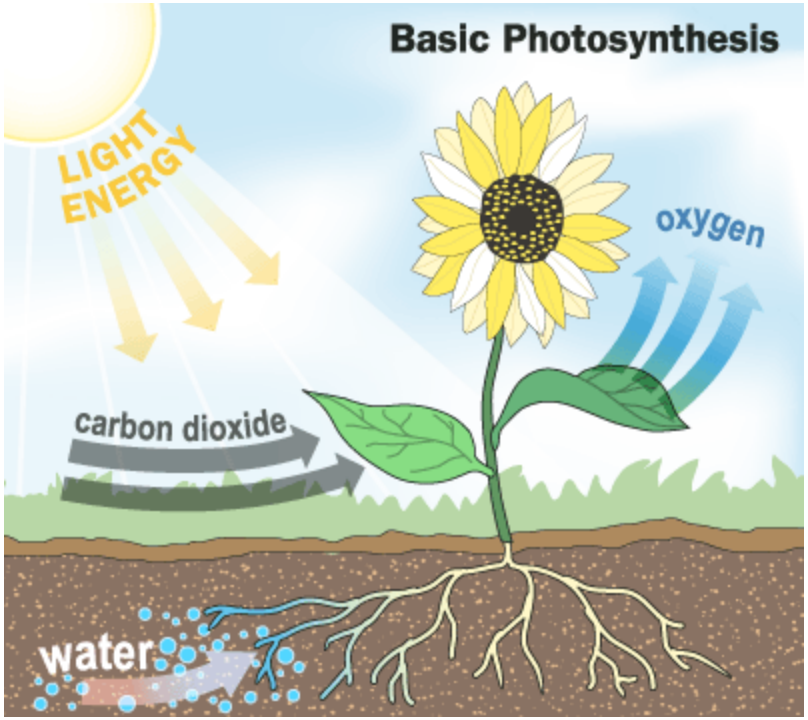
Photosynthesis

Plants making their own food



HL

1. (a) An autotrophic organism is one that makes its own food.

(b) Trap light energy, produce high-energy electrons.

(c) $6CO_2 + 6H_2O = C_6H_{12}O_6 + 6O_2$

(d) Chloroplasts.

(e) Diagram showing inner membrane, outer membrane, starch granule, grana, stroma, DNA, lamella. (Five of these correctly labelled.) (f) Double membrane and its own DNA

OL

1. (a) Using light to make glucose.

(b) (Sun)light.

(c) Trap energy or light.

(d) $6CO_2 + 6H_2O = C_6H_{12}O_6 + 6O_2$

(e) Chloroplasts.

(f) Water.

(g) (ii) Stomata. (iii) Oxygen and carbon dioxide.

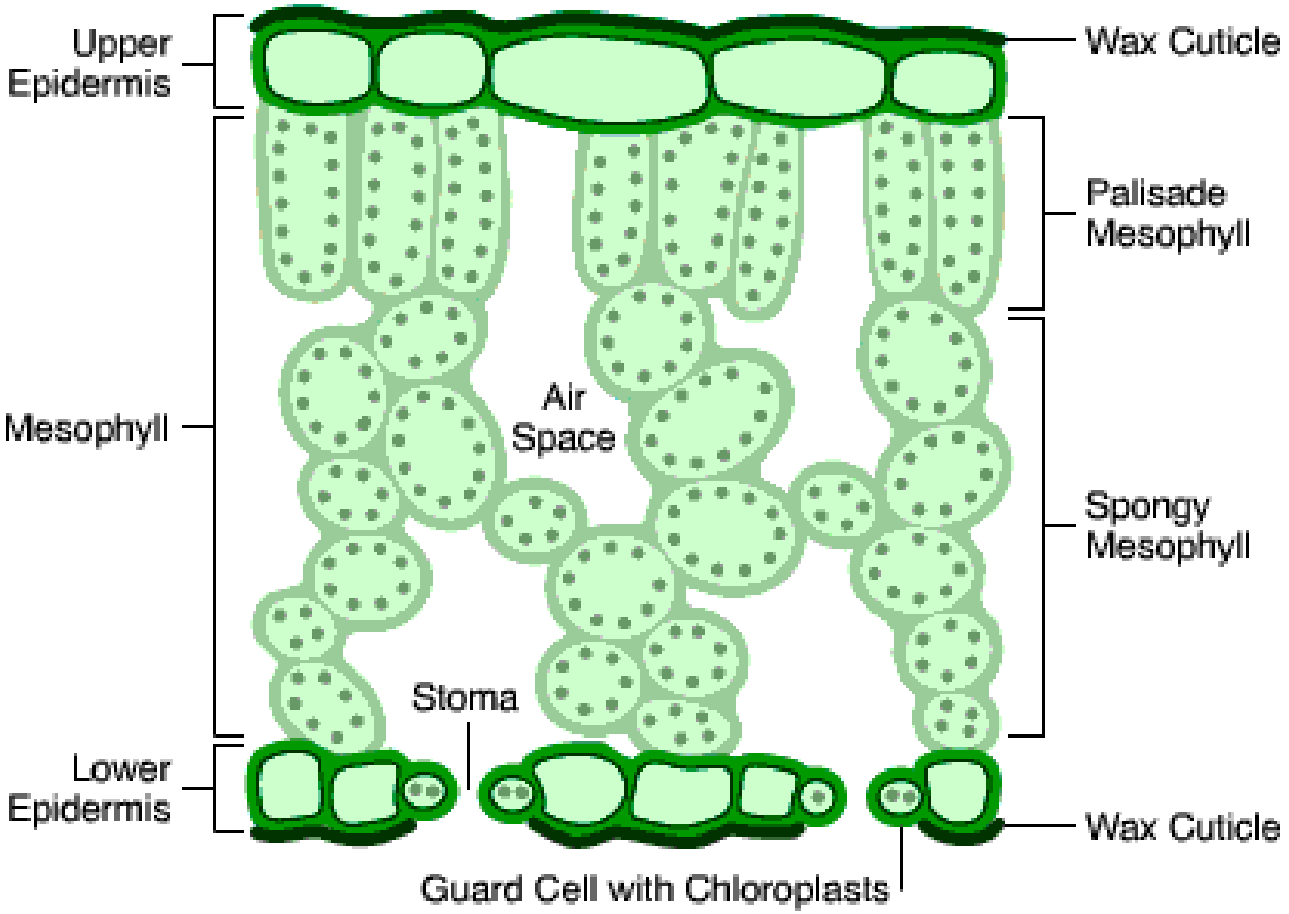
(h) Brighter light, longer light, more carbon dioxide.

(i) No oxygen, no plants, no food for animals.

Role of Photosynthesis

- Plants use it to make food
- Animals get their food from plants
- It produces oxygen which is needed in respiration to release energy
- It is responsible for forming fossil fuels
- It removes carbon dioxide from the air

Structure of a leaf



Adaptations of a leaf to its role in photosynthesis:

- Large and flat
- Thin
- Chloroplasts located close to upper epidermis
- Stomata
- Airspaces
- Veins

Balanced Equation for Photosynthesis

- $6CO_2 + 6H_2O + light \longrightarrow C_6H_{12}O_6 + 6O_2$

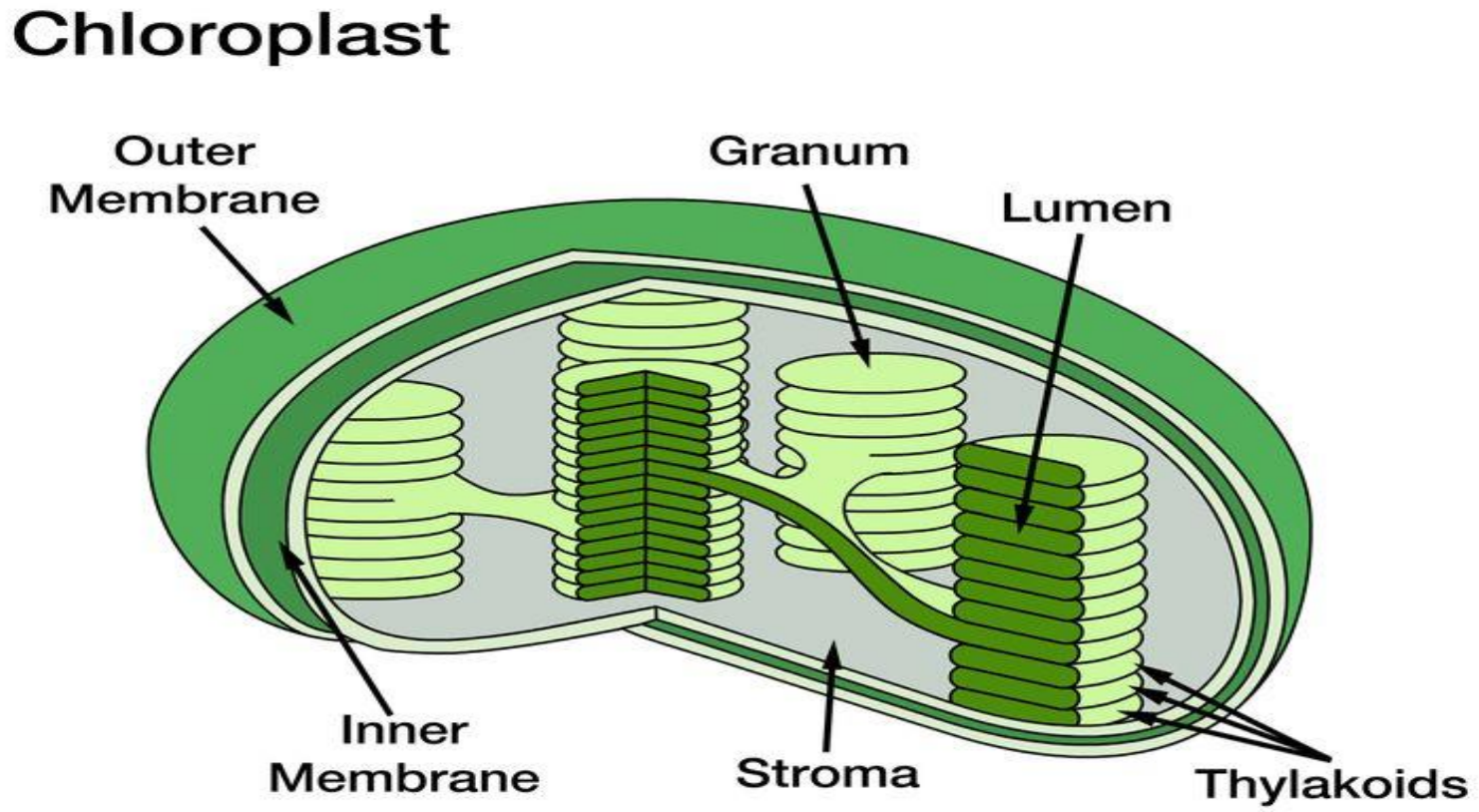
water

glucose

Carbon dioxide

oxygen

Ultra structure of the Chloroplast



The thylakoids contain the chlorophyll which traps the sun's energy

Single sheet of thylakoid -lamella

Stacks of Thylakoids- Granum

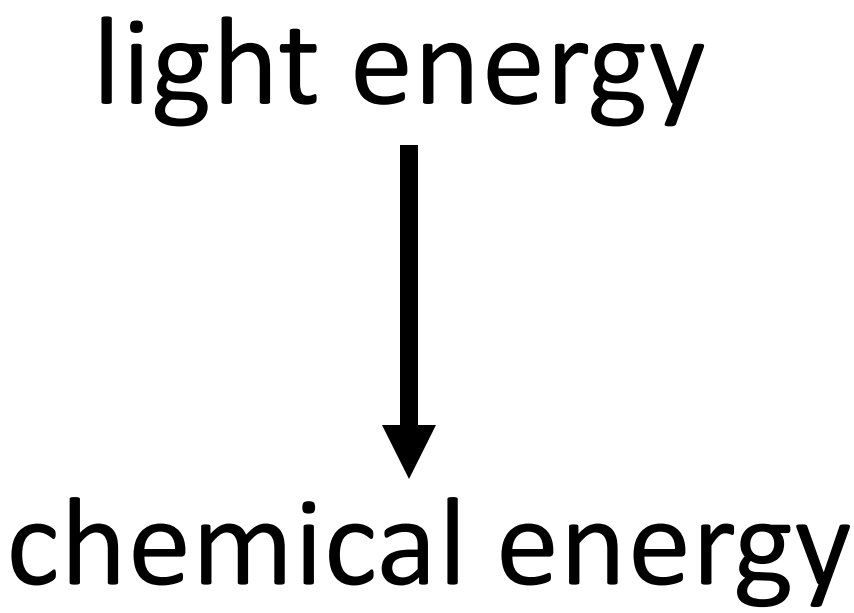
Photosynthesis requires:

- carbon dioxide,
- water,
- light energy,
- chlorophyll.

Photosynthesis produces

- glucose
- waste oxygen

Photosynthesis converts



Learning Check

- What is photosynthesis?
- Why is it important to all life?
- What do plants require for photosynthesis?
- What do plants produce in photosynthesis?
- What kind of energy is light energy changed into in photosynthesis

Stages in Photosynthesis

- Light is absorbed
- Water is split
- Products are produced (4 protons, 4 electrons and oxygen)
- Light energises electrons
- Glucose is formed

Light is Absorbed

- The light that reaches a plant is trapped by chlorophyll
- Chlorophyll is found in the chloroplasts of plant cells
- Therefore photosynthesis occurs in chloroplasts
- The trapped light provides the energy the plants need to make glucose

Water is Split

- Some of the trapped light energy is used to split water into oxygen gas (O_2) protons (H+) and electrons (e-)

- **Summarised as**

$2H_2O$ ⟶ 4H+ and 4e- and O_2

What happens to these Products?

1. The electrons are passed to chlorophyll
2. The protons are stored in a proton pool for later use
3. The oxygen may pass out of the leaf into the atmosphere or else may be used for plant respiration

Light Energises Electrons

- The electrons that were passed to the chlorophyll become energised by some of the trapped light energy -- this changes them into high energy electrons

Glucose is formed

- The high energy electrons along with protons from the proton pool are combined with carbon dioxide to form glucose ($C_6H_{12}O_6$)

Learning Check

- What are the main stages in photosynthesis?
- What is water split into?
- What happens to each of these products?
- What is the trapped light energy used for?

Sources of light for plants

- Sunlight is the natural source of light for plants but they can use artificial light for photosynthesis

- Artificial light is often used in greenhouses stimulate growth

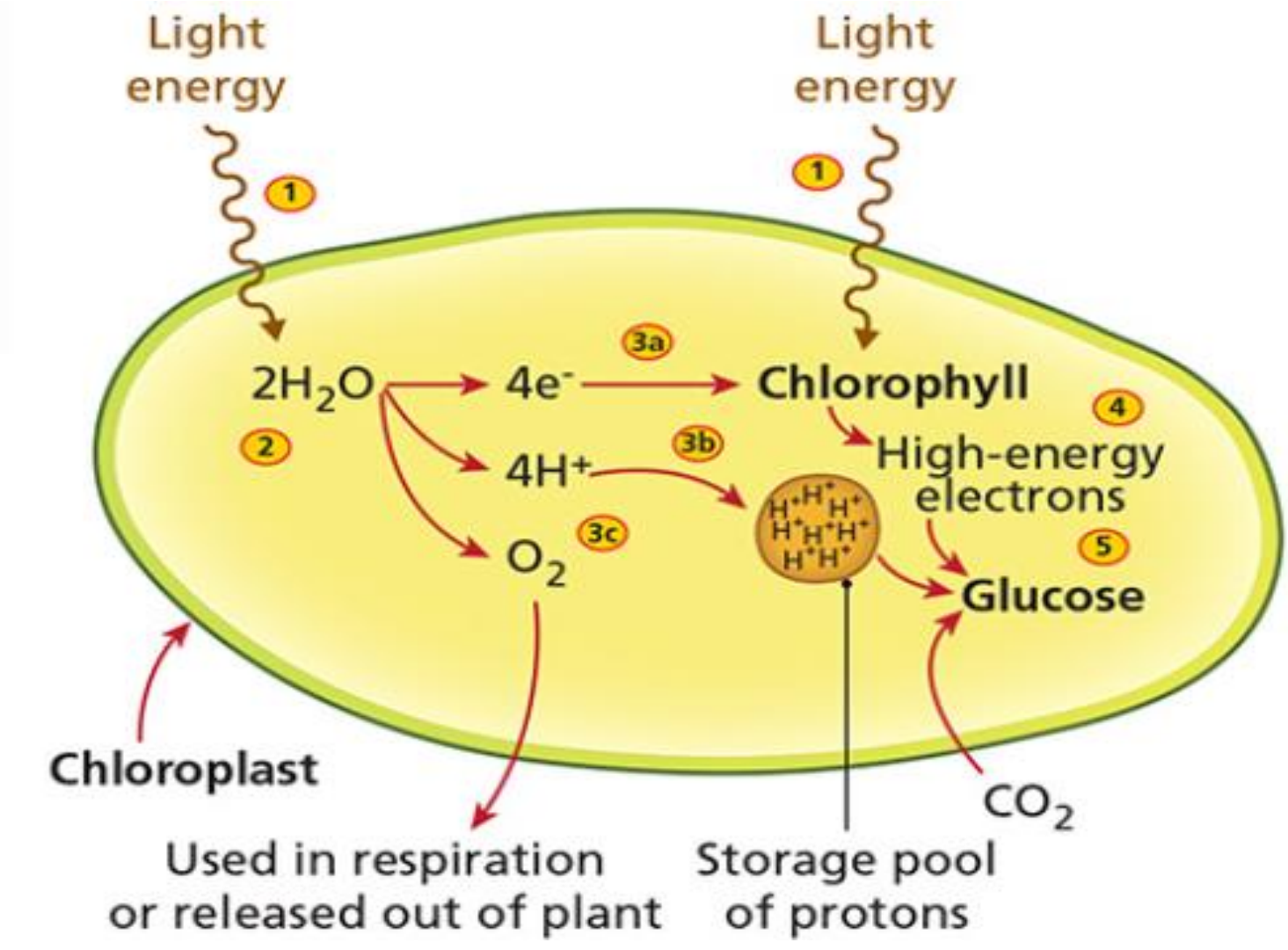
- Increasing light can increase growth up to a certain saturation point where no more light can be absorbed and photosynthesis will level off

Sources of carbon dioxide for plants

- Plants have 2 sources of carbon dioxide one is external the other is internal
- Plants get most of their carbon dioxide from the atmosphere this is external
- Plants get carbon dioxide internally from their own cellular respiration
- Sometimes artificial sources of carbon dioxide are used to stimulate growth eg. burning gas in a green house

Sources of water for plants

- Water is absorbed from the soil by the roots of plants
- This water passes up the stem and is used for photosynthesis


Light energy
Light energy
1
1
2H2O
2
4e-
3a
4H+
3b
O2
3c
Chlorophyll
4
High-energy electrons
5
Glucose
Chloroplast
CO2
Used in respiration or released out of plant
Storage pool of protons

General Summary

In the chloroplast, the energy from the light is **absorbed**.

1. Some light energy is used to release high-energy electrons from chlorophyll.
2. Some light energy is used to split water into H^+ ions (protons), electrons and oxygen.
   - The H^+ ions go into a common pool of protons in the chloroplast.
   - The electrons from water go to the chlorophyll to replace those lost.
   - Most of the oxygen gas is released as a waste product out of the leaf through the stomata.
   - Some of the oxygen produced will be used in the cells of the leaf for respiration.

Carbon dioxide is then combined with the protons and the high-energy electrons and produces glucose (Fig 13.4).

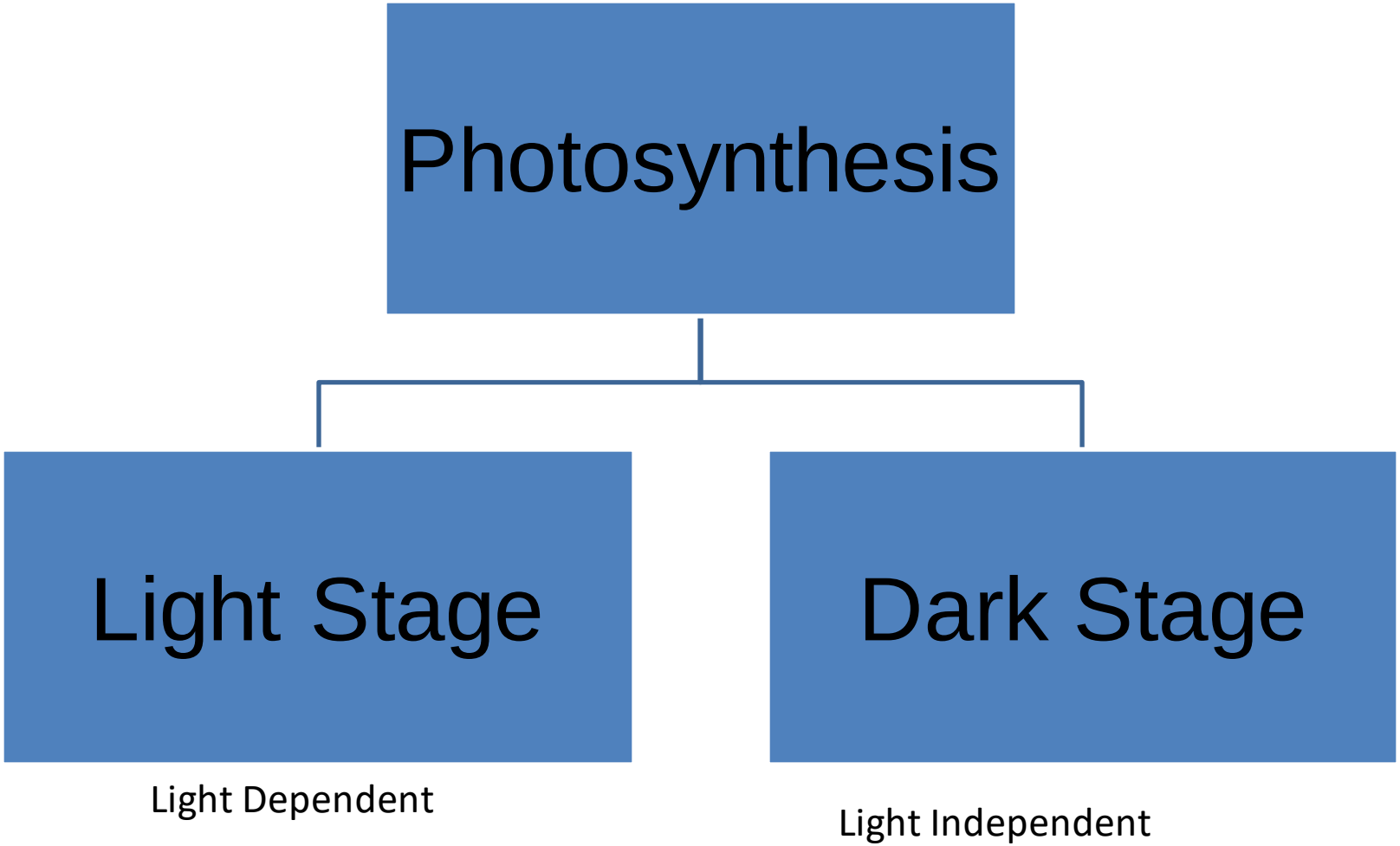
1. The carbon dioxide
   - Enter the leaf through the **stomata**, found mainly on the underside of the leaf.
   - Some carbon dioxide used in photosynthesis comes from respiration within the plant itself.
2. The light for photosynthesis comes from the sun in the natural environment.
3. The water for photosynthesis comes up to the leaf from the roots via the **xylem** vessels in the veins (see Chapter 21).

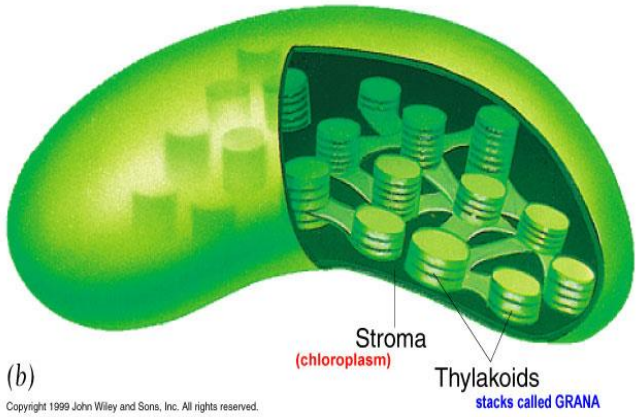
Photosynthesis Extended Study H2.2.9 Syllabus -- Objectives HIGHER LEVEL ONLY

- Explain the role of ATP
- Explain the production of ATP from ADP
- Explain the role of NADP+ in trapping & transferring electrons & H ions.
- Explain the Light Stage/Dark Stage
- State the two-pathway system of electron carriage.

1. Direct to chlorophyll
2. Trapped by NADP+

2 stages of Photosynthesis (HL)





Light Stage (HL)

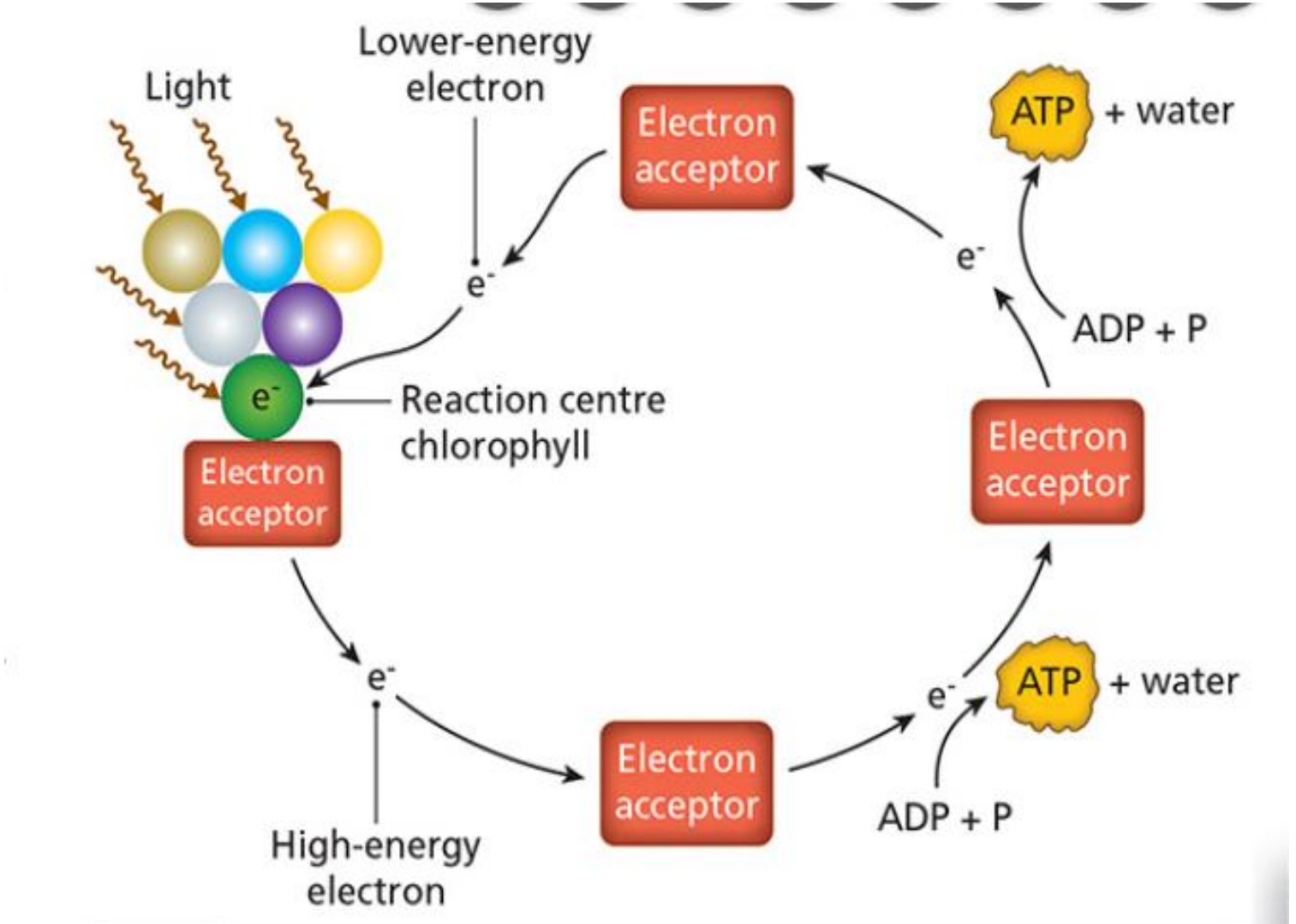
- This takes place in the grana (stacks) of the chloroplast
- It involves the very fast movement of electrons and is not controlled by enzymes
- Light is absorbed by a range of pigment clusters found in the chloroplast (almost all colours of light are absorbed but green is normally reflected)

Light Stage (HL)

- This light energy is transferred to the electron that has been passed to the chlorophyll
- This chlorophyll is in the pigment cluster and is strategically placed near an electron acceptor
- The pigment cluster absorbs as much light energy as possible and passes it to the chlorophyll which passes it to the electron
- The energised electron is passed to the electron acceptor which can the send it on one of two pathways

Learning Check

- Where does the light stage occur?
- Why is it called the light stage?
- Where do the electrons supplied to the chlorophyll come from?
- What absorbs the light energy?
- What is the chlorophyll strategically placed near?
- How many possible pathways can the electron be passed on?



11.10 *Pathway 1: cyclic electron flow*

There are two different pathways involved in Light Phase

Electron Pathway 1 (HL)

- In pathway 1 the electrons pass from the first electron acceptor to a series of other electron acceptors and **back again to the chlorophyll**
- As the electrons are passed around they lose energy
- This energy is used to join a phosphate to ADP to form high energy ATP
- Water is also formed in this process

Electron Pathway 1 (HL)

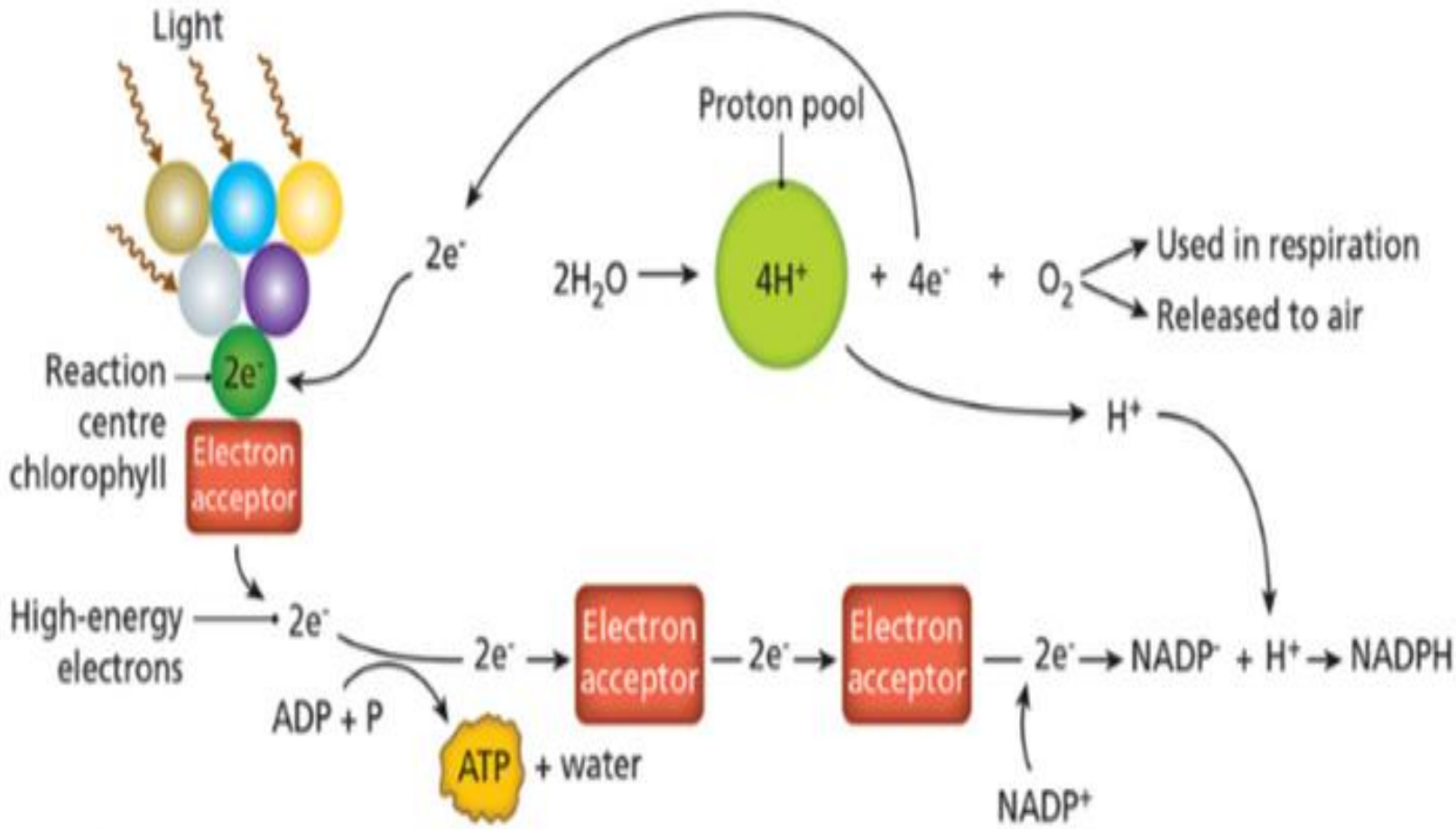
- ADP + Energy + P $\longrightarrow$ ATP + Water

- The addition of phosphate to ADP is called **phosphorylation**

- Because the electron travel in a cycle and returns to its original chlorophyll this process is called **Cyclic Phosphorylation**

Learning Check

- Where does the electron go to from the chlorophyll in pathway 1?
- What happens to the electron as it is moved around?
- What is phosphorylation?
- Why is this pathway called cyclic phosphorylation?
- What are the end products of pathway 1?



11.13 *Pathway 2: non-cyclic electron flow*

Electron Pathway 2 (HL)

- 2 high energy electrons at a time are passed from chlorophyll to the electron acceptor and then along another series of electron acceptors
- In this case the electrons do not return to the original chlorophyll
- They lose energy as they pass from electron acceptor to electron acceptor and this energy is used to make more ATP

Electron Pathway 2 (HL)

- Eventually the 2 electrons are passed to combine with NADP+ to form NADP-
- The chlorophyll molecule is now short of electrons and gains more from the splitting of water
- The splitting of water using light energy is called **Photolysis**

(HL)

- The protons that were stored in the proton pool are attracted to NADP- and combine with it to form NADPH
- Because the electrons start at a chlorophyll and finish at NADPH and form ATP on their way this pathway is known as **Non cyclic photophosphorylation**

Learning Check

- Where do the electrons move to from the chlorophyll in pathway 2?
- What happens to the electrons as they are moved around?
- What is the final destination of the electrons and what does this form?
- What is attracted to NADP-?
- What was the original source of these substances?
- What is photolysis?

Textbook Q2 Solution

2. (a) Light dependent or light stage.

(b) (i) Chlorophyll.

(ii) Cyclic pathway:

1. high-energy electrons produced by chlorophyll using light energy;
2. picked up by electron acceptors;

passed to electron transport chain;

3. energy in electron used to produce ATP;

- 4. low energy electron returns to chlorophyll.

Non-cyclic pathway:

1. water split by light energy;

produces high-energy electrons;

2. passed to electron transport chain;

3. energy used to produce ATP;

4. oxygen released;

5. hydrogen ions (H+) produced; enter the proton pool,

6. O escapes to atmosphere.

(c) (i) Photolysis.

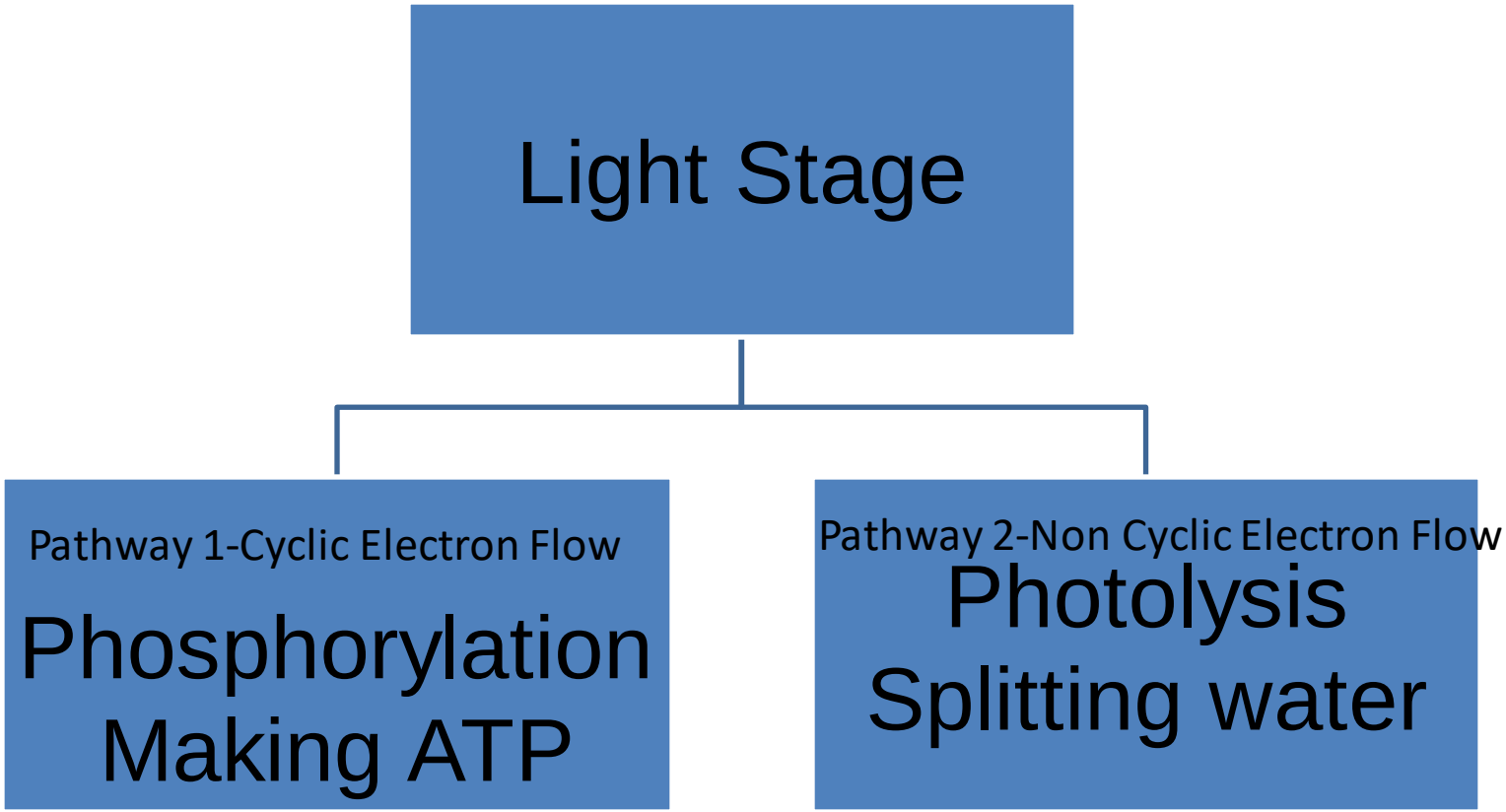
(ii) Product: e- . Fate: passes to electron transport chain; produces ATP.

Product: H+ . Fate: enters proton pool; combines with NADP; form NADPH.

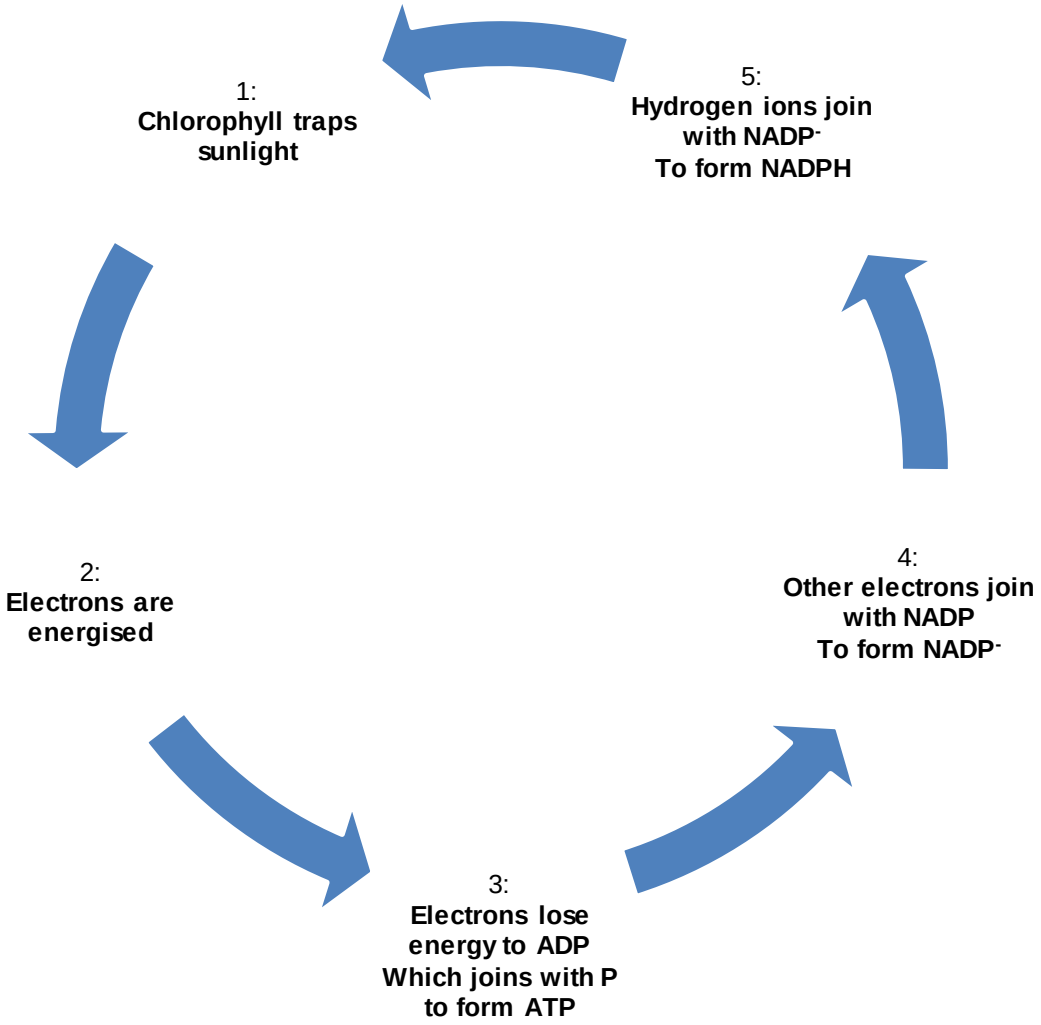
Product: oxygen. Fate: passes into atmosphere; used in respiration or combustion.

- (d) (i) Carbohydrates. (ii) Water.
- (e) (i) Light independent or dark stage.
  (ii) Carbon dioxide (CO_2). (iii) Respiration and combustion

Light stage (HL)

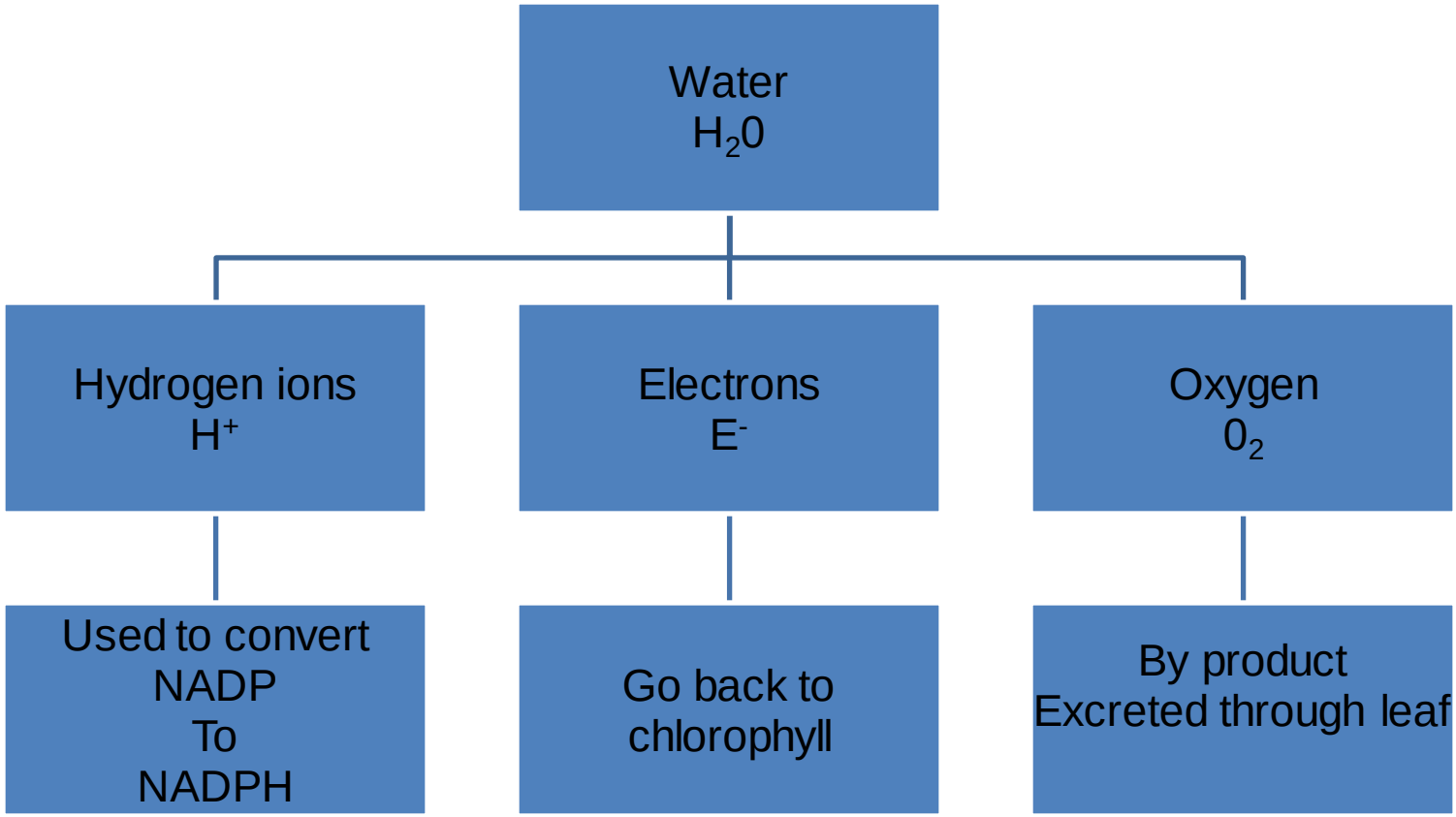


Phosphorylation (HL)



Photolysis (HL)

The splitting of water



End Products of the Light Stage (HL)

- There are 3 end products of the light stage

1. ATP this will provide energy for the dark stage
2. NADPH this will provide protons + energised electrons for the dark stage
3. Oxygen is made when water is split

2. (a) Light dependent or light stage.
(b) (i) Chlorophyll.

ii) Cyclic pathway:

- high-energy electrons produced by chlorophyll using light energy;
- picked up by electron acceptors;
- passed to electron transport chain; energy in electron used to produce ATP;
- low energy electron returns to chlorophyll.

Non-cyclic pathway:

- water split by light energy; produces high-energy electrons;
- passed to electron transport chain; energy used to produce ATP;
- oxygen released; hydrogen ions (H+) produced; enter the proton pool, O escapes to atmosphere.

(c) (i) Photolysis.
(ii) Product: **e- .** Fate: passes to electron transport chain; produces ATP.
Product: **H+** . Fate: enters proton pool; combines with NADP; form NADPH.
Product: **oxygen.** Fate: passes into atmosphere; used in respiration or combustion.

(d) (i) Carbohydrates.
(ii) Water.

(e) (i) Light independent or dark stage.
(ii) Carbon dioxide (CO_2).
(iii) Respiration and combustion

Learning Check

- What are the 3 end products of the light stage?
- Where do each of these products come from?
- What will happen to each of these products?

Learning Check

- What are the 3 end products of the light stage?
- 1) H+ and electrons from NADPH
- 2) Oxygen
- 3) ATP
- Where do each of these products come from
  1) H+ and electrons from NADPH
- 2) Oxygen from splitting of water

  3) ATP=ADP + P

- What will happen to each of these products?

Used in Dark Phase to make Glucose

- NADPH- Dark Phase
- 2) Oxygen released into air or used by plant for respiration

3) ATP=Dark Phase

Dark Stage (HL)

- This may also be called the light independent stage as it can occur in the light but does not need to use it
- It takes place in the stroma of the chloroplast
- It is controlled by enzymes and therefore can be affected by temperature

Dark Stage (HL)

- Carbon dioxide from the air enters the chloroplast where they combine with protons + electrons to form glucose

- This needs energy and protons + electrons

Dark Stage (HL)

- It uses energy got from breaking down

  ATP into ADP + P

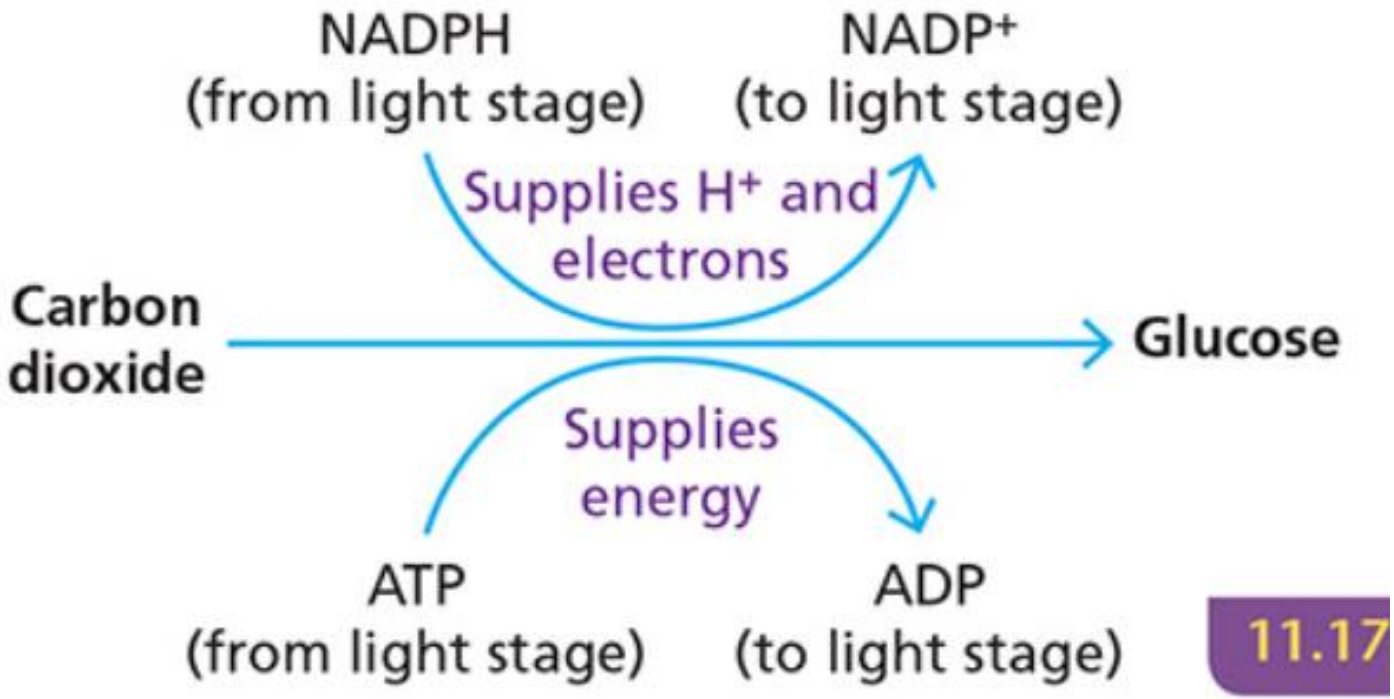
- It uses hydrogen ions and electrons got from breaking down

  NADPH into $NADP^+$ + 2 electrons + H^+

Dark Stage (HL)

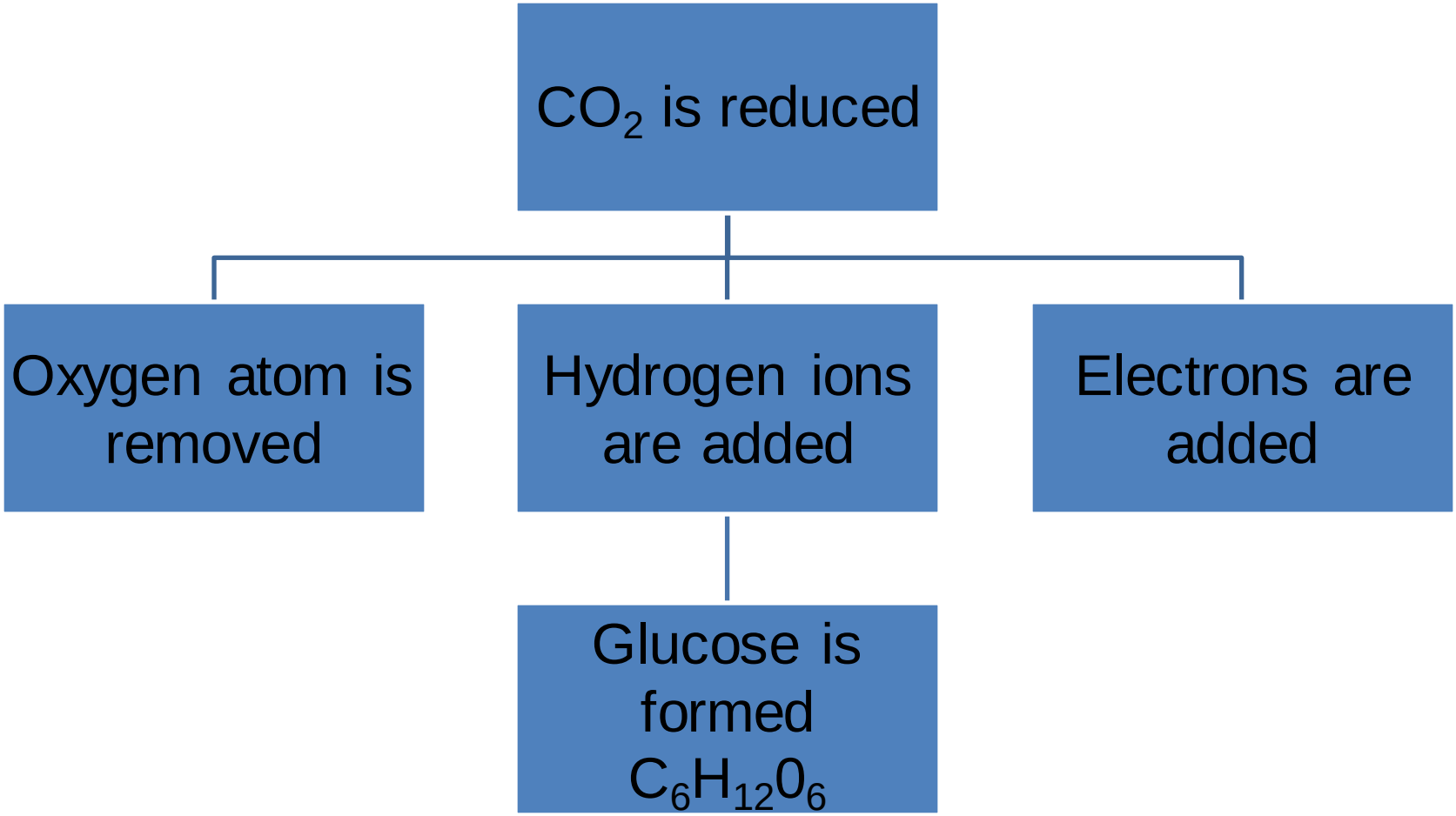
- Remember the addition of electrons to anything is known as reduction

- Carbon Dioxide is **reduced** to glucose


NADPH
(from light stage)
NADP+
(to light stage)
Supplies H+ and
electrons
Carbon
dioxide
Glucose
Supplies
energy
ATP
(from light stage)
ADP
(to light stage)

11.17

Dark Stage (HL)



Learning Check

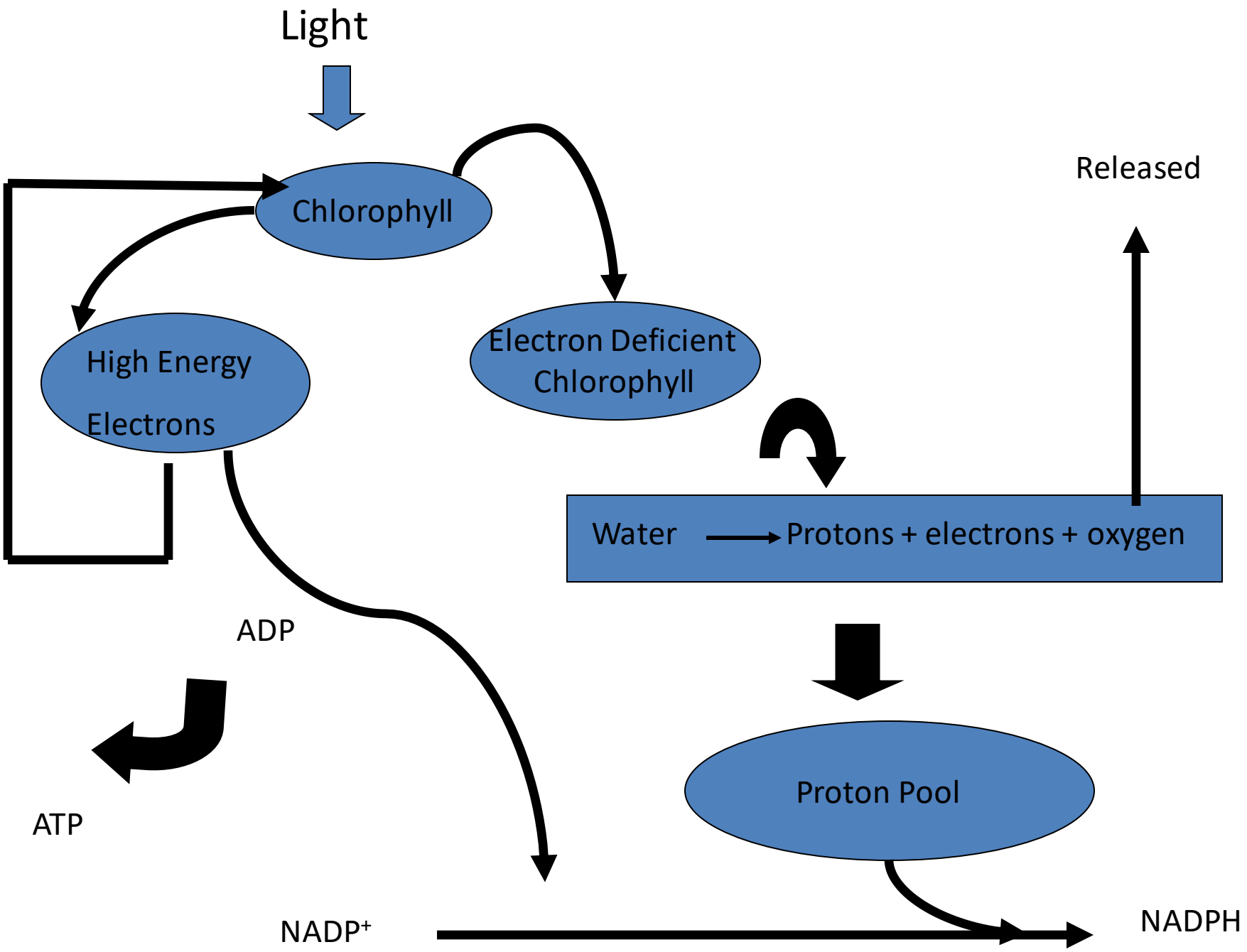
- Why can the dark stage more accurately be called the light independent stage?
- What part of the chloroplast does the dark stage take place in?
- Why is the dark stage affected by temperature?
- What gas is reduced to glucose?
- Where does the energy for this come from?
- What else is needed to reduce the gas? Where do these items come from?

Learning Check

- Why can the dark stage more accurately be called the light independent stage? Can occur with or without Light
- What part of the chloroplast does the dark stage take place in? Stroma
- Why is the dark stage affected by temperature? Affected by enzymes
- What gas is reduced to glucose? Carbon Dioxide
- Where does the energy for this come from? ATP
- What else is needed to reduce the gas? Where do these items come from? H+ and electrons from NADPH

Main events in photosynthesis (HL)

- Light energy is absorbed by chlorophyll
- Water is split
- The electrons are passed to chlorophyll
- The protons are stored in the chloroplasts
- The oxygen is released
- Sunlight transfers energy to electrons
- The high energy electrons, stored protons(the hydrogen ions) and carbon dioxide are used to make glucose


Light
Chlorophyll
Released
High Energy
Electrons
Electron Deficient
Chlorophyll
Water
Protons + electrons + oxygen
ADP
ATP
Proton Pool
NADP+
NADPH

2022 OL Q14b

(b) (i) *Explain the term anabolic.*

Building up of large (molecules) from smaller molecules (using energy)

(ii) *Name the cell organelle in which photosynthesis occurs.*

Chloroplast

(iii) *Name the pigment that absorbs light energy for photosynthesis.*

Chlorophyll

(iv) *What group of biomolecules does this general formula represent?*

Carbohydrate (or sugars)

(v) 1. *Name the other **two** products produced as a result of splitting of water.*

Hydrogen ions **or** H^+

Electrons **or** e^-

2. *Give **one** possible fate for the oxygen.*

Released to the atmosphere **or** used in respiration

(vi) 1. *State a source of CO_2.*

Atmosphere **or** respiration

2. *Structure through which CO_2 enters plants.*

Stomata (*allow* lenticels)

Q14 (b) (i) – (vi)	**Number of correct responses**	1	2	3	4	5	6	7	8	9
	Mark	5	10	15	17	19	21	23	25	27

2021 OL Q17b

Question 17 (b) **30**

(i) *What is meant by the term photosynthesis?*

Making food using (sun)light **3**

(ii) *Name the gas in the air that is needed for photosynthesis:*

Carbon dioxide **3**

(iii) *Name the cell organelle in which photosynthesis occurs:*

Chloroplast **3**

(iv) 1. *Name the product from the splitting of water that is released to the atmosphere:*

Oxygen **3**

2. *Name the product from the splitting of water that is used to form carbohydrates:*

Hydrogen ions (or protons) or H^+ **3**

3. *Name the product that passes to chlorophyll:*

Electrons **3**

(v) *What is the carbohydrate called that is formed by plants in photosynthesis?*

Glucose **3**

(vi) *What is the role of chlorophyll in photosynthesis?*

Trap energy in (sun)light **3**

(vii) *Give **two** environmental factors that affect the rate of photosynthesis:*

Temperature / carbon dioxide (concentration) / pH / water (availability) / mineral (availability) / light (intensity) ***Any two*** **2(3)**

Q17 (b) (i - vii)	**Number of correct responses**	1	2	3	4	5	6	7	8	9	10
	Mark	3	6	9	12	15	18	21	24	27	30

HL 2022 Q14 a & b

Question 14 **60**

(a) (i) *In which cell organelle does photosynthesis occur?*

*Chloroplast **3**

(ii) *Name the pigment essential for photosynthesis.*

*Chlorophyll **3**

(iii) *Describe **one** way in which horticulturists can increase plant yields in greenhouses.*

Heat to (or keep at) optimum temperature **or** more light (or described) **or** use a range of colours of light **or** more CO_2 (or described) **or** hydroponics (or described) **or** any valid non-photosynthetic reason **3**

3

Q14 (a) (i) – (iii)	Number of correct responses	1	2	3
	Mark	3	6	9

(b) (i) *Water is split during stage 1 using the energy in light. What is the name given to this process?*

*Photolysis **3**

(ii) *Identify molecule **X**, produced as a by-product of the splitting of water.*

*Oxygen (or O_2) **3**

(iii) *Identify molecule **Y**.*

*NADPH **3**

(iv) *Describe how molecule **Y** is produced.*

Added (or picked up) electrons (e^-) **3**

Added (or picked up) proton (hydrogen ion or H^+) **3**

(v) *Name stage 2 shown in the diagram.*

*Light independent stage (or dark stage or Calvin Cycle) **3**

(vi) *What does ATP stand for?*

*Adenosine triphosphate **3**

(vii) *What is the role of ATP in stage 2 of photosynthesis as shown in the diagram?*

To transfer energy **or** to carry energy **or** to release energy **3**

(viii) *Identify molecule **Z**, the end product of stage 2.*

Glucose (or formula) **3**