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2018 HIGHER SCHOOL CERTIFICATE COURSE MATERIALS

Preliminary Biology

Patterns in Nature

Term 1 – Week 5

Name ……………………………………………………….

Class day and time ……………………………………………

Teacher name ………………………………………………...

Term 1 – Week 5 – Theory

PLANTS AND ANIMALS HAVE SPECIALISED STRUCTURES TO OBTAIN NUTRIENTS FROM THEIR ENVIRONMENT

- **Distinguish between autotrophs and heterotrophs in terms of nutrient requirements**

NUTRIENT REQUIREMENTS

Since we know that cells require nutrients, this means that the tissues they make up require nutrients. Consequently, organs and systems would require nutrients to continue functioning. As a result, all organisms, whether unicellular or multicellular, require an intake of nutrients.

There are two main ways of obtaining nutrients and organic molecules in an ecosystem – making it yourself and taking it from others.

Organisms that are able to create their own energy-rich organic molecules are called **autotrophs** (*auto* = "self, one's own"; *trophe* = "nutrition"). In contrast, organisms that depend on gaining their organic molecules from others are called **heterotrophs** (*heteros* = "another"; *trophe* = "nutrition")

AUTOTROPHS

By definition, autotrophs are organisms that are able to produce complex organic compounds which can be used as a nutrient (such as carbohydrates and fats) using only simple inorganic molecules and energy from the inorganic sources (e.g. the sun).

Autotrophs are the primary producers in an ecosystem, and do not need to obtain their nutrients from other organisms. They provide the energy-rich organic molecules such as carbohydrates which are required by heterotrophs.

However, they still require several nutrients from their environment:

Water

- Water is essential in all living things as it works as a medium in which chemical reactions and transfer of molecules can occur.
- In photosynthesis, water acts as an energy source (donating electrons) to 'reset' chlorophyll.

Air

- Oxygen and carbon dioxide are both used in plants for metabolic reactions, as well as for photosynthesis and chemosynthesis.

Inorganic minerals

- Some inorganic mineral ions are required for metabolism, although they are cannot be created by organisms.
- Mineral ions have to be taken up from the surroundings.
- Plants absorb minerals through their roots
- Chemosynthetic bacteria can actively transport minerals into their cells from the surrounding

An energy source

- In order to synthesise a compound out of raw materials, energy has to be available.
- Autotrophs can use one of a variety of energy sources, such as sunlight (photosynthesis) or from the oxidisation of inorganic compounds (chemosynthesis).

***Note**:* Fungi are not autotrophs; they absorb nutrients from organic matter and are unable to produce their own organic molecules – classical characteristics of heterotrophs.

HETEROTROPHS

A heterotroph is an organism that is unable to create their own organic nutrients but still requires organic carbon for growth. As a result, they have to obtain organic nutrients from other sources – through predation or parasitism.

Nutrients required by heterotrophs are therefore slightly different from those of autotrophs:

Water

- As previously stated, water is essential in all living things as it works as a medium in which chemical reactions and transfer of molecules can occur.

Air

- Oxygen is required for many heterotrophs in the breakdown of organic molecules. With no oxygen, there is limited energy produced, causing cells to eventually die.

Inorganic compounds

- Inorganic compounds are still required by heterotrophs as they aid in metabolic processes that maintains life.

Organic nutrients

- Unlike autotrophs, heterotrophs obtain their energy from the breakdown of organic molecules (in the form of ATP).
- Heterotrophs have to obtain organic nutrients from either autotrophs or other heterotrophs.

- **Identify the materials required for photosynthesis and its role in the ecosystem**
- **Identify the general word equation for photosynthesis and outline this as a summary of a chain of biochemical reactions**

PHOTOSYNTHESIS

Photosynthesis can be said to be the most important biological process for living things to occupy earth today. It is believed that photosynthetic organisms were responsible for the change from an atmosphere with no oxygen, to one where living things can thrive on oxygen.

Putting chemosynthetic bacteria aside, all energy in the food web comes from the sun, which is caught by photosynthesis. Furthermore, all carbon found in living organisms come from sugars which are synthesised by photosynthesis.

The general formula for photosynthesis is:

$$Water + Carbon\ Dioxide \rightarrow_{Solar\ energy} \rightarrow Glucose + Oxygen$$
$$6H_2O + 6CO_2 \rightarrow C_6H_{12}O_6 + 6O_2$$

The main reactants in photosynthesis are water vapour and carbon dioxide in the air. Solar energy is trapped by **chlorophyll**, a green pigment found in plants. The energy trapped is then used to drive the chemical processes in the **chloroplast** to synthesise glucose, in a process called **carbon fixation**.

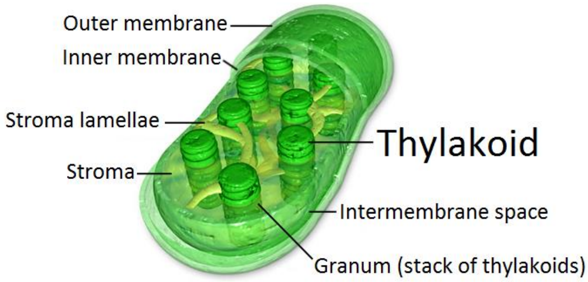
Within the ecosystem, photosynthesis is important in providing organic material (glucose) for food webs as well as replacing the carbon dioxide that is generated by respiration. Glucose is stored within plants unless it is used for cellular processes within the plant.

BIOCHEMICAL REACTIONS FOR PHOTOSYNTHESIS

Photosynthesis occurs within the chloroplast of plants. It is a biochemical process that takes several steps:

Note: You do not need to know the details of how this works

1. **Gathering of light by thylakoids – why solar energy is needed**
   - Within the chloroplast are proteins which gather light, embedded onto a membrane that is tightly folded. The folding of the membrane forms structures that are called thylakoids.
   - Since the membrane is able to be folded into many thylakoids, the effective surface area for collecting light energy within a chloroplast is very large.



   - Chlorophyll is a green pigment that absorbs light, found in large quantities around the light collecting proteins. This gives thylakoids and chloroplasts its characteristic green colour.
2. **Converting solar energy to electrical energy – use of H_2O release of O_2**
   - Chlorophyll absorbs one photon from the sunlight and release one electron.
   - The electron powers a series of reactions that create an energy transfer molecule called NADPH.
   - The electron that is lost by the chlorophyll is regained from water, releasing oxygen in the process. This 'resets' the chlorophyll, allowing it to collect more photons.

Converting electrical energy to chemical energy – use of CO_2 and creation of $C_6H_{12}O_6$

- An enzyme RuBisCO captures CO_2, using the energy from the transfer molecule NADPH.
- A three-carbon molecule is created, which is later converted into glucose.

RESPIRATION

When a heterotroph consumes another organism, all the unused glucose is taken in by the heterotroph. The glucose can then be stored or used in cellular processes such as **cellular respiration**.

Cellular respiration is the process used by heterotrophs to convert organic materials into energy, in the form of adenosine triphosphate (ATP).

It is interesting to note that cellular respiration is virtually the opposite of photosynthesis:

$$\text{Glucose} + \text{Oxygen} \rightarrow \text{Carbon dioxide} + \text{Water} + \text{energy}$$
$$C_6H_{12}O_6 + 6O_2 + 34\text{–}36P_i + 34\text{–}36ADP \rightarrow 6CO_2 + 6H_2O + 34\text{–}36ATP$$

Note: P_i denotes inorganic phosphate. ATP is made out of an adenosine molecule that is attached to three phosphate molecules. The bond between the second and third phosphate is how energy is stored within ATP. When the bond is broken, ATP is split into adenosine diphosphate (ADP) and an inorganic phosphorus (P_i), releasing the energy that was trapped within the bond. When cellular respiration occurs, ADP and P_i are joined together by the energy released from glucose, creating ATP. This ATP molecule then works as a storage medium for energy until it is needed by the body (i.e. the ATP molecule produced is the 'energy' produced by respiration, to be used later by other cells).

- **Explain the relationship between the shape of leaves, the distribution of tissues in them and their role.**

LEAVES

A casual glance at any park, forest or field and you can easily tell that there are a huge variety of leaves in many shades of green, decorating plants. However, are leaves more than just decorative ornaments?

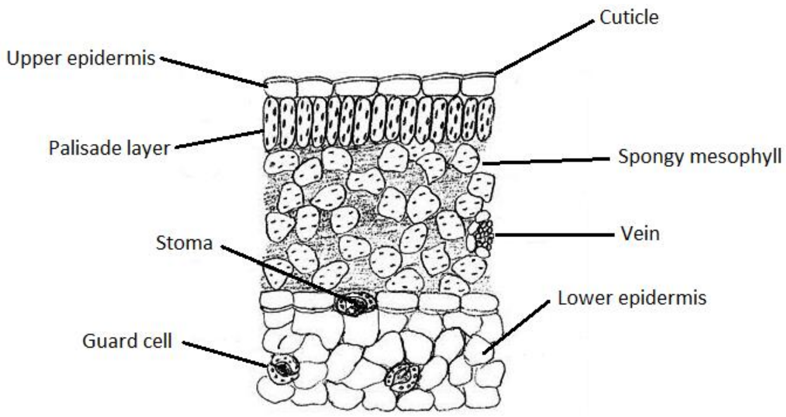
We know that in order for photosynthesis to occur, the green pigment chlorophyll is required. It's no coincidence that leaves are green, being the main site of photosynthesis. Leaves are organs which house chloroplasts, providing them with water and carbon dioxide for them to proceed with photosynthesis.

Like all organs, the various specialised tissues found within leaves are what allow them to function properly.

The tissues within leaves serve three main functions:

Protection

Leaves are organs that are exposed to the environment. On the whole, tissues are organised in such a way that fragile tissues are protected by other more resistant tissues.



Provision

Plants are autotrophs and make their energy through the process of photosynthesis. During times where sunlight is lacking, glucose produced by photosynthesis can be created into energy in the mitochondria. Since photosynthesis requires carbon dioxide and water, the plant needs to have a constant supply of these nutrients.

Leaves greatly increase the surface area for the absorption of carbon dioxide. Specialised structures on the surface of leaves, stoma, control the amount of water that evaporates out of the leaves.

Photosynthesis

The main function of leaves is to undergo photosynthesis thus converting raw materials into energy-bearing organic molecules. Organic molecules are then transported to the rest of the plant where they are either broken down or stored. When stored organic molecules are consumed by heterotrophs, the movement of energy between trophic levels occur.

PROTECTION

Leaves are constantly exposed to direct sunlight, heat, dry winds and heavy rains. In order to protect the important photosynthetic organs, plants have developed various ways to protect their leaves.

1. The **cuticle** is a protective waxy covering of leaves.

The cuticle is located on the **outer surfaces of the epidermis** on leaves. However, they are not considered to be a type of tissue as it is not made out of cells. Rather, it is **secreted by the epithelial cells** of the leaves.

The cuticle is usually much **thicker on the top** of leaves than the bottom, since this is where protection against heat, rain and other physical pressures is most required. Additionally, the waxy layer that is the cuticle **greatly reduces water loss** by evaporation as well as **reducing loss of oxygen and carbon dioxide** by diffusion.

Contamination of leaf tissue by external factors such as microorganisms, virus particles, dirt and water is highly discouraged by the protective cuticle layer.

2. The **epidermis** is a single layer of cells that forms a boundary between the plant and the external environment.

   Epidermal tissue is made of cells that are tightly packed together. This **discourages the entry of foreign particles** through spaces between cells. The tight packing of cells **provides structural support** to leaves. As previously mentioned, the epidermis secretes the chemicals that form the protective cuticle on the outer surface of leaves.

   The epidermis is usually transparent, allowing light to pass through and come into contact with chlorophyll within the leaf. Epidermal cells have low amounts of chlorophyll, showing that they play a limited role in photosynthesis. Instead, the chlorophyll is concentrated in the tissue under the chlorophyll – the mesophyll.

   Trichomes (special name for hair on leaf cells) grow out of some epidermal cells. These trichomes provide further protection from intense heat and dry winds, by trapping air and preventing the movement of moist air away from the leaf surface. Since the speed of evaporation and diffusion is dependant the difference between two environments, the capturing of moist air by trichomes greatly reduces the rate of water loss. Furthermore, some plants have a thick layer of trichomes that **discourage animals from eating them** – it will be like eating a hairy brush!

3. **Guard cells** or **stomata** (singular **stoma**) regulate the exchange of gasses and water vapour between the leaf and the environment.

   Stomata are mainly found on the **underside of the leaf**, away from direct exposure to sunlight and rain. Furthermore, airborne particles such as dirt, bacteria, pollen or viruses are less likely to enter through stomata on the underside of leaves. An exception to this rule is plants that float on water. Since the underside of their leaves come into direct contact with water, the stomata are more concentrated on the upper surface of leaves.

Stomata creates **pores** that pass through the epidermis, making a channel that allows the **exchange of water vapour and gasses**. There are large amounts of stomata on leaves. Some plants may have up to 100,000 stomata per cm^2 of leaf area. As such, plants are able to quickly exchange water and gasses between itself and the environment.

Plants control the opening and closing of the stomata depending on its needs. When stomata are open, water vapour and carbon dioxide gas are able to freely pass through. Since the concentration of water vapour is usually greater within the plant than outside the plant, water vapour tends to evaporate out of stomata. On the other hand, carbon dioxide is more likely to diffuse into plant cells.

The opening of stomata increases the availability of carbon dioxide to the plant, increasing the amount of photosynthesis that can occur. However, water vapour is lost much faster, making opening the stomata highly undesirable in dry weather or climates. Consequently, **the plant has to find a balance between the uptake of carbon dioxide and loss of water by controlling the opening of stomata**.

Stomata contain chloroplasts and thus are able to photosynthesise. This is important because ATP is required to initiate the process that closes stomata.

PROVISION

Carbon dioxide and water are required for photosynthesis. Since photosynthesis is constantly occurring during exposure to sunlight, leaves need a constant supply of these two compounds.

1. **Guard cells or stomata (see previous)**
2. **Vascular tissue** of plants is akin to the veins in our circulator system. There are two types of vascular tissue:
    - **Xylem that** carries water and water-soluble minerals from the roots to the rest of the plant.

      Xylem allows the process of **transpiration** to occur, replacing water lost via photosynthesis and evaporation. Transpiration is the force that 'pulls' water through the xylem, caused by negative pressure when water evaporates from the leaves. The adhesive and cohesive properties of water molecules allow transpiration to take place.

      Since there is a higher concentration of water-soluble materials within the xylem, water moves via osmosis into xylem tissue of the roots. This contributes to transpiration by providing positive pressure to water moving up the xylem.

      In the leaves, water moves by osmosis out of xylem and into the space between cells, providing mesophyll cells with water for photosynthesis.

      Mature xylem cells are dead, leaving only their cell walls which make up xylem tubes.

- **Phloem** that carries organic nutrients, dissolved in sap, to all parts of the plant that requires it.

  In the leaves, phloem cells take in products of photosynthesis from mesophyll cells and move them around the plant. The products of photosynthesis can be either used for metabolism or for storage in the form of shoots or specialised roots (e.g. potato)

  Phloem cells are alive at maturity, and are accompanied by a companion cell. Companion cells help phloem cells function by providing energy required to transfer solutes into the sap within phloem tubes.

PHOTOSYNTHESIS

Photosynthetic cells are mainly found within the leaf, protected by the epidermis and close to the vascular bundle. There are two main types of photosynthetic cells, both extremely rich in chloroplasts which give leaves its green colour.

1. **Palisade mesophyll** are so called because they are lined up in a row, like palisade fencing.
    - The primary site of photosynthesis in plants
    - Positioned towards the upper side of a leaf, maximising exposure to sunlight
    - Cylindrical shape further increases the surface area for light to be absorbed
    - Has the largest number of chloroplasts per cell
2. **Spongy mesophyll** contains a large number of air space between cells, making it look like a sponge.
    - Air space between cells increases the total surface area for the interchange of gasses, namely absorption of carbon dioxide and release of oxygen
    - Less likely to undergo photosynthesis than palisade mesophyll cells
    - Contain less chloroplasts than palisade mesophyll

Aquatic plants do not contain the double layer of mesophyll cells. Instead, they have aerenchyma, which are ‘tubes’ like xylem that allow air to flow easily within the plant.

Term 1 – Week 5 – Homework

- **Distinguish between autotrophs and heterotrophs in terms of nutrient requirements**

1. Outline TWO methods employed by heterotrophs to obtain energy-rich organic molecules. **[2 marks]**

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2. Complete the following table to compare the nutrient requirements of autotrophs and heterotrophs, identifying the source of each nutrient.

Type of organism	Nutrients required	Source of nutrient
Autotroph		
Heterotroph		

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- **Identify the materials required for photosynthesis and its role in the ecosystem**
- **Identify the general word equation for photosynthesis and outline this as a summary of a chain of biochemical reactions**

1. Which of the following statements regarding photosynthesis is TRUE? **[1 mark]**
   a. Photosynthesis is the only method employed by produces within any ecosystem to capture energy
   b. Photosynthesis requires carbon dioxide and oxygen and releases glucose and water, making it an essential part of carbon-based life
   c. Carbon fixation is the process where photosynthesis takes carbon dioxide in the air and creates organic molecules from them
   d. There is only one step in photosynthesis, which is what makes it an extremely efficient tool for capturing energy

2. The products produced by photosynthesis are known as photosynthate. Explain the importance of photosynthate in the ecosystem. **[4 marks]**

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3. The organelle that plays the main role in photosynthesis within plant cells is the: **[1 mark]**
    a. Thylakoid
    b. Chloroplast
    c. Chlorophyll
    d. RuBisCo enzyme

- **Explain the relationship between the shape of leaves, the distribution of tissues in them and their role.**

1. Which of the following pairings of tissues within the leaves and its function is CORRECT?

   [1 mark]

   a. Cuticle – Layer of cells that act as a barrier while allowing light to pass through
   b. Mesophyll – Main site of photosynthesis
   c. Epidermis – Waxy surface that protects plant cells from the external environment
   d. Stomata – Provides leaves with a supply of water

2. "In nature, plant leaves come in various shades of green. Leaves are generally found on the top of trees, and most abundantly in areas with abundant sunlight. In general, leaves are thin yet durable. Some leaves are hairy and unpleasant while others have a waxy surface that causes water to form droplets that easily run off the surface of leaves."

   a. Identify THREE characteristics of leaves that are described by the above paragraph. Describe how each of these characteristics allows leaves to function as photosynthetic organs. **[6 marks]**

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b. With the aid of a diagram, identify the features of leaves that contribute to the characteristics of leaves as described in the above paragraph. **[3 marks]**

3. Name TWO differences you would expect in the distribution of tissue in a blade of grass (normally held vertical) and the leaves of a papaya tree (normally held horizontal). Explain your choices. **[4 marks]**

End of homework