LAB #11 – A Survey of the Living World

Introduction

Scientists have been working to categorize all species of life on our planet since well before the time of Charles Darwin and his Theory of Evolution by means of Natural Selection. In the 1730’s, a Swedish scientist named Carl Linnaeus began the modern system of classification by placing all organisms in one of five major groups he called Kingdoms. The kingdoms he proposed are: Monera, Protista, Fungi, Plantae and Animalia.

Monera includes all of the prokaryotic organisms (those with no nucleus) – for example, the bacteria. The other four kingdoms are eukaryotic (have a nucleus). Protista includes the simplest eukaryotic organisms, most of which are unicellular, though some are multicellular or live in colonies. The Fungi include unicellular and multicellular organisms with a cell wall made of chitin that obtain their nutrients from organic sources outside their body by absorption. The kingdom Plantae contains photosynthetic multicellular organisms with cell walls made of cellulose. Animalia are multicellular organisms without cell walls that obtain their nutrients from organic sources outside their body. They are also distinguished by a very specific pattern of embryonic development.

As part of his “categorization” system, Linnaeus established increasingly more specific sub-groupings within each Kingdom based on particular traits of each organism. The sub-groupings are: (Kingdom), Phylum, Class, Order, Family, Genus, Species. Humans can be categorized as follows based on their features:
Kingdom  Animalia  (see definition above)
Phylum  Chordata  embryonic traits: e.g. dorsal nerve cord and pharyngeal slits
Class  Mammalia  placental birth and mammary glands
Order  Primate  binocular vision, grasping hands and large brains
Family  Hominidae  great apes: humans, chimpanzees, gorillas and orangutans
Genus  Homo  fully bipedal great apes (e.g., lineage leading to humans)
Species  sapiens  modern humans

The scientific discipline of naming organisms is called taxonomy. Rather than use all seven words to name an organism, we commonly use the scientific name employing only the genus and species. The scientific name for humans is Homo sapiens. Note that when we write a scientific name, we use italics and capitalize the genus only.

In the past two decades, with more advanced tools to study the features of organisms, scientists have proposed a new framework to categorize them. In this system, the Kingdom Monera is divided into two new overarching Domains called Bacteria and Archaea, while the four remaining classical Kingdoms are rightly placed under the overarching Domain called Eukarya since they all consist of eukaryotic cells.

In general, the taxonomical classification of species into these groupings is intended to properly reflect the phylogeny of the species – the historical evolutionary relationships among species – the “branching” of the evolutionary tree. Since scientists are continuing to discover new species and our understanding of the phylogeny of a species is becoming more refined, the disciplines of taxonomy and phylogeny are constantly in a state of flux. In fact, evolutionary and organismal biologists continue to discuss and debate these relationships even today.
Part 1: The Domains Bacteria and Archaea

The traditional Kingdom Monera has now been divided into two newly developed levels of taxonomical classification known as Domains. They are Bacteria and Archaea. Both domains consist exclusively of prokaryotic organisms. Bacteria and archaea play hugely important roles in nature including the recycling of elemental nutrients through the decomposition of what we would consider waste or detritus, and the protection of human beings from pathogenic microbes.

You may not realize this, but your gut, skin, oral cavity, and all other surfaces exposed to the outside world collectively contain approximately 10 times as many bacteria as the number of cells in the tissues of your entire body! This is not a bad thing, but a very good thing, since in addition to protecting you from microbial pathogens your microflora also provide vitamins and other nutrients.

Prokaryotes are distinguished by having no nucleus, no cellular organelles, a very small genome (amount of DNA) and are normally much smaller than eukaryotic cells. For example, a typical prokaryote cell has a diameter of 7 µm whereas a typical eukaryotic cell such as a cheek cell has a diameter of 40 µm. While this may not seem like much, in terms of volume this is a huge difference. For example, two spherical cells 7 µm and 40 µm across differ almost 200-fold in volume. Prokaryotes reproduce by a simple asexual cell division process called binary fission. A single bacterium dividing once every 30 minutes can reproduce to a number exceeding 1 million in only 10 hours!

![Diagram of a prokaryote cell](image)

Archaea are prokaryotes that have recently been discovered to have a phylogeny very different from Bacteria. The Archaea have been found to have several biochemical pathways that are more similar to eukaryotes such as transcription and translation. Many species are also distinguished by living in very harsh environments. These species are known as extremophiles (“extreme” “loving”) because they can be found in extremely hot environments (thermophiles) and extremely salty environments (halophiles) among others. Since it is difficult to mimic these harsh environments in the laboratory, it can be extremely difficult to culture these in the lab for study. There are no known species of Archaea that act as human pathogens or parasites.
Bacteria are the prokaryotes that are most familiar to people. Bacteria are found in almost every environment. A single gram of damp soil can contain up to 50 million bacteria. They are found on the skin, in the mouth and even in the intestines of animals. A single human bite can deliver over 1 billion bacteria to a victim. Those in the human gut play an instrumental role in several biochemical reactions that are essential to human survival. Though the vast majority of bacteria are harmless or even beneficial to human beings, some species are pathogenic meaning they can cause infection and disease. Examples include those that cause: ear/nose/throat infections (e.g., Streptococcus pyogenes); skin infections (e.g., Staphylococcus aureus); gastric ulcers (Helicobacter pylori); cholera (Vibrio cholerae); syphilis (Treponema pallidum) and bubonic plague (Yersinia pestis).

Prokaryotes are found in many different shapes, but the most common are cocci ("balls"), bacilli (rod-shaped) and spirilli ("spirals"). The most typical type of throat infection is caused by streptococci (strepto- means "chain") which are arranged as long chains of ball-shaped bacteria. The most typical type of skin infection is caused by staphylococci (staphylo- means "irregular cluster", much like a bunch of grapes). Physicians will prescribe antibacterial drugs to treat bacterial infections, drugs that are usually referred to as simply antibiotics. These include: penicillin, streptomycin and tetracycline. The medication prescribed is specific for the type of bacterium being treated. One should note that viral diseases are treated with antiviral agents, not the usual antibiotics.

![Bacterial Shapes Diagram]

Exercise 1A – Observing Different Species of Bacteria on Nutrient Agar Plates

In order to grow bacteria in the laboratory, we employ sterile technique (avoiding microbial contamination of the bacterial culture and oneself) when we place them on a nutrient agar plate that contains all of the essential ingredients for their growth. You will examine bacterial growth on agar plates of the three bacterial species listed below. Observe the differences in their features: color, texture of a single colony (spot) or streak, etc.

1. Escherichia coli
2. Serratia marcescens
3. Micrococcus luteus

► Describe the differences in appearance on your worksheet.
Exercise 1B – Observing Bacteria under the Compound Light Microscope

1. *Escherichia coli*
2. *Staphylococcus epidermidis*
3. *Bacillus cereus*

► On your worksheet, draw samples of the bacteria above as seen under the microscope.

Part 2: Kingdom Protista

We already examined species of Kingdom Protista in Laboratory #3 – Microscopy and Cells – when we looked at organisms in pond water such as *Paramecium*. Protists are the simplest eukaryotes and have incredible diversity in form and function. Most of them are single-celled (e.g., *Paramecium* and *Amoeba*) while others are multicellular (e.g., seaweed or “brown algae”). They can be phototrophs that use photosynthesis as an energy source or heterotrophs that must rely on other organic sources of energy that they obtain from the environment. Even more interesting are those species that are mixotrophs, able to use either mode to acquire their energy.

The five major groupings of Protists include: Excavata, Chromalveolata, Rhizaria, Archaeplastida and Unikonta. We will examine several different species of Protists that were not observed in the earlier labs.

Exercise 2A – Observing *Trypanosoma*

*Trypanosoma* are single-celled members of the group Excavata. They are one of the small number of protists that can cause serious human disease. They are the cause of Sleeping Sickness and Chaga’s disease and are both transmitted by insect vectors, specifically the tse-tse fly (sleeping sickness) and “kissing bug” (Chaga’s disease), that use human blood for nutrition. Infection by these organisms can be difficult to treat because they can evolve very quickly in a human host, staying ahead of the immune system’s ability to fight it.

1. Obtain a prepared slide of *Trypanosoma*.
2. Using the compound light microscope, observe the long, slender, darker staining organisms outside the disc-like red blood cells.

► Draw an example of what you observe in the circle provided on your worksheet.
Exercise 2B – Observing Diatoms

Diatoms are single-celled photosynthetic algae that are members of the group Chromalveolates. They can be found in an enormous variety of shapes and colors. They are characterized by having glass-like walls made of silicon dioxide. Diatoms are a major portion of the phytoplankton (“plant-like” “floating organism”) that provide the base of the food chain in most marine and fresh water ecosystems.

1. Obtain a prepared slide of diatoms.

2. Using the compound light microscope, observe the diatoms on the slide. In order to observe them you will have to significantly close the diaphragm in the condenser of your microscope to produce more contrast. You may also have to move the field of view to the edge of the cover slip, as they can get pushed to the side when the cover slip is placed upon them.

► Draw an example of what you observe in the circle provided on your worksheet.

Exercise 2C – Observing Forams

Forams are single-celled members of the group Rhizaria. They get their name from the tiny holes (Latin = foramen) located within the tests (bodies). Their shells are composed of calcium carbonate. Like the diatoms, they also are a major portion of the phytoplankton in aquatic ecosystems and are a major part of the foundation of aquatic food chains. When they die, they can form calcium-rich deposits that form sedimentary layers of rock that look like chalk.

1. Obtain a prepared slide of forams.

2. Using the compound light microscope, observe the forams on the slide. In order to observe them, you may have to move the field of view to the edge of the cover slip, as they can get pushed to the side when the cover slip is placed upon them.

► Draw an example of what you observe in the circle provided on your worksheet.
Part 3: Kingdom Fungi

Kingdom **Fungi** includes single-celled and multicellular organisms that are distinguished as **heterotrophs** (“different” “feeders”) that feed by secreting enzymes into the foodstuffs they wish to digest and bringing the digested material into the cell by **absorption**. Fungi also have cell walls made of the polysaccharide **chitin** as opposed to cellulose found in plant cell walls. Along with the bacteria and archaea, fungi have an **essential** role in nature as detritus feeders and decomposers. Thanks to bacteria, archaea and fungi, elemental nutrients are recycled and made available for plants on which we depend for our food and oxygen. Fungi can reproduce by asexual pathways, sexual pathways, or both, depending upon the conditions in which they grow.

Examples of single-celled fungi are the species of yeast we use to make bread and beer such as *Saccharomyces cerevisiae* and those that can cause yeast infections in humans such as *Candida albicans*.

Multicellular fungi have features that allow them to grow into and absorb nutrients from their environment. They generally consist of strings of cells called **hyphae**. The hyphae that spread across the food source and the **rhizoids** that penetrate and anchor the fungus collectively form the “fuzzy looking” structure known as the **mycelium**.

Mycologists ("fungi" “studiers”) have classified the fungi species into five major groups: **Chytrids**, **Zygomycetes**, **Glomeromycetes**, **Ascomycetes** and **Basidiomycetes**. An example of a zygomycete is the common black bread mold called *Rhizopus stolonifer* that can grow under damp and dark conditions. Most people are familiar with the last group called the basidiomycetes (“club” “fungi”) such as the common mushroom called *Agaricus bisporous* that is eaten. We will examine examples of these last two groups.
Exercise 3A – Observing *Rhizopus stolonifer*

**Dissecting Microscope**

1. Obtain a sealed Sabouraud agar plate containing a culture of *Rhizopus stolonifer*.

2. Using the dissecting microscope, examine the white “thread-like” **sporangiophores** and the dark black balls called the **sporangia**. These ball-like structures contain the reproductive cells called **spores**.

   ► Draw an example of what you observe in the circle provided on your worksheet.

![Image of Rhizopus stolonifer sporangiophores and sporangia]

**Compound Light Microscope**

1. Obtain a prepared slide of *Rhizopus*.

2. Use the compound light microscope to examine the sporangiophores and sporangia.

   ► Draw an example of what you observe in the circle provided on your worksheet.

Exercise 3B – Observing Basidiomycetes

**Dissecting Microscope**

1. Obtain a simple whole mushroom. First use the naked eye to observe the **gills** that appear as small thin slats located underneath the dome of the mushroom. Observe the dark brown appearance of the gills. The brown color, as you will soon observe, is produced by millions of tiny dark **spores** used for reproduction. You may also notice that the spores project from small, club-shaped **basidia** (hence the term “club fungi”).

2. Carefully place the mushroom upside down on the stage of the dissecting light microscope. Focus in on the gills and observe the small round spores.

3. One of the major identifying factors for mushrooms is their spore color. The mushroom is put down on a black and a white paper to see what color the spores are by contrast. You can observe this in the demonstration example on the side counter. Note that the color of the underside of the mushroom is not necessarily the color of the spore.

   ► Draw an example of what you observe in the circle provided on your worksheet.
Part 4: Kingdom Plantae

Kingdom Plantae includes multi-cellular organisms that produce their own biological macromolecules through photosynthesis using light as an energy source. With very few exceptions, all plants are photoautotrophic (“light” “self” “feeding”). The importance of plants to other forms of life on our planet cannot be overemphasized. All animals and fungi, for example, depend on plants for their food and much of the oxygen they need for cellular respiration (photosynthetic algae in the kingdom Protista actually produce over half of the oxygen in our atmosphere). Without plants, Earth’s biosphere would consist mainly of bacteria, archaea and protista.

An effective way to approach the more than 280,000 species of plants that have been identified is to examine the chronological history of plants which reveals milestones in the evolution of their structure.

A. Non-vascular plants

The very first plant species to evolve about 500 million years ago were those that could transport materials throughout their body without the need for special tubes or vessels (Latin = vascule). These are called the non-vascular plants or bryophytes (“moss-like” “plant”). There are three phyla of bryophytes: Hepatophyta (liverworts), Bryophyta (moss) and Anthocerophyta (hornworts). Note that the term bryophyte is used as the general word for all non-vascular plants whereas Bryophyta refers to the non-vascular plants that include mosses.

The sexual reproductive cycle of non-vascular plants is fascinating. None of these plants use seeds for reproduction. A mature non-vascular plant has an organ called a sporangium to produce haploid (1n) spores. A male spore will grow into a structure with a reproductive organ called an antheridium. A female spore will grow into a reproductive organ called an archegonium. The antheridium will produce haploid (1n) sperm cells while the archegonium will produce a haploid (1n) egg. The sperm will fertilize the egg within the archegonium leading to the formation of a single cell called a zygote. It is the diploid (2n) zygote that will undergo mitosis to produce a new plant.
**Exercise 4A – Observing Whole Non-Vascular Plants**

1. Go to the table that has examples of non-vascular plants on display.
   ➤ Select one of the species and draw a picture of it in the circle provided on your worksheet.

**Exercise 4B – Observing the General Structure and Antheridia of Moss**

1. Get a prepared slide of *Mnium* (a common moss) with antheridia.
2. Use the compound light microscope to examine the general structure and identify the antheridia.
   ➤ Draw an example of what you observe in the circle provided on your worksheet.

**B. Seedless Vascular Plants**

By 425 million years ago, in order to grow larger, plants evolved special internal tube-like vessels called the **xylem** (water and minerals) and **phloem** (organic nutrients) for transport. We will examine these plant vessels in the next section. There are two phyla of seedless vascular plants: **Lycophytes** and **Pterophytes**.

As detailed above, the seedless vascular plants demonstrate a similar reproductive and life cycle as the bryophytes. They have **sporangia** that produce spores that lead to the production of haploid (1n) sperm and egg. Upon fertilization, a zygote is formed from which the new plant will emerge.

In this investigation, you will observe the simplest forms of Pterophytes called ferns and horsetails. You may be able to observe the sporangia - small brown spots- on the underside surface of the leaves of the fern.

**Exercise 4C – Observing Seedless Vascular Plants**

1. Go to the table that has examples of seedless plants of two Pterophytes, **fern** and **horsetail**.
   ➤ Draw an example of what you observe in the circle provided on your worksheet. If present, you will observe the sporangia on the fern mentioned above.
C. Seed-bearing Vascular Plants

350 million years ago, the vascular plants evolved to have a new mode of reproduction that included a new structure called a seed. In this life cycle and reproductive pattern, plants form male gametes (sex cells) in grains of pollen and female gametes called ova (eggs). These evolutionary adaptations allowed plants to more easily survive in harsh terrestrial environments and widen the dispersal of their offspring. Another adaptive feature was the evolution of leaves with a waxy cuticle that prevents too much water loss.

The first seed-bearing vascular plants to appear in the fossil record were the gymnosperms (“naked” “seed”). There are four phyla in this group: Ginkos, Cycads, Gnetophytes and Conifers. Most people are familiar with everyday conifers (cone trees) such as pines, redwoods and cedars. The largest organisms on the planet are the giant sequoias (Sequoiadendron giganteum) while the oldest organisms are the bristlecone pine (genus Pinus) which can be up to 2,500 years old.

Exercise 4D – Observing Gymnosperms

1. Examine the photographic samples and live samples of Cycads and Gingkos.
   ▶ Draw the structure of a cycad and the leaf of a gingko on your worksheet.

2. Examine the female cone of a pine (the type of cone you are familiar with) and observe the seeds. Then examine the male cone of a pine and observe the pollen.
   ▶ Describe the differences between female and male pine cones on your worksheet.

3. Examine the live sample of the Sequoia female cone. This is one biggest trees in the world.
   ▶ Compare the size of a Sequoia cone to that of a pine cone on your worksheet.

4. Examine photographic samples and descriptions of Welwitschia, Gnetum, and Ephedra in the phylum Gnetophyta.
   ▶ Compare the characteristics of these plants to the gymnosperms on your worksheet.
Exercise 4E – Observing Xylem and Phloem in Angiosperms

The most recently evolved group of plants are the flowering plants or angiosperms (“covered” “seeds”). This name is derived from the fact that in almost all species, the seeds are present in a fruit, which is technically the developed ovary of the plant. The angiosperms belong to a single phylum called Anthophyta. We will examine angiosperms in a future lab in more detail.

In the next exercise, you will observe a cross-section through a stem to observe the xylem and phloem vessels (“vascules”) of a typical angiosperm.

1. Obtain a prepared slide of a cross-section through the stem of a typical angiosperm,

2. Use the compound light microscope to examine the xylem and phloem.

   ► Draw a picture of what you observe in the circle provided on your worksheet. Label the phloem and xylem in your picture.
Part 5: Kingdom Animalia

Kingdom **Animalia** includes an incredibly diverse group of organisms, from the simple sponge to *Homo sapiens*. In the final part of this laboratory, we will first briefly survey nine of the major phyla of animals and their defining characteristics (see table below). We will then finish with a simple dissection of an “owl pellet”, a pellet of regurgitated, indigestible material from a Barn owl. Each pellet has been sterilized and contains one or more complete skeletons of animals consumed by the owl.

Table 1. – Major Phyla of Kingdom Animalia

<table>
<thead>
<tr>
<th>Phylum</th>
<th>Examples</th>
<th>Characteristics</th>
</tr>
</thead>
</table>
| Porifera      | Sponge            | ● Lack distinct body tissues  
                           ● Body plan is amorphous lacking any symmetry  
                           ● Capture food particles that pass through body |
| Cnidaria      | Hydra  
                           Jelly Fish | ● Two distinct types of embryonic tissues  
                           ● Gastrovascular cavity with one opening (proctosome)  
                           ● **Nematocysts** – specialized cells that sting prey |
| Platyhelminthes | Tapeworms         | ● Flat body plan  
                           ● Three distinct types of embryonic tissues  
                           ● Digestive tract with one opening |
| Annelida      | Earthworms        | ● Body plan has distinct segments  
                           ● Three distinct types of embryonic tissues  
                           ● Digestive tract with two openings |
| Mollusca      | Clam  
                           Snails  
                           Octopus | ● Most have a hard outer shell  
                           ● Feed with use of a **radula** to grasp food  
                           ● Wide variety of body plans |
| Nematoda      | Roundworm         | ● Body plan has no distinct segments  
                           ● Alimentary canal but no circulatory system  
                           ● Species commonly act as parasites |
| Arthropoda    | Insects  
                           Crustaceans | ● Body plan has distinct segments  
                           ● Bilateral symmetry of body (left and right)  
                           ● Have jointed appendages |
| Echinodermata | Star fish  
                           Sea Urchin | ● Most are slow moving or stationary  
                           ● Adults show radial symmetry (e.g. pie cut into equal wedges)  
                           ● **Water vascular system** – for movement and feeding |
| Chordata      | Fish  
                           Sharks  
                           Amphibians  
                           Reptiles  
                           Mammals | ● **Notochord** – flexible rod during embryonic development  
                           ● **Pharyngeal slits** – features found on developing embryo  
                           ● **Post-anal tail** – in embryo; may not be present in adult  
                           ● Nerve cord on the dorsal (back) part of the body |
Exercise 5A – Animal Phylum Survey

1. Examine the examples from different Animal Phyla in the demonstration area.
   - Write the names of the species that you observe on your worksheet.

Exercise 5B – Dissection of an Owl Pellet

Owls, as well as eagles and hawks, are birds of prey – they hunt other animals for food. Each species has specialized adaptations for hunting and capturing their prey. Hawks and eagles hunt by day with keen daytime vision.

Barn owls usually hunt at night but may be out in the early morning or early evening. Their large dish shaped head helps pick up sounds like a satellite dish. One ear is positioned higher than the other near the eyes for a special three-dimensional hearing system that can detect position and distance very accurately. They do not need to see to hunt because of their hearing capabilities, but they do have a well developed sense of night vision. They have feet with sharp talons for capturing and killing their prey and a sharp beak for tearing meat.
Barn owls (*Tyto alba*) are found on every continent except Antarctica. They are carnivorous and only eat animal flesh. They capture prey which can be birds, snakes, lizards, frogs, insects, and mammals (primarily mice, rats, gophers, moles, voles, rabbits, shrews, and weasels). They swallow the whole body of smaller prey and tear up larger prey in order to eat them. They then go to their roost and digest the soft parts. The prey’s hair, teeth, feathers, fur, bones, and hard insect parts are compacted to form a pellet which the owl regurgitates several to ten hours after eating. The regurgitation signals that it is time to eat again. An adult barn owl can eat one or more rodents per night. The pellets that they **regurgitate** have been carefully collected and sterilized for your team to dissect. In this exercise, you will act like a bird ecologist to examine what animals a Barn owl consumed.

1. You will need one barn owl pellet in a tray per group.
2. Using wooden sticks and forceps (tweezers) **carefully** pull apart the pellet and separate the solid objects (like bones, feathers, etc.) from it. Use the **identification keys** provided to try to identify what animals your owl has been eating. *You may want to use the dissecting microscope and a source of direct light to assist you with your dissection.*
3. You can glue the bones on a card or plate and take them home. For more information, see the example that has been put on display.

► Write the items that you found in your pellet on your worksheet.

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**Owl Pellet Bone Chart**

<table>
<thead>
<tr>
<th>Rodent</th>
<th>Shrew</th>
<th>Mole</th>
<th>Bird</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skull</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jaw</td>
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<td></td>
<td></td>
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<tr>
<td>Scapula</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Forelimb</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Hindlimb</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Pelvic Bone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rib</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertebrae</td>
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</tbody>
</table>

*Carolina Biological Supply Company*
Exercise 1A

Describe the differences in the characteristics of the three species of bacteria observed on the agar plate:

Exercise 1B

Draw the bacteria that you observe on the three different prepared slides you observe:

Exercises 2A/2B/2C

Draw examples of the three different protists you observe under the compound light microscope:
**Exercise 3A**

Draw examples of the fungus *Rhizopus stolonifer* as viewed on a plate under the dissecting light microscope and on a prepared slide under the compound light microscope.

Dissecting microscope (agar plate)  
Compound light microscope (prepared slide)

**Exercise 3B**

Draw a picture of the underside of the mushroom observed in the dissecting microscope. Observe the gills and spores.

Underside of mushroom under dissecting microscope  
Non-vascular plant __________________________

**Exercise 4A**

In the circle above, draw an example of a typical non-vascular plant that is on display. Write the name of the plant under your drawing.

**Exercise 4B**

Draw a picture of a cross-section through a simple moss *Mnium* showing the antheridia.

Cross section through *Mnium* with antheridia
**Exercise 4C**

In the circle below, draw an example of a typical seedless vascular plant that is on display. Write the name of the plant under your drawing.

Seedless vascular plant ______________________

**Exercise 4D**

As directed in the laboratory manual, draw a picture of the following items:

- Structure of a Cycad
- Leaf of a Ginko

What are the differences between female cones and male cones of a pine tree?

How does the cone of a Sequoia differ from that of a pine?

What are the differences in the structure of gymnosperms and species within gnetophyta?
**Exercise 4E**

Draw a cross section through the stem of a typical angiosperm and label the phloem and xylem on your drawing.

![Cross section through angiosperm stem with phloem and xylem](image)

**Exercise 5A**

What animal species did you observe on display in the laboratory?

**Exercise 5B**

Describe what you found in your barn owl pellet.