Photosynthesis
5.2.1

January 24, 2018

5.2.1 Photosynthesis

Photosynthesis is the process whereby light from the Sun is harvested and used to drive the production of chemicals, including ATP, and used to synthesise large organic molecules from inorganic molecules.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(b)	the structure of a chloroplast and the sites of the two main stages of photosynthesis	The components of a chloroplast including outer membrane, lamellae, grana, thylakoid, stroma and DNA.
(c)	**(i)** the importance of photosynthetic pigments in photosynthesis	To include reference to light harvesting systems and photosystems.

Word and Symbol Equations for Photosynthesis

Word:

$$+ \qquad \longrightarrow \qquad +$$

Symbol:

$$+ \qquad \longrightarrow \qquad +$$

Photosynthesis can be broken down into TWO stages:

The LIGHT-DEPENDENT Reaction

Requires light.
Occurs in the thylakoid membranes of chloroplasts.
ATP and NADPH are produced.
Water is oxidised to oxygen.

The LIGHT-INDEPENDENT Reaction

Does not require light.
Occurs in the stroma of the chloroplast.
Uses the ATP and NADPH from the light-dependent reaction to make
Glucose and other organic compounds from carbon dioxide.

Light Dependent Reaction

5.2.1 Photosynthesis

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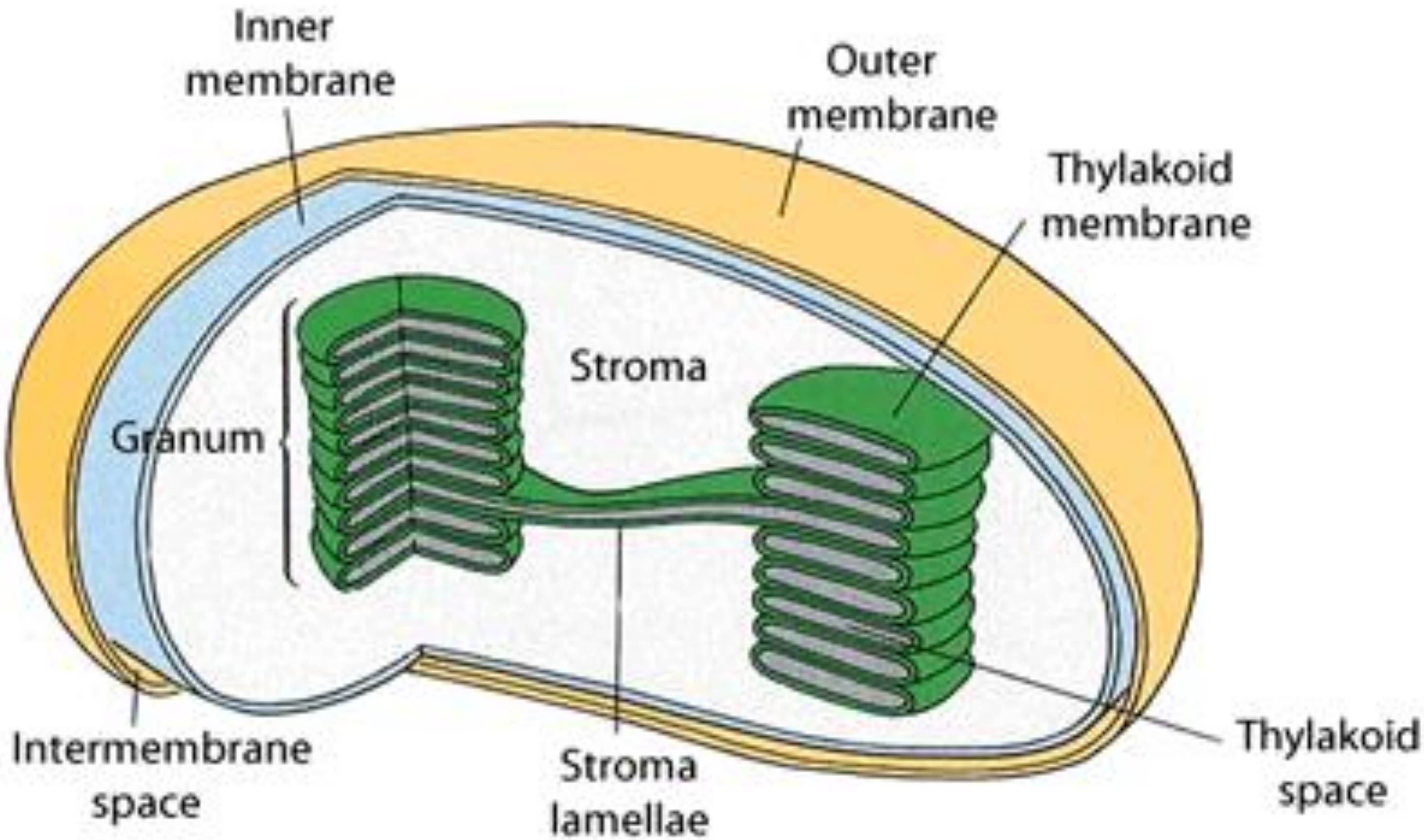
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(d)	the light-dependent stage of photosynthesis	To include how energy from light is harvested and used to drive the production of chemicals which can be used as a source of energy for other metabolic processes (ATP and reduced NADP) with reference to electron carriers and cyclic and non-cyclic photophosphorylation **AND** the role of water.

ATP is synthesised from one of three reactions:

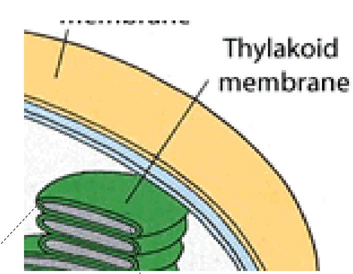
1. **PHOTOPHOSPHORYLATION**. The addition of an inorganic phosphate molecule to ADP in CHLOROPLASTS during PHOTOSYNTHESIS.

2. **OXIDATIVE PHOSPHORYLATION**. The addition of an inorganic phosphate molecule to ADP in MITOCHONDRIA of plant and animal cells during ELECTRON TRANSPORT.

3. **SUBSTRATE-LEVEL PHOSPHORYLATION**. The addition of an inorganic phosphate molecule to ADP from DONOR MOLECULES, such as the formation of pyruvate in glycolysis.


Inner
membrane
Outer
membrane
Thylakoid
membrane
Stroma
Granum
Intermembrane
space
Stroma
lamellae
Thylakoid
space

Chloroplasts contain the photosynthetic pigments – **chlorophyll a, chlorophyll b, carotene** – that absorb light energy needed for photosynthesis.



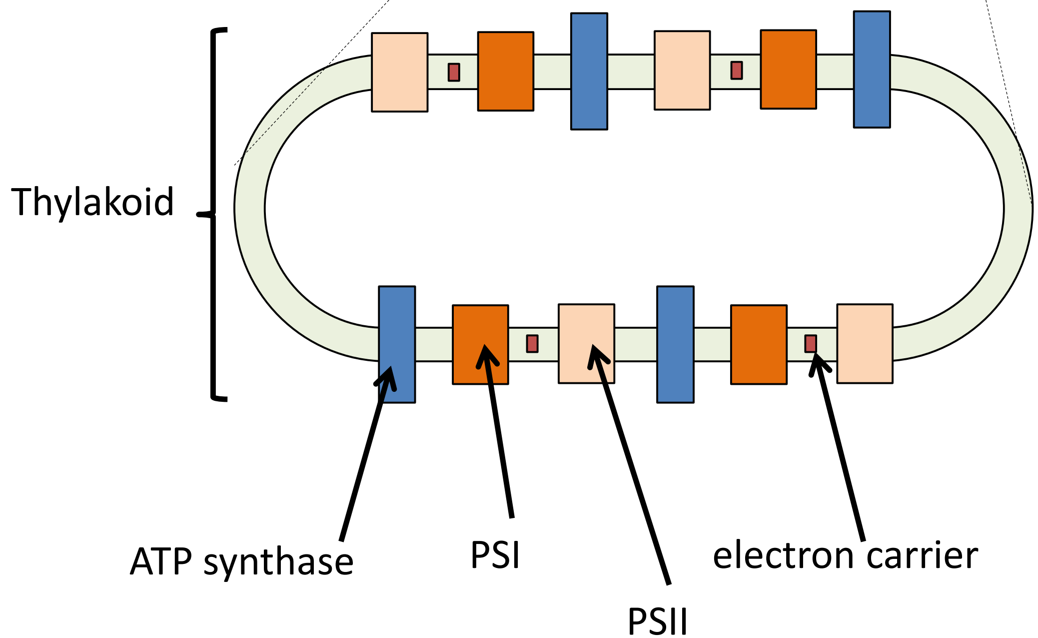
These pigments are attached to the thylakoid membranes, in association with proteins. These pigment + protein complexes are called **PHOTOSYSTEMS**.

A membrane with some proteins, an electron carrier and ATP synthase, used to create ATP. Sound familiar…

PHOTOSYSTEM I (PSI)
Absorbs light best at a wavelength of 700nm

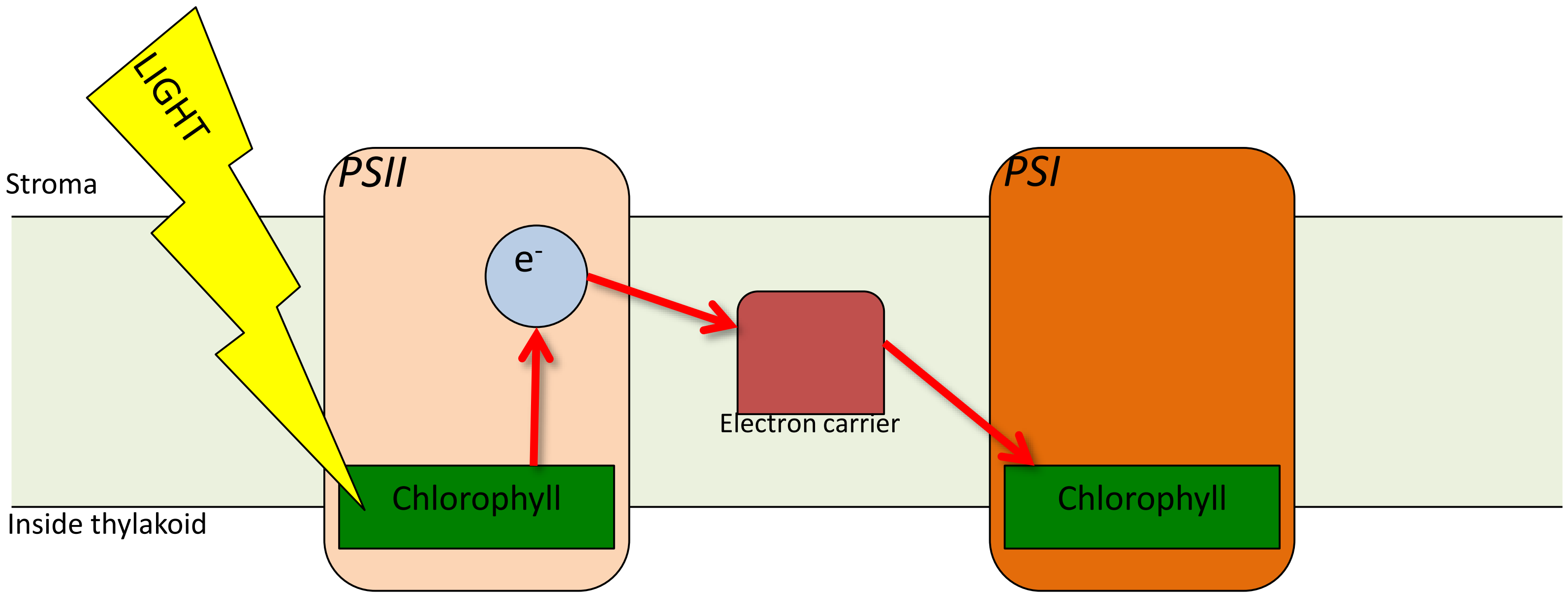
PHOTOSYSTEM II (PSII)
Absorbs light best at a wavelength of 680nm.

Both contain a mixture of chlorophylls a & b, and carotene.



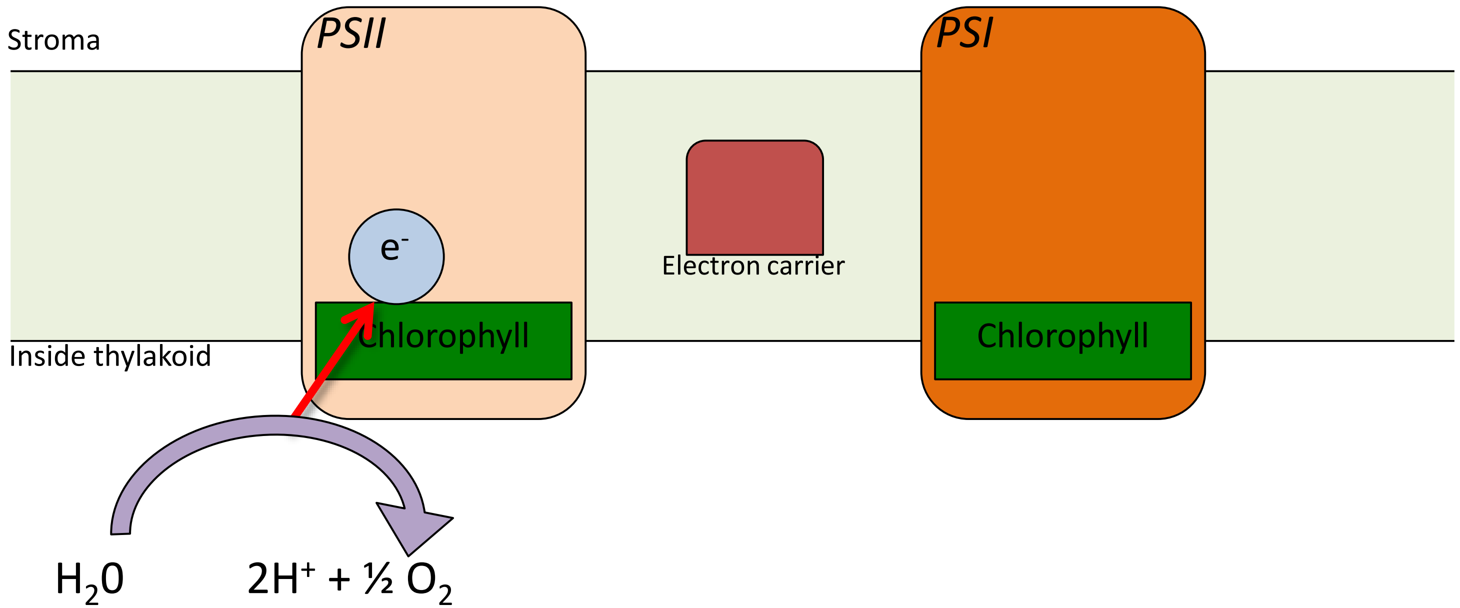
Non-Cyclic Photophosphorylation

1. Light energy excites electrons in chlorophyll.



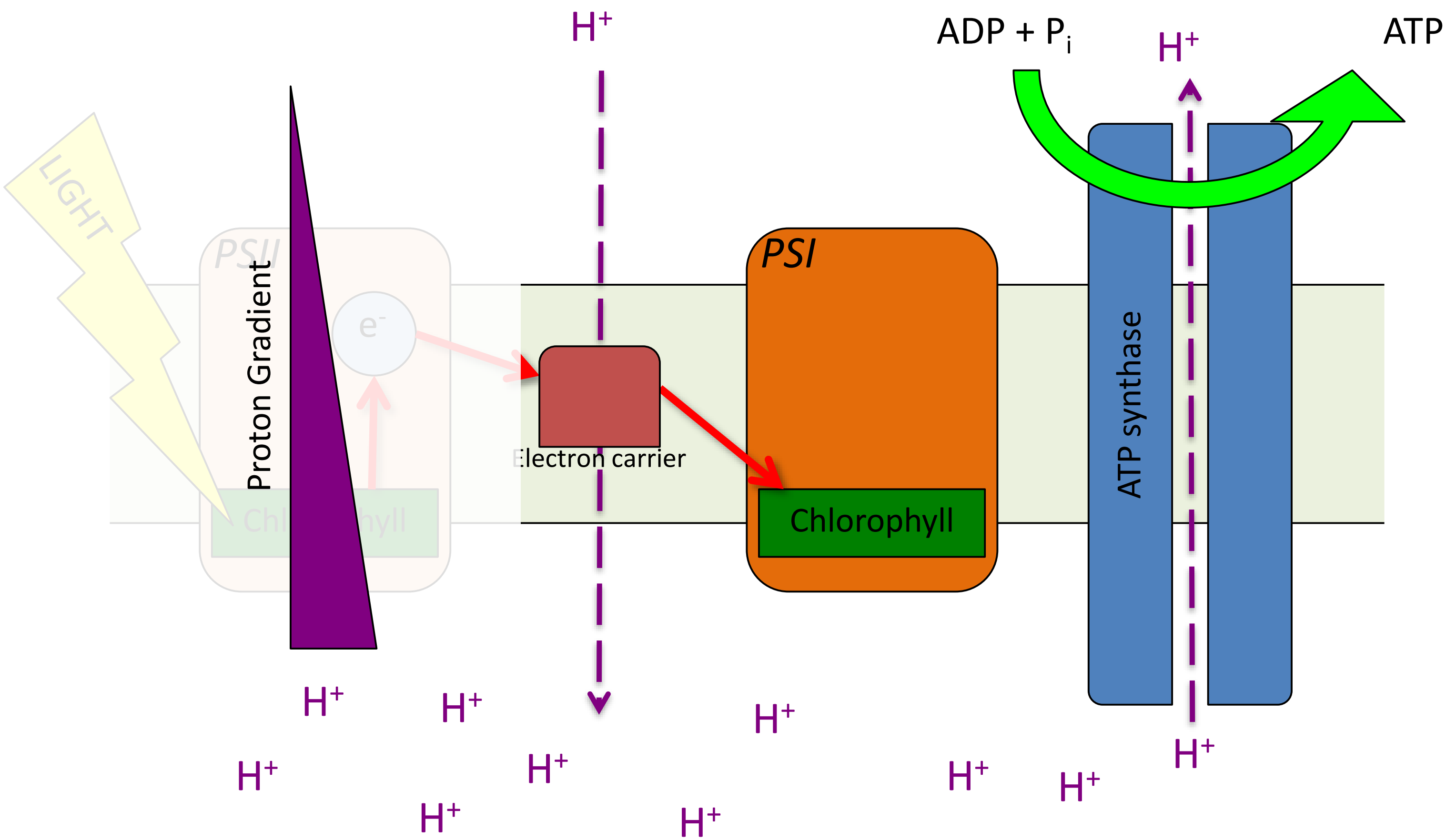
- Light energy absorbed by **PSII**.
- Light energy excites electrons in **chlorophyll**.
- Electrons move to a higher energy level.
- High energy electrons move along the **electron transport chain** to **PSI**.

2. **Photolysis**



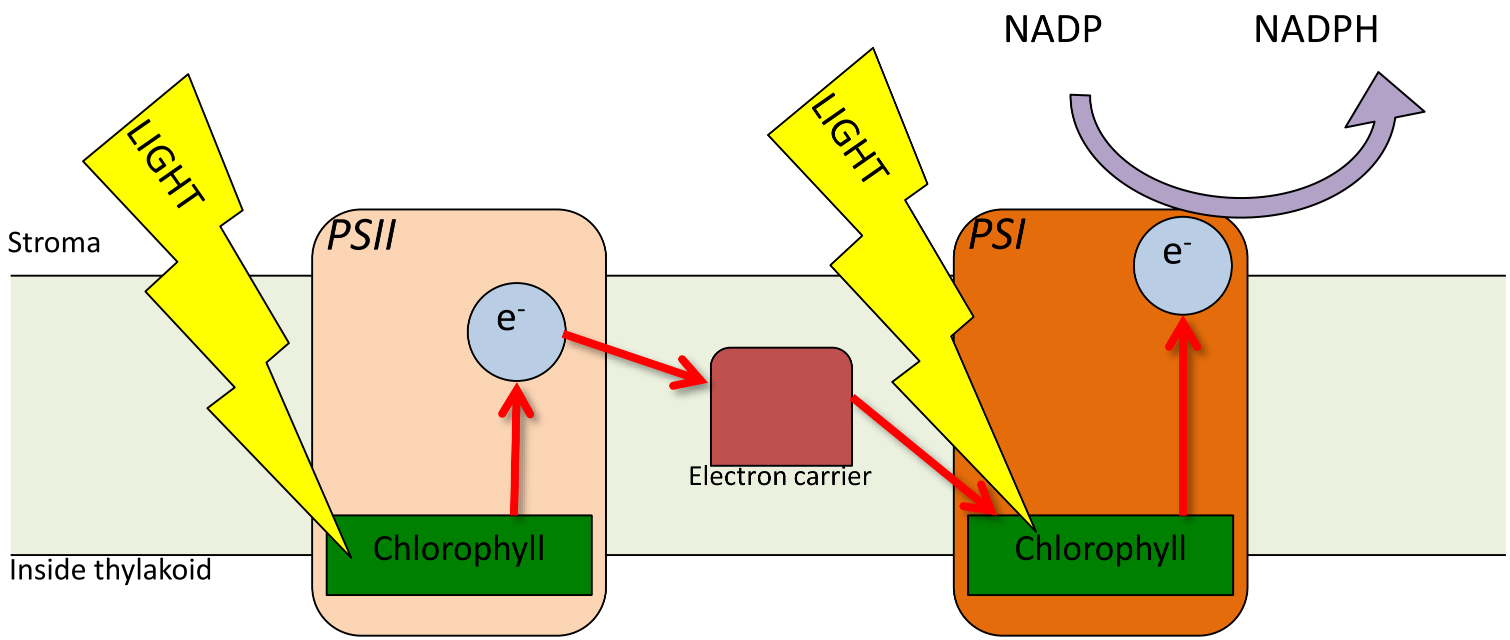
- As the excited electrons from chlorophyll leave **PSII** to move along the electron transport chain, they must be replaced.
- Light energy splits water into protons (H^+), electrons and oxygen.

3. <u>Energy from the excited electrons makes ATP.</u>



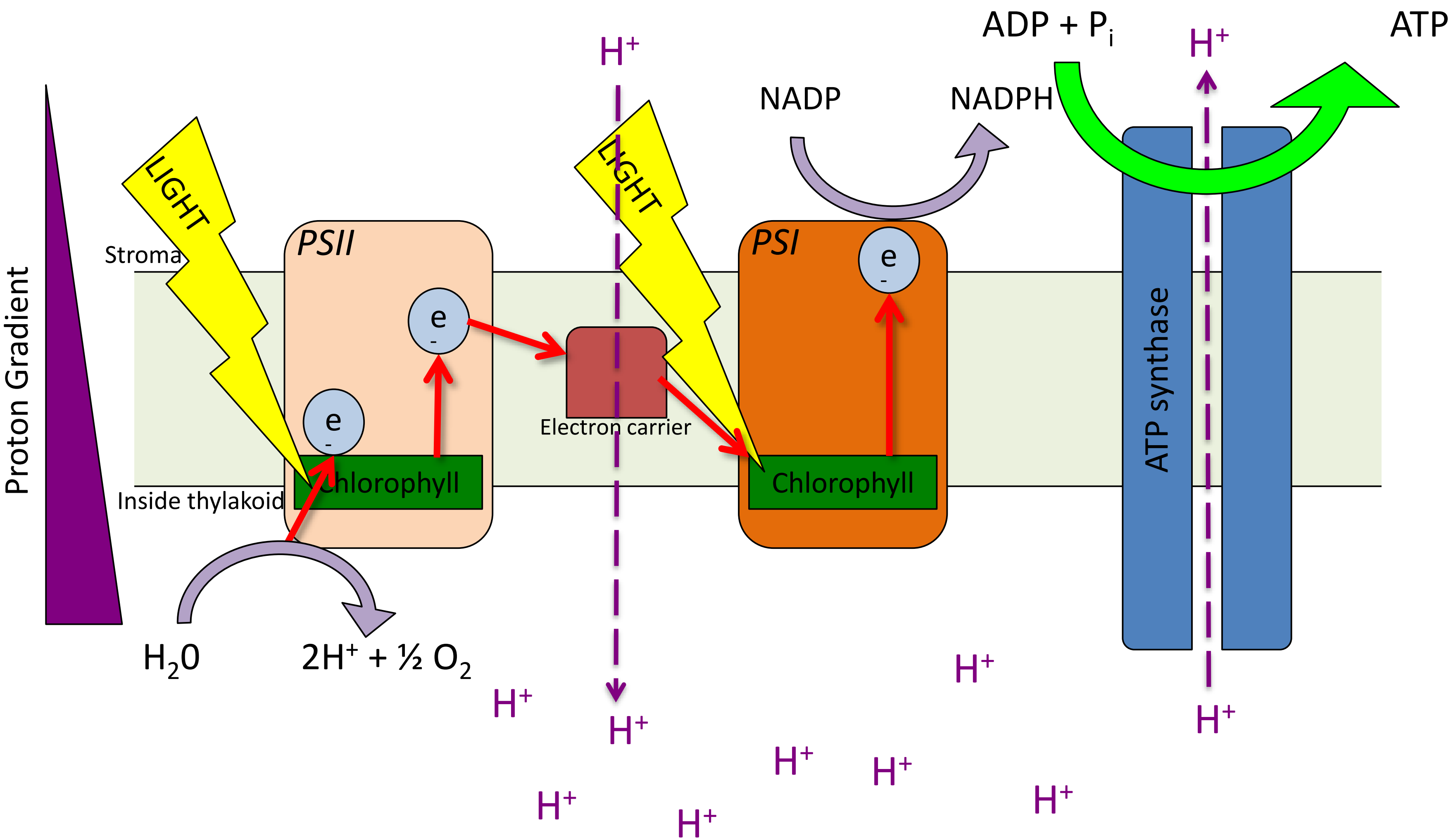
- The excited electrons lose energy as they move along the **electron transport chain**.
- This energy is used to transport **protons (H^+)** into the **thylakoid** .
- This means that the thylakoid has a higher concentration of protons that the stroma.
- This forms a **proton gradient** across the membrane.
- Protons move down their concentration gradient, into the stroma, via an enzyme called **ATP synthase**.
- The energy from this movement combines **ADP** and phosphate to form **ATP**.

4. Energy from the excited electrons generates reduced NADP.



- Light energy is absorbed by **PSI**.
- This excites the electrons again to an even higher energy level.
- These electrons are transferred to NADP, along with a proton from the stroma, to form **reduced NADP**.
- Reduced NADP is used in the Light-Independent reaction of photosynthesis.

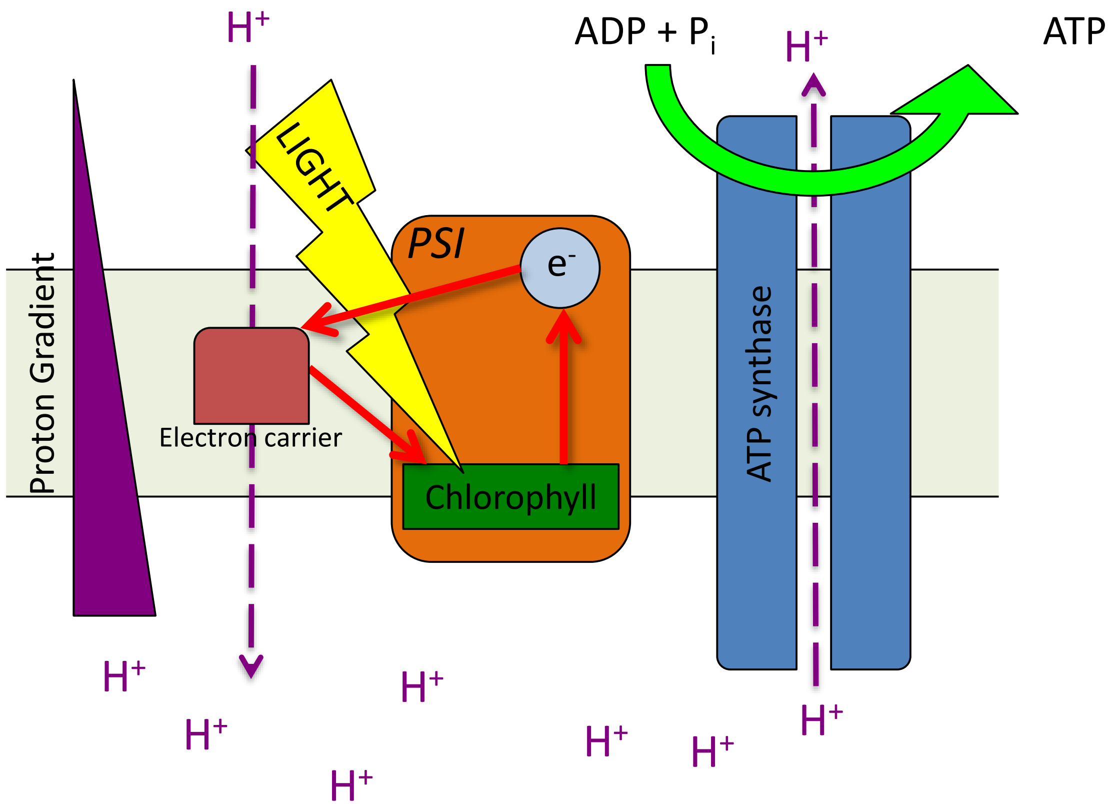
Non-Cyclic Photophosphorylation



The H^+ produced by photolysis supplement those imported into the thylakoid by the electron carrier

Cyclic Photophosphorylation – for very active plant cells, such as guard cells, that need a bit more ATP

- Produces small amounts of **ATP**.
- Only uses **PSI**.
- 'Cyclic' because the electrons from the chlorophyll molecule are not passed onto NADP, but are passed back to PSI via **electron carriers**.
- Electrons are recycled and can repeatedly flow through PSI.
- Does not produce any reduced NADP or oxygen.



To Do:

1. Fact Recall and Application Questions p. 34 &35 CGP text book. Self-mark, p. 238.

2. Label the diagrams.

3. Word Sort activity.

4. Past paper questions.

Light Independent Reaction
(also called the CALVIN CYCLE)

5.2.1 Photosynthesis

Photosynthesis is the process whereby light from the Sun is harvested and used to drive the production of chemicals, including ATP, and used to synthesise large organic molecules from inorganic molecules.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(e)	the fixation of carbon dioxide and the light-independent stage of photosynthesis	To include how the products of the light-dependent stage are used in the light-independent stage (Calvin cycle) to produce triose phosphate (TP) with reference to ribulose bisphosphate (RuBP), ribulose bisphosphate carboxylase (RuBisCO) and glycerate 3-phosphate (GP) – **no** other biochemical detail is required. HSW8
(f)	the uses of triose phosphate (TP)	To include the use of TP as a starting material for the synthesis of carbohydrates, lipids and amino acids **AND** the recycling of TP to regenerate the supply of RuBP.

Occurs in the stroma of the chloroplast.

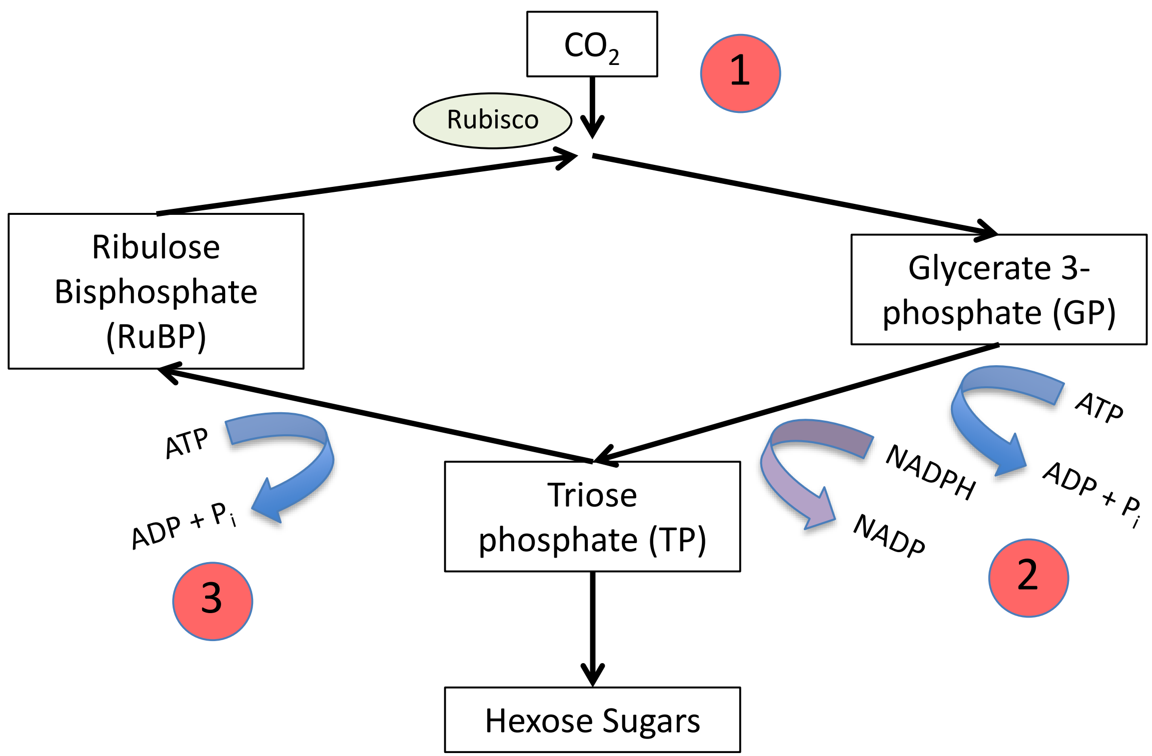
Uses the ATP and NADPH produced in the light-dependent reaction to produce Hexose Sugars, Lipids and Proteins.

Hexose Sugars: 6 carbon sugars, e.g. Glucose, which can be joined together to make more complex carbohydrates that the plant needs, e.g. sucrose, starch, cellulose.

The light-independent reaction uses Carbon dioxide to make **TRIOSE PHOSPHATE (TP)** and **RIBULOSE BISPHOSPHATE (RuBP)**.

The TP is used to make the hexose sugars and other organic substances.

The reaction is a cycle, and so the end product (RuBP) is also the starting product of the next cycle, similar to the Krebs cycle in respiration.

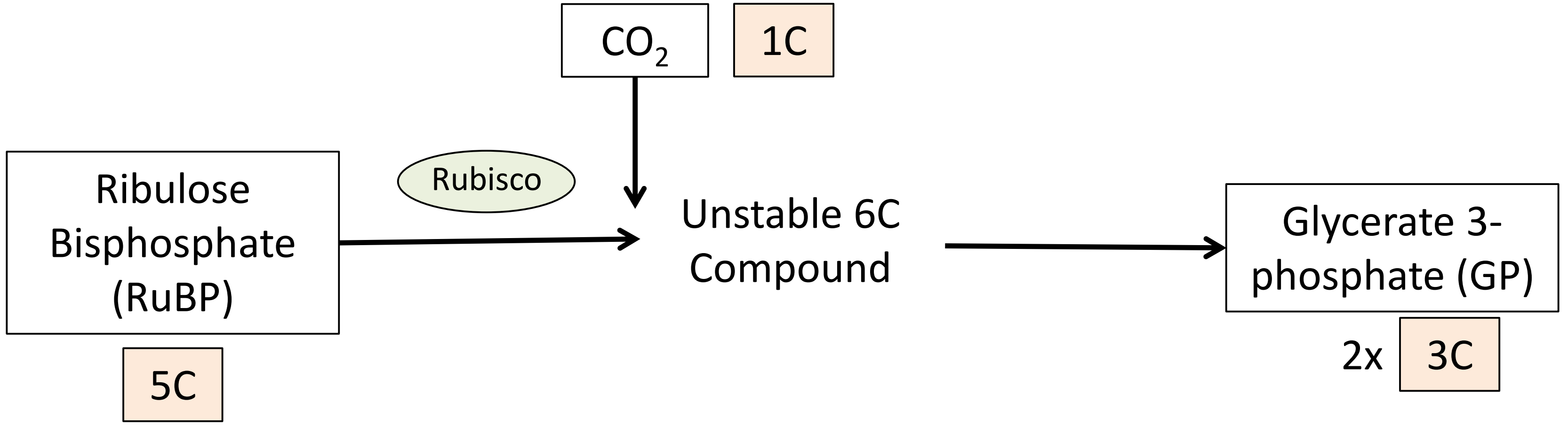


1

Carbon dioxide entering the stroma combines with RuBP.

This is catalysed by Ribulose bisphosphate carboxylase (Rubisco).

This produces an unstable 6C compound which rapidly breaks down into two molecules of 3C GP.

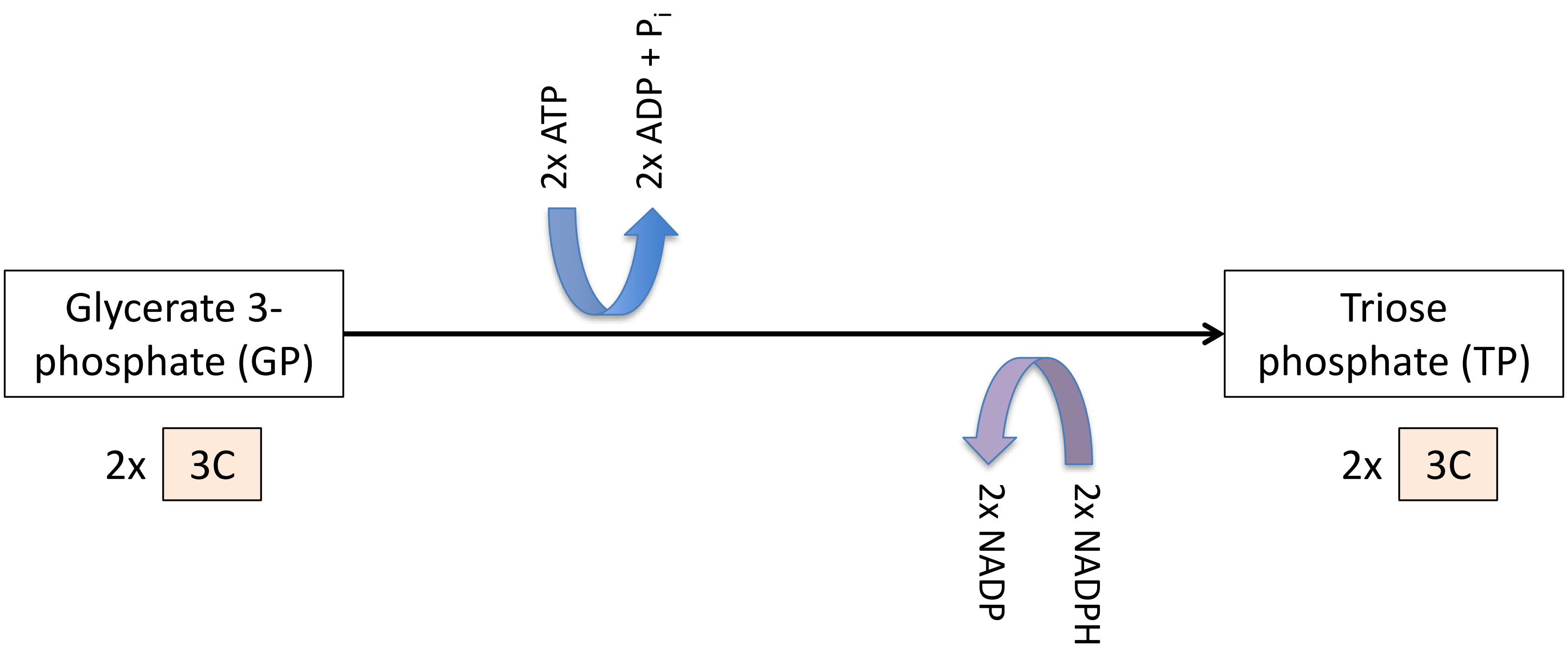


2

The 3C GP is **REDUCED** to the 3C TP.

ATP from the light-dependent reaction provides the energy for this.

The H^+ ions come from the NADPH. Both ADP + P_i and NADP are recycled back to the light-dependent reaction.

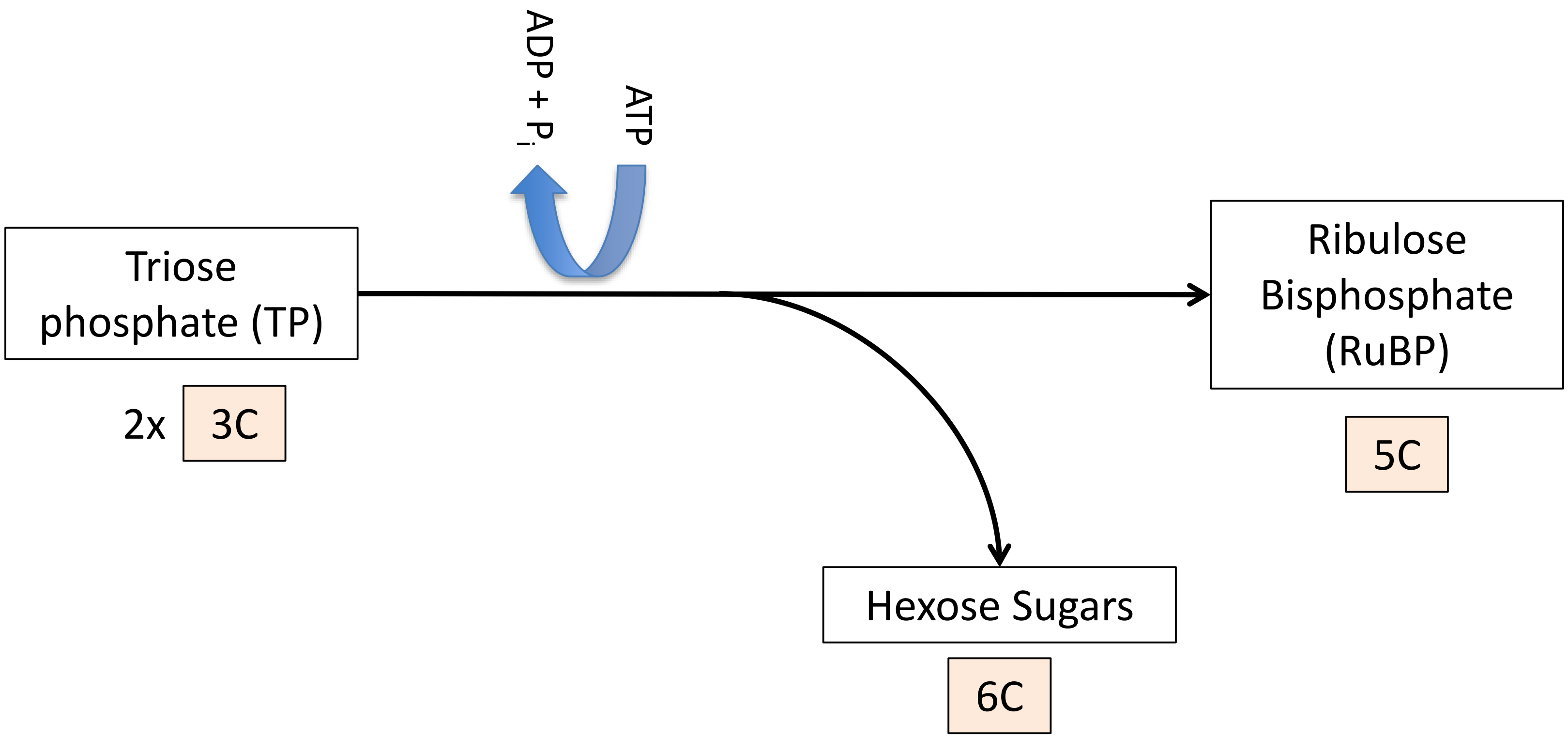


3

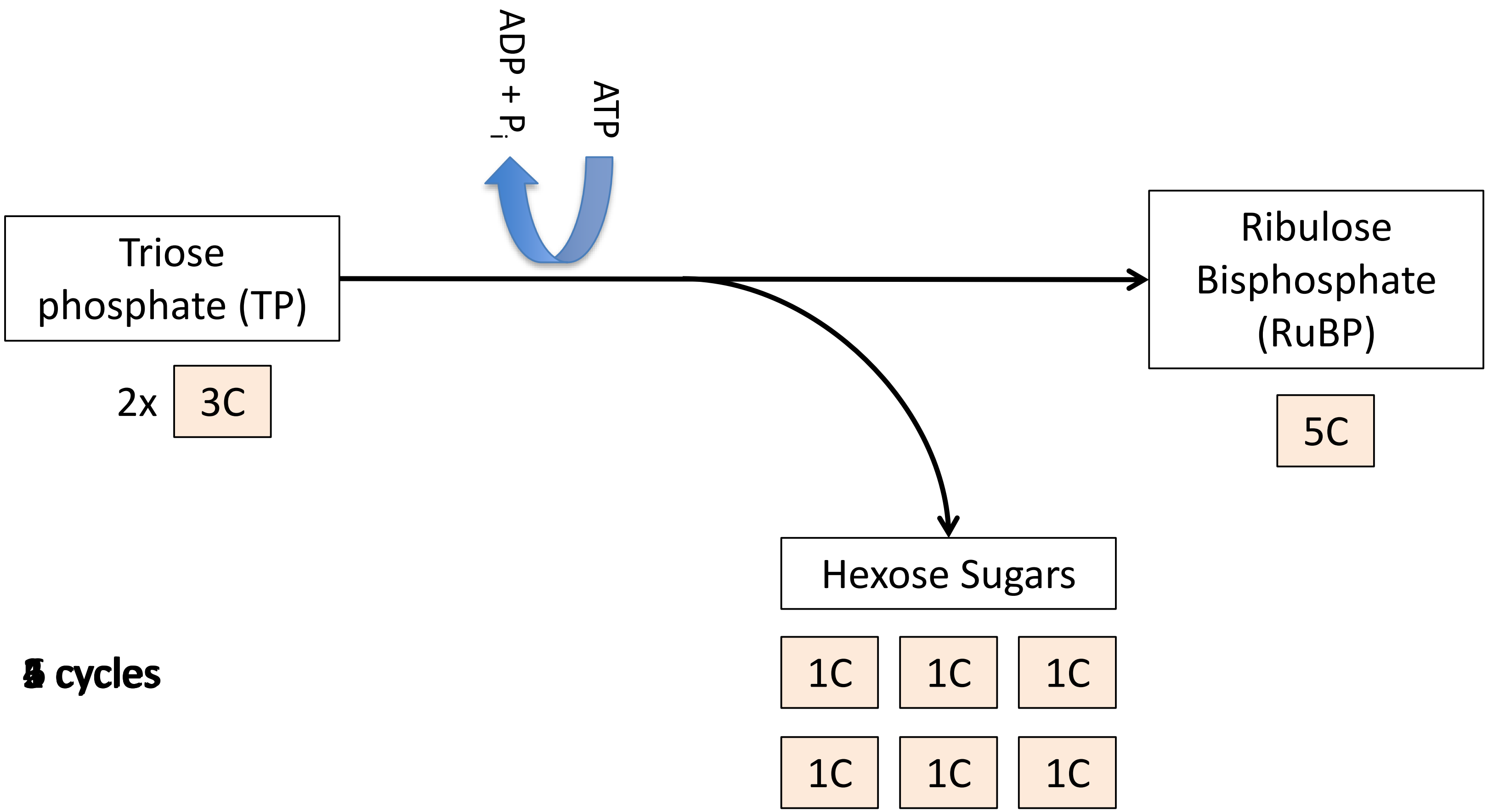
RuBP is regenerated from the TP, using energy from the remaining ATP.

TP is also converted into the hexose sugars and other useful organic molecules.

However, in each cycle there are 2x 3C TP molecules used to produce a 6C hexose sugar and the 5C RuBP. How?



It turns out that in each cycle TP donates only 1C to the formation of a hexose sugar, and so the Calvin Cycle has to cycle 6 times to make one hexose sugar.



To Do:

1. Produce your own diagrams (overview plus the three stages).

2. Fact Recall and Application Questions p. 38 CGP text book. Self-mark, p. 238.

1. Past paper questions.

Limiting Factors

5.2 Energy for biological processes

5.2.1 Photosynthesis

Photosynthesis is the process whereby light from the Sun is harvested and used to drive the production of chemicals, including ATP, and used to synthesise large organic molecules from inorganic molecules.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(g)	**(i)** factors affecting photosynthesis **(ii)** practical investigations into factors affecting the rate of photosynthesis.	To include limiting factors in photosynthesis with reference to carbon dioxide concentration, light intensity and temperature, and the implications of water stress (stomatal closure) **AND** the effect on the rate of photosynthesis, and on levels of GP, RuBP and TP, of changing carbon dioxide concentration, light intensity and temperature.

Research:

1. What are the limiting factors of photosynthesis?

2. How do each of these limiting factors affect the levels of GP, RuBP and TP?

You have 70 mins to research and produce a 2 minute presentation to the class.