UNIT G – SEED-PRODUCING PLANTS

Imagine living outdoors and not being able to move. No walking, talking, or texting – nothing, not even seeing or hearing! The things we do, as part of our everyday lives would immediately become challenges. From where would we get our food? How would we eat, get rid of wastes, reproduce? The simplest things like taking a drink of water would be impossible. We would certainly perish!

No matter whether you imagined yourself in a city, on a mountain, a valley, a desert, or a forest, or even in someone's back yard, in winter or in summer – survival would be impossible. These are the many challenges faced by plants. The terrestrial plants in the last unit, the mosses and the ferns are specialized to survive on land. They make their own food; they have ways of obtaining water and ways to prevent its loss. However, they are not entirely successful; they are still restricted by their dependency on water for the motility of sperm for sexual reproduction.

The plants in this unit produce gametes specifically adapted to get around this barrier and, as a result, have a more successful terrestrial existence. They also produce **seeds**. In some respect, seeds are like spores. Both are genetic packages capable of growing into organisms. Seeds, however, unlike spores, are embryonic – the result of fertilization and they contain a food source to satisfy the nutritional requirements of the new plant until it becomes truly autotrophic. Plants, which produce seeds, are called **spermopsids** (Kingdom Plantae, Phylum Tracheophyta, and Subphylum Spermopsida).

INTRODUCTION TO SPERMOPSIDS

A moment's thought should enable one to begin to generate a seemingly endless list of spermopsids. Practically every land plant that is not a fern or a moss qualifies (vegetables, trees, shrubs, flowers, and so on). These thousands of plants are clustered into two groups based on their seeds. One group, known as **gymnosperms** produces "naked seeds", seeds that are directly exposed to the air (*gymnos* is Greek for naked). Most evergreen trees fall into this category. Plants in the other group produce enclosed seeds that are completely covered by protective tissues (like pods, fruits, or shells). Members of this group are called **angiosperms**. Angiosperms can be further subdivided into two categories based on their seed structure. Some seeds naturally split into two halves (such as beans, peas, and sunflower seeds), where others do not (like corn, wheat and barley). These subdivisions are named **dicotyledon** and **monocotyledon**, respectively. Other distinctions between monocots and dicots will become a focus later in this unit.

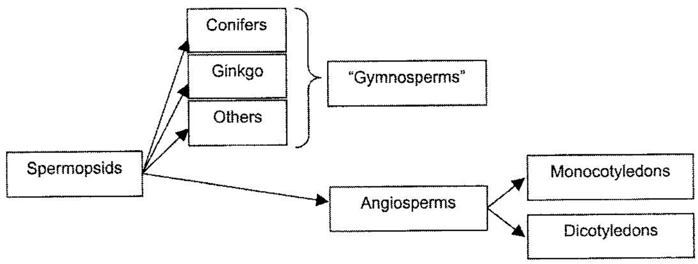

Figure G-1. Diversity of Spermopsids

Before considering the specializations enabling spermopsids to be so successful on land, it is important to consider some plant tissues. **Tissues** are groups of cells that work together in some functional way. Growth of plants, for example, is a function of **meristematic** tissues, which are clusters of cells that undergo **mitosis**. The newly-produced cells become specialized to form parts of the plant body that not only make the plant bigger, but also specialize and contribute to the plant's adaptations for survival on land. Meristematic tissue found at the tips of roots and stems, called **apexes**, primarily contributes to elongation, making the roots grow deeper and the stems grow taller. Cells in the **apical meristems** also produce plant hormones like **auxins**, and **gibberellins**, which control the rate and direction of growth.

Another important type of meristematic tissue is the **vascular cambium**, which runs the length of the plant body. New cells produced by the vascular cambium contribute to the increasing diameter (girth) of plant stems as they specialize to form **vascular tissue**, which transports water and nutrients throughout the plant and provides structural support for the plant as it grows.

Other plant tissues include parenchyma, collenchyma, and sclerenchyma. These tissues are formed from cells that specialize for storage, protection, and/or photosynthesis. Plant organs, like stems, roots, and leaves are comprised out of varying combinations of these tissues – adaptations for the unique requirements of individual types of plants. Plants are often grouped according to their specializations for survival in their habitats. **Xerophytes**, like cacti, not only have extensive root systems to obtain water, but also stems that are specialized to store water and reduce its loss. **Hydrophytes**, like water lilies, are less concerned about water and more concerned about gas exchange for photosynthesis. **Halophytes**, like marsh grass have a high tolerance for the mineral and salt content in the soil and water they depend on.

TRANSPORT SYSTEM OF PLANTS

As unique as the survival requirements of different plants are, there remains a measure of commonality to the distribution and arrangement of the tissues. An excellent example of this is vascular tissue forming the transport system of plants. Perhaps the greatest hardship to survival on land relates to a plant's requirement of water for photosynthesis. The water has to come from the ground, so **roots** have to be able to absorb it. Photosynthesis occurs, for the most part, in **leaves**, so specializations have to exist to transport the water up to the leaves. Leaves are specialized to make sugar, but not necessarily to use it. The sugar is used for growth and reproduction, which occur elsewhere, so plants have to be specialized to move the sugars to where they are needed or to storage sites until they are needed. These transport requirements are met by the vascular system.

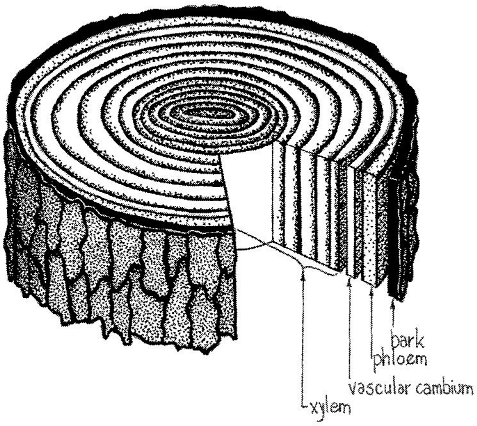

Figure G-2. Cross-section of a Tree. *Beneath the bark of a tree lies the transport system, which is produced by the vascular cambium. To the outside of the vascular cambium, newly-produced cells specialize to form phloem tissue, whereas those produced on the inside become xylem tissue. The xylem forms annular rings as cell production changes with the seasons.*

Vascular tissue comes from vascular cambium – meristematic tissue that runs the length of the plant body. The cells produced by vascular cambium specialize in different ways to take on different components of this transport function, depending on their location in the plant body. Examination of a growing stem will provide the clues to understanding this. As new cells are produced at any given location along the vascular tissue, some will be located closer to the center of the stem, others closer to the outside. It may be that this difference in location exposes the cells to slightly different conditions, and this is all that it takes to cause the cells in each area to specialize in one of their preprogrammed ways.

Cells on the inside of the vascular cambium specialize to form **xylem** tissue; cells on the outside form **phloem** tissue. Cells of the xylem transport water and dissolved nutrients up from the root tips to the organs of photosynthesis. Cells of the phloem transport the sugar-rich fluid away from where it is produced to growth centers and to roots for storage. Each of these two tissues is in turn made up of a combination of transport and support cells. Water enters the vascular tissue through specialized epidermal cells of the root tips called root hair cells. The water is drawn in by **osmosis** created by the transport of mineral nutrients into the cells. It is then conducted towards the vascular tissue by osmosis, which draws it constantly towards higher concentrations of dissolved substances in the tissues of the root tips. Once into the vascular tissue, the water enters the xylem where it is prevented from moving back out by a waxy layer, the **Casparian strip**, that surrounds it. Water is drawn up the xylem as a result of the evaporation of water from the leaves. This process is called **transpiration**. Water molecules are cohesive and tend to stick together, so when a water molecule evaporates from leaves, it pulls a next molecule up to take its place. Compounding this action millions of times over accounts for the movement of the water and dissolved nutrients up a plant stem.

In temperate regions of the earth, where there are four distinct seasons, the growth rate of trees through the different seasons, year after year, depends on environmental conditions. They grow fastest in good conditions (spring) and then concentrate their energies for reproduction and seed development (late spring and summer) before growing conditions change. By autumn, the trees are preparing for **dormancy** over winter to wait for the next growing season. In more tropical regions, where there are wet vs. dry seasons, the rapid growth occurs in the wet seasons. In the tropics, themselves, where good conditions for growth always prevail, the cycle of growth, reproduction, and dormancy hardly exists.

When the vascular cambium divides, new xylem cells develop to the inside increasing the girth of the tree. During rapid growth periods (spring), the new cells are large. During slower growth periods, the new cells are smaller, and during dormancy, there may be no new cells produced at all. Different sized xylem cells produce wood of different densities. The effect of this produces annular rings (annual rings) and the grain patterns in wood. Similarly, phloem cells get produced to the outside of the vascular cambium. As growth continues, the outer phloem cells get damaged and die, contributing to the development of bark, which protects the growing masses of new phloem and xylem tissue. The older (innermost) layers of xylem cells often cease to be able to transport water because they get too plugged up with cellulose. This region becomes known as the **heartwood**. The **sapwood** is made up of the layers of xylem that are still functioning.

Trees are of huge value to humans. Wood is a precious commodity – one of the few renewable resources. It can be harvested for lumber production and biomass fuels. Trees like pine, fir, cedar, and hemlock (generally called softwoods) are all Gymnosperms. Hardwood trees including oak, maple, birch, ash, mahogany, and teak are dicotyledons, a subphylum of the Angiosperms.

Some angiosperms never grow into woody trees, and do not have annual rings. Plants like these (clover, buttercups, and dandelions, most flowers and vegetables, to name a few) are often termed herbaceous. Many are **perennial** and grow year after year, but they die back in winter (non-growing seasons) and new growth, with new shoots begins every spring. They have no opportunity to form woody tissues.

G-1. Concept Check-up Questions:

1. What is the distinction between a gymnosperm and an angiosperm?
2. Describe the role of each of these plant tissues:
   a. meristematic tissue
   b. vascular tissue
3. Where is meristematic tissue found in a plant?
4. Distinguish between xerophytes, hydrophytes and halophytes
5. What types of tissues does vascular cambium produce and what is the specific function of each?
6. How are annular rings formed?

Gymnosperms

The forests of BC are rich with gymnosperms. Most gymnosperms are **coniferous** or cone-producing trees. Some common examples are pine, cedar, and fir. The cones they produce are their reproductive structures. Their leaves are either modified into **needles**, or are scale-like as in the cedars and junipers. Both of these features as well as the general shape of the tree and the appearance of the bark contribute to the relatively easy identification of most gymnosperms.

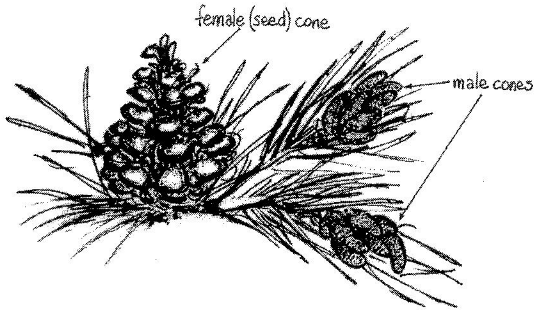

Figure G-3. Reproductive Structures of Conifers. *Conifers typically produce male and female cones. Male cones are produced annually. They are smaller and release pollen when mature. The female cones of some species take three years to mature. They contain seeds between their scales.*

The plant body of all spermopsids is a 2N sporophyte on which gamete-producing structures develop. The fertilization process that follows the production of gametes is very similar for all spermopsids, though the plants themselves have different structures and specializations. Gymnosperms produce both male and female cones. **Pollen**, produced by **male cones**, is a multi-cellular structure specialized to be transported by the wind. Each pollen grain has specialized cell containing three nuclei – a **pollen tube nucleus**, and two **sperm nuclei**. The female cones produce and retain **ovules**, each one with an **ovum** that can be fertilized. When pollen lands on an ovule, its pollen tube nucleus controls the development of a **pollen tube**, which continues to elongate and grow into the ovule for the fertilization of an ovum.

Each sperm nucleus unites with a different haploid nucleus in the ovule. The one that unites with the ovum produces the zygote, which becomes the **embryo**. The other one unites with two **polar body** nuclei producing the **endosperm**, which becomes food for the embryo as it grows into a large enough photosynthetic structure to make its own food.

A seed contains the embryo and the endosperm. The seeds that gymnosperms produce are "naked", or exposed to the air. In cones, these seeds can be found between the **cone scales**. A rich source of food (because of the endosperm), they are sought after by the likes of squirrels and chipmunks.

ANGIOSPERMS

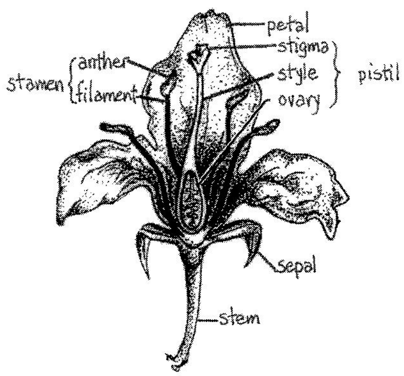

Figure G-4. Flower Structure. *Flowers are very diverse in their structure, yet have incredible unity. The photosynthetic sepals and petals typically surround the male stamens (anthers plus filaments), which surround the female pistil (stigma, style and ovary). Pollen is produced in the anthers and lands on the stigma. Pollen tubes grow down the hollow style to conduct sperm to the ovules. The ovary in this illustration is shown cut away to reveal the ovules.*

Where the reproductive organs of the majority of gymnosperms are cones, angiosperms produce **flowers**. This has led to their nickname, flowering plants. There are two subclasses of angiosperms, which are similar in many ways, yet are very distinct from each other by the structures of almost every part of their plant bodies. The flowers of some, particularly monocots, like the grasses, are hardly recognizable as flowers at first glance. Neither fragrant, nor colorful they are still (however) homologous to highly prized roses and orchids. Flowers are actually modified sets of leaves growing at the tips of stems. Considering the parts of a flower, the innermost structures are the female parts, collectively called the **pistil** (some flowers have multiple pistils). Each pistil has three parts: The top is the **stigma**, which is often sticky so pollen adheres to it. The neck of the pistil is called the **style**. The pollen tubes grow down the styles of flowers. At the bottom is the **ovary** in which the ovules, and later the seeds develop. These female parts are surrounded by the male structures called the **stamens**. Each stamen has two parts, the **filament**, which holds up the **anther**. The anthers produce pollen. Outside of the stamens are the **petals** and, finally, the **sepals**. The petals are sometimes very pigmented to attract potential pollinators. The sepals are photosynthetic, protecting and helping feed the flower while in the bud stage. Most flowers have all four sets of modified leaves, but some flowers are male only, where others are female only. Gender specific flowers like these have three sets of modified leaves instead of four, like most flowers.

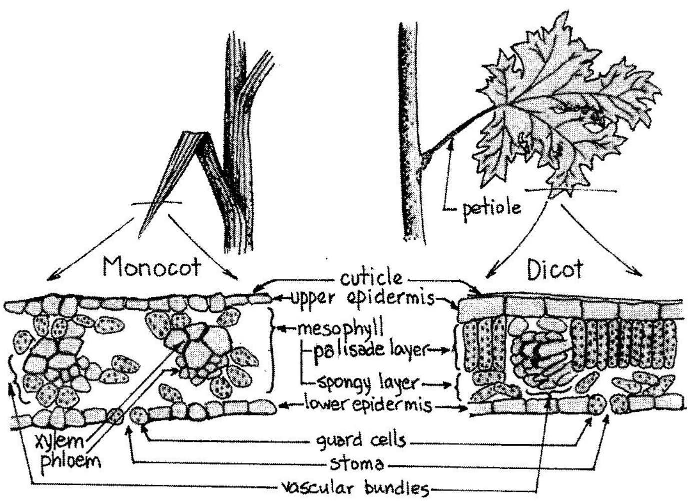

Figure G-5. Angiosperm Leaves. *Leaves of dicots are distinguishable from monocots by their branching vein pattern and petiole. Both of these features are absent in monocots. Microscopically, one could expect to find cross-sections of a series of vascular bundles in a monocot, where in a dicot they may appear far less organized due to the branching nature of their veins. Each vascular bundle has larger, thicker-walled xylem cells (top) and phloem cells surrounded by bundle sheath cells. Another distinguishing feature is the structural uniformity of the cell types in the dicot mesophyll.*

The components of the flowers of monocots are arranged in multiples of 3's (either 3, 6, 9 etc.). Dicot flowers develop with structures in multiples of 4 or 5. A flower with 12 petals and 12 stamens is sometimes unidentifiable as a monocot or a dicot unless other characteristics of the plant are taken into account. Additionally, the flower components of some angiosperms are so highly modified that the features of other organs of the plants have to be considered before a correct identification can be made.

Leaves, the photosynthetic organs of plants, are also very specialized. Where most gymnosperms have needle-like leaves modified to conserve water, the leaves of monocots and dicots are usually flat and broad, yet easily distinguished from each other in other ways. Veins in leaves are actually strips of vascular tissue. In monocots, these veins run parallel to each other, where they branch in dicots. In monocots, the leaves seem to be continuous with the stem of the plant that they grow from. Dicot leaves, in contrast, have a **petiole** (leaf stem) and a definite point of attachment to the branch. For plants that **defoliate** (drop their leaves in poor growing conditions, like winter), there is a strip of cells where the petiole attaches to the branch. These cells that break down and form a seal to allow leaves to fall off without damaging the rest of the plant.

When viewed in cross-section, the leaves of monocots and dicots show additional distinctions. Because of the parallel vein structure in monocots, a cross-section through a monocot leaf reveals a series of vascular bundles. A view of a dicot leaf, in contrast, may or may not contain a vascular bundle depending on the particular section of leaf used. The vascular bundle may even be at an angle. Both leaves have cuticles for waterproofing, an upper epidermis, and a lower epidermis. Typically, the lower epidermis is speckled with guard cells and stomata leading to air spaces between the spongy cells of the middle of the leaf, or mesophyll layer. Dicot leaves are also easily identifiable by the uniform nature of their palisade cells. Photosynthesis occurs in the mesophyll layers as well as in guard cells of leaves.

Monocot roots do not get as massive as dicot roots. Often referred to as **fibrous**, monocots roots cover a huge surface area concentrated in the first few centimeters of soil. Grass sod is a good example of this. The roots of dicots get more massive and form large root systems that probe deep into the soil where their absorptive tips function. A dicot root system can anchor and support a much larger plant than a monocot root system. The randomly arranged vascular bundles in the stems of monocots are extensions of the vascular bundles in the roots. This arrangement is not sufficient for dicots as the vascular tissues aggregate together increasing the efficiency for the bulk transport of materials through their larger root systems. Additionally, some dicots grow specialized underground structures like **taproots** and **tubers** (actually an underground modified stem) to store food reserves, products of photosynthesis. A carrot is a taproot; a potato is a tuber.

Cross-sections of the stems of non-woody herbaceous angiosperms also exhibit distinctions between monocots and dicots. The vascular tissues in monocots are located in discrete packages called vascular bundles, which are fairly randomly distributed in the stem. Each vascular bundle has a few cells of vascular cambium in it. In contrast, the cells of the vascular cambium in dicots form a concentric ring towards the outside edge of the stem therefore the vascular bundles develop in a ring as well.

Figure G-6. Palmate Vein Pattern. *The branching vein pattern of a maple leaf is very easily recognized. It is called palmate because of the way the veins seem to "finger out" in five directions from a common point as with the palm of one's hand.*

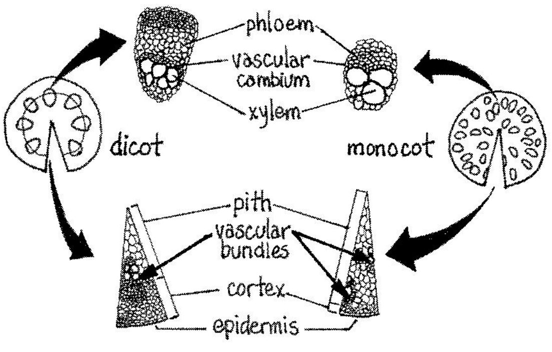

Figure G-7. Non-woody Angiosperm Stems. *Cross-sections of non-woody stems can be used to identify whether the plant is a monocot or a dicot. In the illustration to the left, the stem on the right shows a monocot, with vascular bundles scattered throughout the stem. The one on the left is a dicot, with its characteristic concentric ring of vascular bundles.*

G-2. CONCEPT CHECK-UP QUESTIONS:

1. Describe the fertilization process that leads to seed development.
2. Contrast the male and female parts of a flower in terms of their structure, function and location.
3. What causes defoliation?

CHECK YOUR UNDERSTANDING

MULTIPLE CHOICE:

1. Which plant produces a seed with only one cotyledon?
   A. Pea.
   B. Corn.
   C. Peanut.
   D. Sunflower.
2. Which **BEST** describes a tissue?
   A. Part of an organ.
   B. A set of cells that function together.
   C. A cluster of cells in the same place.
   D. A set of identical cells that have a unified function.
3. Plants grow by mitosis in their
   A. parenchyma tissue.
   B. collenchyma tissue.
   C. meristematic tissue.
   D. sclerenchyma tissue.

4. Where on a plant is an apex?
   A. In a flower.
   B. Along the stem.
   C. Under the leaves.
   D. At the tip of a branch.

5. In which growing conditions would you find xerophytes, hydrophytes, and halophytes (respectively)?
   A. Mineral rich, aquatic, dry.
   B. Aquatic, dry, mineral rich.
   C. Dry, aquatic, mineral rich.
   D. Dry, mineral rich, aquatic.

6. A boring tool is used to drill a hole into a tree. Which sequence of tissues would it encounter?
   A. Phloem – xylem – vascular cambium.
   B. Phloem – vascular cambium – xylem.
   C. Xylem – vascular cambium – phloem.
   D. Xylem – phloem – vascular cambium.

7. Which process accounts for the movement of water into a root hair and on to the xylem?
   A. Pressure exerted on the roots by the surrounding soil.
   B. Active transport of which creates osmotic pressure.
   C. Diffusion due to the difference in concentration of minerals.
   D. Osmosis due to the osmotic pressure created by the surrounding ground.

8. The Casparian strip is a
   A. tissue that conducts water from root xylem to stem xylem.
   B. set of cells allowing water into the xylem from the root hairs.
   C. waxy layer around the xylem preventing water from leaving.
   D. protein-rich layer controlling water movement in a vascular bundle.

9. Which distinguishes gymnosperms from angiosperms?
   A. Angiosperms have broad, flat leaves; gymnosperms never do.
   B. Gymnosperms produce cones for reproduction, angiosperms don't.
   C. Angiosperms produce flowers for reproduction, gymnosperms don't.
   D. Gymnosperms have needles, angiosperms don't.

10. Under which conditions would the chance of transpiration be the greatest?
    A. Hot and dry.
    B. Cold and dry.
    C. Hot and humid.
    D. Cold and humid.

11. The dark lines forming the annular rings of a tree are made out of dense
    A. xylem cells that form in poor growing conditions.
    B. xylem cells that form in good growing conditions.
    C. phloem cells that form in poor growing conditions.
    D. phloem cells that form in good growing conditions.

12. A seed cone of a gymnosperm is a
    A. 2N structure in which 1N structures develop.
    B. 2N structure in which 2N structures develop.
    C. 1N structure in which 1N structures develop.
    D. 1N structure in which 2N structures develop.

13. Which of these is the **TRUE** of pollen?
    A. Multicellular and male.
    B. Multicellular and female.
    C. Multinucleate and male.
    D. Multinucleate and female.

14. During angiosperm fertilization, pollen nuclei do **NOT**
    A. fertilize ova to produce embryos.
    B. cause ovules to develop into fruit.
    C. fertilize polar bodies to produce endosperms.
    D. cause the growth and elongation of pollen tubes.

15. What is the location and function of endosperm?
    A. In a flower to attract pollen.
    B. In a seed to feed the embryo.
    C. In fruit to protect the embryo.
    D. In pollen required for fertilization.

16. Which statement about flowers is **CORRECT**?
    A. Sepals are photosynthetic.
    B. The female parts surround the central male part.
    C. Pistils are male parts, where stamens are female parts.
    D. The style is the source of energy and fragrance for the flower.

17. What features are associated with both a maple and an oak leaf?
    A. Parallel vein pattern and a petiole.
    B. Parallel vein pattern, but no petiole.
    C. Branching vein pattern and a petiole.
    D. Branching vein pattern, but no petiole.

18. Leaves change colour and fall from trees because of
    A. Increased photosynthesis and cell division in the petiole.
    B. Decreased photosynthesis and cell division in the petiole.
    C. Increased photosynthesis and cell deterioration in the petiole.
    D. Decreased photosynthesis and cell deterioration in the petiole.

19. What is the function of a cotyledon?
    A. Promote downward root growth and upward shoot growth.
    B. Facilitate gas exchange for both photosynthesis and respiration.
    C. Store water absorbed by root hairs to use when water is less available.
    D. Provide nutrients to a plant embryo until it can conduct photosynthesis to make its own.

20. Which of these **BEST** describes a monocotyledon?
    A. Six petals per flower with parallel veins in leaves.
    B. Six petals per flower with branching veins in leaves.
    C. Twelve petals per flower with leaves modified into thorns.
    D. Twelve petals per flower growing on very short stems.

WRITTEN ANSWERS:

1. Distinguish between the following:
   a. heartwood vs. sapwood
   b. spore vs. seed
   c. needle vs. leaf
   d. male cone vs. female cone

2. How do the processes of osmosis and transpiration contribute to the movement of water in a plant stem?

3. Describe the function and location of the Casparian strip.

4. What is "wood"? What types of cells is it made out of and what kinds of plants develop wood?

5. Distinguish between monocots and dicots on the basis of the structure of seeds, flowers, stems leaves, and roots.