Rewarding Learning

eGUIDE//Biology

Biochemistry, Genetics and Evolutionary Trends

Unit A2 2 5.7 Kingdom Plantae

This e-book is designed to complement other support materials and enhance the understanding of this unit for students at GCE level. The topics covered are in accordance with those topics present in the current specification.

Contents

Kingdom Plantae

5.7

Learning Outcomes from A2 2 5.7

Students should be able to:

- Demonstrate knowledge and understanding of the key features of a moss with particular reference to their restriction to moist habitats
- Demonstrate knowledge and understanding of the key features of a fern in terms of adaptations to terrestrial life
- Demonstrate knowledge and understanding of the key features of a flowering plant in terms of adaptation to terrestrial life.

Kingdom Plantae

Plants vary in size and complexity from tiny mosses to very large trees. All are eukaryotic and multicellular and generally possess photosynthetic pigments such as chlorophyll and are therefore autotrophs.

Scientists believe that the first plants started their life in water. This enabled them to absorb water and nutrients directly from their surroundings, and also be physically supported by their environment. As they evolved through time, they graduated to living on land and so had to adapt to terrestrial conditions. Mosses are thought to be the first plants to make the move from water to land.

Terrestrial plants face a number of environmental challenges such as:

- Risk of desiccation
- Nutrient availability
- Support (when not surrounded by water for support)
- Regulation of gas exchange (related also to water loss and therefore desiccation)
- Temperature fluctuation
- Developing successful mechanisms for reproduction.

As increasingly complex and more highly evolved plant groups, are examined, a progression in the mechanisms plants have evolved to adapt to terrestrial life can be seen.

Adaptations to living on land include:

- living and growing only in moist settings
- dormancy during periods of drought
- resisting desiccation by having a waterproof outer layer to reduce water loss
- the development of stomata to enable and regulate gas exchange and water loss
- development of complex and more highly specialized body parts such as roots, stems and leaves to carry out different functions
- development of specialized vascular tissue; xylem and phloem, to transport water and nutrients throughout the plant
- incorporation of lignin into cell walls to give strength and support
- reproduction by means of seeds which are resistant structures to protect the embryo, have an integral energy supply and can also function as a dispersal mechanism
- exploiting insects and other animals in pollination and seed dispersal mechanisms.

In this resource mosses will be looked at, followed by ferns and then to the most highly evolved and successful plants; flowering plants, comparing their adaptive mechanisms as we do so.

The **CCEA Fact File on 'Taxonomy and Classification'** contains more information. The BBC two series – 'The Private Life of Plants' provides useful clips for this section. http://www.bbc.co.uk/programmes/b01qbw1w/episodes/guide

Division Bryophyta – Mosses

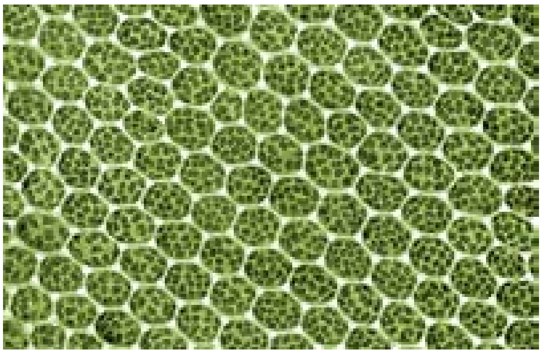
Mosses are non-vascular, non-seed bearing vascular land plants.

Close-up abstract of a patch of sphagnum moss (Sphagnum papillosum) growing in a heathland boggy habitat in Norfolk, UK.

Moss spore capsules. Macrophotograph of the stalked capsules (spore cases) of a club moss (Funaria hygrometrica). The capsules are borne on spiralling stalks which curl up in dry conditions and unwind when they are damp.

For a diagram of moss structure see http://bryophytes.science.oregonstate.edu/page3.htm

Mosses are tiny plants (they rarely gain a height of more than a few cm) that lack tissue specialisation - they have no vascular system, true roots, leaves or stems.
They also lack a waxy cuticle to prevent water loss, and are reliant on their immediate surroundings for water and to keep moist. Therefore they inhabit moist, shady areas. They can grow on soil, rocks, concrete, rooftops and any other moisture-laden area. Some have become adapted to changes in water availability by reverting into a dormant stage in dryer periods. Their 'leaves' are mostly one cell thick, and the cells contain chlorophyll in chloroplasts, therefore they are photosynthetic autotrophs. Without any vascular tissue, they rely on the turgidity of their cells for support.



Moss leaf. Brightfield illuminated light micrograph of a section through a leaf from a moss (Plagiomnium rostratum) plant, showing the network of cells arranged in a roughly hexagonal pattern, with their cell walls (bright lines) between them.

Mosses are anchored to the surface of the substrate they are growing on by means of rhizoids, simple hair-like projections, which grow out of the epidermal cells of the moss and also facilitate the uptake of water and mineral ions. The rhizoids do not penetrate the substrate deeply, which limits them to growing in areas where water and nutrient ions are found close to the surface. Mosses can also take in water and mineral ions over their whole surface but this will also leave them at risk of desiccation, if water becomes unavailable. They rely on osmosis and diffusion for movement of substances through the plant.

Reproduction is by means of spores, rather than seeds. The spores are formed in brown capsules (see image of spore capsules below) at the top of thin, stalk-like structures called seta. The spores will germinate after dispersal if they land somewhere where there is sufficient moisture. They, unlike seeds are not resistant to desiccation.

Moss spore capsule. Coloured scanning electron micrograph (SEM) of the mouth of a capsule (spore case) of a moss (Funaria hygrometrica). Mosses reproduce by means of spores (small orange spheres) which are dispersed from the mouth of the capsule by the numerous rays (pink) that snap open. Each capsule is borne on a spiralling stalk that is coiled up in dry weather and unrolls only in damp conditions.

Mosses are considered to be ‘pioneer plants’ as they can colonise bare areas of ground for example, after a fire.

Questions (from CCEA past paper May/June 2010 Unit 2)

a) Moss plants of the genus *Polytrichum* (photograph A below) are upright and have well developed rhizoids. They form dense tufts as shown in the photograph. These features allow *Polytrichum* species to grow on rocks and walls, both of which are relatively dry.

A

Polytrichum commune moss with sporophytes

B

Light micrograph of bog moss

i) Suggest how the following features allow these plants to grow in relatively dry areas.
- Well-developed rhizoids
- Growth in dense tufts

ii) Explain how the plant is supported to keep it upright.

b) Photograph B shows a moss plant of the genus *Sphagnum*. This moss covers the waterlogged soils of peat bogs. The lower part of the plant is dead and there are no rhizoids. Water and mineral ions are absorbed directly through the 'leaf-like' structures.
Suggest reasons for the following features, characteristic of *Sphagnum*.
- The absence of rhizoids and the dead lower parts of the plant.
- The ability to absorb water and mineral ions into the 'leaf-like' structures, an ability not shared by the leaves of ferns or flowering plants, members of the division Tracheophyta.

Division Tracheophyta – Vascular Plants

Examples include:
Ferns – non-seed bearing vascular plants
Angiosperms (flowering plants) – seed bearing vascular plants

The vascular plants represent a step further in evolution.
They possess:

1) Vascular tissue consisting of:
   Xylem – for the transport of water. Composed of non-living tracheids and vessel elements, stiffened by lignin.
   Phloem – for the transport of food (sugars). Composed of living sieve elements (non-lignified).

Vascular tissue is found in a central column or stele. Due to the presence of vascular tissue, plants can grow larger than mosses as they are not reliant on water and turgid cells for support.

2) True leaves, stems and roots

Adaptations of vascular plants to terrestrial life;

- vascular tissue (as above)
- have a well-developed waxy cuticle covering aerial parts of the plant
- have developed stomata in the epidermis for gas exchange
- a developed root system, which anchors the plant in the ground and facilitates the uptake of water and mineral salts from the soil
- aerial leaves with a large surface area for absorption of sunlight
- a developed stem, which supports the leaves and orients them in such a way as to maximise incident sunlight. It has vascular tissue to conduct water and nutrients from the soil, and food from the photosynthetic parts of the plant to where they are needed.

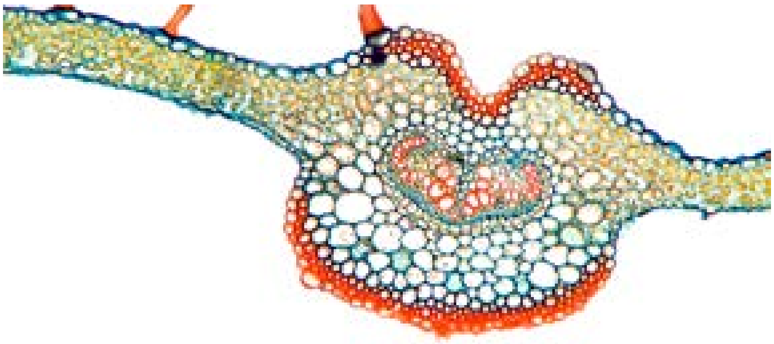
Ferns (Filicophyta)

Ferns are vascular plants but do not have seeds or flowers. They are a diverse range of plants with a worldwide distribution. The majority of ferns inhabit warm, damp places. They grow profusely in tropical areas; few are found in dry, cold places. Ferns vary in size from a few centimetres, to tree ferns, which can be up to 20m in height. Some grow freely as terrestrial plants; others exist as epiphytes, growing on other plants. Their stems never become lignified.

Giant ferns (Angiopteris erecta) along a stream in lowland rainforest, northwest Panay,

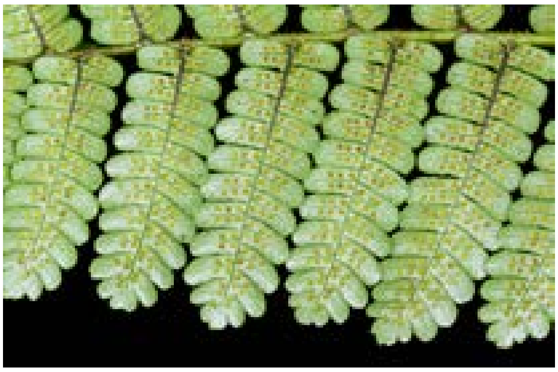
Although diverse, ferns typically:

- possess vascular tissue; xylem and phloem.



Fern (Adiantum capillus-veneris) leaf. Light micrograph of a section through a leaf from a maidenhair fern, showing the midrib (vein, large, centre) containing the vascular bundle.

- supported by the presence of the vascular bundle (the thickened walls of xylem vessels) and turgidity of cells
- possess a horizontal underground stem called a rhizome that grows partially underground. True roots grow out of the rhizome
- possess a waterproof cuticle to help prevent desiccation
- possess stomata to regulate gas exchange, water loss and temperature regulation
- possess true leaves called fronds, which are deeply divided and grow out of the rhizome – leaves are divided into primary (pinnae) and smaller divisions (pinnules) which develop from an axis or rachis.



The underside of a fern leaf. The numerous brown structures are sori, each of which consists of many sporangia. Mother cells within the sporangia undergo meiosis to produce spores which are released when the sporangia dry out and split open. In conditions of continuous dampness a spore will germinate on the ground.

- reproduce via spores – each frond is potentially a spore bearing leaf or sporophyte, which may under favourable conditions, develop a series of brown areas called sori (singular: sorus) on the undersurface of the leaf. Each sorus is composed of many spore cases in which haploid spores are produced by meiosis. Spores are not resistant to desiccation and only germinate in moist conditions.

Flowering plants (Angiosperms)

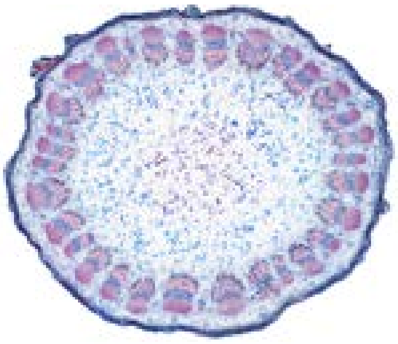
Angiosperms are seed-bearing vascular plants.

They represent a further increase in complexity in comparison to ferns, possessing all the water-retention and support features of ferns such as:

- presence of a specialized vascular system
- differentiation into root, stem and leaf structures

but in addition:

- vascular tissue is arranged in bundles around the pith and is more complex and efficient than in ferns
- they possess a more complex plant body
- reproduction is through seed production rather than spores.



Sunflower stem. Light micrograph of a section through a young stem from a sunflower (Helianthus annuus), showing a ring of vascular bundles. The outer stem is covered with a thin epidermis (dark blue). Under the epidermis is a layer of flexible collenchyma (dark blue) for support. The cortex and pith is composed of parenchyma tissue (light blue). The vascular bundles have an outer layer of sclerenchyma tissue (crimson). Next is the phloem (dark blue) with phloem tubes, parenchyma and companion cells. Then the xylem (red) and at the end of the xylem are patches of fibres (red). In between the phloem and xylem is the cambium

Seed production is an important advance as each seed contains;

- an embryonic plant
- food storage tissue or endosperm
- a hardened protective coating/seed coat.

Therefore the seed;

- protects the embryo from desiccation
- provides it with an integral source of energy/food and raw materials for initiating growth
- acts as a dispersal unit through different mechanisms.

Dandelion clockhead. Seedhead of the dandelion flower (Taxacum officinale)

Other adaptations of angiosperms to terrestrial life include;

- production of pollen, which can be dispersed by wind or animals. Angiosperms have exploited wind, insects and other animals as pollination agents to enable male gametes to reach female gametes. This promotes genetic variation.
- seed dispersal by wind, water and animals aids the distribution of angiosperms over a wide range of habitats.

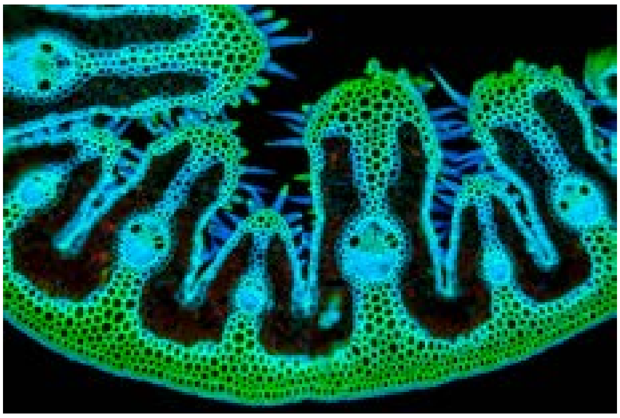
Further adaptations of flowering plants

Modifications of roots, stems and leaves have also enabled some vascular plants to further adapt, grow larger, succeed and survive in a variety of sometimes extreme environmental conditions for example xerophytes in drought conditions.

1. Xylem tissue has developed into wood in trees giving more support and enhancing water retention properties.

Colour enhanced Scanning Electron Micrograph (SEM) of Beech (Fagus sylvatica) wood in lateral section,

2. Xerophytes are plants adapted to live in dry/drought conditions.



Ammophila arenaria leaf. Light micrograph of a section through a marram grass (Ammophila arenaria) leaf in fluorescence light, showing the characteristics that help reduce water loss. The outer epidermis consists of a layer of thick cuticle and layers of thick walled sclerenchyma (green), while the inner epidermis is folded and hairy to trap water vapour. Chloroplasts (dark-red), phloem (blue) and xylem vessels (green) can also be seen.

Look at the above image of marram grass, which inhabits sand dunes and similar places which are sandy and/or suffer from a lack of available water. They have evolved survival adaptations such as:

- they possess a thick waxy cuticle; which cuts down water loss by:
  acting as a barrier to evaporation; and
  creating a shiny surface which reflects heat and mitigates temperature rises.

- rolled leaves: some xerophytes roll their leaves in hot and windy conditions. The inner surface of the leaf is covered in hairs. Stomata are also located in the inner surface. The rolled leaf and hairs act to trap moist air, reducing transpiration from the stomata. In addition, a smaller leaf surface area is exposed to drying winds
- sunken stomata: stomata may be sunk in pits in the epidermis. Moist air is trapped here and this reduces the rate of evaporation
- small leaves: many possess small, needle shaped leaves. These leaves are often circular in cross section, reducing the surface area for evaporation
- succulent stems: some xerophytes, called succulents, will store water in their stems
- some plants have spines: spines give protection from animals, provide shade from the sun and collect moisture
- an extensive shallow root system: extensive shallow root systems enable the rapid absorption of large quantities of water when it rains.

Cane Cholla (Cylindropuntia spinosior) with fruit, El Camino Heritage Center near Socorro, New Mexico

Cape aloe (Aloe ferox). Photographed in Grahamstown, Eastern Cape, South Africa.

Q. In marram grass, the plant rolls its leaves in hot, dry conditions with the use of hinge cells. Why do the leaves not remain like this despite the conditions in the external environment? What disadvantage(s) may it pose to the plant?
AS level. G.19. Xerophytes (Ms Cooper), Ms Cooper's A level Biology looks at the adaptations described above.
https://www.youtube.com/watch?v=1_r6T810BM4
Transport in Plants: Transpiration & Xerophytes discusses xerophyte adaptations (from 3mins 35 secs to 5 mins 46 secs).
https://www.youtube.com/watch?v=ejJi0-EI06M
This link to 'Xerophytic adaptations of stonecrop' looks at some adaptations in this plant include reversed stomatal rhythms – stomata are closed during the day and open at night.
http://www.saps.org.uk/saps-associates/browse-q-and-a/502-what-are-the-xerophytic-adaptations-of-stonecrop

Question CCEA May/June 2011, Unit 2 Page 19 Q8 (part of)
The kingdom Plantae contains the mosses (division Bryophyta), the ferns (division Tracheophyta: subdivision Pteridophyta)and the flowering plants (division Tracheophyta: subdivision Spermatophyta). Discuss how mosses, ferns and flowering plants are differently adapted for life on land.