrons, and oxygen.

What is the name of this process?

Part C Chlorophyll

Which letters in **Figure 1** label molecules/complexes that contain chlorophyll *a* molecules? Select all that apply.

- [ ] A
- [ ] B
- [ ] C
- [ ] D
- [ ] E
- [ ] F
- [ ] G

Part D Proton pumping

In **Figure 1**, protons (hydrogen ions) are initially transported from an area of low concentration to an area of high concentration.

What is the name given to this kind of transport?

After being transported from an area of low concentration to and area of high concentration, the protons then move back to the area of low concentration through a channel protein that also acts as an enzyme.

What is the name of this channel protein/enzyme?

Part E Electron movement

What is the name give to a series of protein complexes that electrons move along, releasing energy as they do so? (e.g. between D and E in **Figure 1**)

Adapted with permission from OCR A Level November 1999, Biology, Molecules and Life, Question 7