PLANTS

4.1 PHOTOSYNTHESIS

Objectives :

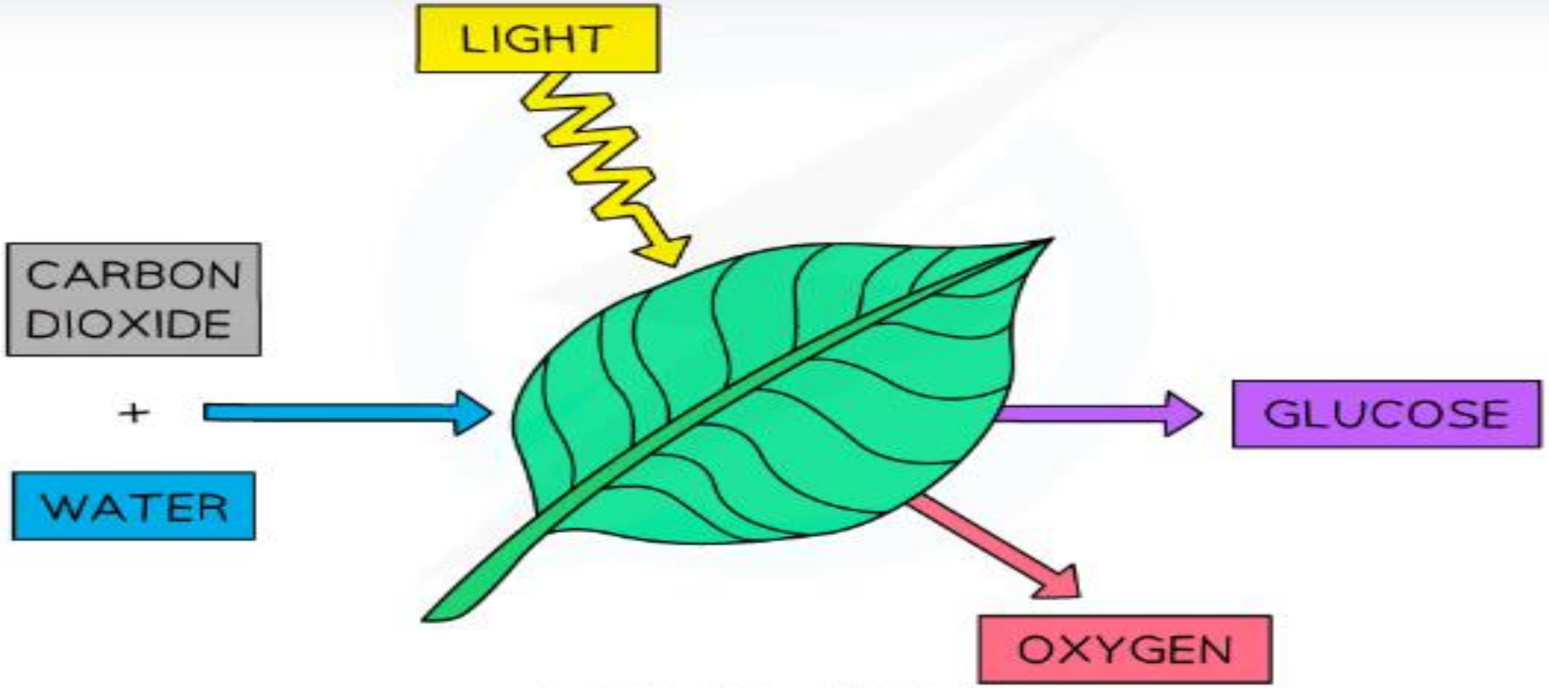
- *Describe the functions of the different parts of the leaf*
- *Describe the structure of the chloroplast*
- *Draw an annotated diagram of the chloroplast*
- *Describe Explain the action and absorption spectra of chlorophyll a and b*
- *Practical Skill: Separation of photosynthetic pigment by chromatograph and calculation of Rf Value.*

Resources :

Student book pages 79,80,81,82,83.

https://www.youtube.com/watch?v=uSSgiI3a6ZU introduction to photosynthesis

https://www.youtube.com/watch?v=TQRWHKvSop8 structure of the leaf



The basic equation of photosynthesis as it takes place in a leaf

$$6\,CO_2 + 6\,H_2O \xrightarrow[\text{CHLOROPHYLL}]{\text{LIGHT}} C_6H_{12}O_6 + 6\,O_2$$

Recall that :

- Chemical reactions can be **exothermic** or **endothermic**
- Photosynthesis is an example of an endothermic reaction and an **anabolic** reaction, where the required energy input is in the form of light energy
- Energy is needed to produce carbohydrates and other carbon compounds from carbon dioxide
- The energy is not lost - it is **stored in chemical form** in the carbohydrates that are produced

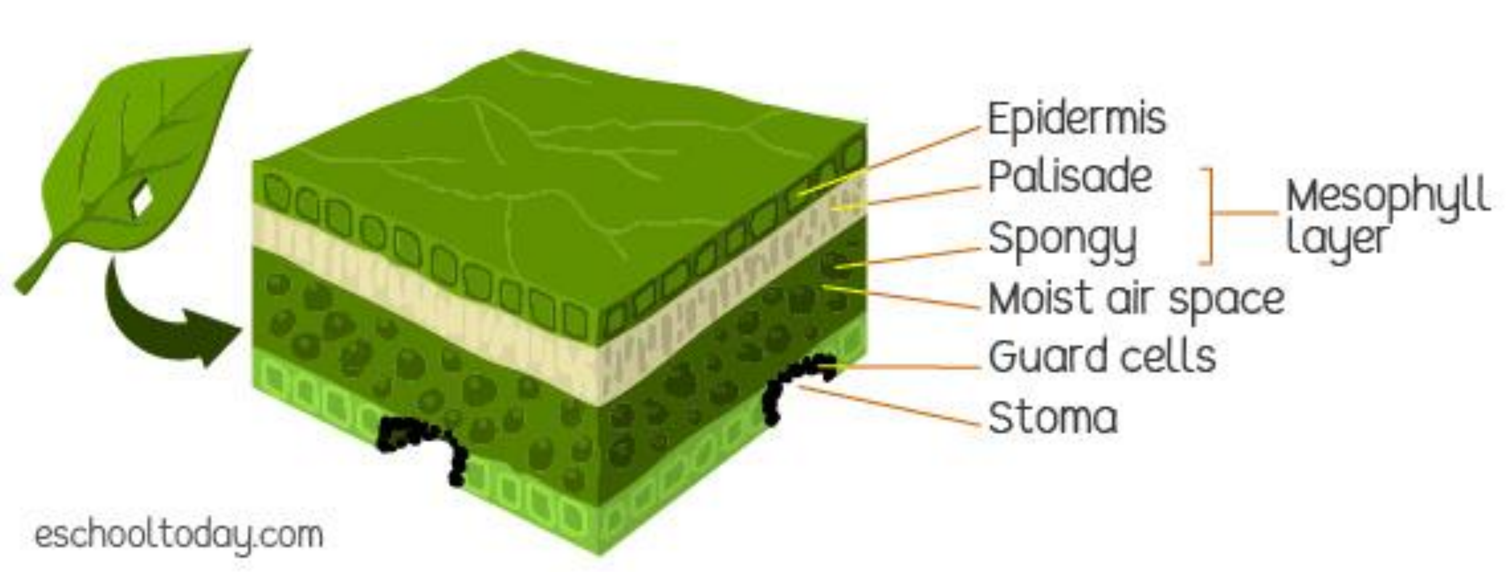
Plants are multicellular eukaryotes which make the base of most food webs. They have the ability to make their own food using water, carbon dioxide and light through a process called photosynthesis. Plants have two transport systems: xylem which transports water and phloem which transports food from leaves to the rest of the plant.

Photosynthesis

is the process by which plants use inorganic water and carbon dioxide to produce organic compounds in cells using light energy. This process takes place in the chloroplasts of leaves.

Leaves

The leaf is the site of photosynthesis. To understand how photosynthesis takes place, we need to understand the structure of the leaf and how the leaf is adapted to perform its function.



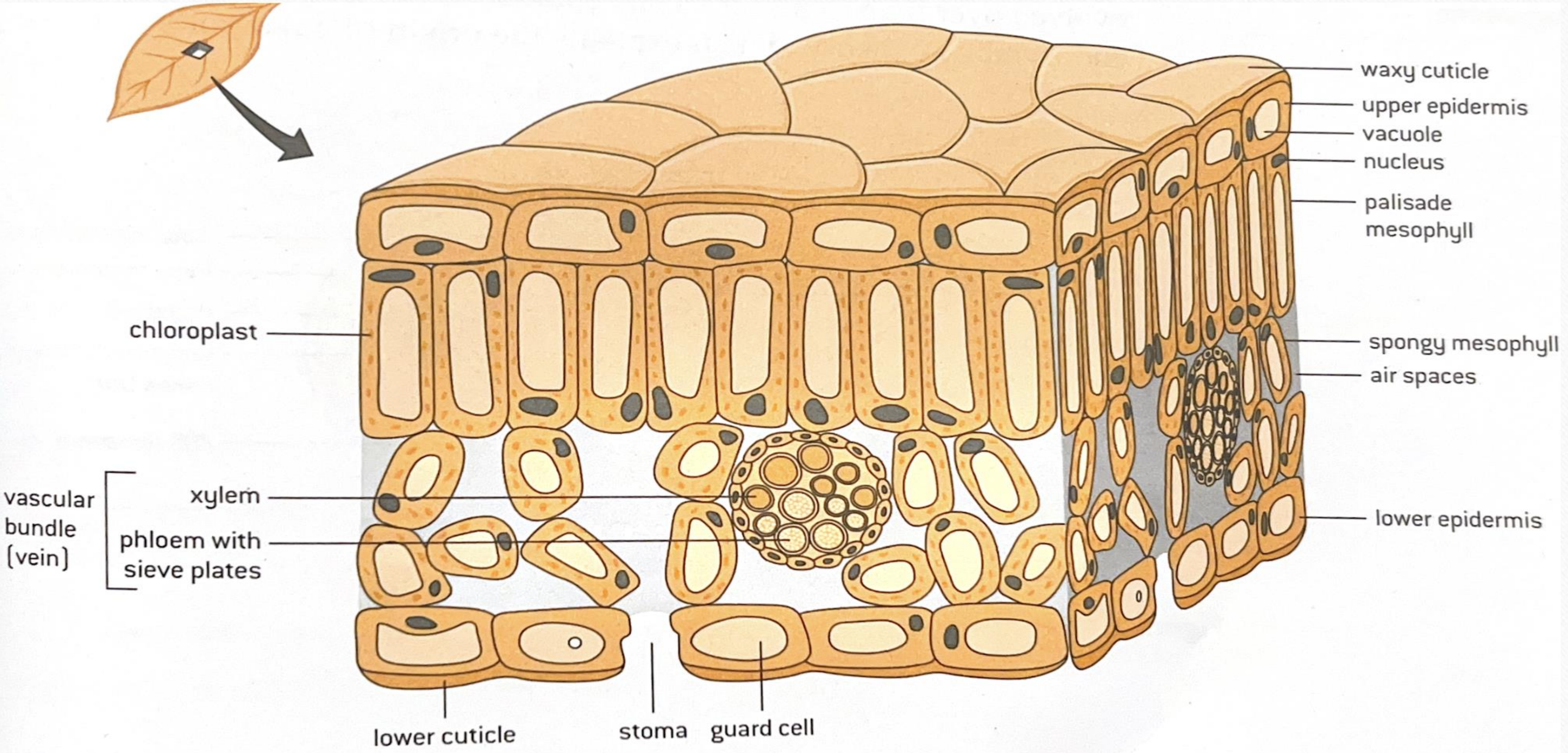


Figure 1. A cross-section of a leaf

The structure of the leaf is adapted to enable it to carry out its functions, as described in table 1.

Table 1. Structure of leaves

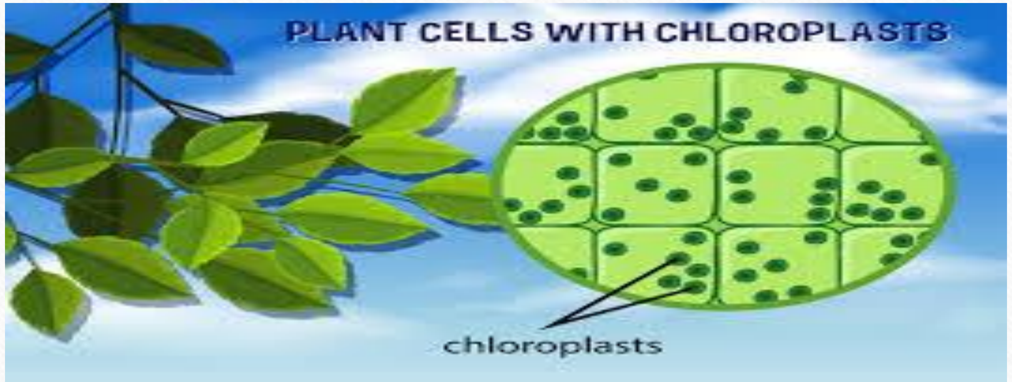
Structure	Adaptation	Function
Cuticle	Made of wax	Prevents water loss
Upper epidermis	Thin and transparent	Allows light to pass through
Palisade mesophyll	Contains many chloroplasts	Absorbs light for photosynthesis
Spongy mesophyll	Has air spaces	Facilitates gas exchange; the air spaces allow rapid diffusion of oxygen and carbon dioxide
Vascular bundle (vein)	Consist of xylem and phloem	The xylem transports water, and the phloem transports the products of photosynthesis to the rest of the plant
Lower epidermis	Contain stomata	Allows carbon dioxide to diffuse into the leaf and oxygen and water vapour to diffuse out

Chloroplast

Chloroplasts are tiny organelles in plant cells where photosynthesis takes place .

They are mainly found in the palisade layer inside the leaf. Chloroplasts contain chlorophyll, which is the main pigment of photosynthesis. It is believed that chloroplasts were once photosynthetic bacteria that were ingested by larger prokaryotes to provide organic matter to the larger cell. The photosynthetic bacteria evolved over time to become chloroplasts.

This theory is called the endosymbiotic theory, which explains the origin of eukaryotic cells.



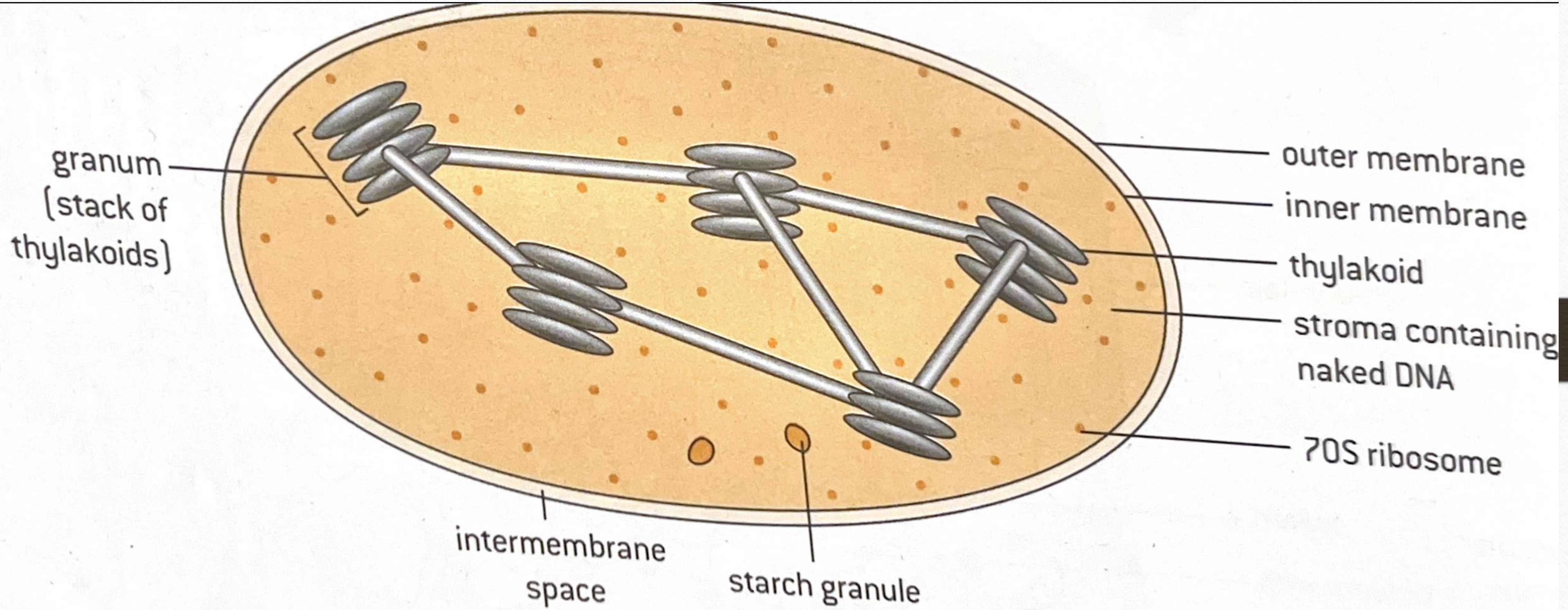


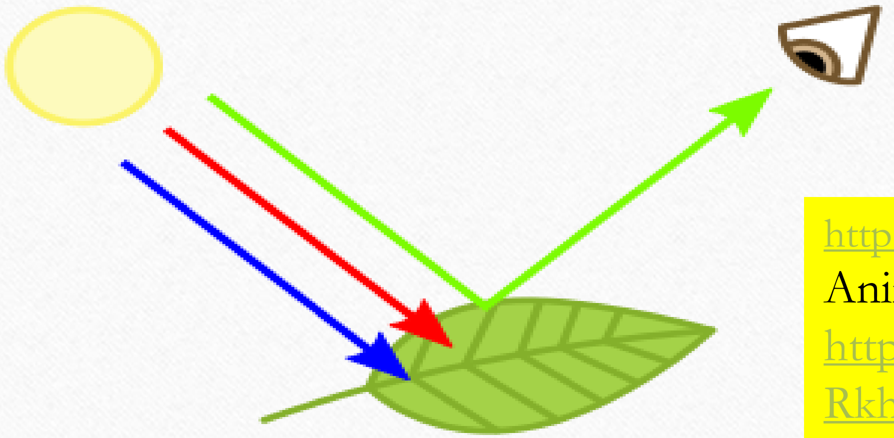
Figure 2. The structure of the chloroplast

Table 2. The main structure of the chloroplast

Structure	Adaptation
Stroma	Contains many enzymes which are important for photosynthesis.
Thylakoids	The site of photosynthesis. It contains chlorophyll which is needed for light absorption. Thylakoids have a large surface area to allow for more light absorption. Thylakoids are packed together in a structure called a granum.

Most plants have green leaves. This tells us that they do not absorb the green part of the spectrum well – green light is reflected and makes the leaf appear green. Looking closely at the structure of plant cells we can see that the green colour is due to the chloroplasts, which contain a green pigment called chlorophyll.

Chlorophyll is unable to absorb green light, which it reflects, but it does absorb other wavelengths well. Red and blue light are absorbed particularly well and provide the energy needed for photosynthesis. The red and blue ends of the visible spectrum are the wavelengths that the photosynthetic pigments in plants absorb most efficiently. The rate of photosynthesis is highest when plants absorb these wavelengths.



https://www.youtube.com/watch?v=pwymX2LxnQs
Animation
https://www.youtube.com/watch?v=WYKBEYRkhLg absorption of red and red

Chlorophyll

Chlorophyll is the main photosynthetic pigment. Chlorophyll absorbs specific wavelengths of visible light (figure 3). It absorbs red and blue light most effectively, while it reflects green light; this is why it appears green in colour.

There are different types of chlorophyll, mainly **chlorophyll a and b**, which differ very slightly in the wavelength they absorb most efficiently.

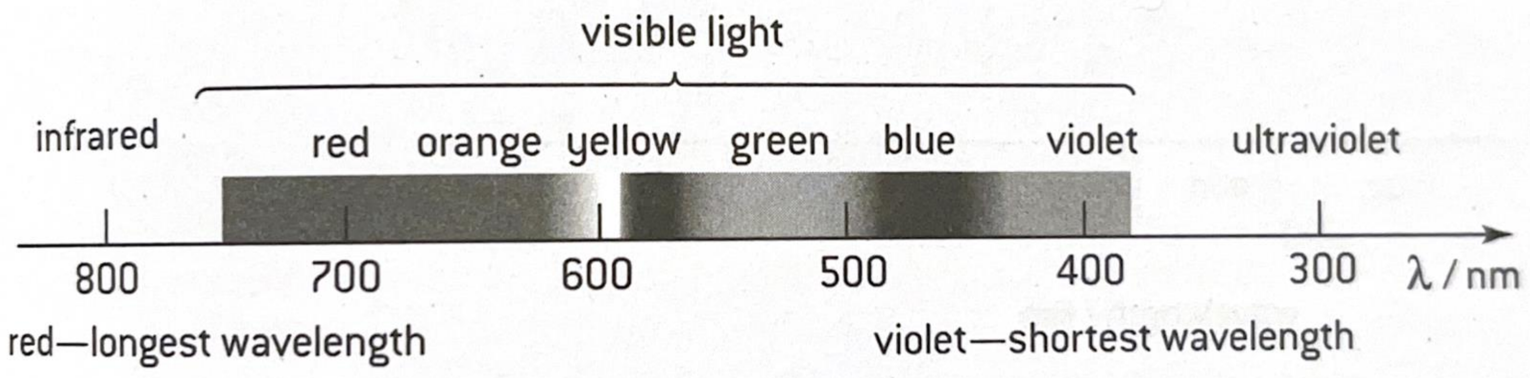
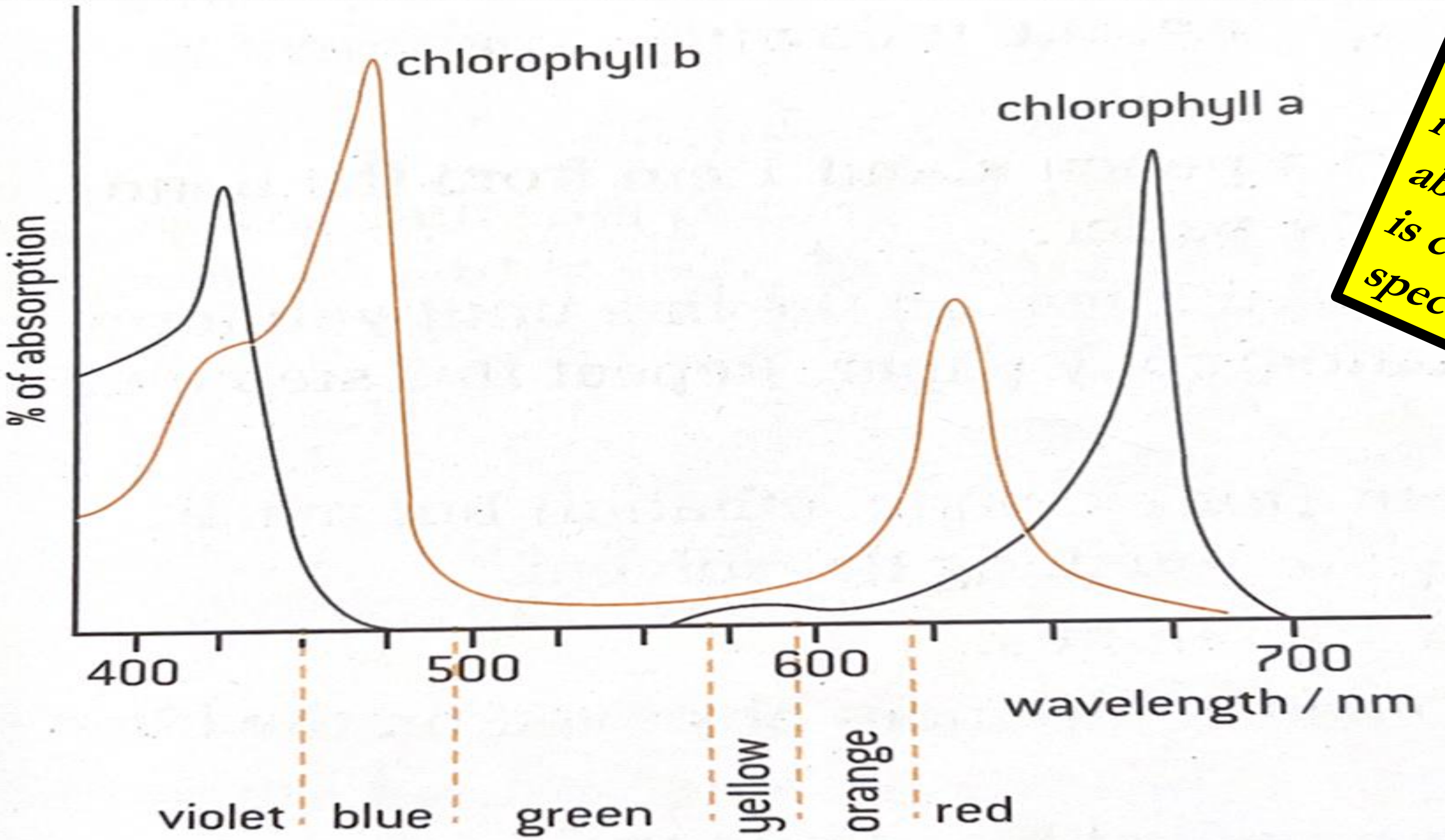


Figure 3. The range of wavelengths in visible light

The graph in figure 4 shows the percentage of light absorbed by chlorophyll for each wavelength of light. The following can be noted from figure 4:

- The highest absorption is seen with the violet-blue light. There is also good absorption with the red-orange light. This is because chlorophyll absorbs red and blue light most effectively.
- The lowest absorption is seen with the green-yellow light. This is because green light is reflected by chlorophyll, and therefore not absorbed.



A graph showing the range of wavelengths absorbed by a pigment is called an absorption spectrum.

Figure 4. The absorption spectrum of chlorophyll a and b

Chlorophyll is the main photosynthetic pigment. The graph above is the absorption spectrum for the two commonest forms of chlorophyll, a and b.

The absorption spectrum shows that chlorophyll absorbs red and blue light most effectively. Small amounts of green light are absorbed but most is reflected, making structures containing chlorophyll appear green to us.

https://www.youtube.com/watch?v=dwz3qozDiyI **chlorophyll a and b**

The action spectrum (figure 5)

is a graph that shows the rate of photosynthesis for each wavelength of light. Compare the action spectrum with the absorption spectrum of chlorophyll a and b (figure 4). It can be noted that the rate of photosynthesis is the least (at a minimum) at the green wavelength of light, while it is the highest with the blue and red light.

The action spectrum shows that there is some use of green light in photosynthesis, even though chlorophyll absorbs little of it. This is because **accessory photosynthetic pigments** are present, which absorb some green light that can be used in photosynthesis.

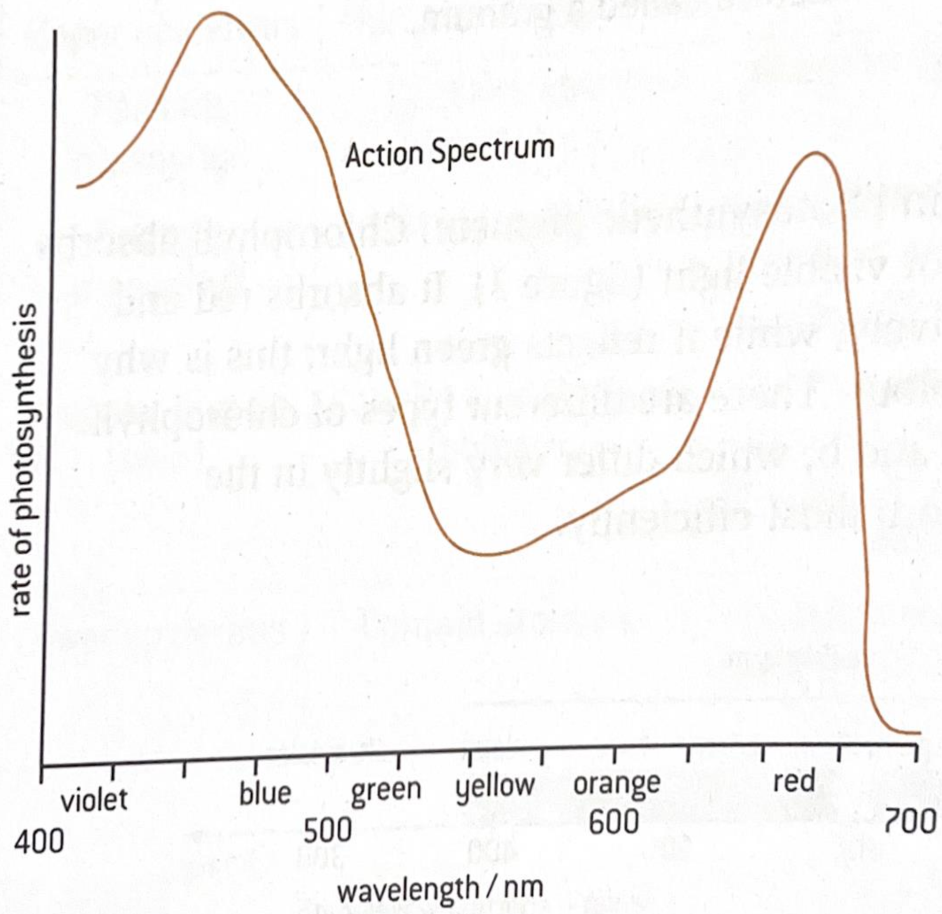


Figure 5. The action spectrum

Question

Which of the following statements best describes why the majority of plants appear green?

A. Chlorophyll reflects the light most strongly in the green portion of the visible spectrum.

B. Chlorophyll absorbs light most strongly in the green portion of the visible spectrum, followed by the red portion.

C. When chlorophyll absorbs light, it releases electrons.

D. The human eye is more sensitive to green light.

Question

Which option correctly completes the sentence below?

Photosynthesis is an example of _________.

A. An exothermic reaction.

B. A catabolic reaction.

C. An endothermic reaction.

D. Net energy loss.

Practical skills: Separation of photosynthetic pigments by chromatograph

Paper chromatography can be used to separate photosynthetic pigments. Plants and other photosynthetic organisms can have a combination of photosynthetic pigments such as chlorophyll, carotenes and others. The process of chromatography separates molecules based on the different solubility of these molecules in a specific solvent. You might carry out the following experiment in a DP Biology class (figure 6):

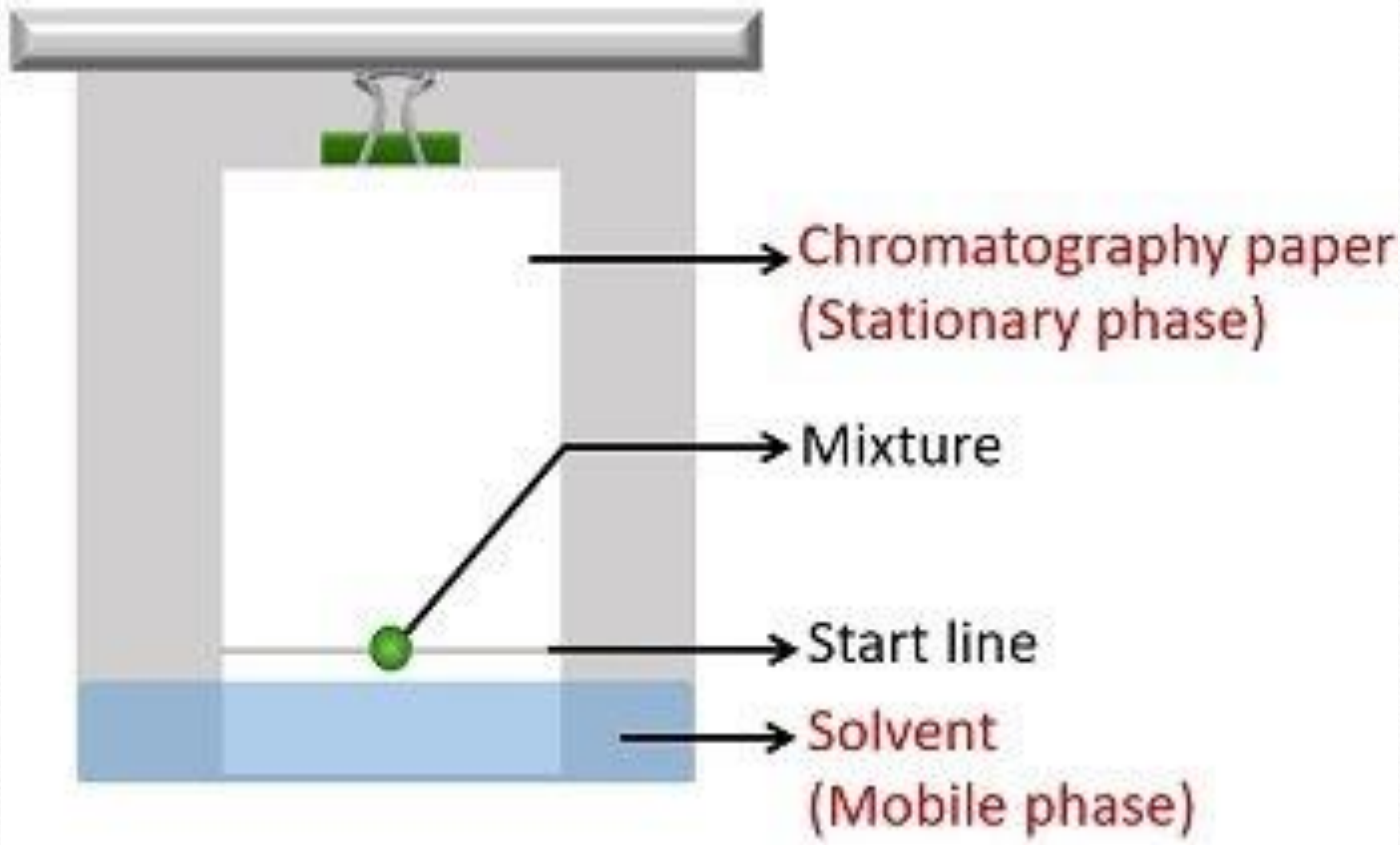
- Draw a horizontal line with a pencil about 1 cm from the bottom of a piece of chromatography paper.
- Use a small coin to press down a leaf on the line until you form a green line on the chromatography paper.

  Repeat this step un the line is fairly dark.
- Place the paper in a solvent (for example, ethanol) but make sure that the green spot is not touching the solvent.
- Allow it to stand for 20 to 30 minutes.
- Calculate the R, value for each component observed on the filter paper:

$$Rf = \frac{\text{distance travelled by compound}}{\text{distance travelled by solvent}}$$

The more soluble the pigment, the further the movement of the pigment, and therefore the higher the Rf value. Different pigments may be identified by comparing their Rf values.

https://www.youtube.com/watch?v=W56RHxu2Hpc


Chromatography paper
(Stationary phase)
Mixture
Start line
Solvent
(Mobile phase)