UNIT F – SEEDLESS PLANTS

The Plant Kingdom is tremendously diverse. It includes organisms ranging from pond scum to huge trees, moss, lawn grass, flowers, everything in between and much beyond. All plants need water and carbon dioxide to conduct photosynthesis to make glucose for food and growth. They either have to live in water, where some CO_2 is dissolved, or be exposed to the air with its more abundant CO_2 and be specialized in some way to obtain water.

The variations displayed by plants permit taxonomists to cluster them in a number of ways. The focus of this unit is on a selection of plants that do not produce seeds. Here algae, moss and ferns are considered in terms of their habitats, body forms, specializations, and patterns of reproduction. The next unit is devoted to seed-producing plants, the **spermopsids**.

Introduction to Algae

The term "algae" is reserved for plants that are generally multicellular and aquatic. They are further unified because they lack **vascular tissue**. Vascular tissue is a system of tube-like cells, which allows plants to transport water and other substances internally. Algae grow extensively, but without vascular tissue, they cannot get massive because they rely on diffusion for the distribution of materials inside their tissues. Algae also lack leaves, stems, and roots. These terms are reserved for plants with vascular tissue. Algal structures, which are analogous to these, are simple in comparison. Most algae have specialized anchoring devices called **holdfasts**. To compensate for the lack of a rigid supportive stem, many have float-like devices to provide buoyancy, which holds them up in the water. Their stem-like structures are called **stipes**. Instead of leaves, they have **blades**, which are often broad photosynthetic structures that float on or near the surface of the water to maximize the capture of light.

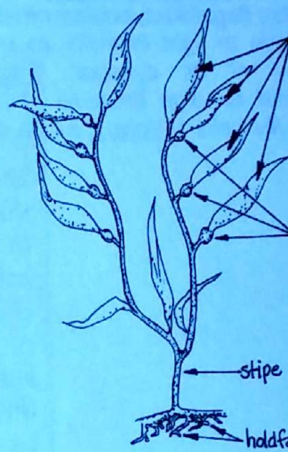

Figure F-1. Body Plan of an Alga. *Typically, algae are anchored by a holdfast and have one or more floats to ensure that their photosynthetic organs, called blades, are elevated towards the light.*

In order to understand the classification of algae, it is important to consider some pigment molecules required for photosynthesis. The visible component of sunlight contains the complete **spectrum** of colours ranging from red through to violet. Different colours (wavelengths) of light have different amounts of energy. Different pigment molecules absorb energy associated with the different colours. The essential pigment molecule for making glucose is **chlorophyll**, which primarily absorbs the energy from the red and blue wavelengths of light. The other pigment molecules support photosynthesis as well. The light energy they absorb gets passed along to chlorophyll for the process. The ability of plants to be effective solar energy gatherers is a factor of the actual pigment molecules they contain. The photosynthetic parts of plants usually appear shades of green because these are the wavelengths of light that are reflected, as opposed to being absorbed by chlorophyll. There are different variations of chlorophyll. The most significant one is called chlorophyll-a.

Deep water will often appear blue because the blue portion of the light spectrum with its characteristic energy and wavelength is able to penetrate water to a greater degree. The differential ability of colours of light to penetrate the depths of water creates a range of habitats suitable for algae. **Red algae**, (Phylum **Rhodophyta**) contains chlorophyll-a, chlorophyll-d as well as the accessory pigment, **phycobilin**. Phycobilin is efficient at absorbing the blue wavelengths of light. Because blue light will penetrate water the farthest, the red algae can live at the greatest ocean depths.

Phylum **Phaeophyta** comprises the **brown algae**. These algae contain chlorophyll-a and chlorophyll-c as well as an accessory pigment called **fucoxanthin**. They are often shades of yellowy-brown in colour and store their food as specialized starches and oils. **Green algae**, Phylum **Chlorophyta**, are predominantly green due to the presence of chlorophyll-a and chlorophyll-b. These plants manufacture starch as a storage carbohydrate, have cell walls made of **cellulose** and are abundant in fresh water in addition to marine habitats, unlike the red and brown algae, which are predominantly marine. Collectively, marine algae are often referred to as **seaweed**.

GREEN ALGAE

Included in Phylum Chlorophyta are unicellular forms, like ***Chlamydomonas***, colonial ones, like ***Volvox***, filamentous algae like ***Spirogyra*** and ***Oedogonium***, and leaf-like forms like ***Ulva***. Each of these body forms have advantages and disadvantages and when put in this sequence, this set of algae demonstrates a series in the development of a multicellular body form bearing significant similarities to terrestrial plants.

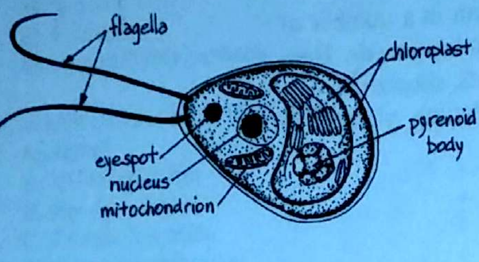

Figure F-2. Chlamydomonas. *This organism is a unicellular, flagellated, photosynthetic eukaryote that is sensitive to light intensity as evidenced by the presence of its eyespot. Chlamydomonas is considered an alga because of the similarities it bears to the cells of Volvox, a colonial green alga.*

Chlamydomonas are unicellular egg-shaped green algae with two **flagella**. They can be found in damp soil, and ponds. Each alga has a light sensitive **eyespot**, which is not capable of vision and serves only help the organism detect light for photosynthesis. Its chloroplast fills most of its interior. A specialized spot on the chloroplast called a **pyrenoid body** serves as the center for starch production. Unlike the rest of the green algae, *Chlamydomonas* lacks cellulose in its cell walls. This facilitates two small **contractile vacuoles** that function continuously to help maintain a correct water balance with its environment. *Volvox*, a **colonial** green alga is made out of dozens of cells, each one similar to *Chlamydomonas*. It illustrates three important steps in bridging the gap between unicellular and multicellular body forms. Firstly, when it is broken apart, it will repair or regenerate the missing parts by the mitotic division of remaining cells. Secondly, there is some exchange of cytoplasm and chemicals between the member cells, which constitutes molecular communication. This is important for coordinating locomotion and other life processes. Finally, although most cells in the colony are the same, a few have become specialized into cells that can leave the colony for sexual reproduction. Their presence may represent a primitive organ, characteristic of more complex plants.

Spirogyra and *Oedogonium* are **filamentous** green algae made out of colonies of cells attached end-to-end. Pond scum and the slime that can be found growing on rocks and other vegetation on the shores of ponds, slow-moving streams and calm lake areas is actually this type of algae. Similar to *Volvox*, when a filamentous alga breaks, it can continue to grow. Reproduction in this manner is called **fragmentation**. These algae have also developed another specialization, a holdfast**,** which serves to anchor each plant, making them **sessile**, as opposed to **motile**, as are *Chlamydomonas* and *Volvox*.

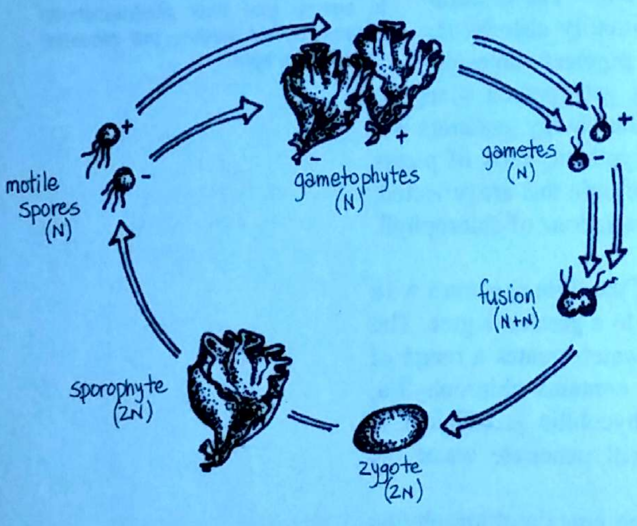

Figure F-3. Simplified Life Cycle of Ulva. *Meiosis occurs in the diploid (2N) plant resulting in the formation of haploid (N) spores. These genetically distinct spores grow into haploid plants, which produce gametes. Fusion of gametes (= fertilization) forms a 2N zygote that develops into the diploid plant.*

Ulva is a common marine green alga that has a completely different body plan. Sometimes called "sea lettuce", *Ulva* has leafy-like blades. In the life cycle of *Ulva* and other similar green algae, the **zygote** develops into a **diploid** plant. This plant produces **haploid** flagellated spores by meiosis. These spores are genetically different (called + and –, as opposed assigning them a gender) and grow into haploid plants. These plants are structurally similar to the diploid plant that develops from the zygote. Each of these plants produces flagellated **gametes**, which fuse to produce the zygote.

It is important to note that there are two different plants in this life cycle. One grows from the zygote and produces spores. This is called a **sporophyte** or spore-producing plant. The other one results from the germination of spores and produces gametes. This one is called the **gametophyte** or gamete-producing plant. *Ulva* is biologically significant because of the similarity of its life cycle to that of moss, and ferns, which are land plants.

Although only presented for *Ulva*, all members of this phylum have both an **asexual phase** and a **sexual phase** in their life cycles. The asexual phase allows the species to increase in numbers without the involvement of another member of the species. The sexual phase with its inherent complications and requirements for coordination promotes genetic variability through the combining of chromosomes from different individual plants. The resulting zygote (much like a seed) is a relatively impervious structure, which can withstand harsh conditions such as winter temperatures to grow into a new individual when suitable conditions prevail. This life cycle pattern, very common in the plant kingdom, is called **alternation of generations.** A sporophyte generation, which produces **spores** (asexual), alternates with a gametophyte generation, which produces gametes (sexual).

F-1. CONCEPT CHECK-UP QUESTIONS:

1. What algae structures correspond to stems, leaves, and roots?
2. Which plant pigment is the most important for photosynthesis? What is the role of other plant pigments?
3. What three abilities does Volvox have, which are absent in unicellular organisms?
4. Name an advantage and a disadvantage for each of the body forms of green algae.
5. Why are green algae biologically significant?
6. Describe alternation of generations.

MOSSES

Hardships of Life on Land

Life on land is very demanding compared to the aquatic existence of algae for several reasons. Firstly, all plants need a constant supply of water to deliver materials to and transport wastes away from the cells. For aquatic plants, with the abundance of water, this is not a problem. On land, the larger, more massive the plant, the greater a problem this becomes. Secondly, where plants need light for photosynthesis, too much light will tend to dry out any plant tissues exposed to air due to the increased evaporation of water. Thirdly, CO_2 dissolves in water and aquatic plants can obtain it by diffusion. Similarly, the O_2 produced by photosynthesis will diffuse into the water and become dissolved in it. On land, where these gasses are components of air, and not dissolved in water, a different mechanism controlling gas exchange exists. Finally, successful reproduction depends on the dispersal of gametes and zygotes. Aquatic organisms produce swimming cells, which utilize the environment for distribution; on land these types of reproductive cells (and their resulting zygotes) are in constant danger of drying out.

Mosses are members of Phylum **Bryophyta**. In addition to moss (Class **Musci**), this phylum also includes **liverworts** and **hornworts**. All bryophytes are typically small land plants that lack vascular tissue. They must balance their need for sunlight against the potential for dehydration. As a result, they can only survive in certain places where water is abundant like forested areas, or along the sides of streams, in the shade, etc.

When one visualizes moss, often only the gametophyte (or gamete-producing) plant comes to mind. It is small, green (photosynthetic), leafy, and can grow into a carpet-like covering on surfaces if the conditions are right. Because it is more obvious and longer-lived than the alternative sporophyte generation, these green plants are called the **dominant generation**. A really close look at moss gametophyte reveals a collection of intricate tiny plants. Each one has a shoot with leafy parts and a root-like structure. Because moss lacks vascular tissue, these structures are not true stems, leaves, or roots. The root-like structures are called **rhizoids**.

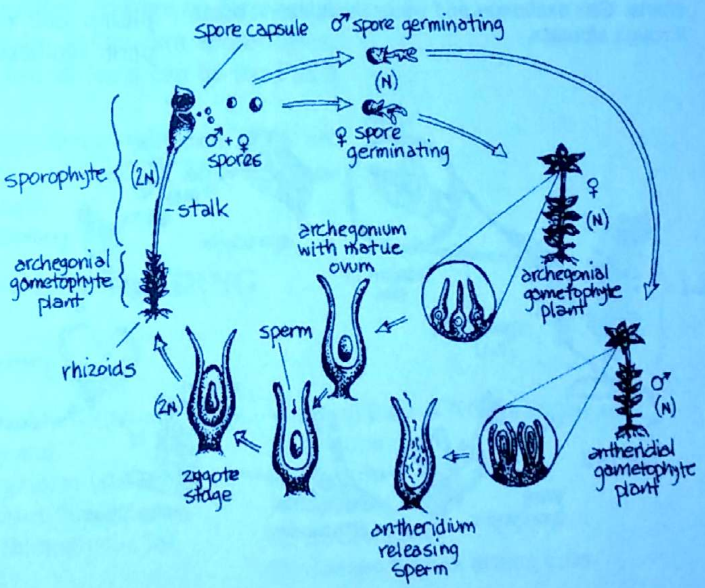

Figure F-4. Moss Life Cycle. *Photosynthetic gametophyte plants are either haploid male (antheridial) and produce sperm, or haploid female (archegonial) and produce ova. Fertilization, achieved after sperm swim through whatever water is available, results in the formation of a diploid zygote. The zygote grows into the sporophyte plant, which gets nutrients from the gametophyte. Cells in the spore capsule divide by meiosis to produce the haploid spores.*

Moss is adapted to surviving on land without being able to transport water. It relies on the properties of water, like **capillary action** and **osmosis** for its distribution throughout the body of each plant. Its success is contributed to by the fact that its size does not outgrow the availability of water. One moss called ***Sphagnum*** lives in bogs where water is constantly available. Individual plants of this genus can grow to several meters long. Dried up bogs of *Sphagnum* form **peat moss**.

The dependency of moss on water becomes obvious when their reproductive cycle is considered. During the sexual stage of their life cycle, male moss plants produce flagellated sperm in structures called **antheridia**. The corresponding female organ where an ovum develops is called an **archegonium**. Sperm swim in order to reach an ovum. Further analysis of the moss life cycle reveals another specialization for land survival - the sporophyte develops from the zygote while it is still enclosed by the cells of the archegonium. This sporophyte is not fully photosynthetic; it also relies on nourishment provided to it from the gametophyte. Often, the spore capsules are designed to propel spores away from the capsule to aid their dispersal to an area where they can **geminate** and grow.

FERNS

Ferns are classified as **Class Filicinae** in **Phylum Tracheophyta**. All tracheophytes have **vascular tissue** specialized for transporting water and nutrients. With this tissue, they are less dependent on a constant, abundant supply of water and therefore less restricted in their possible habitats than plants like moss. Ferns are relatively simple, yet very successful tracheophytes. They range from only centimeters tall to being "tree-like". They inhabit all continents of the earth.

Vascular tissue is composed of two different types of conducting tissues: **xylem**, which transports water and mineral nutrients from the roots into the stems and leaves, and **phloem**, which transports the sugary products of photosynthesis in the plant body. The phylum takes its name from a particular cell type in the xylem called a **tracheid**. Tracheids have thick **cellulose** cell walls, which help to strengthen the plant and hold it upright on land.

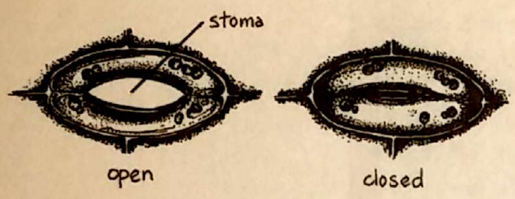

Figure F-5. Stomata: Open and Closed. *Guard cells are pairs of sausage-shaped cells surrounded by epithelial cells. During times of high water availability, the cells gain water and bulge outward to open the space between them. The space is a stoma. Gas exchange and water transpiration occur through stomata.*

Ensuring efficient gas exchange without dehydration, another requirement of a terrestrial existence, is made possible by specialized openings called **stoma** (plural: stomata) on the leafy surfaces of land plants. These openings are regulated by the availability of water. When water is present, the **guard cells**, which surround each stoma, become plump and open the stoma. This way, gases are exchanged, enabling photosynthesis.

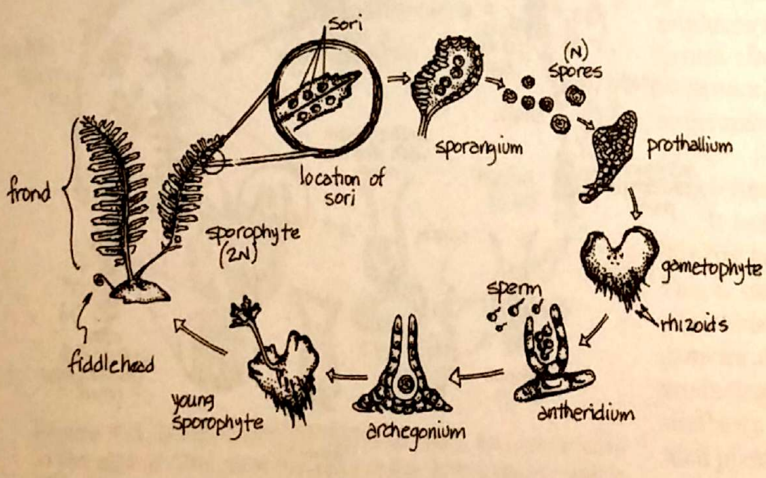

Figure F-6. Fern Life Cycle. *Ferns are diploid sporophytes that produce clusters of sporangia in structures called sori on the lower side of their fronds. These produce and release haploid spores, each of which can germinate into a prothallium, which further develops into a tiny, heart-shaped gametophyte plant. This haploid plant produces the archegonium and antheridium, which produce egg and sperm, respectively. Fertilization results in a new sporophyte plant.*

The fern life cycle displays both a sporophyte and a gametophyte generation giving these plants both multiplicity as well as genetic variation. The leafy green, often fan-like structures are called **fronds**. Fronds are the most recognizable structures in the fern life cycle therefore they are called the dominant generation. On the lower side of fronds grow **sori** (singular sorus), which contain clusters of sporangia. The sporangia produce haploid spores by meiosis. Each spore that germinates grows into a haploid photosynthetic gametophyte, called a **prothallium**. Mature gametophytes that subsequently develop are tiny heart-shaped plants, which will produce gametes in specialized structures called archegonia and antheridia. The embryo resulting from fertilization grows into a young frond called a **fiddlehead** and on into another sporophyte.

Both ferns and mosses have adapted to a terrestrial environment, but in totally different ways. The moss is limited in its size and habitat because of its water dependency. The fern is less limited in both of these because of the presence of vascular tissue, though it still depends on water for successful sexual reproduction.

F-2 CONCEPT CHECK-UP QUESTIONS:

1. How is moss adapted to survive on land in terms of:
   a. Obtaining and distributing water within its tissues
   b. Balancing dehydration due to exposure with water availability
   c. Distributing or dispersing gametes and spores
2. Contrast the life cycle of a moss and a fern in terms of:
   a. Dominant generation
   b. Dependency of the sporophyte on the gametophyte
3. Explain why ferns are more widely distributed on Earth than moss.

ECOLOGICAL CONSIDERATIONS

One's initial thoughts about the significance of seedless plants may be that they are not all that important. In terms of food chains and food webs of organisms, these plants, like all others, are extremely significant. Except for some bacteria and protists, plants are the only organisms that capture the seemingly endless supply of solar energy and convert it into a form that animals, including humans, can use. Furthermore, seedless plants create habitats and microhabitats for animals. In the oceans of the world, many fish find refuge and food in seaweed beds. In the forests, many tiny animals like insects and spiders make their homes in moss. In more tropical areas, where ferns grow into large, tree-like plants, a whole different set of organisms may be found thriving in their shade and undergrowth.

Mosses are ecologically significant as **pioneer plants** in the process of **succession**, particularly in swamps that are drying up. Mosses are among the first land plants that can survive. Eventually, as the old swamp becomes increasingly solid, and earthy, the area will support small shrub growth, and later, trees.

Human uses of these plants add to their significance. Some seaweed is used directly as food (e.g., **dulse**), where others are used in the food industry to make smoothening agents and gels. One example that has already been encountered is **agar**, which is used in microbiology as a growth medium for bacteria. Agar is also used as a smoothening agent in foods such as ice cream, yogurt, and puddings etc. Humans use mosses and ferns in horticulture where they are grown for decorations and houseplants. *Sphagnum* forms peat moss, which is used in sandy soils to help retain water. Tender young fern sporophytes, fiddleheads, are eaten as a delicacy in some places. Large tropical ferns can be used as a building material.

The significances of the plants considered in this unit are often overlooked. They are major producers of glucose, therefore serving as a fundamental food source. They colonize bare soils, create habitats, and are useful to humans in many ways.

CHECK YOUR UNDERSTANDING

MULTIPLE CHOICE:

1. Which is **NOT** a correct match?
   A. Float – buoyancy.
   B. Holdfast – anchorage.
   C. Stipe – conduct water.
   D. Blade – photosynthesis.

2. The seaweeds of BC's coast are
   A. chlorophytes and phaeophytes.
   B. phaeophytes and rhodophytes.
   C. chlorophytes and rhodophytes.
   D. phaeophytes, chlorophytes, and rhodophytes.

3. Pigments other than chlorophyll-a capture light energy and
   A. store it to make glucose later.
   B. make products other than glucose.
   C. pass it along to chlorophyll-a for making glucose.
   D. make glucose, but not as efficiently than chlorophyll-a.

4. Which of these is **NOT** a feature of *Chlamydomonas*?
   A. Flagella.
   B. Eyespots.
   C. Pyrenoid body.
   D. Communication among cells.

5. Green algae is considered to be the **MOST RELATED** to land plants because it
   A. has vascular tissue, which other algae lacks.
   B. is equipped with guard cells and stomata to control gas exchange.
   C. is predominantly a sporophyte, where other algae are gametophytes.
   D. stores glucose as starch, rather than oils, or other carbohydrates.

6. Which of these ideas does **NOT** support the notion that Volvox is a multicellular colony?
   A. It has simple tissues and organs.
   B. Most of the component cells are very similar to each other.
   C. If broken apart, it can reassemble or replace the missing parts.
   D. There is some communication between the component cells.

7. The holdfasts of *Spirogyra* are an advantage and a disadvantage because they
   A. anchor the plant and absorb chemicals from the soil.
   B. anchor the plant and make it an easier target for herbivores.
   C. enable it to absorb chemicals from the soil, which may be toxic.
   D. enable it to grow long increasing the chance of fragmentation.

8. The biologically significance of *Ulva* is that it
   A. is eaten as dulse.
   B. can grow on land and in water.
   C. has a similar life cycle as moss.
   D. is harvested for agar production.

9. Which of these is the **LEAST** problematic for moss growing on land?
   A. Drying out in the sun.
   B. Getting soaked in the rain.
   C. Obtaining water through its roots.
   D. Obtaining enough light for photosynthesis.

10. Moss is a member of
    A. Phylum Bryophyta.
    B. Phylum Phaeophyta.
    C. Phylum Chlorophyta.
    D. Phylum Tracheophyta.

11. Correctly complete this sentence: Stomata open to let…
    A. CO_2 in and O_2 and H_2O out.
    B. O_2 in and CO_2 and H_2O out.
    C. CO_2 and H_2O in and O_2 out.
    D. O_2 and H_2O in and CO_2 out.

12. Which statement is **TRUE** about moss?
    A. The gametophyte gets some nutrition from the sporophyte.
    B. The sporophyte gets some nutrition from the gametophyte.
    C. The gametophyte and sporophyte equally support each other.
    D. The sporophyte and gametophyte live independently from each other.

13. Meiosis in moss occurs in the
    A. spore capsule.
    B. spores before germination.
    C. gametes before fertilization.
    D. male and female gametophyte.

14. Which of these is present in ferns but **NOT** in moss?
    A. Chlorophyll-a.
    B. Guard cells and stomata.
    C. Structures that produce spores.
    D. Structures that produce gametes.

15. Finish this sentence to make a **TRUE** statement about alternation of generations: Sporophytes produce…
    A. gametes that grow into sporophytes, which produce spores.
    B. spores that grow into gametophytes, which produce gametes.
    C. spores that grow into sporophytes, which produce gametes.
    D. gametes that grow into gametophytes, which produce spores.

16. Finish this sentence to make the **BEST TRUE** statement about the roles of vascular tissues: H_2O and dissolved minerals are conducted up to leaves by…
    A. xylem, where phloem transports the products of photosynthesis down a stem.
    B. phloem, where xylem transports the products of photosynthesis down a stem.
    C. xylem, where phloem transports the products of photosynthesis away from leaves.
    D. phloem, where xylem transports the products of photosynthesis away from leaves.

17. A fiddlehead is an immature
    A. sporophyte frond.
    B. gametophyte frond.
    C. sporophyte prothallium.
    D. gametophyte prothallium.

18. Sori are specializations found on
    A. fronds. They release spores.
    B. fronds. They release gametes.
    C. gametophytes. They release spores.
    D. gametophytes. They release gametes.

19. Which is the **LEAST LOGICAL** sequence during succession?
    A. Lichen – trees – grass – moss.
    B. Moss – grass – shrubs – trees.
    C. Ferns – grass – shrubs – trees.
    D. Algae – moss – grass – shrubs.

20. Which phylum of algae is believed to be the most related to terrestrial plants?
    A. Phylum Bryophyta.
    B. Phylum Phaeophyta.
    C. Phylum Rhodophyta.
    D. Phylum Chlorophyta.

WRITTEN ANSWERS:

1. List and describe the function of each of the main body parts of a typical alga.
2. Why can red algae be found growing at greater depths in the ocean than brown algae?
3. What characteristics unify the green algae?
4. Contrast each of the following:
   a. sporophyte vs. gametophyte
   b. asexual vs. sexual
5. a. Suggest three reasons why life on land for a plant requires additional specializations compared to life in the water.
   b. How have terrestrial plants solved each of the problems you identified in 6a.
6. What determines where moss can grow?
7. Describe the components of vascular tissue.
8. a. Name three ecological roles of non-seed producing plants.
   b. Name three economic roles of non-seed producing plants.