BIOL 1403: *ANIMAL BIOLOGY*
LABORATORY MANUAL

Fall 2014

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PREFACE

This first online edition of Biology 1403, Foundations of Biological Science – Animal Biology has been funded by a CSUEB Alternative Learning Solutions grant. Photos and illustrations included in this manual have been gathered from a variety of open access sources. In addition, some of the text was contributed from past and current Biol 1403 instructors, including Drs. Ned Lyke, Sam McGinnis, Susan Opp, and James Murray, and Kelly Decker, and revised based on comments from former and current Biol 1403 Teaching Assistants, former Biol 1403 students and Organismal Lab Coordinator, Mr. William Roan. We appreciate the contributions of all that have participated.

With all of this said, please note, nothing is perfect, and the editor would appreciate any suggestions, comments and/or corrections regarding any of the material included in this manual.

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INTRODUCTION

Welcome to the laboratory portion of this introductory course of Biol 1403: Animal Biology! During the coming you will participate in a series of laboratory exercises that are planned to give you an introduction to some of the fascinating aspects of the field of animal biology. You will learn basic skills of observation, collecting and interpreting data, and gain some understanding of the immense diversity of animal life and how these animals (and a few animal-like organisms) are adapted to the environments in which they live.

Laboratory classes will be conducted in North Science 313. Access to the room for review and individual and group study will be available during those times when classes are not in session (please note class session times in Table 1 below). Your laboratory instructor will provide you additional information on accessing the room and issues of security.

Table 1. Schedule of 1403 labs for Fall 2014. Labs sections with a “1” preceding the letter are the freshman only labs. Lab sections with a “2” preceding the letter are labs open to students of all standings.

LAB	DAY OF THE WEEK	TIME OF THE DAY
1A	Wednesday	9:20-11:50a
1B	Wednesday	2:40 - 5:10p
1C	Wednesday	5:30 - 8:10p
1D	Thursday	9:20-11:50a
2A	Thursday	2:40 - 5:10p
2B	Friday	9:20-11:50a
2C	Friday	2:40 - 5:10p

There are a number of general rules about the operation of our animal biology laboratories with which you should become familiar. We will review these with you on the first day of lab.

DISSECTION INSTRUMENTS

In addition to engaging in observation, you will be exploring the internal and external anatomy of a variety of animals. There are a few dissecting tools that you will be provided with that will be useful in your examination of the organisms we will be working with. These include: scissors with at least one sharp tip, forceps, a scalpel with replaceable blades, dissecting needles, and a blunt nose probe. These are all basic instruments that will be provided to every group of four students on a weekly basis. Check with your laboratory instructor if these items are not available to your group on your table.

STUDY SUGGESTIONS

1) You will discover that the Animal Biology lab period is too brief for you to become totally comfortable with all of the characteristics information which will be discussed in this course. However, reading through each assigned reading before coming to class and staying on task during lab will be immensely helpful in making good use of your time while in lab. In addition, the most important lab materials will be available for study during off-lab hours. Thus, coming to lab outside of class time and engaging in post-lab review of the specimens and concepts, along with a spirit of inquiry on your part, will go a long way to making you significantly more comfortable with the material for which we are holding you responsible. Lab will be available for open study when there are no scheduled labs in session. Table 1 provides a list of all of the lab periods.

2) Science is generally a cooperative venture; and so it is in this course. So, work closely with your lab partners during your lab activities. We also encourage you to work with others as you study your lab material outside of the lab period.

3) A number of figures have been included with this laboratory manual. You will find it useful to make additional sketches and written notes to aid in the retention of information learned during laboratory. Your lab (composition) notebook and the margins of your personal copy of your lab are available for your note-taking and sketch-making use.

LABORATORY EXPECTATIONS: What do you have to know?

1) **Taxonomy**. You will be expected to know the higher level taxonomy as specified by your instructor. This may include: domain (e.g., Domain Eukarya), kingdom (e.g., Kingdom Animalia), phylum (e.g., Phylum Cnidaria) and class (e.g., Class Anthozoa) for most organisms but you should check with your instructor to make sure. Appendix 1 lists all higher order scientific names used in this manual. You should also be able to use the correct generic names (i.e., “sea star”, “segmented worm”, etc.) for all of the specimens studied in the lab.

2) **Characteristics Uniting or Dividing Organisms into the Same/Different Taxonomic Groups**. Far more important than the name of each higher taxon are the major anatomical characteristics which characterize groups of organisms and can often be used to distinguish one taxon from another. Sharing or not sharing certain characteristics in common may also help with establishing evolutionary

relatedness or distance between groups of organisms. These characteristics are printed in boldface type in each chapter.

3) **Significance/Form/Function of Defining Taxonomic Characteristics.** You will be provided with many ecological, physiological, developmental and behavioral characteristics for the various taxa. It is critical that you not only know the names of characteristics that separate or unite organisms but that you understand the definition and function of these characteristics. between each group.

LABORATORY PRACTICALS

1) You will have a laboratory practical (i.e., with specimen-based stations that you would need to visit) during the middle and end of the quarter as part of the assessment of your knowledge of the concepts covered in lab. You can consult your syllabus for specific dates for these practicals.

2) Each week, there will be sample laboratory practical questions placed out in lab for you to consider. We encourage you to regularly visit these questions and discuss the problems with one another and your lab instructor as part of your preparation for the real thing.

CHAPTER 1

USING MICROSCOPES FOR BIOLOGICAL STUDY

Objectives

Students should be able to:

- describe the general differences between optical and electroni microscopes to understand their use in biological research
- point out the features of the compound and dissecting microscopes and describe their functions
- demonstrate how to use the compound and dissecting microscopes
- calculate the magnification power of a given compound or dissecting microscope
- calculate the size of a specimen viewed under a compound microscope

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Introduction to Microscopy

The microscope systems that CSUEB faculty, staff and students commonly use or have access to are based on two different principles of obtaining energy to visualize specimens: the **optical microscope** using light waves or modified light waves, and the **electron microscope** using an electron beam.

Optical Microscopes

1. **Bright-field microscope** – This is the standard compound binocular or monocular microscope usually associated with the biology laboratory. Light waves from the sun or lamp, after passing through a condenser lens, pass through a specimen on a slide, then an objective lens of varying magnification, and finally through an ocular lens before entering the eye for imaging and interpreting.

2. **Dissecting microscope** – A variation of the above-described microscope, this microscope is used to visualize surface features of specimens. The light waves from similar sources are reflected off the surfaces and pass through objective and ocular lenses before entering the eye.

3. **Confocal microscope** – Allows for visualization deep within living and fixed cells and tissues. Also allows user to collect sharply defined optical sections from which three-dimensional renderings can be created. This is achieved by the use

of spatial filtering to eliminate out-of-focus light or flare in specimens that are thicker than the plane of focus.

Electron Microscopy

1. **Transmission electron microscope –** (aka TEM). Uses a high voltage to generate a beam of electrons through electromagnetic lenses and specially prepared specimens. The image of the specimen is seen on a phosphorescent screen.

2. **Scanning electron microscope –** (aka SEM). Similar to the transmission microscope in utilizing electrons as the source of energy, in this case the SEM operates much like a dissecting microscope in that the electrons are reflected off of the surface of specimens. The electrons then are picked up by a detector that digitizes the image and transmits it to a TV monitor for observations.

During your time in the Department of Biological Sciences you will have the opportunity to see most, if not all, of these systems in operation, use them, and understand their value to the biologist. In the meanwhile, for this exercise, we will focus on familiarizing ourselves with the two types of microscopes used regularly in this course.

The Compound and Dissecting Microscopes

Two of the most useful instruments in the animal biologist's laboratory are the compound and dissecting microscopes. Since the development of the simple microscope by **Anton van Leeuwenhock,** the scientist credited with being the "first microbiologist" in the late seventeenth century, biologists have relied on these instruments to gain considerable insight into the structure and function of organisms. Microscopes today consist of an almost bewildering array of sophisticated instruments – bright field, phase, dark field polarizing, differential interference contrast, and inverted optical microscope as well as scanning and transmission electron microscopes; they are all important tools of the modern biologist.

In the Biol 1403 laboratory, we use **<u>binocular compound microscopes</u>** and **<u>dissecting microscopes</u>** for student use during lab exercises and as tools assisting demonstration and study. These microscopes are used to magnify, resolve and clarify many of the finer details of animal structures. A phase contract microscope with attached color video camera, VCR unit, and television monitor may also be available for instructor and student use.

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The Compound Microscope

This particular instrument is used for the study of small, generally translucent animals, cells, tissues, and other structures. It utilizes transmitted light passing through a specimen located between two lens systems.

Becoming Familiar with the Microscope

ACTIVITY 1-1: Obtain a compound microscope from the laboratory cabinet (unless it is already placed on the table in front of you) and use the diagram of the compound microscope (Figure 1.1; also, see poster in classroom) to identify the important components of this instrument. These components include the following:

- **Ocular Lens** – the lens closest to the eye. Usually 10x in magnification.

- **Body Tube** – the primary cylindrical portion of the microscope that houses the lens systems.

- **Nosepiece** – a revolving unit that holds a set of three or more objective lenses. It is moved by carefully grasping with the fingers and rotating until it clicks into position for a lens.

- **Objective Lenses** – a complex set of small lenses that magnify the specimen according to the power engraved on the side of the lens. Our microscopes have four lenses: 4x, 10x, and 40x and 100x (immersion oil lens). (More information on the oil immersion lens is below.)

- **Arm** – the main structural support for the body tube. Use this element to carry the microscope.

- **Stage** – a platform with clips to hold a slide in place under the objective lens. Some microscopes have mechanical stages that clamp the slide into a special bracket which is then moved by knobs.

- **Aperture of the Stage** – the hole in the stage which allows light to pass through from the condenser.

- **Condenser Lens** – a sub-stage lens system that focuses the light on the specimen. This lens may be locked in position or adjustable.

- **Iris Diaphragm** – an adjustable opening under the condenser lens that controls the amount of light entering this lens.

- **Sub-stage Illuminator** – a low-voltage light located in the base of most modern microscopes to provide illumination for the specimen. Older microscopes use an adjustable reflecting mirror to direct light from a microscope lamp to the condenser lens.

- **Coarse Adjustment Knob** – this is used to raise or lower the body tube to initially focus the specimen. It is used only with low magnification lenses.

- **Fine Adjustment Knob** – generally somewhat smaller and outside the coarse adjustment knob, it is used for final adjustment of focus and varying the plane of focus through the depth or thickness of a specimen.

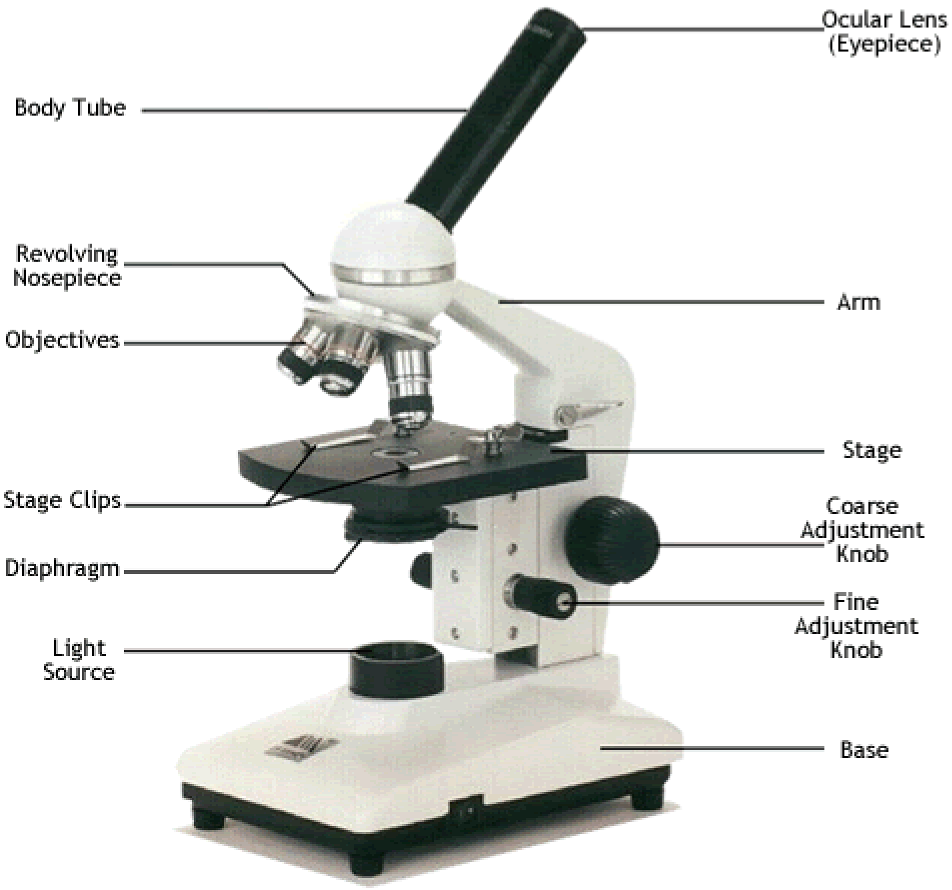

Figure 1.1 The parts of the compound microscope.

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Using the Compound Microscope: Magnfication Capabilities

ACTIVITY 1-2: As you are now aware, the compound microscope has two separate lens systems; the ***ocular (or eyepiece)*** and the ***objective lens***. Eypeice magnification is usually 10x, depending on the model of microscope (the magnification is written on the tube of the lens).

1. Take a look at the oculars on your compound microscope again.

Q. What is the magnfication of your microscope's ocular lens?

The objective lens magnifies your specimen beyond what the ocular achieves. Your microscope has four objective lenses, which you can rotate into place. The **total magnification** of your specimen equals the magnification of the eyepiece multiplied by the magnification of the objective lense in place.

The magnifying powers of a microscope alone do not allow you to see objects smaller than those you can see with just your eyes. A microscope must also have good **resolution**. Resolution is the minimum distance between two objects that allows them to be seen as two objects. For instance, a bright spot in the sky may be resolved into two stars with a good telescope; a telescope with less resolution will just magnify the single bright spot.

The compound microscope you are using has better resolution than your eyes or a magnifying glass. Electron microscopes have even better resolution. Although we do not have an SEM (scanning electron microscope) or TEM (transmission electron microscope) at CSUEB, you will regularly see electron microscope images (= **micrographs**) in lecture and lab presentations, in your readings, out on display and during your research experiences as a biology student/student taking biology courses.

2. Consider the **oculars** and the **objective lenses**.

   Q. ***What are the various magnification capabilities of your microscope? (Hint! There are four objectives so you should have four different answers; You can use the space below to write out your math).***

Using the Microscope: The Oil Immersion Lens

We will not be using the oil immersion lens during this exercise but it is certainly worth taking a moment to discuss it. As you have probably noticed, the light intensity decreases when magnification increases. The oil immersion lens (100x) gives a very high magnification, but even more light is lost. Viewing the specimen through oil helps the microscope capture more light.

When you use oil immersion, you cannot go back to the dry objective lenses. These lenses can be ruined if oil gets on them. If yiou decide to use oil, make sure you have finished looking at your specimen at lower powers of magnification.

When you are finished using oil immersion with your slide, lower the stage and remove the slide. If it is a prepared slide, wipe the oil off the slide and the oil immersion lens with **lens paper only**. If it is a wet mount, dispose of the coveslop and slide as instructed by your instructor.

Using the Microscope: The Field of View

ACTIVITY 1-3: You can estimate the size of a specimen that you are viewing with a microscope but you will need to know the size of the **field of view** in order to do it. The field of view is the area that you see when looking through the microscope and, as you will see, its size depends on the strength of magnification.

1. Obtain an “e” slide from your instructor.

2. Place the prepared slide of the letter “e” onto the center of the stage under the **objective lens** until the light shining through the hole in the stage shines through the “e”. Secure the slide with the **stage clips**.

3. Carefully move the **coarse adjustment knob** until the letter “e” comes into view. Move the slide until the “e” is in the center of your **field of view** (the circle of light you can see through the **eyepieces**).

4. Use the **fine focus knob** to bring the “e” into sharp focus. If you have a **focusing ring** on one of the eyepieces, close your eye on the side with the focusing ring and adjust the fine focus until the image is in focus with your open eye. Close your other eye and use the focusing ring to focus the image for your open eye. Then, open both eyes and look through the microscope. You should now have the focus for both eyes adjusted.

5. Look at the "e" on the slide itself and then through the microscope. Look at the "e". on the slide itself and then through the microscope.

   Q. Is it oriented in the same way? Explain.

6. Try moving the slide from right to left and up and down, using the stage controls.

   Q. How does the image seen through the microscope move relative to how you are moving the actual slide?

7. Center the "e" in your **field of view** again. Without changing any settings, rotate the next higher **objective lens** (10x) around until it clicks into place.

   NOTE: Do not use the coarse focus when the higher objectives are in place. The space between the slide and the objective lens becomes very small, and you risk smashing them into each other. If your microscope is properly adjusted and you slide is not unusually thick, you will be safe using the fine focus at higher magnifications.

   Q. What happened to the size of the "e" after you increased the magnification?

   Q. What happened to the size of the field of view?

   Q. What happened to the intensity of light?

Q. What happened to the distance between the objective and the specimen?

8. Use the **fine focus** to focus the "e" and try to adjust the **diaphragm** to change the amount of light coming through your specimen. With specimens on a higher magnification, closing the **diaphragm** often increases the contrast, allowing you to see internal structures better. Also try adjusting the light intensity.

9. Again, without changing any settings, rotate the next higher objective into place (40x).

Q. What happened to the size of the "e"?

Q. What happened to the size of the field of view?

Q. What happened to the light intensity?

Q. What happened to the distance between the objective and the slide?

Using the Microscope: Measuring/Calculating the Size of a Specimen

Because a ruler does not fit on the microscope with a slide, it cannot be used to directly measure specimens on a microscope.

ACTIVITY 1-4: This exercise indicates the size of the field of view so that you have a better idea of the size of your specimens.

1. Return your microscope to the lowest objective (4x) and lower the **stage**. Place a clear metric ruler on the stage with the millimeter (mm) markings over the hole in the stage. Use the **coarse focus knob** to focus on these markings, placing the millimeter markings so that they go across the diameter of the **field of view**.

    Q. How many millimeters across is the field of view?

2. Now, try the next higher objective (10x).

    Q. How many millimeters across is this field of view?

3. Try the next higher objective (40x). At this magnification, the field of view will be less than 1 mm, so it CANNOT be measured directly with the ruler. Instead, use the following formula to determine the diameter of this field of view and record the value on the data sheet:

$$\text{High power diameter} = \text{Low power diameter} \times \frac{\text{Low power magnification}}{\text{High power magnification}}$$

Q. Based on this formula, what did you calculate your field of view at 40x to be?

4. Carefully remove the ruler from the microscope and look at the millimeter markings.

   Scientists use metric units of measurement because they are based on powers of 10. There are 1,000 mm in a meter; in other words, a millimeter is 1/1000 of a meter. Because many specimens are much smaller than a millimeter, they are measured in a metric unit that is 1/1000 of a millimeter (a millionth of a meterl). This unit is called a *micrometer* and is abbreviated *µm*.

   Q. Try out this practice problem. If your field of view is 6 mm, how many µm does this equal to?

5. Convert your measurements of the fields of view at 4x, 10x and 40x power (questios 1-3) into micrometers.

   Q. What are your measurements of the fields of view at 4x, 10x and 40x power in micrometers?

   Low power (4x):

   Medium power (10x):

   High power (40x):

Sizes of some typical cells are shown in Figure 1-2.

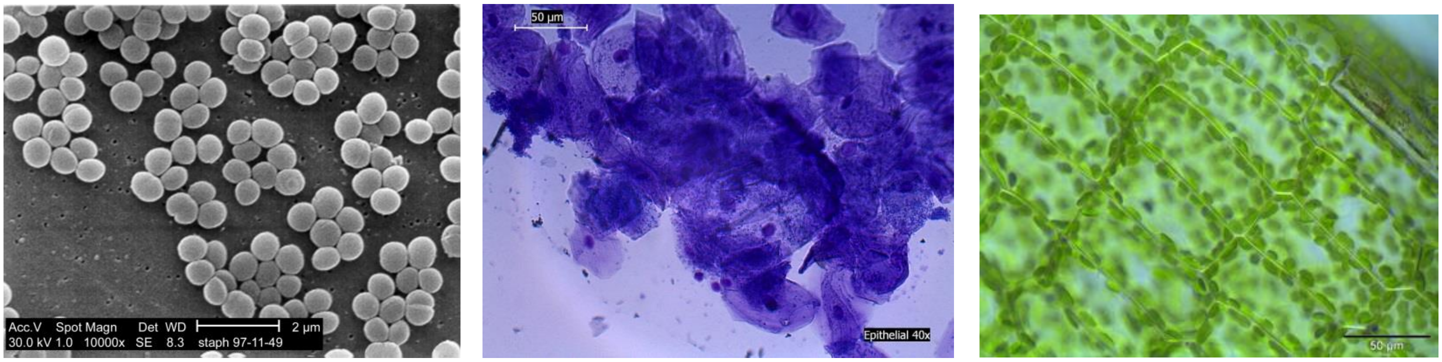

Figure 1.2. a) Typical prokaryotic cell: Staphylococcus sp., b) epithelial cells from inside human mouth, and c) *Elodea* plant cells.

Making a Temporary Slide Mount

Often, biologists are interested in making temporary slides of specimens so that they can examine them with a microscope. Temporary slides have the advantage of short preparatory time; but because they dry out rather quickly, they are of little long-term value. So, as an alternative, a wet mount may be used. A wet mount involves suspending a specimen, such as a living organism(s) or material that needs to be kept moist, in a drop of water on a slide. The material to be observed is suspended in the water and, following the placement of a cover slip, can be observed using a compound microscope.

You will be making a wet mount of protist samples as part of your laboratory exercises associated with chapter 2. The steps for preparing the wet mount will be discussed at that point in the lab manual.

Do you know the parts of the binocular microscope? Quiz yourself at: http://www.biologycorner.com/microquiz/index.html

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The Dissecting Microscope.

Dissecting microscopes, also known as a stereoscopic microscopes, differ in a number of ways from compound microscopes. First, they have much lower magnification capapbilities compared to compound microscopes. Dissecting microscopes typically have a zoom-type objective lens system with a continuously variable range of magnification controlled by a **magnification knob** on the top of the microscope head. There is a **focus knob** and a source of transmitted light (adjustable). The **binocular eyepieces** (= **ocular lenses**) have a magnification of 10x and the zoom lens complex permits magnification from 0.7x to 3x; therefore, magnification capabilities for thesemicroscopes range from 7x to 30x. Another difference from the compound microscope is that the **stage** is much farther from the objective lens, allowing large objects to be placed on the stage.

Although their magnification capability is generally less than that of a compound microscope,dissection microscopes have several advantages over compound microscopes. First, they have a large **depth of field** so you can observe thick objects with most parts in focus at the same time. Second, you can illuminate your sample using incident light as well as **transmitted light** so that thick objects which will not transmit much light can be illuminated adequately enough to view.

The above-described and other feature make dissecting microscopes good at producing three-dimensional view of specimens on the microscope stage. Thus, these microscopes are especially useful for viewing whole (i.e., not tissues or sections) zoological specimens of small to moderate size where great magnification may not be necessary. They are often used during animal dissections to allow observers to get a closer view of an anatomical feature.

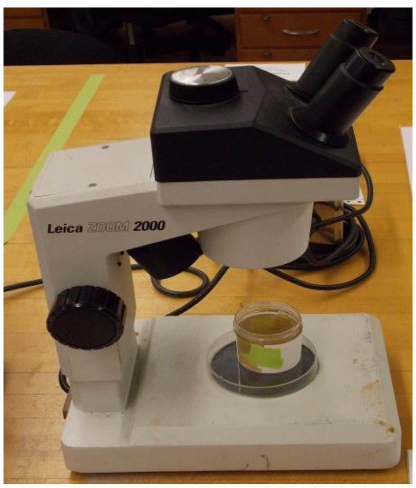

Figure 1.2. A dissecting microscope .

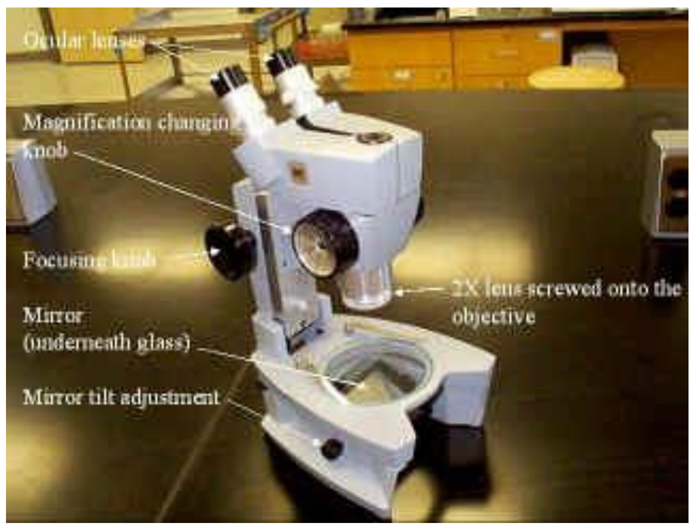

Figure 1.3. A dissecting microscope with the parts labeled.

ACTIVITY 1-5: Familiarize yourself with the different parts of the dissection microscope. Be sure to identify and review the functions of the ***ocular lenses, microscope head, zoom control/magnification knob, focus adjustment knobs, stage and reflecting mirror***.

1) Obtain a dissecting microscope. If you need to move the microscope, **be very careful** in moving it, making sure that you always carry them with one hand under the stage base.
2) Using Figures 1.2 and 1.3 as a guide, identify the basic parts of the microscope.

Care of the Microscope

Please observe the following directions and cautions about the use of the compound microscope.

1. Always carry this equipment with two hands, one on the body tube, and the other under the base of the microscope. Carry in a vertical position and do not swing it around; the ocular lens might fall out!

2. Place the microscope away from the edge of the laboratory bench, though sufficiently close to permit comfortable use without having to lean too far from your chair. Make sure the electrical wire does not drape over the edge of the bench where it could be caught by an elbow or knee!

3. Do not remove any lenses.

4. Keep the microscope clean:
    a) Use only lens paper (provided in table trays) for cleaning the lenses. Do not use any cloth or paper that might scratch the glass of the objective or ocular lenses.
    b) Do not touch lens surfaces with your fingers – they are oily!
    c) Clean up all spills, including water, immediately. Ask for assistance if necessary.

5. When beginning to observe a slide always start with the lowest power lens and advance sequentially to the higher power lenses. The latter lenses are longer than the low power lenses and, thus, have less “working distance” from the microscope slide. Be especially careful when switching to a higher lens, observing from the side of the nosepiece to be sure the lens will not strike the slide or coverslip before rotating it into place. Thick mounted specimens usually cannot be observed with the high power lenses.

6. The coarse adjustment knob alters the distance between the objective lens and the stage by either moving the objective lens, or by moving the stage. Note which direction of rotation brings the lens and stage farther apart – this is how you prepare the microscope for changing to a different lens.

7. Make it a practice not to focus downward with the coarse adjustment when using the high power lens. This will usually result in a broken cover glass, if not a broken slide.

8. Eyestrain, eyeglasses, and backache:
    a) Keep both eyes open, even with the monocular microscope. If necessary, cover one open eye with your hand until you get used to the practice of “seeing” with one eye.
    b) If your eyes become tired after long and intensive use focus them on something in the distance – look out the window!
    c) You should be able to look into the microscope without stretching, slouching, or tilting the microscope. Adjust the chair height if necessary. Your instructor can assist you.

CHAPTER 2

THE PROTISTS

Objectives

Students should be able to:

- explain why this group is not viewed as a Kingdom anymore
- indicate the number of recognized "supergroups" of protistans
- describe the relative relatedness of groups of protists to members of other biological kingdoms
- identify an organism as a protist
- describe characteristics of protists known as "the protozoa"
- explain why these are *not* animals/explain the major characteristics of this varied group
- describe similarities and differences between protists and animals
- identify/describe the means of locomotion seen in living or model protistans

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Currently, scientists recognize four major groups – kingdoms – in the Domain Eukarya: Plantae, Fungi, Animalia and Protista. When invoking the taxonomic classification of "kingdom", the implication is that all of the members of that kingdom descended ultimately from a common ancestor – i.e., the group is **monophyletic**. Results of scientific studies, however, demonstrate that the protist group is not a monophyletic one. Indeed, there are some protists that are more closely related to members of other eukaryotic kingdoms than they are to one another. Thus, to place them all within a "Kingdom Protista" would be misleading and inaccurate. For now scientists use the term "protists" to refer to the group of mostly single-celled organisms once placed into one Kingdom together. And with this group, the term "kingdom" is used loosely, if at all.

Currently, there are six "supergroups" of protistans recognized. Some of these organisms are more closely related to animals and fungi, while others are more related to plants.This large, heterogeneous group of organisms exists as solitary or colonial eukaryotic cells, many of enormous complexity. They are found primarily in aquatic habitats of fresh, brackish or saltwater. Some are terrestrial, and a significant number are **symbiotic**, living on or in other organisms. The organisms we will examine briefly in this course are members of a group called the "protozoa", the animal-like protists.

Protist Supergroups

Scientists currently recognize six supergroups of protists. Protozoans can be found in several of these supergroups. A description of various types of protozoans is provided below:

Protist Supergroup: ***CHROMALVEOLATA***

Many of these protists have **alveoli**, membrane-lined sacs, which aid in the regulation of the diffusion of materials across the plasma membrane. It has been suggested that these protists may have evolved through extremely ancient **secondary endosymbiotic** events.

Q. What is endosymbiosis? Secondary endosymbiosis?

This group includes organisms critical to many to ecosystems.

e.g., Paramecium (a ciliate)

Members of the genus *Paramecium* are very common protozoans. These single-celled organisms comprise a large number of species that are found in freshwater habitats around the world. These cells are very easy to culture and have been used for numerous experiments in cellular genetics, nutrition, biochemistry and cytology.

These protists have **cilia** surrounding their body, which they use for locomotion and nutrition. They also have specialized vacuoles which they use to degrade food particles and locomotion. *Paramecia* have two types of nuclei: one macronucleus that controls cell metabolism and growth and one or more micronuclei, which contains the genetic material.

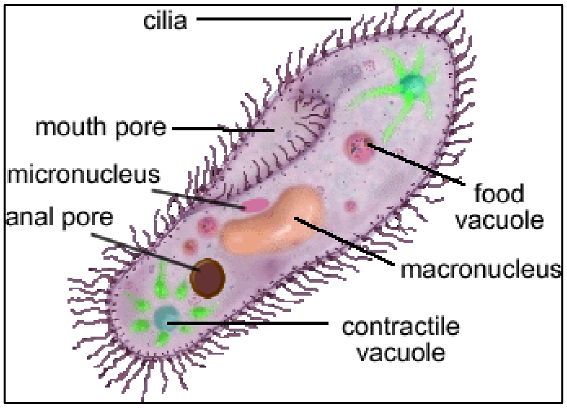

Figure 2.1. Drawing of a Paramecium. Another name for "mouth pore" is cytostome.

The cell is surrounded by a **pellicle** which gives the ciliates a firm body shape. The **oral groove** is a funnel-shaped indentation on one side of the cell that conveys food to the **cytostome**. At the cytostome, food vacuoles form and move into the interior of the cell where digestion occurs.

Contractile vacuoles, used for **osmoregulation**, are prominent features of these cells and can be seen in the anterior and/or posterior cytoplasm. These organelles, with careful observation, can be seen to gradually fill with fluids and then quickly contract to release the fluids outside the cell.

With careful regulation of the amount of light entering the microscope (***what part of the microscope do you adjust?),*** the rapid movement of the cilia on the surface of the cell can be observed. Just under the pellicle and perpendicular to the surface of the cell are many spindle-shaped organelles called **trichocysts**.

Under certain stimuli the trichocysts release a fluid that hardens in water to form long, slender, thread-like filaments. The tangle of these filaments is believed to have a protective function, and in some ciliates they are used for food capture. The trichocysts are best observed by adding a small amount of a stain like methylene blue to the culture. While this will probably kill the *Paramecium* that come in contact with it, the initial reaction is to discharge a number of trichocysts which are then stained.

You will use a prepared slide and a wet mounts of (live) Paramecium to more closely examine the above-described structures.

ACTIVITY 2-1: **Viewing a Prepared Slide of *Paramecium*.**

1. Each individual should perform this task.

2. Obtain the *Paramecium* slide available in the slide box in front of you on your student bench (i.e., the table).

3. Clean all of the microscope **objective lenses** with **lens paper** (available on the student bench).

4. Place the slide on the stage and secure it to the stage with the **stage clips**.

Figure 2.2 Prepared *Paramecium* specimen.

5. Turn on the **light** and adjust the light intensity to a medium setting. Move the **condenser** to its highest position and change the **iris diaphragm** until you are familiar with is effect on illumination. You may find that you will wish to adjust the amount of light entering the microscope lens systems depending on the specimens.

6. Look through the **eyepieces**. Adjust the distance between the two eyepieces by gently pushing them together or pulling them apart as you look through them. Experiment until you can see one circle of light withg both eyes.

7. Rotate the **coarse focus knob** until the **stage** is as low as possible.

8. Click the **low power objective lens** (scanning power) into place. If you have difficulty locating a specimen, try focusing on the edge of the cover glass and then moving into the area of the specimen.

9. Once you have located the the specimen, try viewing the specimen under the next two higher objectives (i.e., 10x and 40x).

10. See how many of the features labeled in Figure 2.1 you can identify.

ACTIVITY 2-2: Make a wet mount of a sample of Paramecium

1. Each individual should perform this task.

2. Obtain a glass **depression slide** (= **well slide**) and a coverslip from your student bench. Be sure that the slides and coverslips are clean before use. If not, wash gently in running tap water and dry with a towel or Kimwipe tissue. Handle slides and coverslips only by their edges.

Figure 2.3. Live *Paramecium*.

3. Visit the living culture of *Paramecium* and use a pipette to place one or two drops of of the solution into the depression on the slide.

4. Place the coverslip over top of the the specimen/depression in the slide.

   NOTE: When using a standard (non-depression) slide, you would need to complete a few extra steps when placing on a coverslip. You would need to allow one edge of the coverslip to contact the slide; then slowly lower the entire coverslip by tipping it down to the slide. Do not drop the coverslip horizontally onto the slide as air bubbles may be trapped under the coverslip. *You would want the entire coverslip/slide interface to be wet, but the liquid should not extend beyond the edge of the coverslip. Remove excess water with a Kimwipe.*

5. Once you have completed making the wet mount, begin viewing your specimen using a microscope.

   Q. Should you use a compound or dissecting microscope for this activity? Explain.

6. You may find that these cells move rather quickly about their habitat, making examination of the details of their morphology tricky. Spend some time, however, observing the general patterns of locomotion and other behaviors before moving on.

7. If available, add a drop of methyl cellulose and a coverslip to the slide.

***Q*: What would adding the methyl cellulose to the slide do?**

8. See how many structures indicated in Fig. 2.1 you can identify in your living specimens. Also, record the behavior you observe in these organisms.

*PLEASE NOTE: It may be possible to see the **macronucleus** and one or more **microcnuclei**. Paramecium, like other ciliates, reproduces both asexually and sexually, the latter by a special process known as **conjugation**.*

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e.g., ***Plasmodium*** **(an apicomplexan)**

These protists are fusiform in shape, with an apex in their body, which aids them in movement. These parasitic protists cause malaria. The life cycle of these organisms requires two hosts: an insect (mosquitoes) and a primate (e.g., humans).

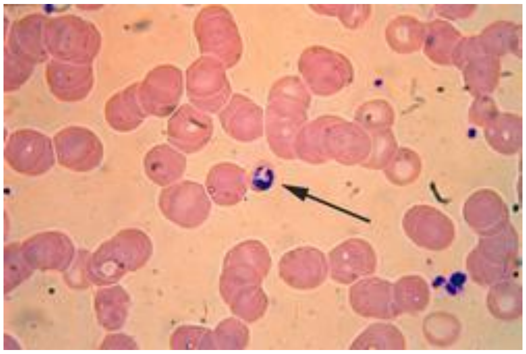


Figure 2.4. The arrow points to the purple-colored protist (*Plasmodium*), the pinkish spheres are blood cells.

Figure 2.5. *Anopheles* mosquito taking a blood meal. This is how a human becomes infected with *Plasmodium* and contracts malaria.

Protist Supergroup: *AMOEBOZOANS*

This group includes protists known as amoeba and plasmodial slime molds. These protists are very closely related to both animals and fungi. Members of this phylum of protozoans move by means of elaborate extensions of the cytoplasm called **pseudopodia**. This type of locomotion is called **amoeboid** and is characteristic of all members of this supergroup. While many of the unikoknts are “naked”, with no rigid outer body covering, a wide variety of species have complex shells and skeletons and are among the most striking of all the protists.

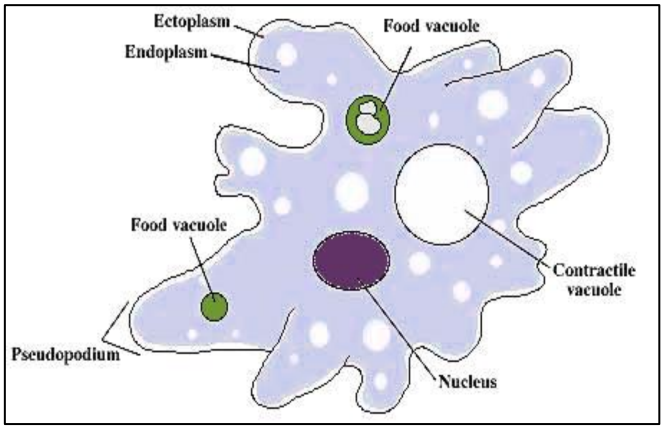


Figure 2.6. Drawing of an *Amoeba proteus*.

e.g., Entamoeba histolytica *(an amoebozoan).*

These protists cause amoebic dysentery, which is also known as Montezuma's Revenge. People usually contract this through contaminated water and food.The protists make their way into the intestinal tract,ultimately causing ulcers, diarrhea and/or blood loss and anemia.

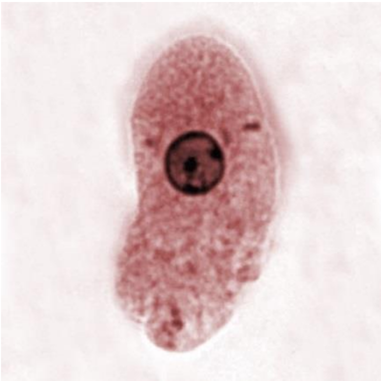


Figure 2.7. Micrograph of *Entamoeba histolytica*.

ACTIVITY 2-3: Viewing a Prepared Slide of *Amoeba proteus*.

1. Each individual should perform this task.

2. Obtain the *Amoeba* slide which is available in the slide box in front of you on your student bench (i.e., the table).

3. Place one of the slides on the **stage** and secure it with the **stage clips**.

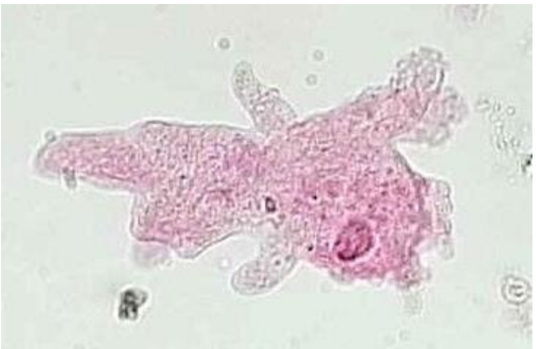


Figure 2.8. Prepared *Amoeba* specimen.

4. Turn on the **light** and adjust the light intensity to a medium setting. Move the condenser to its highest position and change the **iris diaphragm** until you are familiar with is effect on the illumination. You may find that you will wish to adjust the amount of light entering the microscope lens systems depending on the specimen.

5. Look through the **eyepieces**. Adjust the distance between the two eyepieces by gently pushing them together or pulling them apart as you look through them. Experiment until you can see one circle of light withg both eyes.

6. Rotate the **coarse focus knob** until the **stage** is as low as possible.

7. Click the **low power objective lens** (scanning power) into place. If you have difficulty locating a specimen, try focusing on the edge of the cover glass and then moving into the area of the specimen.

8. Once you have located the the specimen, try viewing the specimen under the next two higher objectives (i.e., 10x and 40x).

9. See how many of the features labeled in Figure 2.6 you can identify.

ACTIVITY 2-4: Make a wet mount from a live culture of Amoeba proteus

1. Each individual should perform this task.

2. Obtain a glass **depression slide** (= **well slide**) and a coverslip from your student bench. Be sure that the slides and coverslips are clean before use. If not, wash gently in running tap water and dry with a towel or Kimwipe tissue. Handle slides and coverslips only by their edges.

Figure 2.9. Live *Amoeba* specimen.

3. Visit the living culture of *Amoeba* and use a pipette to place one or two drops of of the solution into the depression on the slide.

4. Place the coverslip on the specimen.

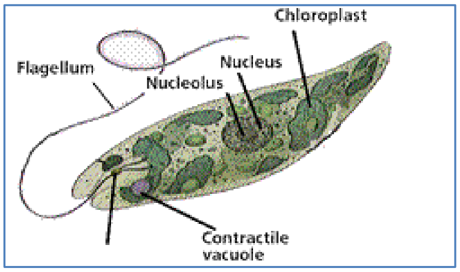
5. Once you have completed making the wet mount, begin viewing your specimen using a microscope.

   Q. Should you use a compound or dissecting microscope for this activity? Explain.

6. Study the activity of these protists and take note of what you are seeing. Be sure to observe the general pattern of locomotion.

Protist Supergroup: *EUGLENOZOA*

These organisms have a **flagellum**, a long, tail-like structure which can be helpful in locomotion. Some of these protists have an "excavated" groove which likely serves as the anchor point for a flagellum.



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e.g., ***Euglena***

These protists have qualities of both plants (e.g., chloroplasts) and animals (e.g., flagellum, heterotrophy). They can be **heterotrophic** or **photosynthetic** and some are human parasites.

Figure 2.9. *Euglena* sp., a member of the protist supergroup Excavata.

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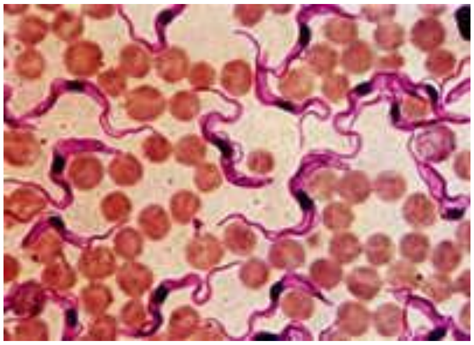
*e.g.,**Trypanosoma***

There are two species of these parasitic protists, which cause African sleeping sickness. These organisms have a **complex life cycle**, two hosts: an insect (tsetse fly) and a mammal (e.g., humans). These parasites move about within the blood vessels of the human host.



Q. How might these cells' long flagellum make them well-adapted for their way of life?

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*e.g.,**Giardia***

These protists become prolific in water contaminated with human feces. Drinking *Giardia*-contaminated water can cause "beaver fever" in humans, resulting in intestinal pain, severe diarrhea and loss of appetite.

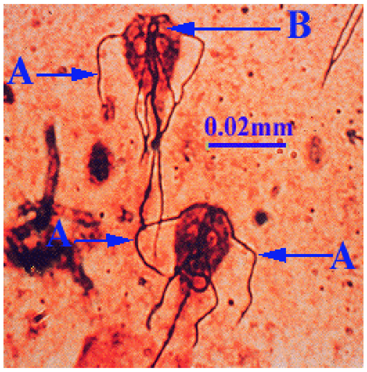

Figure 2.11. Photograph of the protist *Giardia*, with A = flagellum and B = the main body of the protist.

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*e.g.,**Triconympha***

These large multi-flagellated protists are found in the posterior intestines of termites. These remarkable cells are indispensable to the life of the termite as they provide the necessary enzymes to enable the termite to digest the cellulose ingested with particles of wood and other vegetation. The termite, in turn, provides a stable habitat for the growth and reproduction of the protozoan.

Figure 2.12. Photo of *Trichonympha*

When two (or more) organisms live together in close association, it is called a **symbiotic relationship**. Symbiotic relationships in which the two partners both receive a benefit from living in the relationship are called **mutualisms**. The relationship between *Triconympha* and termites can be described as a mutualistic one, where the protist receives food and shelter as part of the deal.

Interestingly, it has been suggested that *Triconympha* has bacteria living in it, which aid the protist in digesting the cellulose it takes in. If this is true, it would also be accurate to describe the relationship between *Triconympha* and these cellulose-digesting bacteria as mutualistic.

General Hints to Aid in Observations of Protozoans

Protozoans are very small. Thus studying them in lab can be challenging. The information below descrbies common strategies that can make observing these organisms more effective and efficient:

Dealing with "Contaminants"

When viewing a wet mount that either you or a biological supply company prepared from a stock solution, it is not uncommon to find other small organisms moving around in the target species. This is because it is time-consuming and expensive for biological supply companies to develop and maintain single species cultures. So, while the stock solution may primarily contain the target species, other species maintained at the biological supply company may also be present in the specimen. For example, there is often frequent "contamination" of our cultures by a small flagellated protist known as *Chilomonas*, which serves as food for some species and is often useful to have in cultures. Other "contaminants" may be other species of protists or possibly rotifers, which are microscopic (or close to it), primarily freshwater invertebrates which feed on detritus and protists.

It is not an efficient use of your time to try and separate out the study species from the rest of the orgainsisms in your sample. Consequently, if you find more than one type of organism when viewing your *Amoeba* and *Paramecium* wet mount samples, be sure that you are able to distinguish the species you are required to study and concentrate on observing and learning the characteristics of that organism. on working with them while recognizing that other cells, frequently flagellates, are in the cultures.

<u>Protists Can Be Fast-Moving</u>

Many species of protists move fairly quickly (the Amoeba is one exception) about their habitats and are difficult for all but the experienced observer to examine with any understanding of their structure. Methyl cellulose, a clear, viscous material that can be added to a wet mount, can be a valuable aid in observations of protozoans. That is because this material makes it more difficult for these cells to move about, thus slowing them down. It can be added to a slide prior to adding the protozoan culture or mixed on the slide with an already existing culture.

<u>Viewing Protozoan Structures</u>

It is also possible to use a number of different stains to highlight particular structures of protozoans. These stains are generally added to the outer edge of coverslips and carefully drawn under and into the culture to gradually stain the cells. Various stains will be suggested in the following descriptions.

<u>Other Resources for Studying Protozoans</u>

In addition to this lab manual and your textbook, the laboratory has a number of reference charts, books, and other materials to aid in your understanding of the structure and function of the protozoa. Consult these as necessary, but do take advantage of these sources of information – countless numbers of students and zoologists have learned much from doing a little extra reading and other observations.

CHAPTER 3

INTRODUCTION TO KINGDOM ANIMALIA

Objectives

Students should be able to:

Kingdom Animalia

- describe the characteristics thatdifferentiate animals from biological organisms placed in other taxonomic kingdoms
- elaborate on the characteristics that animal cells have in common
- describe what is meant by surface area to volume ratio
- demonstrate how surface area to volume ratio can be calculated
- discuss how differences in surface area to volume ratio can influence biological function in animals at the cellular and whole organism levels.

The review of the animal phyla is presented with demonstration material and materials to be used at your laboratory bench. The demonstration materials are located around the periphery of the laboratory, on the side benches, under microscopes or other visualization equipment, in aquaria and terraria, and/or on wall posters and photographs. Written descriptions accompany much of this material.

There is a lot of information that has put out with the demonstrations. So you may need a reminder of what is the information you will be responsible for. You are responsible for knowing the specific information indicated in this lab manual and that your instructors have highlighted with you during the lab through lecture, group discussion, student learning outcomes and any other materials they indicate is important**.** Note that the demonstration materials feature examples of common species, and information about the animals' characteristics and interesting features. You should view these as selected specimens that will permit you to examine more closely some of the characteristic features of the animals within each phylum. A disadvantage of this "selected specimen" approach is that it often gives a biased view of a particular group of animals and you should be aware that other representatives of the phylum, class, order, etc. do not necessarily share all the same morphological and functional characteristics observed in our demo specimens. Nevertheless, you are responsible for knowing the information as is described at the beginning of this paragraph.

Kingdom Animalia

This laboratory exercise is the first of a number of exercises that are designed to introduce you to the members of the Kingdom Animalia. In contrast to the Protists, the members of the Kingdom Animalia are much more complex organisms. There is great diversity within the kingdom, as you will come to see; but despite that diversity, all animals have a number of characteristics that they share in common. These include: 1) they are **heterotrophic**; 2) they exhibit sexual reproduction which involves formation of a **diploid zygote** from **haploid** **gametes (i.e., eggs and sperm)**; 3) their early development includes a **blastula** stage Another characteristic animals share in common is the fact that they - or should I say we - are **multicellular** and have more than one type of cell.

A Closer Look at Animal Cells

You will have many more opportunities to explore issues related to cells in Biol 1401. However, for now, we will take a brief look at animal cells with this next activity. As I am sure you have learned prior to this course, every cell has the following components:

- **Plasma membrane** defines the limits of the cell and regulates the internal environment of the cell (see Figure 4-18 in the text).
- **Genetic material**, in the form of DNA, contains information needed for cell maintenance and for cell reproduction.
- **Cytoplasm** uses information in the DNA to perform cell processes.

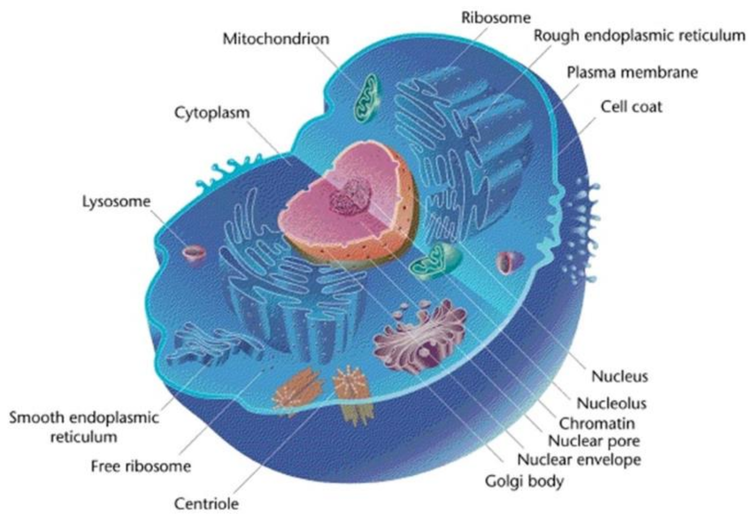

Figure 3.1. An animal cell.

Beyond that, all animal cells have additional structures that are important to their function.

***Q*. Here's a challenge for you! Can you give the name AND function of at least five additional structures that all animals have in common without looking at Figure 3.1?**

ACTIVITY 3-1: In this next section, you will be using a microscope to examine an animal cells. The source of these cells? YOU!

***Q*. Would a compound or dissecting scope be better to use for this? Explain.**

1. Students can work together but each individual should make their own slide.
2. Gather the following materials: a clean (standard) microscope slide, a coverslip, a sterile toothpick, and a bottle of methylene blue stain.
3. Gently scrape the inside of your cheek with the flat side of the toothpick. Smear the toothpick on the center of the slide and add one drop of methylene blue.
4. Next, place the coverslip on the slide.
5. Place your slide on the microscope stage. Remember, always begin on the low power and use the coarse focus knob and fine focus knob to locate the specimen

***Q*. How many of your animal cells do you count on this slide?**.

6. When you find some cheek cells on low power, center these cells and increase to medium power, then to high power.

   ***Q**. What cellular structures can you identify?*

   ***Q**. What cell structure primarily absorbed the methylene blue stain? Vl/hat is the significance/function of this structure?*

7. Calculate the length of one of your cheek cells.

   ***Q**. How many micrometers across is one cheek cell?*

NOTE: As we move forward from this exercise, keep in mind that animals as a group are believed to have evolved from a group of protist cells living colonially. From those relatively small, simple, but certainly functional beginnings, organisms as complex and multi-celled as we are eventually evolved. As we move from one animal group to the next throughout the quarter, we will gain some insight into how the complexity we see in ourselves arose over time in animals.

8. When you have completed this exercise, dispose of this slide in the designated disposal container.

Surface Area to Volume Ratio

All living organisms are composed of cells, and, as you know, cells are small. The plasma membrane regulates everything that enters or leaves a cell (e.g., oxygen, nutrients, waste products, etc). Although a large cell has more plasma membrane than a small cell, the large cells has proportionally less membrane with which to regulate its volume than the small cell.

The relationship between surface area and volume can be demonstrated by comparing the surface areas and volumes of different-sized boxes or blocks. These will represent different sized/shaped animal cells.

ACTIVITY 3-2: Measuring Surface Area to Volume Ratio

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1. Choose a small box and a larger box.
2. With a metric ruler, measure the surface area of each box in centimeters.

> ***Q. What is the formula for calculating surface area?***

> ***Q. Your boxes/blocks have six sides. How should you calculate their surface areas? (Show your math).***

3. Using a metric ruler, calculate the volume of each box in centimeters.

> ***Q. What is the formula for calculating volume?***

Q. How should you calculate the volume of your boxes/blocks? (Show your math).

4. Now, figure out the surface area-to-volume ratios for each of your of your boxes/blocks by expressing the two values you measured in a ratio (surface area : volume).

Q. Which box/block, the smaller or the larger one, had the largest surface area-to-volume ratio?

Q. What do your findings suggest to you with respect to cell size? Why are cells so small?

Just like with their cells, the shape and size of the overall animal – i.e., whether they are large or small, flat or not, etc. - can affect a variety factors. One area where this is true is with the exchange of materials between the environment and the organism. For example, with gas exchange, animals breathe oxygen in and breathe carbon dioxide out.

Q. What is the oxygen that is taken into the body used for?

Q. Where does the carbon dioxide that is released from the body come from? In other words, why is it building up inside the body such that it needs to be releaseed?

A small organism like a brine shrimp, has a relatively large surface area: volume ratio. As a consequence, it can take in all of the oxygen it needs by diffusion across the surface of its body. However, a large organism, like an elephant, a squid, or even a crab, has a much smaller surface area: volume ratio. So, although it could theoretically use diffusion to perform gas exchange with the environment and deliver the oxygen (and carbon dioxide) to where it needs to go, it would not be able to do so very effectively or efficiently. Consequently, while a small animal may be able to “get away” with not having certain organ systems like a respiratory system or a circulatory system, a larger animal needs respiratory organs such as lungs for taking in oxygen.

Another area where the size and shape of an animal can influence biological function is with respect to regulation of water stores. Water is harder to retain in smaller organisms as compared to larger organisms. Larger organisms have a lower surface area to volume ratio or, in other words, larger animals have more of a core – more pathways and longer distances over which the water needs to travel – such that it is more difficult for it to escape the body. Conversely, smaller organisms have a larger surface area to volume ratio and less of a core. The organs and other structures in the middle of these smaller bodies are still relatively close to the surface and, thus, there is more opportunity for water to escape.

Q. ***Considering the information above, compare two animals with similar body shapes but different sizes—for example, a house mouse and a raccoon. Which animal would you expect to hhave an easier time maintaining body heat on a cold day? Why?***

Q. ***Which would cool down faster in the shade on a cool day? Why?***

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Animal Characteristics

There is an enormous diversity among the animals, much more than we will be able to discuss during this course. However, in these laboratories we will present some of the more important animal groups, their distinguishing characteristics, and give you the opportunity to examine live and prepared specimens of representatives of these animals.

- Anatomical/Physiological:
  e.g., Unicellular vs. Multicellular?
  e.g., Level of Organization? (Cell vs. Tissue vs. Organ)
  e.g., Type of Skeleton (endoskeleton vs. exoskeleton vs. hydrostatic)?
  e.g., Separate sexes vs.Hermaphroditic?
  e.g., Sexual Dimorphism?

- Developmental:
  e.g., Protostome vs. Deuterostome?
  e.g., Larval stages, Metamorphosis?
  e.g., Incomplete Metamorphosis vs. Complete Metamorphosis?
  e.g., With parasites: Simple vs. Complex Life Cycle?

- Ecological/Behavioral:
  e.g., Habitats?
  e.g., Diet, Feeding Behavior?
  e.g., Sexual or Asexual Reproduction?
  e.g., In hermaphrodites: Self-fertilization, Cross-fertilization or Both?

As we consider these animal groups and their features, similarities and differences, think about questions that go beyond just what the characteristics that unite or divide animals groups are. Ask questions like:

- How certain characteristics that exist in a particular animal group relate to how they live?
- Do you see any similarities between animals that are not considered to be all that closely related but that live in a a particular environment?
- Why are certain animals in the same phylum but different classes?

CHAPTER 4

THE SPONGES (Phylum Porifera)

Objectives

Students should be able to:

- identify the level of organization seen in these animals (cellular level)
- identify the cells that are unique to sponges and describe the function of these cells (choanocytes)
- describe and/or diagram the movement of water through a sponge including the names of the regions the water moves through (incurrent pores or ostia, choanocytes, spongocoel and osculum)
- identify spicules from an example on a slide, describe their function and know what materials they can be made of (silica, calcium carbonate)
- identify the skeletal material of a commercial bath sponge (spongin)

Phylum Porifera

Members of the Porifera are commonly called the sponges, a unique group of animals that are among the simplest animals in the animal kingdom. The sponges have only a **cellular level of body organization**; they do not have well-defined tissues, organs, or organ-systems. Some biologists have suggested that sponges represent a "population of cells" all interacting with each other in an unorganized fashion, as opposed to representing a discrete organization of cells and tissues as is the case in most animals.

Adult sponges are all **sessile** and are attached to solid substrates in their marine or freshwater habitats. Many species of sponges have characteristic shapes and symmetry, but others exist as amorphous masses of cells that grow slowly on the substrates. Sponge species are either solitary or colonial and may grow to extremely large sizes, particularly the deep water marine species.

The name Porifera means "pore-bearing" and this is one of the chief characteristics of the sponges. The body wall of these animals is characterized by numerous pores and canals which permit water from the surrounding environment to enter the sponge and circulate throughout the sponge body. The water in the sponge is moved by the activity of specialized cells called **choanocytes** (= or collar cells) that have an elongate **flagellum** extending from the top end of the cell. In addition, the apical end has a “collar” consisting of microvilli (= small, fingerlike projections) that aid in the capture of food material and sperm during the reproductive season (Figure 4.1). In many sponges the **choanocyte**-lined canals lead to an internal cavity called the **spongocoel**, which in turn opens to the outside through an opening called the

osculum. In the most complex sponges, the choanocytes are found in specialized flagellated chambers that have canals leading into and out of them, and eventually to the outside.

Even with their relatively simple body form sponges still require some sort of skeletal material to support the cells and give some functional shape to the body. This **endoskeleton** (= internal skeleton) is often composed of **spicules** (Fig. 4.2), which are stiff organic fibers made of either calcium carbonate or silica (= silicon dioxide), a major component of sand and many rocks, and occur in a wide variety of sizes and shapes. In some sponges, the endoskeleton is made of **spongin**, a more flexible material that is similar to human hair. These structural characteristics are of great importance to scientists studying sponges as an aid in the identification of individual species. The vast majority of sponge species possess silicon dioxide spicules and the largest group has a skeleton that is a combination of these spicules and spongin. Before the development of synthetic sponges it was possible to find "bath sponges" in markets that were actually the spongin skeletons of marine sponges!

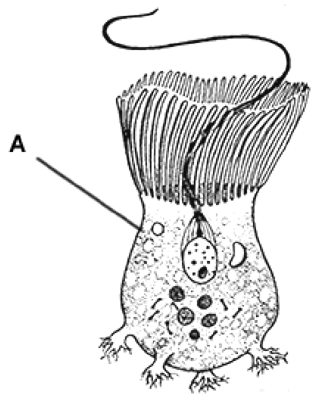

Figure 4.1 A sponge choancoyte.

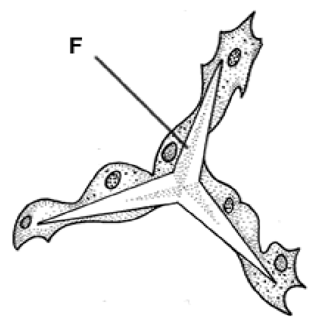

Figure 4.2 A sponge spicule.

Q. Why do you think that sponges that had spongin rather than silicon dioxide or carbon calcium spicules were sold as household bath sponges?

ACTIVITY 4-1:

1. Examine demonstration slide of the spicules (on the side bench).

Q. How do you think spicules work as a skeleton for those sponges that possess them?

Representatives of all three groups of sponges are available for you to examine in lab:

Calcareous Sponges

These are the simplest group of sponges. They have calcium carbonate spicules, well-defined body shape and radial symmetry. The representative specimen of this class is the genus *Scypha*, a small vase-shaped sponge (Fig. 4.3). These sponges reproduce asexually by **budding**. Budding is the process where cells of the parent sponge differentiate and grow outward from their body as a little bud-like structure. As these buds grow, they may break off. If this occurs, the broken-off piece can become a new individual. These buds often originate from the base of the *Scypha* parent. In the event that the buds do not separate from one another, the result is a cluster of individuals.

Figure 4.3 *Scypha* sp.

Developing larvae are in the form of large masses of cells scattered throughout the sponge body. After early development in the body of the adult they are released into the surrounding sea water for a short, free-swimming period before they settle on substrate. Then, if all goes well, they develop into an adult sponge.

ACTIVITY 4-2:

1. Examine the specimen(s) of calcareous sponges on the display benches.
2. While examining these specimens, review the characteristics that make these all poriferans (members of the Phylum Porifera).

Q. What is the one major characteristic that we discussed that separates these calcareous sponges from the siliceous and spongin-based sponges?

ACTIVITY 4-3:

1. Examine the slide(s) of calcareous sponge *Scypha* available in the slide box on your student desk.:

Crossection (Fig. 4.4)

Scypha uses the flagella on its **choanocytes** to draw water through its body so it can capture small suspended particles of food. The water is drawn in through the **incurrent canals**, passes through the radial canals, and finally out through the **spongocoel**.

The **spongocoel** is an empty space in the middle of the body. It is not comparable to the coelom of other animals, because there are no organs in it; it's just an empty tube through which water is expelled.

Longitudinal Section (Fig. 4.5)

At higher magnification, you will be able to make out several types of cells. The **choanocytes**, or collar cells, perform the essential functions of pumping water by action of the flagellum, and capturing food particles with their collar of microvilli. The **incurrent canals** and **radial canals** are lined with **choanocytes**.

Amoebocytes are mobile cells with an amoeboid (= or irregular) shape. They perform various functions including taking up food, creating spicules and formation of gametes. They can also differentiate to become other cell types. The **amoebocytes** are surrounded by a layer of extracellular matrix material called **mesohyl**.

Pinacocytes are flattened cells that form the outer layer of the sponge. **Porocytes** are cells that allow water into the cell. These cells are located all over the sponge body.

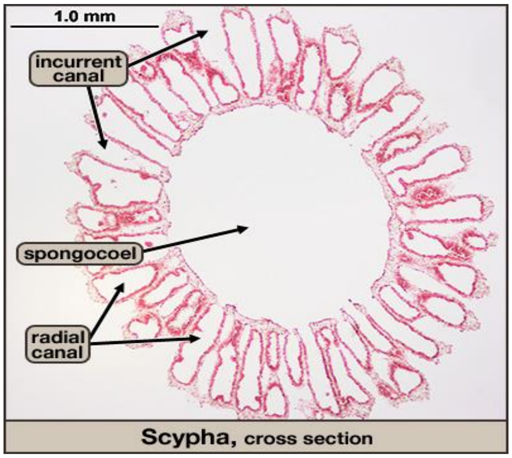

Figure 4.4. Cross section of a *Scypha* sponge.

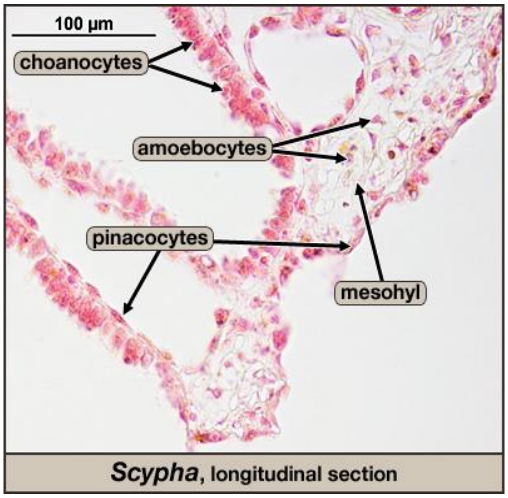

Figure 4.5. Longitudinal section of a *Scypha* sponge.

You can use Figure 4.6 below to help you visualize the external and internal structure and water flow through this type of this type of sponge.

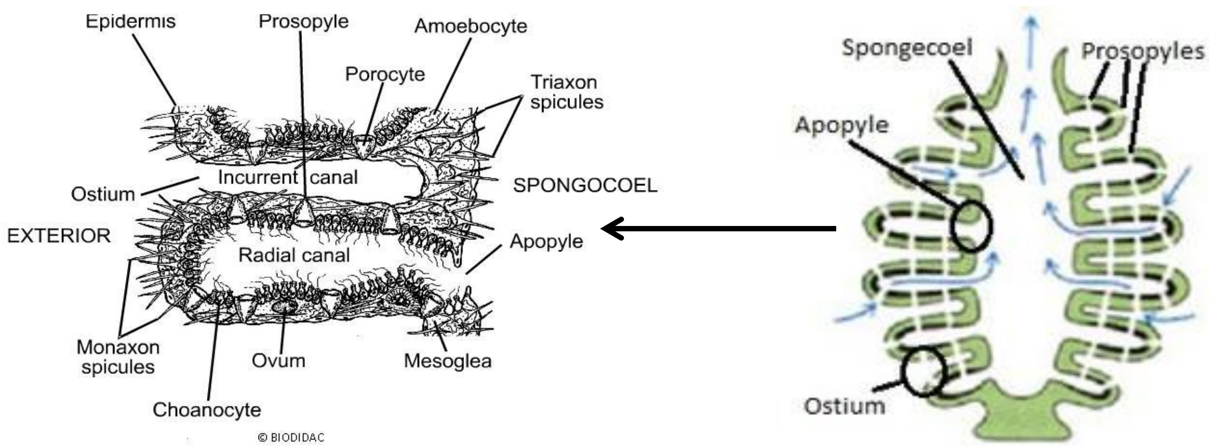

Figure 4.6. Cutaway view of the body wall of the sponge *Scypha*. The flow of water from the surrounding environment into the spongocoel of the sponge is illustrated.

Glass Sponges

The glass sponges (see Fig. 4.7) are characterized by spicules made of silica (= silicon dioxide; see Fig. 4.8) consisting of six rays intersecting at right angles, like a toy jack. Glass sponges are widely viewed as an early branch within the Porifera because there are major differences between extant hexactinellids and other sponges.

A great example of a glass sponge is the genus *Euplectella*, the Venus Flower Basket. The Venus Flower Basket is a type of sponge found in deep ocean waters in the western Pacific Ocean. Note the intricate arrangement of the silicon dioxide spicules.

Figure 4.7. General view of a vase-shaped glass sponge.

ACTIVITY 4-4:

1. Examine the dried specimen(s) of the siliceous sponges on the display benches.
2. While examining these specimens, review the characteristics that make these all poriferans (members of the Phylum Porifera).

Q. What is the one major characteristic that we discussed that separates these siliceous sponges from the calcareous and spongin-based sponges?

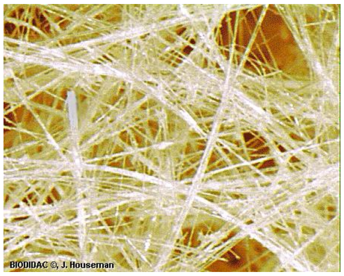

Figure 4.8. Detailed view of the large spicules of a glass sponge.

Commercial and Freshwater Sponges

The largest group of sponges is the Demospongiae, whose skeleton is composed of **spongin** and silicon dioxide **spicules**. There are a variety of members of this sponge group on display along the back bench. Some of these sponges were collected right from the San Francisco Bay. For example, the (formerly) bright orange-red sponges are of the genus *Microciona* and are commonly found on docks, wharf pilings, and other solid substrates around the Bay (Fig. 4.9).

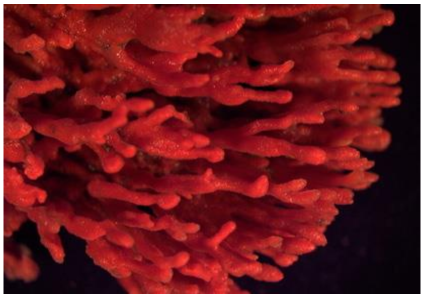

Figure 4.9. *Microciona*, an example of Demospongiae.

Microciona has been commonly used by the developmental biologist as it is possible to separate the sponge into its individual cells, and with proper conditions, to have the cells reaggregate to form a new sponge. Much information about cell-cell interaction and recognition has been gained through experimental work with these sponges.

ACTIVITY 4.5:

1. Examine the specimen(s) of commercial and freshwater sponges on the display benches.
2. While examining these specimens, review the characteristics that make these all poriferans (members of the Phylum Porifera).

CHAPTER 5

JELLIES AND THEIR RELATIVES (Phylum Cnidaria)

Objectives

Students should be able to:

Phylum Cnidaria

- identify the level of organization seen in these animals (tissue level)
- identify the structures that are unique to cnidarians and describe the function of these structures (nematocysts or cnidocytes)
- describe and identify the two body forms of cnidarians (polyp and medusa)
- identify cnidarians as having radial symmetry
- identify cnidarians as having the simplest form of nerve transmission (a nerve net)
- identify the gastrovascular cavity of a cnidarian and describe the function of this body region (cont'd next page)
- Four Classes:
    - **Class Hydrozoa**
        - identify members of this class (look for *Hydra*, *Obelia* and Portuguese man-of-war)
        - identify the features that place members in this class
    - **Class Scyphozoa**
        - identify members of this class (i.e., true jellyfish, look for *Aurelia*)
        - identify the features that place members in this class
    - **Class Anthozoa**
        - identify members of this class (look for sea anemones and corals)
        - Identify the features that place members in this class
        - describe how corals form coral reefs
    - **Class Cubozoa**
        - identify members of this class
        - Identify the features that place members in this class

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Phylum Cnidaria

This phylum of animals is well known because of animals such as jellyfish, sea anemones, the Portuguese man o' war, and corals. This group is characterized by a number of morphological and functional features that have made the cnidarians a group of relatively sophisticated organisms with interesting and surprising adaptations to the marine and freshwater habitats in which they are found.

The morphological characteristics which appear in this phylum are a foundation on which the higher invertebrate animals are built. Perhaps most significant is the

tissue level of body organization. Cnidarians are composed of a number of different cell types and many of these operate together to form tissues. The outer layer of cells in the adult cnidarian is known as the **epidermis** and is derived from an embryological tissue known as the **ectoderm**. The **epidermis** includes **epithelio-muscular cells**, **sensory cells, nerve cells, cnidocytes,** and **gland cells**. The epidermis is separated from the inner layer of cells by a variously thickened layer of secreted intercellular material, the **mesoglea**. These secretions arise from the **ectoderm** or the **endoderm**. The endoderm comprises the inner embryological tissue that gives rise to the adult inner tissue known as the **gastrodermis.** The gastrodermis is primarily for digestion, although it also contains muscle cells, nerve cells, gland cells, cnidocytes, and reproductive cells. The Cnidaria, with these two basic embryological and adult tissue layers, are often referred to as **diploblastic** animals. This is in comparison to other animals which have three embryonic tissue layers (the third is **mesoderm**) and are referred to as **tripoblastic**.

All the members of the phylum Cnidaria have **radial symmetry**. With this kind of symmetry, the body is organized around a central axis where any imaginary plane passing through the center of the animal divides the body into mirror images. Particularly advanced species of sea anemones have **biradial symmetry**, a variation of radial symmetry.

This is the first group in the animal kingdom to have a well-defined nervous system, the **nerve net**. The nerve net is a complex network of neurons extending over and through the tissues. Another feature shared by many species is the presence of two body forms, the **medusa** and the **polyp**, during the life cycle of the animal. A significant number of cnidarians, however, have only one body form (e.g., sea anemones and other anthozoans).

Perhaps the most distinguishing characteristic, and the one from which the phylum name is derived, is the presence of **cnidocytes**. Cnidocytes are specialized cells that produce **nematocyst** capsules and filaments (see Fig. 5.1).

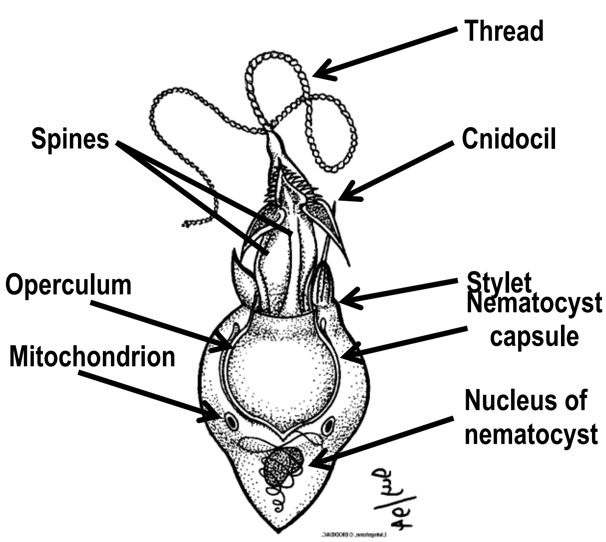


Figure 5.1. Discharged cnidocyte showing the discharged stinging tube.

These intracellular elements are used as "stinging capsules*' which can aid the cnidarian in securing food. These stinging capsules shoot out from the cell and, after coming into contact with a prey item, can inject a toxin into it. The nematocysts may also aid the cnidarian in defending itself from possible harm.

These animals also have an extensive internal cavity, the **gastrovascular cavity**, which is used primarily for digestion of food. The **gastrovascular cavity** is often filled with body fluids and, consequently, serves as a **hydrostatic skeleton** to provide internal support for the tissues. The mouth opening into the gastrovascular cavity is surrounded by cnidocyte-covered tentacles that are used for food capture.

The Cnidaria consists of four classes: Class Hydrozoa, Class Scyphozoa, Class Anthozoa, and Class Cubozoa. We have information and/or specimens representing all four groups in the lab.

Class Hydrozoa

The Hydrozoa are generally regarded as the least highly derived (= most primitive) of the Cnidaria. The majority of species have an **alternation of generations** between the polyp and medusa stage. The best local example of this is *Obelia*, a **hydroid** common to the docks of San Francisco Bay (Fig. 5.2). The polyp stage of *Obelia* consists of feeding and reproductive polyps, the latter producing the medusa stage by asexual budding of the small jellies from specialized tissues. The medusae continue to mature while swimming about in the sea water, eventually producing gametes that are spawned into the water where fertilization takes place. Subsequently the fertilized egg (= **zygote)** develops into a **planula larva** that settles on the substrate and develops into a new polyp generation.

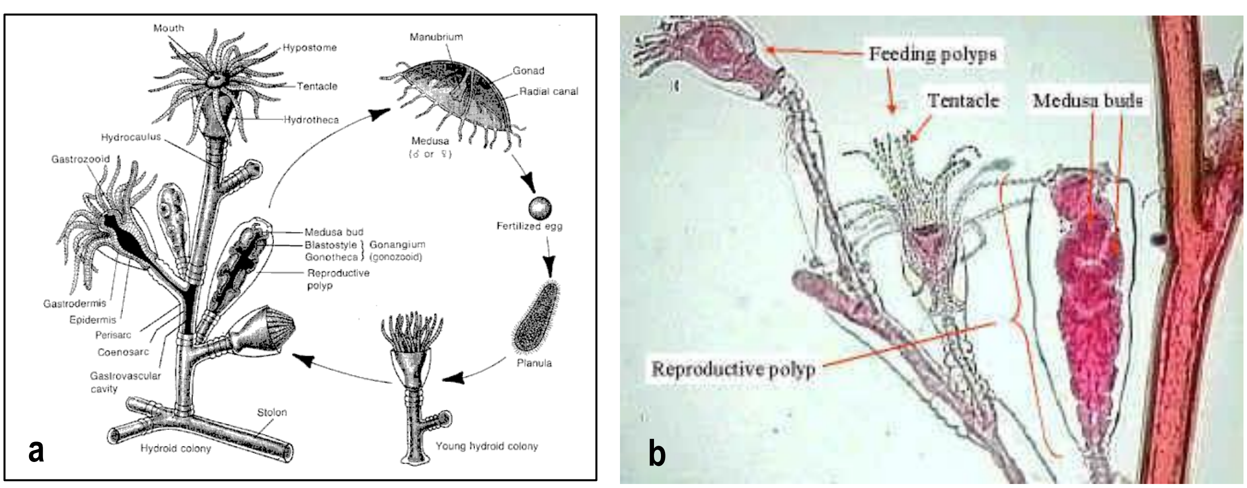


Figure 5.2. a) Life cycle and b) key structures of *Obelia.* The life cycle of this cnidarian includes a polyp stage, a medusa stage and a planula larva stage. This colonial polyp produces male and female medusa by means of sexual reproduction. These medusae, in turn, produce gametes (i.e., sperm and eggs), which fuse to form a zygote. The zygote develops into a planula larva which matures to form a new generation of colonial polyps.

ACTIVITY 5-1:

1. Examine the specimens of the various hydrozoans available on the back bench and in the slide box at your desk. Available specimens include:
   - *Obelia*: Use the slide (and preserved specimens if available) to examine:
     - the polyp stage, noting the feeding and reproductive polyps.
     - the small medusa stage
   - *Hydra:* Check out the bud!
   - *Physalia* (the Portuguese Man-of-War): an unusual type of colonial and polymorphic hydrozoan; has a float full with air that aids in navigation.

The classic example of this phylum and class of animals is the freshwater genus *Hydra* (Figure 5.3), which is often used in biology laboratories. It is a very useful teaching and experimental animal, but it is a somewhat unusual hydrozoan. This cnidarian does not have a medusa stage in its life cycle and it is able to reproduce both asexually and sexually!

ACTIVITY 5-2:

1. Examine the slide of the *Hydra* exhibiting asexual reproduction. This specimen is budding.

2. Observe the live *Hydra* on the back/side benches. If available, pipette a few live zooplankton (*Daphnia*) into the dish and observe the feeding behavior of *Hydra*. Be sure to look for the movement of the tentacles, firing of nematocysts, and ingestion of the food into the gastrovascular cavity. Make a few sketches of what you see in the notes section of your lab manual to document the method of feeding in this cnidarian.

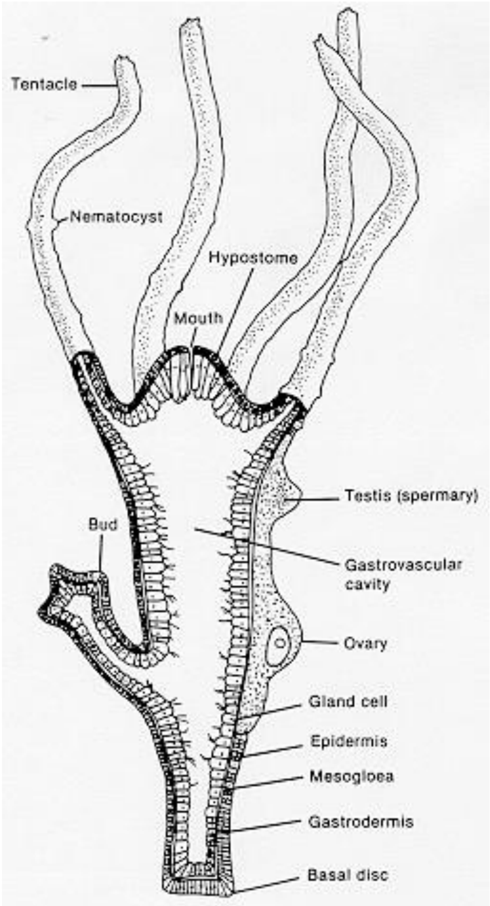


Figure 5.3. The key morphological features of the genus *Hydra*.

Class Scyphozoa

The Class Scyphozoa consists of the "true" jellies. These animals are typically much larger than hydrozoans and are primarily found in the medusa stage. Scyphozoans typically exhibit a polyp stage that is generally very small and used almost exclusively for asexual reproduction (i.e., budding) of the medusa stage. Some of the adult jellies in this class reach as much as three meters (= 9ft 10in) in diameter. We do not have any specimens that large in the Bay Area, however!

ACTIVITY 6-3:

1. Examine the preserved specimens of the wide ranging genus *Aurelia*. Look for the basic features of the class (Figure 6.4).

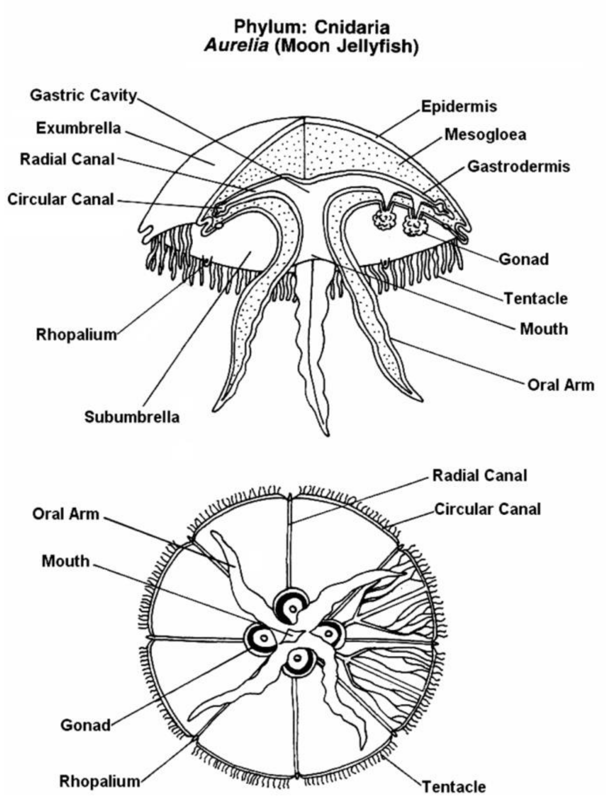


Figure 5.4. A labeled diagram of *Aurelia*, the Moon Jelly. Moon jellies likely got their name from their whitish disc-like bodies and their habit of nocturnal swimming near the surface of the sea.

Class Anthozoa

The Class *Anthozoa* is represented in California waters primarily by numerous species of sea anemones that live attached to solid substrates in the rocky intertidal on dock pilings, and even on the mudflats of the San Francisco Bay. The genus *Metridium* is particularly abundant around docks, while the genus

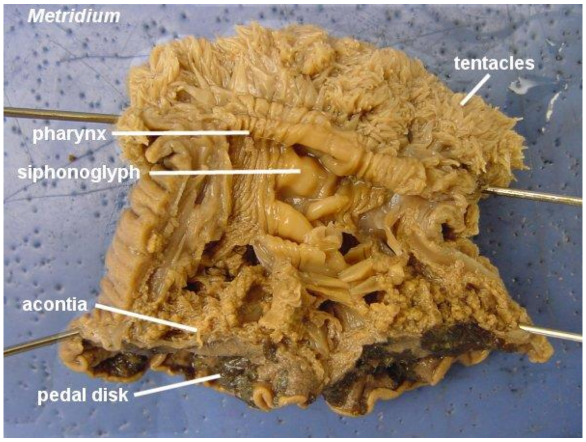
Anthopleura occupies broad expanses of rock in the upper tidal zones along the open coast. Hard and soft corals, sea pens, sea fans, and sea pansies are also species of the class *Anthozoa* and are found in marine habitats around the world. Members of this class are considered to be the most advanced of the *Cnidaria* and this is reflected in their morphology and behavior.

ACTIVITY 5-4: Examine the *Metridium* specimen and see if you can identify:

1. any of the basic cnidarian features
2. any class-level features

Refer to Figure 5.5 below to help you during this exercise.

Like other anthozoans, *Metridium* exhibits increased complexity of the gastrovascular cavity, relative to members of other cnidarian classes. This design allows for more efficient digestion of food and distribution to the cells of the body.



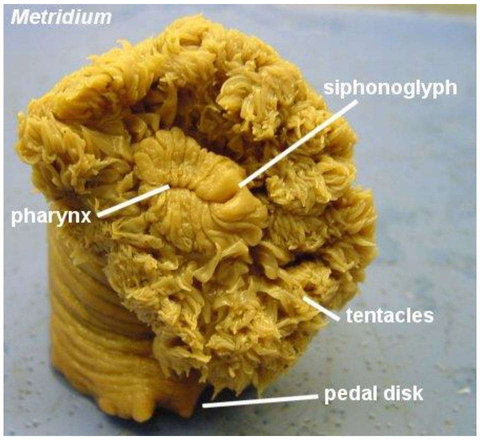


Figure 6.5. Labeled, preserved specimen of the internal and external anatomy of *Metridium*.

ACTIVITY 5-5: Examine the various coral exoskeletons.

<u>Note</u>*: Although coral reefs do not occur in our part of the world (there is a single species of solitary coral along the central California coast) we have preserved skeletal masses of these solitary and colonial animals. Take note of the very large numbers of individual polyps that comprise a single colonial animal.*

ACTIVITY 6-6: View the video of live *Nematostella*, a native burrowing sea anemone, feeding. These are animals are great for observing the feeding methods of the cnidarians. While watching the video, note how the sea anemones' tentacles grasp the food and deliver it to their mouth.

Class Cubozoa

Once lumped in with the schyphozoans, box jellies (Fig. 5.6) are now placed in their own class. They look very similar to a typical scyphozoan jelly, but they tend to swim much faster than the average jelly. They are also good at maneuvering around objects in their environment and appear to have fairly well-developed eyesight.

Scyphozoans and cubozoans are easy to tell apart in that cubozoans appear to have a square shape when viewed from above (hence, their name!). They also have four evenly spaced tentacles or, alternatively, bunches of tentacles.

Currently, 20 species of box jellies are known to science. They tend to be found in tropical and semitropical waters. One box jelly found in Australia, *Chironex fleckeri*, is considered to be one of the most deadliest creatures in the world and have even been associated with some human fatalities.

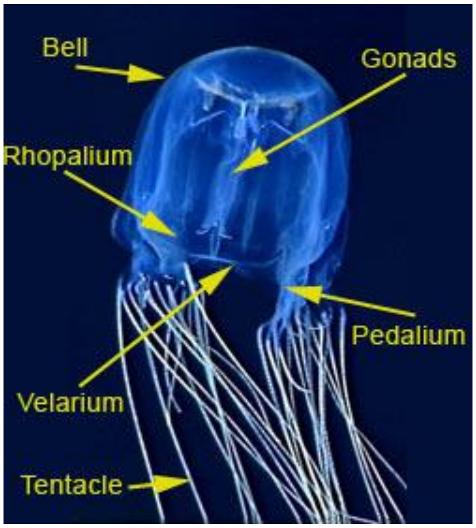


Figure 5.6. A box jelly

FOR MORE INFORMATION…

- **Jellieszone -** http://jellieszone.com/aboutjellies.htm.
 You will find lots of cool photos and great information about jellies and other gelatinous marine organisms!

- **The Jellies Experience** - http://www.montereybayaquarium.org/efc/jellies.aspx
 Check out this wondrous exhibit at the Monterey Bay Aquarium (http://www.montereybayaquarium.org/) featuring different types of jellies and other related species!

- **Introduction to Cnidaria** - http://www.ucmp.berkeley.edu/cnidaria/cnidaria.html
 Find out more about cnidarians on this informational page on the U.C. Berkeley Museum of Paleontology website!

CHAPTER 6

THE FLATWORMS (Phylum Platyhelminthes)

Objectives

You should be able to:

- identify:
  - the <u>level of organization</u> seen in these animals
  - the type of symmetry seen in these animals
  - the number/type of <u>embryonic tissue layers</u> found in these animals
  - the <u>type of skeleton</u> found in these animals
  - whether a <u>coelom is present</u> and, if so, in what form
  - which organ systems are present
- describe the significance of the <u>cuticle</u> in these animals
- indicate if nervous, respiratory, circulatory (open/closed?), osmoregulatory/excretory, or digestive systems (incomplete/complete?) are present and, if so, in what form
- describe the movement in these animals
  - significance of having longitudinal muscles but not circular muscles
- indicate whether these animals are <u>monoecious</u> or <u>dioecious</u>
- describe the types of habitats in which these animals can be found
- describe the kind of lifestyle these animals live
- recognize this phylum and the following classes

  - **Class Turbellaria = planaria**
    - characteristics
    - lifestyles
    - <u>location and function of external anatomical characters</u>: pharynx, auricles, eyespots

  - **Classes Trematoda and Monogenea = flukes and monogeneans**
    - characteristics
    - lifestyles
    - <u>location and function of external anatomical characters</u>: mouth, oral sucker, ventral sucker

  - **Class Cestoda = tapeworms**
    - characteristics
    - lifestyles
    - <u>location and function of external anatomical characters</u>: scolex (with hooks and suckers, but NO MOUTH), neck, proglottids (immature and mature)

PHYLUM PLATYHELMINTHES

The members of this phylum, the "flatworms", represent a considerable evolutionary advance over the poriferans and cnidarians. The flatworms include such common animals as the freshwater planaria, and the more evolved parasitic animals known as the flukes and tapeworms. Their advancements over the poriferans and cnidarians include:

1. They have an **organ-system level of development and body organization** with complex tissues and organs.
2. The animals are organized along an anterior-posterior axis resulting in **bilateral symmetry** and locomotory movements directed forward into the environment.
    a. A reflection of the latter characteristic is seen in **cephalization**, the concentration of nervous and sensory structures at the anterior end of the worms.
3. These animals are **tripoblastic**. The presence of a well-developed **mesoderm** that fills the interior and develops into a number of tissues in adults.
4. They have developed the first **excretory** and **osmoregulatory system** in the animal kingdom that is composed of **flame cells** and a series of ducts.
5. In addition to the characteristics above, it should be noted that these worms lack an internal body cavity (unlike what we will see in the other worm phyla). Flatworms are **acoelomate** animals, with their bodies packed tight with cells and tissues. There is no internal body cavity to provide space in which organs can be suspended, thus allowing them the potential to move independently from the rest of the body. There is no fluid-filled internal body cavity to provide shock absorption to the internal structures in the instance that the animal is impacted on the outside.

The Platyhelminthes consist of three classes of worms and representatives:

Class Turbellaria

Class **Turbellaria** is a complex group of mostly free-living flatworms found in marine, freshwater and terrestrial habitats. The best and most readily available example of a turbellarian is the common freshwater form known as *Dugesia*, the **"planarian"** (Fig. 6.1). They can be found living in ponds and streams on the underside of vegetation and debris.

ACTIVITY 6-1: Study the prepared whole mount and cross section slides of the planaria available in the slide box at your desk.

Q. Which microscope should you use for this activity? Explain.

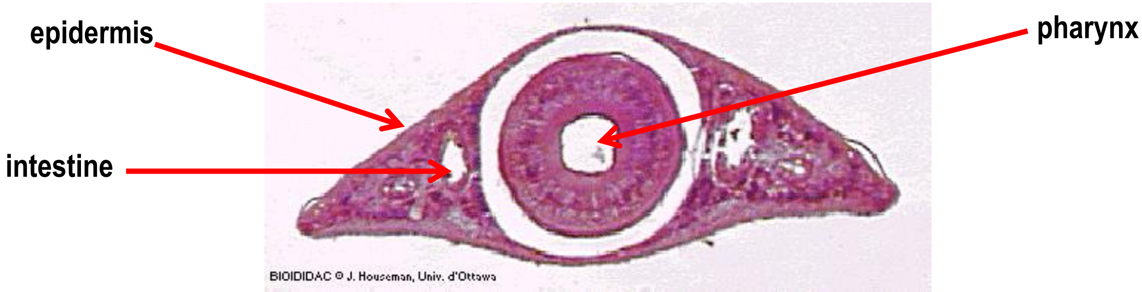


Figure 6.1. Crossection of a planarian in the region of the pharynx.

1) Take a look at the slides of the whole mount of the planarian and the injected digestive system in the slide box on your student bench:
   a) Determine the anterior and posterior lobes of the intestine; they have numerous **diverticula** (= side branches).

Q. What is the significance of the extensive branching in the digestive system of the planarian?

a) Identify the following structures, using **Fig. 6.2** to help you.

- **eyespots**
- **Intestine**
- **nerve cord**
- **pharynx**
- **ciliated epidermis**
- **gonad**

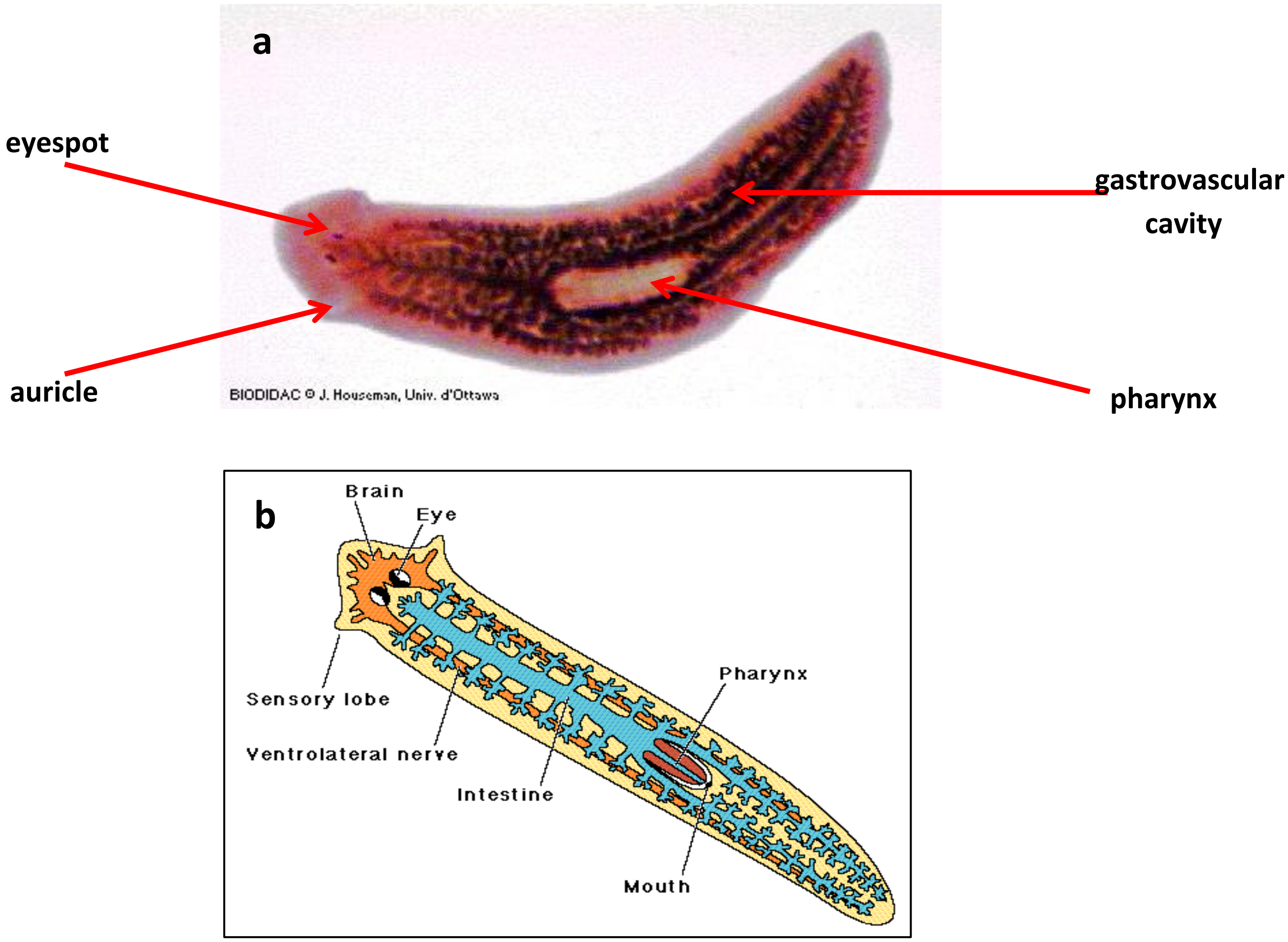


Figure 6.2. Photograph of the ventral side (a) and a drawing of a dorsal view (b) of a planarian.

ACTIVITY 6-2: Live specimens and prepared slides of planaria are available in the laboratory.

1. Observe the live planarian in the small bowl of freshwater at your desk. Use a microscope to get a better view of the animal.

   Q. What kind of microscope should you use for this? Explain

   a) As you observe the planarian, identify the following structures:
      - **auricles**
      - **eyespots**
      - **mouth opening**
      - **pharynx**

***<u>Q.</u>* How does the planarian move? What structures/mechanisms help the planarian to move?** *(Hint.You may want to use your lab manual and any other resources you have access to answer this question).*

***<u>Q</u>.* Do you think planaria are photonegative or photopositive? Why?**

2. If your instructor give you the “go ahead”, use a light source and other materials with which you are provided to design a quick experiment to test the **<u>hypothesis</u>** you described above and determine if your planarian is **<u>photonegative</u>** or **<u>photopositive</u>**.

   ***<u>Q.</u>* After you finish carrying out your experiment, describe your experiment, results and conclusion.**

3. If your instructor gives you the “go ahead”, provide the planarian with a bit of food and see if you can observe the planarian as it is feeding.

   Q. ***Describe what you observed while the planarian was feeding.***

4. Read through any additional materials on the turbellarians, making sure to take note of any important factors that help highlight important phylum and class characteristics.

Classes Trematoda and Monogenea

The flukes are members of the Classes Trematoda and Monogenea and all species are either external or internal parasites of other animals at some stage in their life cycle. The basic morphology of these animals is similar to that of the turbellarians, but the flukes have evolved suckers and hooks to aid them in attaching to their hosts. They also possess a **cuticle**, which is a complex and protective covering on their external surface.

A number of species of flukes are very serious parasites of humans, causing enormous medical and economic problems throughout the world. The Chinese liver fluke (*Clonorchis sinensis*) provides one example (Fig. 6.3). This flatworm is a parasite found in the Far East; humans become infected with it by eating poorly cooked or raw fish.

Clonorchis has two suckers, an **oral sucker** surrounding the mouth and a **ventral sucker,** that they use to attach to their host. The digestive tract begins with the **mouth** and leads into a muscular **pharynx**, a short **esophagus**, and two **intestinal ceca** (pouches). Nitrogenous wastes are released via the posterior **excretory pore**.

ACTIVITY 6-3: Examine the prepared whole mount slide of *Clonorchis sinensis*. Identify the structures below. Use **Figure 6.3** to help you.

Digestive Structures

- **mouth**
- **oral and midventral suckers**
- **pharynx**
- **esophagus**
- **intestine**

Male Reproductive Structures

- **pair of posterior testes**
- **seminal vesicles**

Female Reproductive Structures

- **ovary**
- **uterus with eggs**
- **yolk glands**
- **seminal receptacles**

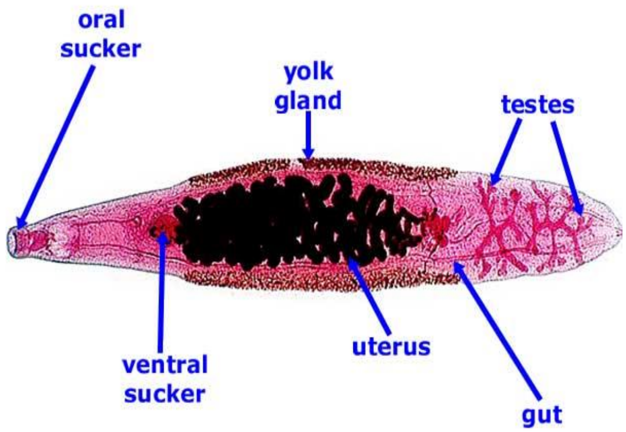


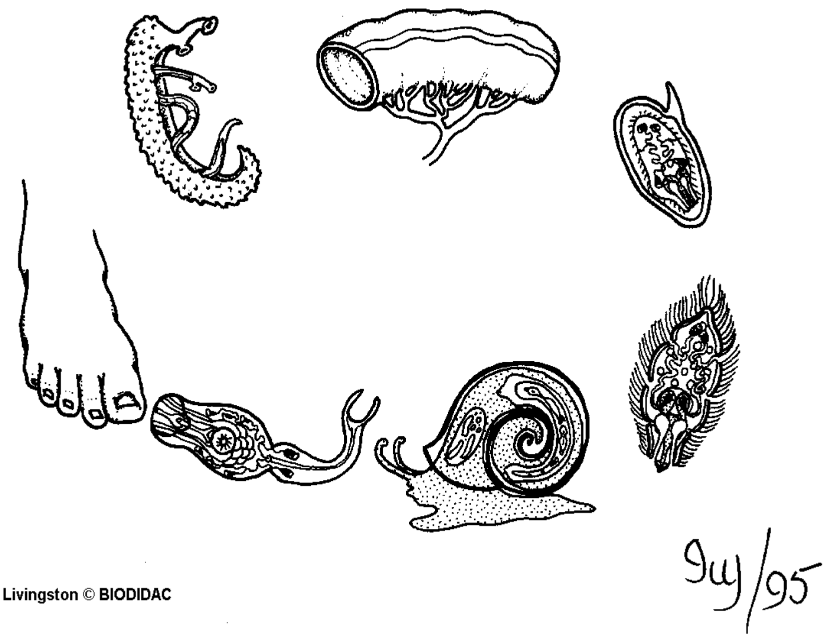
Figure 6.3. Whole mount of *Clonorchis sinensis*, the Chinese liver fluke.

Clonorchis sinensis is **monoecious**, meaning that it has both male and female reproductive structures. Cross-fertilization occurs between individuals and, at the time of copulation, sperm is transferred from the testes to the genital pore. Copulating individuals exchange sperm via their **genital pores**, and the sperm from the other individual is temporarily stored in its **seminal receptacles**. The **yolk glands** provide yolk for nourishment of the developing eggs. Eggs appear as black dots in the **uterus**, in which they mature.

This flatworm has a **complex life cycle** involving a number of larval stages and often two (e.g., a snail and the golden carp) or more intermediate hosts. After the eggs are fertilized, they are released from the adult into the bile duct of their human host. If the human sheds the eggs in an appropriate environment (moist or aquatic), they may be consumed by snails. The eggs hatch and larvae emerge; after several developmental changes, a different larval stage leaves the snail. If consumed next by a golden carp, this larval form will burrow into the muscles of the fish and encyst there. From there, if humans catch infected fish, and eat them raw or in an undercooked form, the larvae will be transferred to the human host. They make their way up the person's bile duct and into their liver where the larvae metamorphose into the adult form; and the cycle begins again.

Two other flukes of interest to humans are the genera *Schistosoma*, an adult human blood fluke, and *Fasciola hepatica*, a sheep liver fluke. Both are on demonstration with adjacent text explaining something of the nature of the parasitic infections.

ACTIVITY 6-4: Visit the demo on *Schistosoma,* the adult human liver fluke. Read through the materials on this flatworm and its life cycle. Label **Figure 6.4** as is appropriate to the life cycle of this parasite.



Livingston © BIODIDAC

Figure 6.4. Life cycle of the trematode *Schistosoma* sp.

2) Visit the demo of the sheep liver fluke, *Fasciola hepatica*. Examine the whole mount of this fluke and read through the corresponding materials regarding its life cycle.
3) Read through any additional materials on the trematodes and monogeneans, making sure to take note of any important factors that help highlight important phylum and class characteristics.

Class Cestoda

Members of the Class Cestoda, the tapeworms, are perhaps the most well-known flatworms. These flatworms are entirely parasitic. The adult stage of these **endoparasites** is generally found in the intestines of vertebrate hosts, and the larval stages are found in a wide variety of invertebrate and vertebrate hosts.

The morphology of tapeworms is highly modified compared to other members of the phylum (see Fig. 6.5). Their body plan basically consists of three major sections:
a) a **scolex**, which is the head, and is covered with hooks and suckers; b) a neck; and c) a series of **proglottids**, which are reproductive units containing both male and female reproductive elements.

Q. What do you think are the purpose of the hooks and suckers on the scolex?

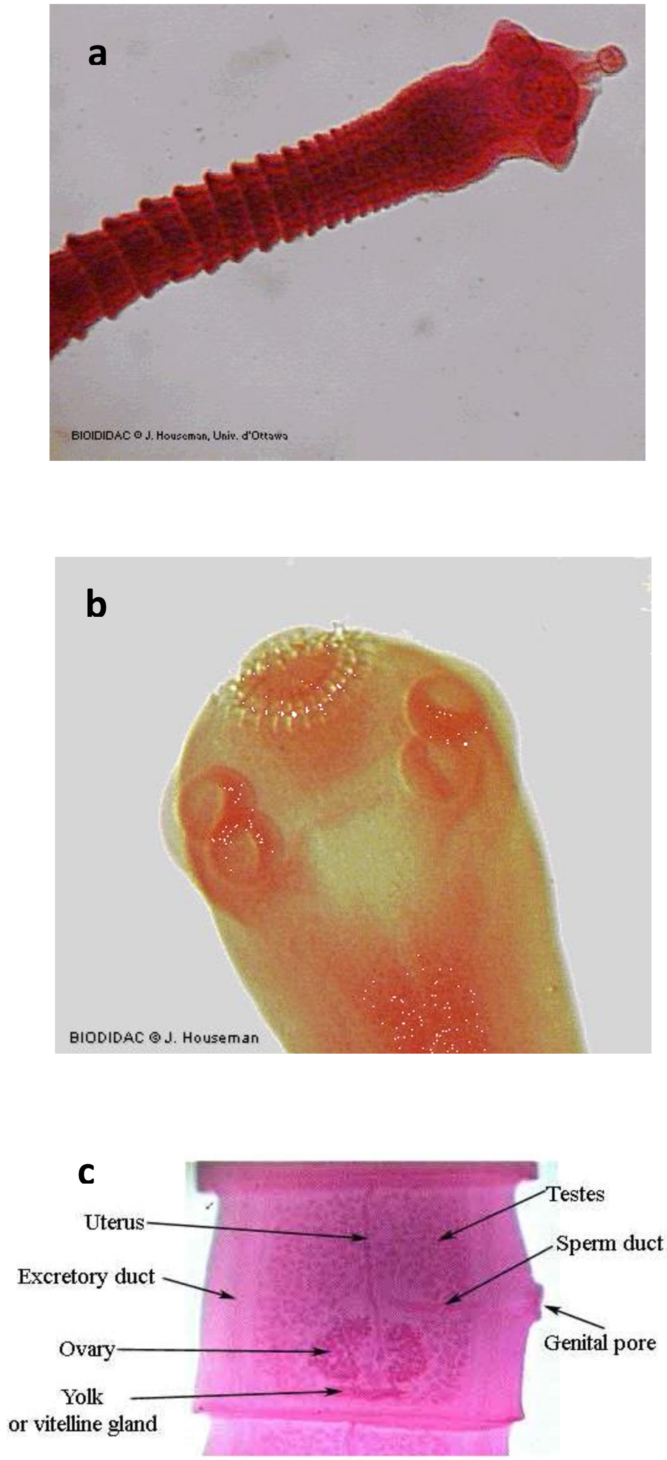


Photo taken by Susan Petro

Figure 6.5. Tapeworm body (a), scolex (b) and mature proglottid (c).

The tapeworms' proglottids are in different stages of maturation, with the newest ones added in at the neck and the most mature ones located closest to the posterior end the worm. The body is covered by a protective **cuticle**.

Tapeworms do not have a formal digestive system which is made possible by their highly **dorsoventrally** flattened body; and they do not ingest their food. Instead, they get their nourishment by absorbing the predigested nutrients of their host!

ACTIVITY 6-5: Become familiar with the general design of the tapeworm body:

1) Using a dissection microscope, examine the slide of the*Taenia pisiformis* **proglottids** in different stages of maturation. This slide is located in the slide box at your table.
2) Visit the collection of preserved tapeworms on demonstration to get a sense of the diversity within Class Cestoda.
3) Take a look at the plastic model of the tapeworm on demonstration and become familiar with the design of the cestode body including the **scolex**, **hooks** and **suckers**, and **proglottids**.
4) Read through any additional materials on the cestodes, making sure to take note of any important factors that help highlight important phylum and class characteristics.

Like the flukes many species of tapeworms are serious parasites of humans and animals, causing enormous medical and economic problems. One example is the genus *Taenia*. Two species belonging to this genus commonly infect humans - the beef and the pork tapeworm. Another common species is found in dogs and cats.

Other examples of tapeworms that can infect humans include members of the genus *Echionococcus*. These are tiny adult worms which have only 3 to 4 proglottids. It is the larval stages, however, which are the serious human parasites, causing the development of large cysts filled with thousands of developing larvae.

Q. How do you think these parasites might be passed to another host?

Another parasite is the tapeworm of the genus *Diphyllobothrium*, one of the largest tapeworms found in humans (contracted after eating infected fish), and potentially reaching lengths of up to 15 meters (~45 feet)!

FOR MORE INFORMATION…

- **University of California Museum of Paleontology – The Platyhelminthes**
  http://www.ucmp.berkeley.edu/platyhelminthes/platyhelminthes.html
  Information on the flatworm phylum can be found here.\
- **Animal Diversity Web – Platyhelminthes** -
  http://animaldiversity.ummz.umich.edu/accounts/Platyhelminthes/
  Information about the Platyhelminth phylum and associated classes can be found here
- **Parasitic Worms (Helminths)** - http://parasitology.com/worms/index.html
  Information on the parasitic worms of this group – the trematodes, flukes and tapeworms – can be found here.

CHAPTER 7

THE SEGMENTED WORMS (Phylum Annelida)

Objectives

You should be able to:

- identify:
    - the <u>level of organization</u> seen in these animals
    - the type of symmetry seen in these animals
    - the number/type of <u>embryonic tissue layers</u> found in these animals
    - the <u>type of skeleton</u> found in these animals
    - whether a <u>coelom is present</u> and, if so, in what form
- describe the significance of <u>segmentation</u> in these animals
    - are these segments "equal" or "unequal" in size, internal/external structures?
- indicate if nervous, respiratory, circulatory (open/closed?), osmoregulatory/excretory, or digestive systems (incomplete/complete) are present and, if so, in what form
- describe the movement in these animals
    - contribution of circular and/or longitudinal muscles to this movement
    - significance of setae/chaetae?
- indicate whether these animals are monoecious or dioecious
    - is cross-fertilization a characteristic?
- describe the types of habitats in which these animals can be found
- describe the kind of lifestyle these animals live
- Recognize this phylum and the name and important characteristics of the following classes:

    - **Class Polychaeta = polychaete worms like *Nereis***
      You should be able to describe these animals':
        - characteristics
        - lifestyle
        - <u>function and location of external anatomical characters</u>: parapodia, palps/tentacles, setae (= chitinous bristles)

    - **Class Oligochaeta = oligochaetes worms like the earthworm**
      You should be able to describe these animals':
        - characteristics
        - lifestyles
        - <u>function and location of external anatomical characters on dissected animal</u>: clitellum, mouth, anus, setae
        - <u>function and location of internal anatomical characters on dissected animal</u>: 5 aortic vessels (pumping hearts), dorsal blood vessel, ventral blood vessel, metanephridia, seminal vesicles, seminal receptacles, pharynx, gizzard, intestine, septa

- **Class Hirudinea = leeches**
  You should be able to describe these animals':
  - characteristics
  - lifestyles:
  - location and function of external anatomical characters: anterior sucker (surrounding mouth), posterior sucker, visible external segmentation (= annulations; distinguishes them from flukes!!)
  - use in medicine

Phylum Annelida

The three classes of worms which comprise this phylum are found in marine, freshwater, and terrestrial habitats, and in occasional symbiotic relationships with other organisms. The most obvious external feature of the annelids is the division of the body into a number of **equal segments** along the length of the worm. The repetition of body parts is not only external but is also seen internally in the repetition of body organs. This repetition is particularly important as it permits the various segments to become specialized for certain functions.

Another important and derived feature of the annelids is the presence of a well-developed **coelom**. This "true" body cavity is lined by mesodermally derived tissue, is filled with fluid, serving as a **hydrostatic skeleton**, and is particularly useful in the complex locomotory movements of the worms.

Other general features shared by these worms is a **complete digestive tract**, a well-developed **closed circulatory system** that pumps blood throughout the body, an **osmoregulatory** and **excretory system** of segmental units called **nephridia**. and a central nervous system comprised of a **dorsal brain** and a **ventral longitudinal nerve cord**.

Depending on the group, these worms may either be monoecious (oligochaetes and hirudineans) or dioecious (polychaetes). Their **reproductive systems** vary in complexity from simple gonads and ducts to complex systems with accessory glands and precise mechanisms for the movement of the gametes to accomplish fertilization.

Phylum Annelida is organized into three classes, all of which are represented in the materials made available in lab.

Class Polychaeta

This group of annelids is the most diversified class. Largely marine, a number of species are important and colorful members of marine animal communities. The body segments each have a pair of lateral appendages known as **parapodia** that are used for locomotion. Additionally, the head is well-developed with **eyes**, **palps**, **tentacles**, and **bristles**.

Our best examples are live and preserved specimens of the clam pile worms, the genus *Nereis*, that are used commonly as fishing bait (and that you worked with during the osmoregulation experiment). The polychaetes are very common in the marine habitats along the central California coast and additional species of polychaetes representing the diversity of the class are on demonstration.

ACTIVITY 7-1: *A Polychaete Representative: The Clamworm*

1. Read through the natural history notes provided to you on the table.
2. Observe the clamworm in the finger bowl in front of you.
3. Examine the animal closely and take note of its morphology (you can use **Figure 7.1** to help you with your examination) and behavior.

Q. How does the combined action of the parapodia and the musculature of the body wall affect the locomotory movements of the worm?

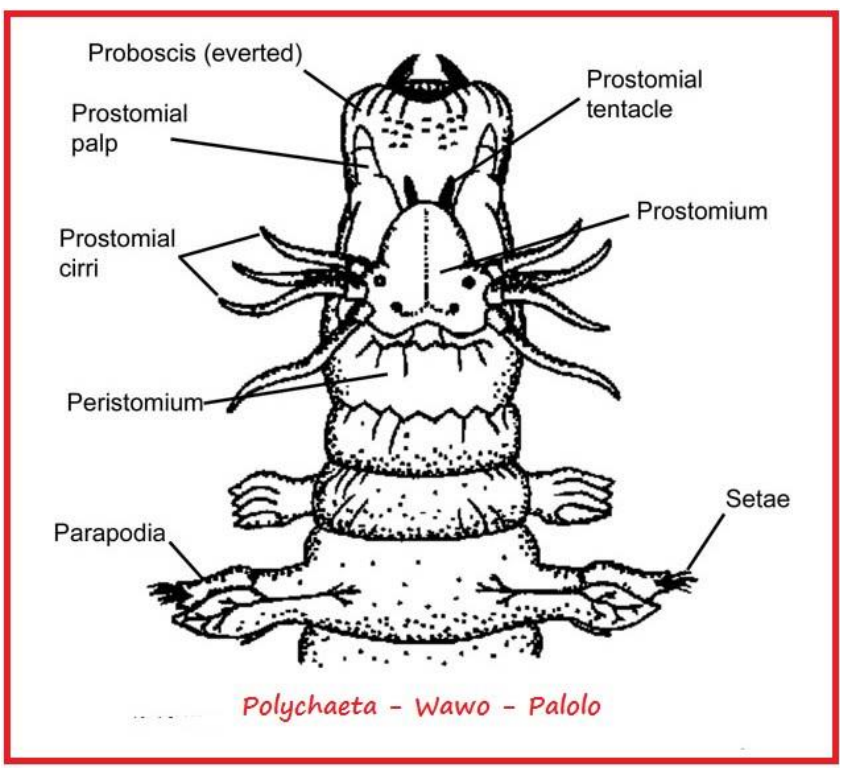


Figure 7.1. Dorsal view of a representative polychaete worm.

ACTIVITY 7-2: *Osmoregulation Experiment.*

1. Work in groups of two or four for this exercise.
2. Consider the osmoregulation experiment set up in front of you on your student bench.

   Q. What is the question being investigated?

   Q. Based on what you have observed and learned so far about the clamworm, what is your hypothesis regarding the answer to the question being examined?

3. Read through the explanation of the experimental set up and how it was carried out.

   Q. Now that you are familiar with the experimental set up, what predictions would you make as an extension of your hypothesis? (Hint: If your hypothesis is true, what would you expect to happen in the experiment?)

4. Get a copy of the class data generated for this experiment and discuss its signficance.

Q. ***After examining the data, what conclusions can you make regarding your hypothesis?***

Q. ***Was your hypothesis supported? Why or why not?***

ACTIVITY 7-3: Look at the rest of the display items and read through any additional materials on the polychaetes, making sure to take note of any important factors that help highlight important phylum and class characteristics.

--

Class Oligochaeta

Everyone knows the earthworm. They are the best representatives of this class of annelids. Earthworms, which are members of the genus *Lumbricus*, are excellent worms, not only for fishing, but also for gaining some understanding of annelid structure and function.

These animals are specialized for burrowing through the ground and do not have parapodia or elaborate head appendages which would interfere with their locomotion. The anterior end of the body contains the **mouth** over which hangs a fleshy lobe, called the **prostomium**. Along the length of the worm's body are **setae**, which are small, bristles made of a complex carbohydrate known as **chitin**. At the posterior end of the animal is the **anus** which is in the form of a vertical slit.

Q. What do you think the function of the setae are?

Another external feature characteristic of the oligochaetes is the **clitellum**, an enlarged, glandular, ring-like structure near the anterior end of the body. This structure serves as an aid in copulation and production of the cocoon for the developing embryos (Fig. 7.2). A pair of small excretory pores can be found on the **lateral** or **ventral** surfaces of each segment, except the first few and the last. On the sides of segment 14, the openings (female pores) of the oviducts can be seen. The openings of the sperm ducts (male pores), with their swollen lips, can be found on segment 15.

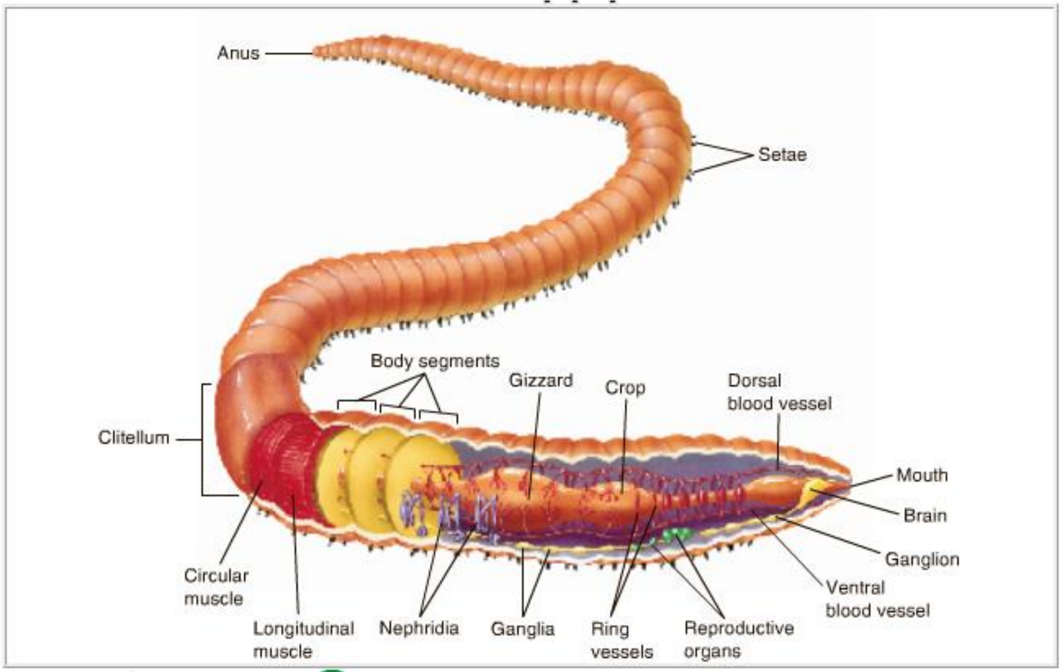


Figure 7.2. Internal anatomy of a representative oligochaete, an earthworm.

ACTIVITY 7-4: Visit the live earthworm demo. Note the differences in the external morphology of *Lumbricus* compared to that of the polychaetes. Identify the following structures in the earthworms:

- **mouth**
- **anus**
- **segments**
- **setae**
- **clitellum**

Although earthworms are oligochaetes, their internal morphology is similar to most other annelids. In general, annelids have formal nervous, digestive, circulatory and osmoregulatory/excretory systems. There is no formal respiratory system; respiration generally occurs via diffusion through epidermis. You will examine the internal morphology of a typical annelid through a dissection of an earthworm.

ACTIVITY 7-5: Dissection of an Earthworm.

External Anatomy

1) In groups of four, obtain an earthworm and a dissection pan.
2) Place your worm in the dissection pan, making sure to place the worm a little closer to one side of the pan than the other.
3) Examine your earthworm and determine the dorsal and ventral sides.
4) Locate the two openings on the ventral surface of the earthworm:
   - The openings toward the anterior of the worm are the **sperm ducts**. The openings near the clitellum are the **genital setae**. Label them on the worm pictured to the right.
   - Locate the dark line that runs down the dorsal side of the worm, this is the **dorsal blood vessel**. The **ventral blood vessel** can be seen on the underside of the worm, though it is usually not as dark.
5) Locate the worm's **mouth** and **anus**. Note the swelling of the earthworm near its anterior side - this is the **clitellum**.
6) Run your hands up and down the sides/ventral portion of the earthworm to feel the **setae**.
7) Label **Figure 7.3** with the external features you observe.

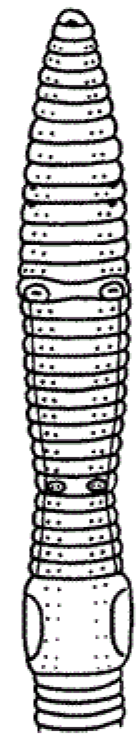


Figure 7.3. Ventral side of an earthworm. Use this to label the external features you have identified on your dissection specimen.

Internal Anatomy

8) Place the specimen in the dissecting pan DORSAL side up.
9) Locate the clitellum and insert the tip of the scissors about 3 cm posterior.
10) Cut carefully all the way up to the head. Try to keep the scissors pointed up, and only cut through the skin.
11) Spread the skin of the worm out, use a dissecting needle to gently tear the septa (little thread like structures that hold the skin to organs below it).
12) Place pins in the skin and secure it to the pan to hold it apart; angle the pins out so that they are not in your way.

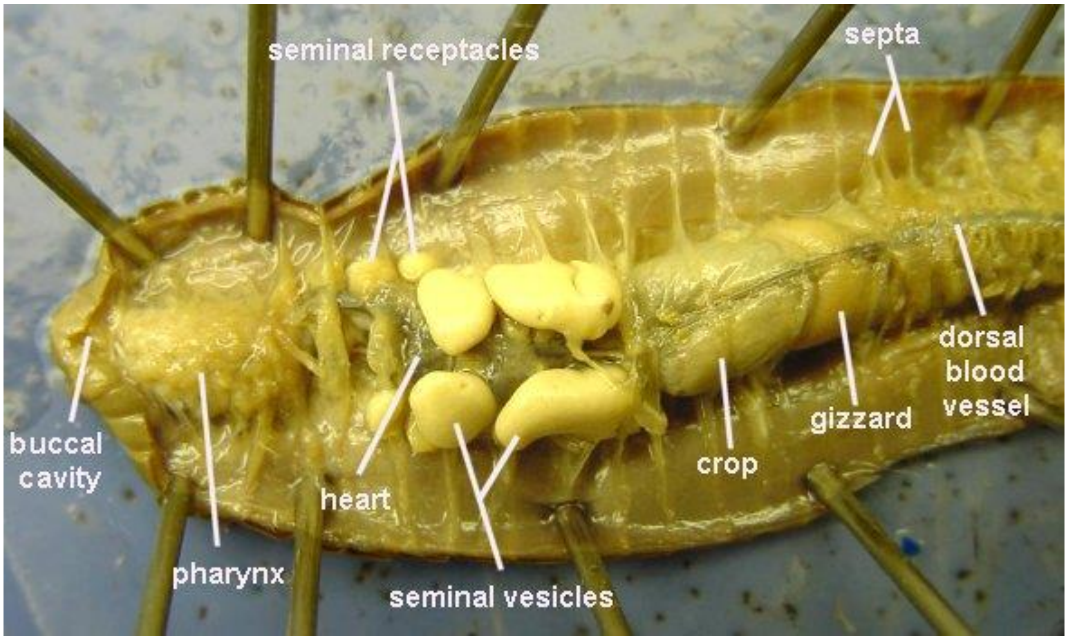


Figure 8.4. Lateral view of the anterior internal anatomy of an oligochaete.

13) Using **Figures 7.4. - 7.7** and the dissecting guides on the table, identify the following structures, making sure to take note of their form and function:

Reproductive Structures – *Oligochaetes are* ***monoecious***

- **<u>Seminal vesicles</u>** – light-/cream-colored, male reproductive organs comprised of three sacs. These are used for producing sperm. *(Testes are embedded in the seminal vesicles, and a sperm duct leads from each vesicle to the male gonopores on segment 15).*
- **<u>Seminal receptacles</u>** - female reproductive organs; white, spherical structures; stores sperm until copulation; *(ovaries are located a few segments down on segment 13; an oviduct runs from each ovary to a female gonopore on segment 14)*
- **<u>Clitellum</u>** – swelling toward the anterior end of body; aids in cocoon formation.

Digestive System

- **<u>Mouth</u>** - is located at the anterior end of the body
- **<u>Prostomium</u>** - fleshy lobe hanging over the mouth
- **<u>Pharynx</u>** - muscular structure just behind the mouth; esophagus extends from the pharynx into the crop
- **<u>Esophagus</u>**
- **<u>Crop</u>** - large, thin-walled sac behind the pharynx; serves as a temporary storage organ for food; leads to the gizzard

- **Gizzard** - posterior to the crop; grinding organ.
- **Intestine** - the site of digestion and absorption; runs from the gizzard to the anus.

Circulatory System

- **Dorsal blood vessel** – dark brownish-red vessel running along the dorsal side of the digestive tract; contains blood that flows toward the head.
- **Aortic vessels (= the heart)** – five pairs; encircles the esophagus, just posterior to the pharynx. Carefully tease away the tissues to expose the arches of the heart. If you are careful, you can expose all 5 of them.

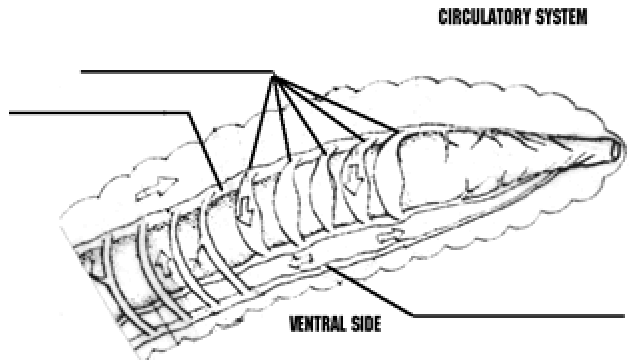


Figure 7.5. Lateral view of the anterior portion of an earthworm. Use this to label the circulatory system structures you have identified on your dissection specimen.

- **Ventral blood vessel** - located opposite to the dorsal blood vessel; cannot be seen at this time because the digestive system covers it

Osmoregulatory/Excretory System

- **Nephridia –** paired, tubular structures located along the inner lateral body wall; may be difficult to see – ask your instructor for assistance if necessary

Nervous System

- **Ventral nerve cords –** paired structures running ventrally along the length of the body; terminate anteriorly at the brain
- **Dorsal ganglia (= the brain) –** paired, white spherical structures on the dorsal side of the head; represents the thickening of the anterior end of the ventral nerve cords

6) When you are finished examining your earthworm specimen, remove the dissecting pins and discard your specimen in the biohazard container. Then rinse off the pins and dissecting pan and put them back where you got them.

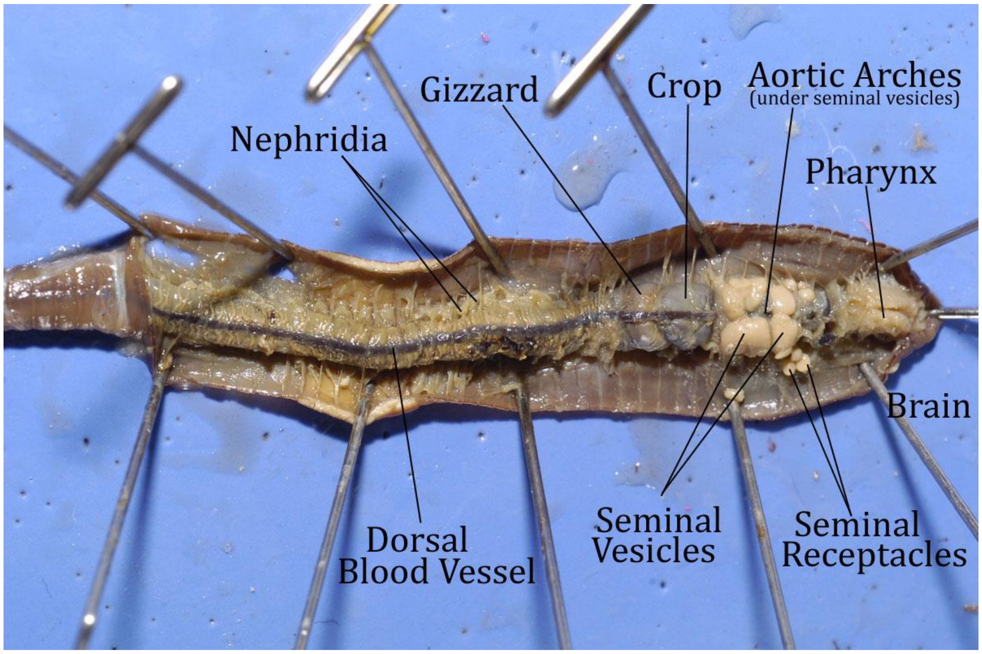


Figure 7.6. The internal anatomy of *Lumbricus* sp., the earthworm.

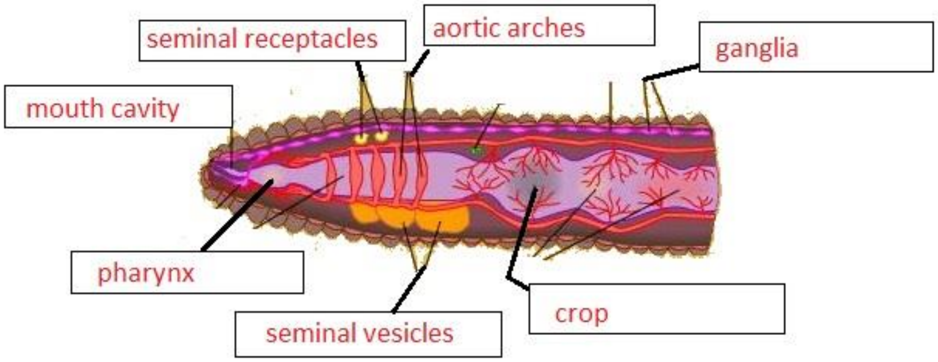


Figure 7.7. Lateral view of the internal anterior anatomy of an earthworm.

ACTIVITY 7-6: Look at the rest of the display items and read through any additional materials on the oligochaetes, making sure to take note of any important factors that help highlight important phylum and class characteristics.

Class Hirudinea

The leeches have the worst reputation of the annelid worms, primarily because of the stories about them being blood-suckers. Although many species of leeches do live as **ectoparasites**, feeding on the blood of a number of other species, most leeches are free-living. Free-living leeches can be found in freshwater habitats, while others are terrestrial or marine habitats.

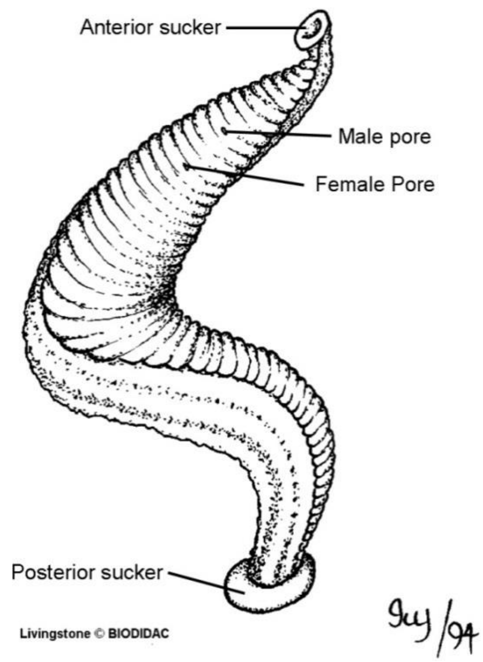


Figure 7.8. A leech.

Regardless of their lifestyle, the segments surrounding the mouth are modified into a small **anterior sucker**. These worms also have a **posterior sucker** which aids parasitic forms in securing onto their host. There are chitin-based jaws in the leech mouth, which parasitic forms use to release the blood of their host. Parasitic leeches precede wound creation with the application of an **anesthetic**, to keep the host from detecting their presence. They then follow wound creation with the secretion of an **anticoagulant** to stop the host's blood from clotting.

Leeches are **monoecious** like oligochaetes. In addition, they have a specific number of segments and a **clitellum** is developed only during the reproductive season (Fig. 7.8).

ACTIVITY 7-7: Examine the live and/or preserved specimens of leeches.

1) Note:
   - the dorsoventrally flattened body
   - the presence of anterior and posterior suckers
   - thick muscular body walls
   - the absence of parapodia and head appendages.

ACTIVITY 7-8: Look at the rest of the display items and read through any additional materials on the leeches, making sure to take note of any important factors that help highlight important phylum and class characteristics.

FOR MORE INFORMATION…

- **Virtual Earthworm Dissection -** **http://www.mhhe.com/biosci/genbio/virtual_labs/BL_14/BL_14.html**
  You will be able to go through a virtual dissection of an earthworm at this site!
- **Bumblebee.org** - **http://www.bumblebee.org/invertebrates/ANNELIDA.htm**
  You can find some information about the annelid phylum and classes.

CHAPTER 8

THE Mollusks (Phylum Mollusca)

Objectives

You should be able to:

- identify:
  - the level of organization seen in these animals
  - the type of symmetry seen in these animals
  - the number/type of embryonic tissue layers found in these animals
  - the type of skeleton found in these animals
  - whether a coelom is present and, if so, in what form
- indicate if nervous, respiratory, circulatory (open/closed?), osmoregulatory/excretory, or digestive systems (incomplete/complete) are present and, if so, in what form
- indicate whether these animals are monoecious or dioecious
- describe the types of habitats in which these animals can be found
- describe the kind of lifestyle these animals live
- Recognize this phylum and the name and important characteristics of the following classes:
  - **Class Polyplacophora** = **chitons**
    You should be able to describe these animals':
    - characteristics
    - lifestyles
    - location and fonction of external anatomical characters: large ventral foot, radula, dorsal plate with eight plates
  - **Class Bivalvia = clams, mussels, scallops, and their relatives**
    You should be able to describe these animals':
    - characteristics
    - lifestyle
    - function and location of external anatomical characters on dissected animal: umbo, valves (there are two)
    - function and location of internal anatomical characters on dissected animal: wedge-shaped foot, adductor muscles (anterior and posterior), gills, labial palps, siphon, intestine, mantle (lining inside of valves), visceral mass
  - **Class Gastropoda = snails, slugs, nudibranchs and their relatives**
    You should be able to describe these animals':
    - characteristics
    - lifestyles
    - location and function of external anatomical characters: radula, shell, torsion

- **Class Cephalopoda = squid, octopi, and chambered nautili**
  You should be able to describe these animals':
  - characteristics
  - lifestyles:
  - <u>location and function of external anatomical characters on the dissected animal</u>: eyes, pen, mouth with beak, siphon, tentacles and arms, mantle, fin
  - <u>function and location of internal anatomical characters on dissected animal</u>:

Phylum Mollusca

Most people are familiar with mollusks - clams, snails, squid, octopi, oysters (which comprise many of the "sea shells" folks find on the beaches), and their relatives. The mollusks have attracted the interest of biologists and non-biologists for thousands of years. This is due, in part, to the intrinsic beauty of many molluscan shells and their use as objects to use as jewelry, art, and for trade, as well as to construct dishes and pave highways. Of course, many species are important sources of food for humans; clams, oysters, snails, squid, and octopi are consumed in large quantities as part of peoples' normal diet.

There are four major classes of mollusks: the **<u>Polyplacophora</u>** (the chitons), **<u>Gastropoda</u>** (the snails and slugs), **<u>Bivalvia</u>** (the clams, mussels, and other bivalves), and **<u>Cephalopoda</u>** (octopuses = octopi, squid, cuttlefish, and chambered nautilus). On the surface, representatives of these classes look very different from one another; but it turns out that they share a few basic characteristics that tie all of them together as mollusks. All mollusks have a generalized body plan with the following features:

1) an anteriorly placed **<u>head</u>** of different configurations depending on class
2) **<u>soft, unsegmented body</u>** with an outer tissue layer
3) the **<u>mantle tissue</u>**, responsible for protection and. usually, secretion of the **<u>calcium carbonate</u>** **<u>shell</u>**.
4) a broad, muscular, **<u>ventral foot</u>** used for locomotion,
5) a dorsal **<u>visceral mass</u>** containing the digestive, circulatory, reproductive, osmoregulatory, excretory, and other systems
6) a mantle cavity in which are found the respiratory structures, the **<u>gills</u>** or **<u>lungs</u>**.

Many of the mollusks also have a **<u>radula</u>**, which is a rasping device used as an aid in food gathering and/or processing.

<u>Class Polyplacophora</u>

The common name for these mollusks is **<u>chiton</u>**. They are exclusively found in marine habitats, preferring the rocky intertidal zones in temperate regions of the world. The class is considered to be a less highly derived group ol mollusks, close in form to the ancestral type. Chitons utilize their broad, muscular foot in combination with the mantle tissue to cling tightly to rocks, and to move slowly over the substrate grazing on algae with their radula. Chitons are particularly abundant along the central California coast.

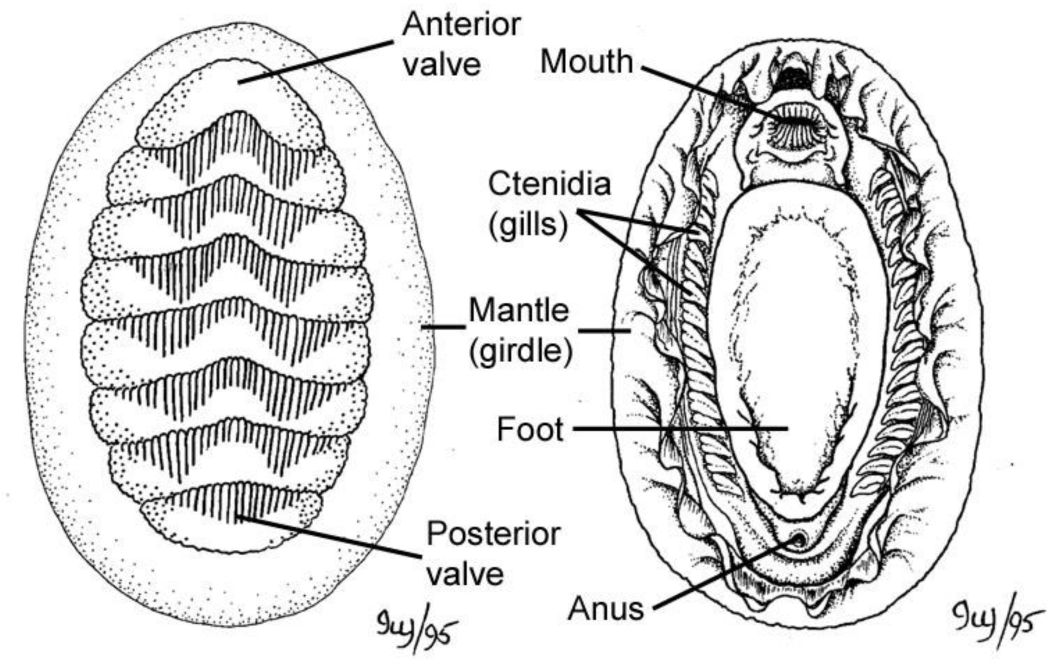


Figure 8.1. Dorsal and ventral view of the external anatomy of a chiton.

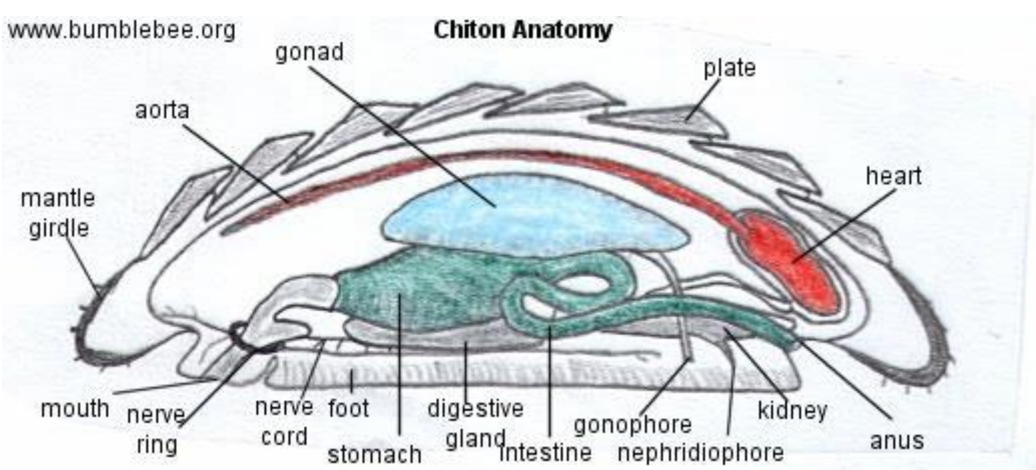


Figure 8.2. Internal anatomy of a chiton.

ACTIVITY 8-1: Study the chiton specimens, photos and writeups on display. Be sure to identify the following structures using Figures 8.1 and 8.2 to help you if necessary:

- foot
- mantle cavity with numerous individual gill filaments
- dorsal shell consisting of eight separate plates
- unspecialized head; mouth is positioned anteriorly

You might find it useful to make sketches of these animals' form, noting those characteristics that characterize the class and the phylum.

ACTIVITY 8-2: Look at the rest of the display items and read through any additional materials on the chitons, making sure to take note of any important factors that help highlight important phylum and class characteristics.

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Class Gastropoda

Members of this class of mollusks include a wide diversity of animals including the marine, freshwater and terrestrial snails, limpets, abalone, sea slugs, sea hares, and terrestrial slugs. They are the most successfully adapted of all the mollusks and comprise the largest number of species. All of the gastropods are built on a basic morphological plan best exemplified in the complex morphology of a snail.

--

ACTIVITY 8-3: Study the gastropods on display. Be sure to identify the typical gastropod characters listed below, using Figure 8.3 to help you if necessary:

- an obvious **head with tentacles**
- **muscular foot**; used for locomotion
- **spirally coiled shell**
- soft **visceral mass**; extends dorsally into the shell

Limpets and abalone are characteristic gastropods of our coastline, although abalone are now only rarely found in the intertidal zone. These animals are characterized by cone-shaped shells, broad, muscular feet, and an herbivorous diet utilizing a well-developed radula.

Q. Check out the abalone shell on display. What might be the function of the holes on the dorsal side of the abalone shell?

(NOTE: For more information on abalone declines in California, see the bibliography at the end of this chapter.)

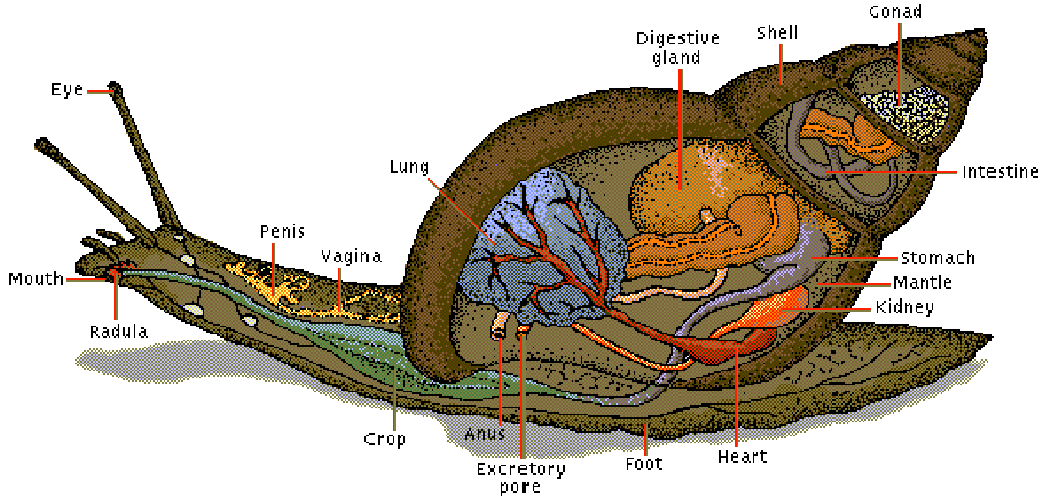


Figure 8.3. Internal anatomy of a typical gastropod. Figure from Microsoft Encarta Online Encyclopedia.

The most beautiful of all of the mollusks, and perhaps of all animals, are the nudibranchs or sea slugs (Figure 8.4). These marine animals are common in SF Bay area intertidal zones as well as intertidal zones up and down the waters off of the west coast. The Biology department's own Dr. Jim Murray knows this well. He works on the neurobiology and behavior of a species of nudibranch within the genus *Tritonia*.

Figure 8.4. A nudibranch.

Nudibranchs do not have a shell, are often characterized by ***ceratae***, which are projections from the dorsal body wall, ***rhinophores*** for sensory functions, and ***branchial plumes*** for respiration.

ACTIVITY 8-4: Look at the rest of the display items and read through any additional materials on the gastropods, making sure to take note of any important factors that help highlight important phylum and class characteristics.

Class Bivalvia

As the name implies As the name implies members of this class of mollusks are characterized by the presence of a **bivalve shell** located on the lateral sides of the soft, visceral mass of these animals. The bivalves are considerably modified from the generalized molluscan plan, a reflection of their sluggish, burrowing or sessile habits. The **shell valves** are joined on the dorsal midline by a **ligament** and are held together by strong adductor muscles extending through the visceral mass. Most bivalves have a wedge-shaped **foot** that can be extended between the lateral shells and are used for locomotion and burrowing into the substrate. The **mantle tissue** covers the **visceral mass**, encloses the **mantle cavity**, secretes the shells, and is posteriorly modified to form a pair of **siphons** to direct water currents into and out of the mantle cavity. (Use

Within the mantle cavity are well-developed **gills** that serve not only as respiratory organs, but also as filters, using a combination of **cilia** and **mucus** to trap food particles brought in with the water currents. The food is transferred to the digestive system by movement of the cilia on the surface of the gills along a food groove on the ventral side of the gills, across **labial palps**, and into the mouth. Many bivalves have a unique device called the **crystalline style** located in the stomach that is used to pull the food/mucus material into the gut and begin enzymatic breakdown of the food.

These are a number of bivalve species that can be found in the Bay Area. *Mytilus* is a species of bivalve that can be found attached to solid substrates found around the world including the SF Bay. The horse mussel, *Ischadium*, is another bivalve, found at the outer edge of Bay salt marshes. The small clam, of the genus *Macoma*, can be found burrowed into the upper mudflats of the Bay.

ACTIVITY 8-5: Study the bivalves on display including:

- Plexiglass model of clams
- Demo slide: transverse section of gill
- Demo slide: *Glochidia larva*

Be sure to identify key Mollusk (phylum level) and Bivalve (Class-level) characters, particularly those listed below. Use Figures 9.5-9.6 to help you if necessary. Also use the variety of bivalves on demonstration to get an idea of the diversity of this class. Note especially the differences in:

- Shell shape
- Shell size
- Shell ornamentation

ACTIVITY 8-6: Dissection of a (preserved) clam.

External Anatomy

1) In groups of four, obtain a clam and a dissection pan.
2) Place your clam in the dissection pan. Examine your clam and identify the following (using Figure 8.5 if you need it):
    - **the dorsal vs. ventral vs. lateral sides** (*Note: the clam is laterally flattened and is resting on one of its sides).*
    - **anterior vs. posterior sides**
    - **umbo**
    - **valves**
    - **growth rings**

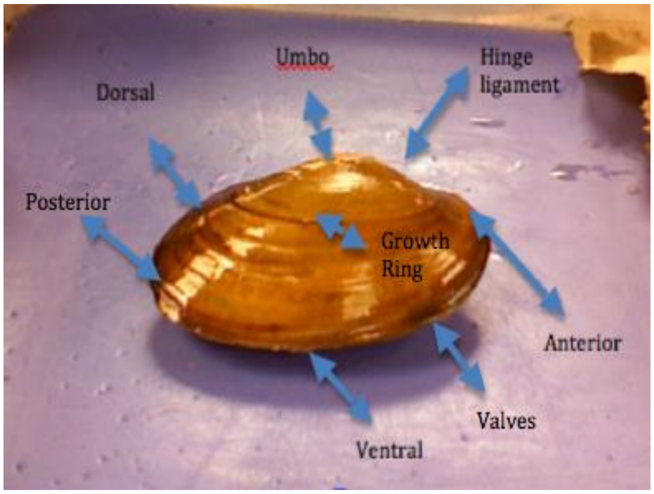


Figure 8.5. External anatomy of a clam

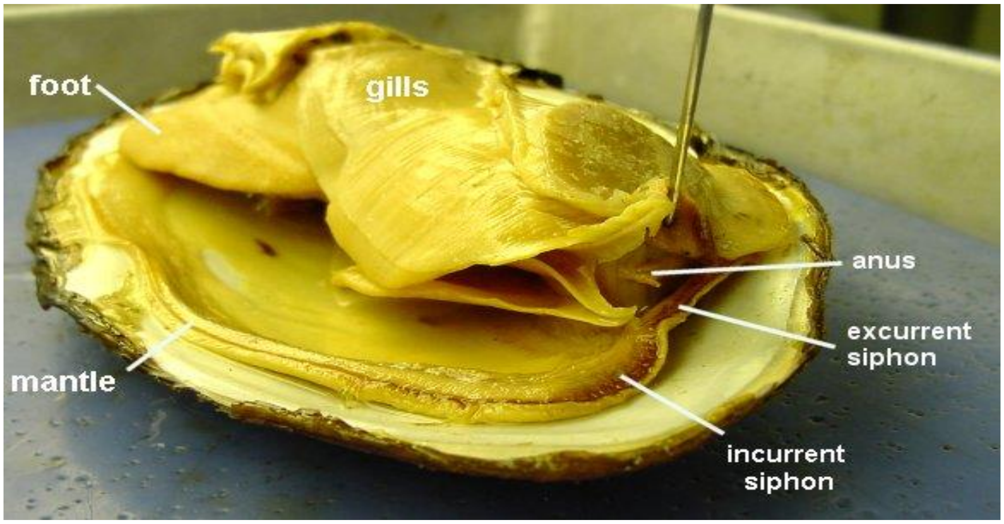
Internal Anatomy

3) Carefully open the clam by inserting a scalpel between the two shell valves. Keeping the blade close to the inner surface of the shell, cut the adductor muscles until you can pry the two valves all of the way open. *Note: You may have to go back and forth cutting each of the adductor muscles and doing what you can to pry the two valves apart. Continue to do this until you are able to pry the vales all of the way open*.

4) You are now ready to explore the internal anatomy of the clam. You can use Figure 8.6.to aid in the identification of the following structures:
    - **mantle tissue**
    - **siphons**
    - **anterior and posterior adductor muscles**
    - **gills**
    - **labial palps**
    - **foot**

5) Carefully bisect the visceral mass along a dorsal-ventral plane to locate the:
    - **gonads**

- **stomach / digestive gland**
- **intestine winding through the visceral mass**
- **heart (located on the dorsal side around the intestine)**



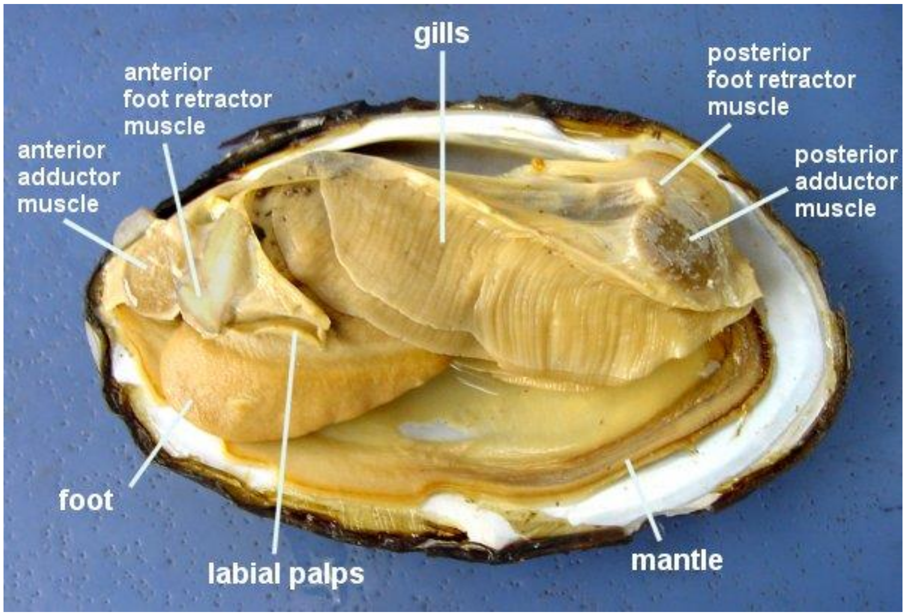


Figure 8.6. Internal anatomy of a clam.

ACTIVITY 8-7: Look at the rest of the display items and read through any additional materials on the bivalves, making sure to take note of any important factors that help highlight important phylum and class characteristics.

Class Cephalopoda

The chambered nautilus, cuttlefish, squid and octopus represent the most highly derived animals within the phylum. Their morphology reflects the active, predatory lifestyle they lead in marine habitats around the world. Some members, such as the squid, are found in open water actively swimming and feeding on small fish, shrimp and other invertebrates. Others, like the octopus, are bottom dwellers, leading secretive lives, crawling along the bottom feeding on various invertebrates and fish. All have a mouth with a **beak**, that looks similar in design to a bird bill but that contains a **radula** inside. This beak aids the cephalopods in holding and tearing their prey;

All cephalopods are characterized by a muscular **mantle tissue** that actively pumps water through the **mantle cavity** and over the **gills.** The water exits through a **siphon** that serves as a **jet-propulsion**" device for many cephalopods, propelling them through the water. These cephalopods have eight or ten **arms/tentacles** used for food capture and locomotion.

They have a well-developed head with a pair of **eyes** that are similar to vertebrate eyes in structure and function. The brain, central nervous system, and other sensory structures reflect the sophisticated behavior patterns of the cephalopods, which are considered by most biologists to be the most advanced of all the invertebrate animals. Two interesting structures employing the pigment melanin are used for protection. One is the **chromatophores**, pigment cells located in the epidermis over the surface of the body that expand and contract to alter the color patterns of the animal. The second is an **ink sac** located near the distal end of the intestine. This organ produces an intensely dark fluid pigment that is ejected out of the siphon to form a dark cloud that confuses predators.

One of the most widespread squid belongs to the genus *Loligo*. These animals are found in many regions of coastal marine waters around the world and serve as an important source of food for humans and other animals.

ACTIVITY 8-8: Study the cephalopod specimens on display. Be sure to identify key mollusk (phylum level) and cephalopod (Class-level) characters, particularly those listed below. Use Figures 8.7-8.8 to help you if necessary.

- **Arms vs. tentacles (= modified foot)**
- **Mantle**
- **Eyes**
- **Siphon**

- **Beak**
- **Gills (internal)**
- **Ink sac (internal)**

In groups of four, with the aid of Figures 8.7-8.9 and the additional dissecting charts on your table, you will now dissect a squid.

ACTIVITY 8-9: Dissection of a (fresh) Squid.

External Anatomy

1) In groups of four, obtain a squid and a large dissection pan.
2) Place your squid in the dissection pan. Examine your squid and identify the following external characteristics:
    - **arms and tentacles with suckers**
    - **head (do not confuse this with the mantle region)**
    - **eyes**
    - **mouth with beak**
    - **mantle**
    - **siphon**

Internal Anatomy

3) Using a scalpel and/or dissecting scissors, carefully open the squid's mantle cavity. Pull slightly up when using the scissors so as not to damage the organs just below.
4) You are now ready to explore the internal anatomy of the squid. You can use Figures 8.8-8.10 to aid you in the identification of the structures below. As you examine these structures think about their function and how they operate together to enable these animals to be active, effective predators in their habitats.
    - **mantle tissue**
    - **mantle cavity**
    - **ink sac**
    - **stomach**
    - **intestine and anus**
    - **liver**
    - **gills**
    - **branchial hearts**
    - **systemic heart**
    - **retractor muscles**
    - **cecum (male)**
    - **testis**

- **ovary**
- **nidamental glands**
- **pen** (= internal shell; you can remove this to get a closer look by snipping the posterior section of the mantle, just below where the pen; then just pull it out).

Q. What do you notice about this internal shell? Is there any calcium carbonate in this shell?

Q. What organ systems do the characteristics listed above represent (see potential options below)?

Circulatory System
Respiratory System
Digestive Systems
Reproductive System
Osmoregulatory/Excretory System

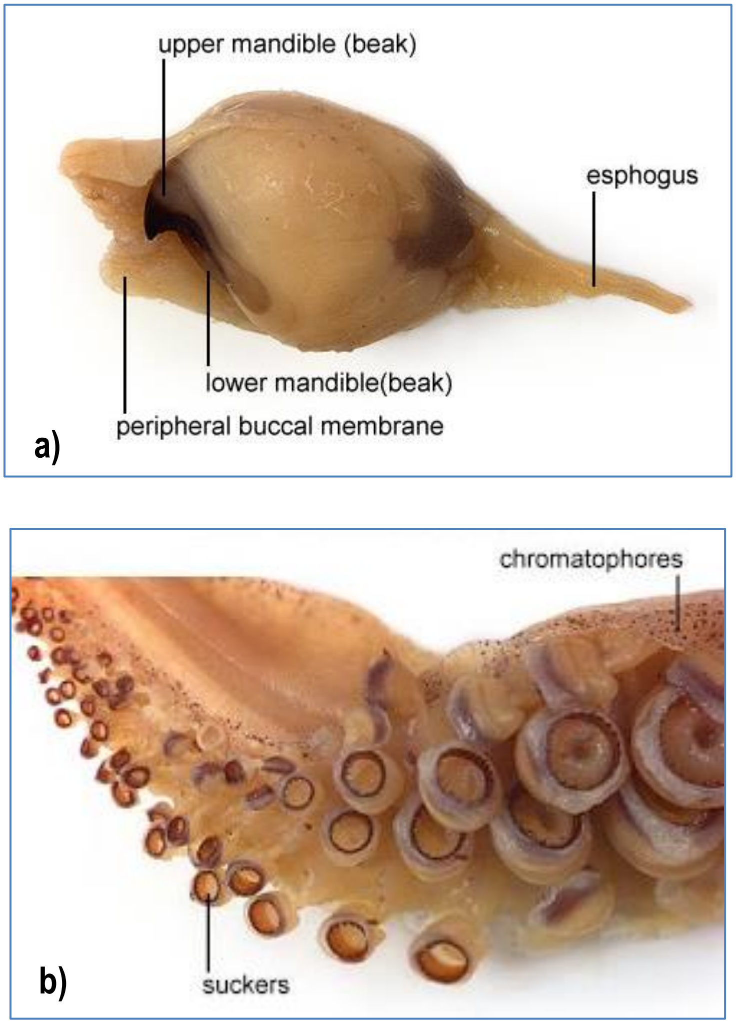


Figure 8.7. Mouth anatomy (a) and (b) close up a tentacle of a squid.

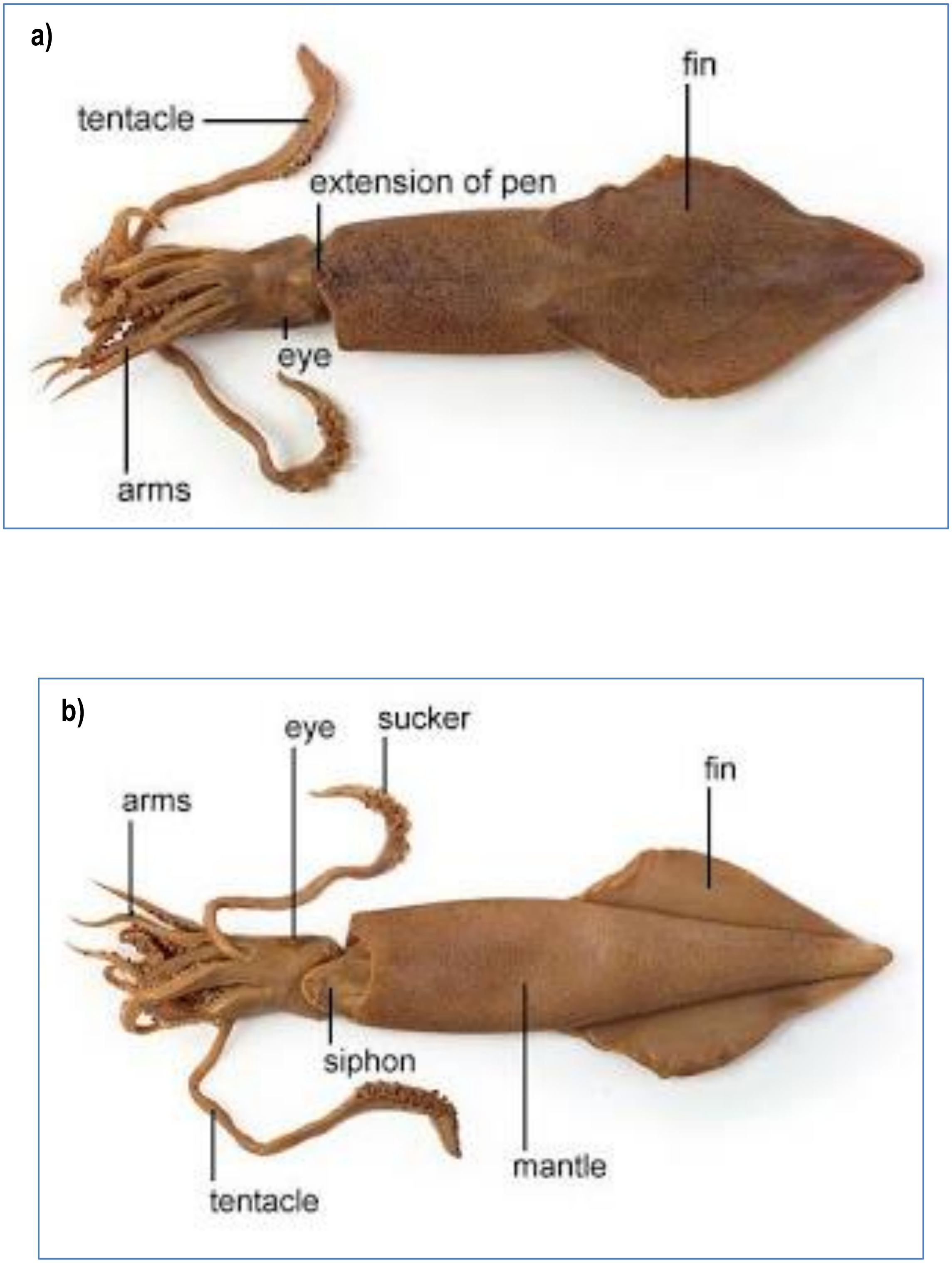


Figure 8.8. Dorsal (a) and ventral (b) view of the external anatomy of a squid.

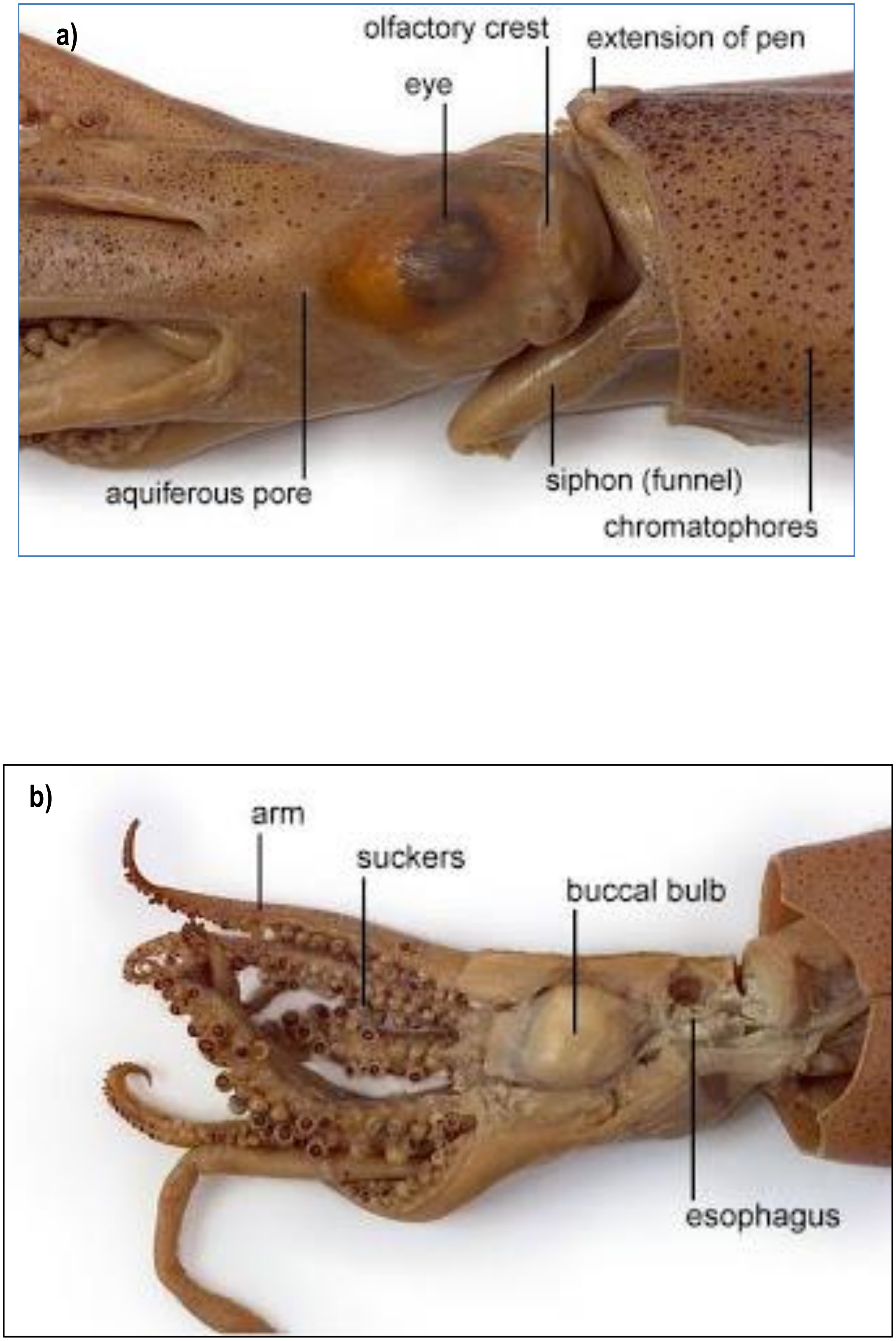
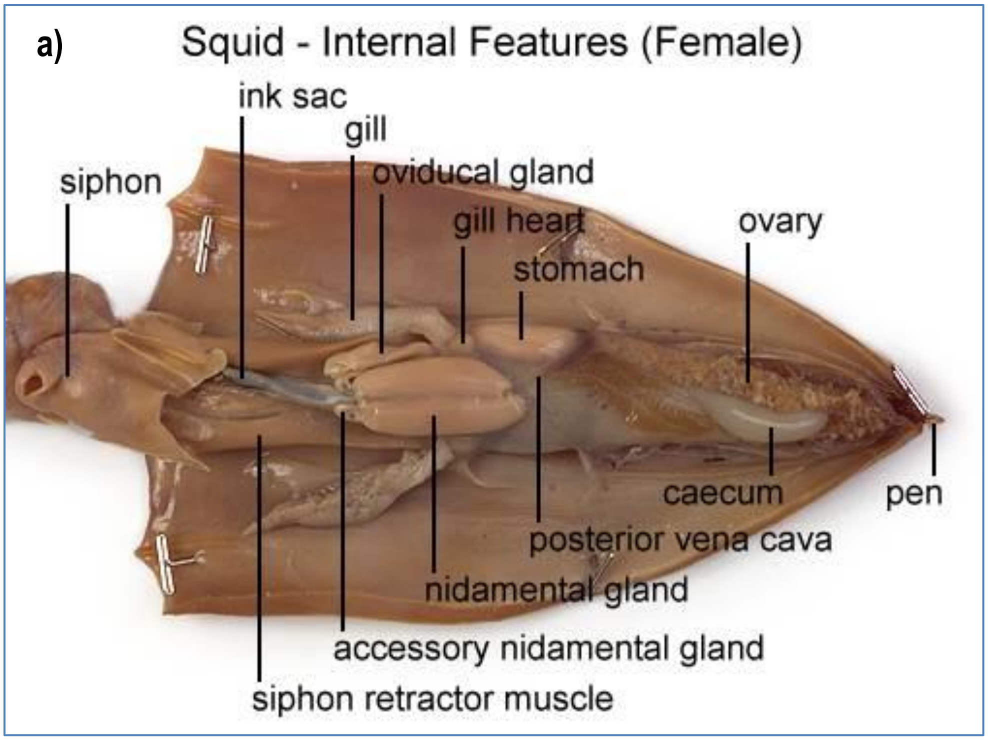


Figure 8.9. Anterior external (a) and anterior internal (b) views of a squid.



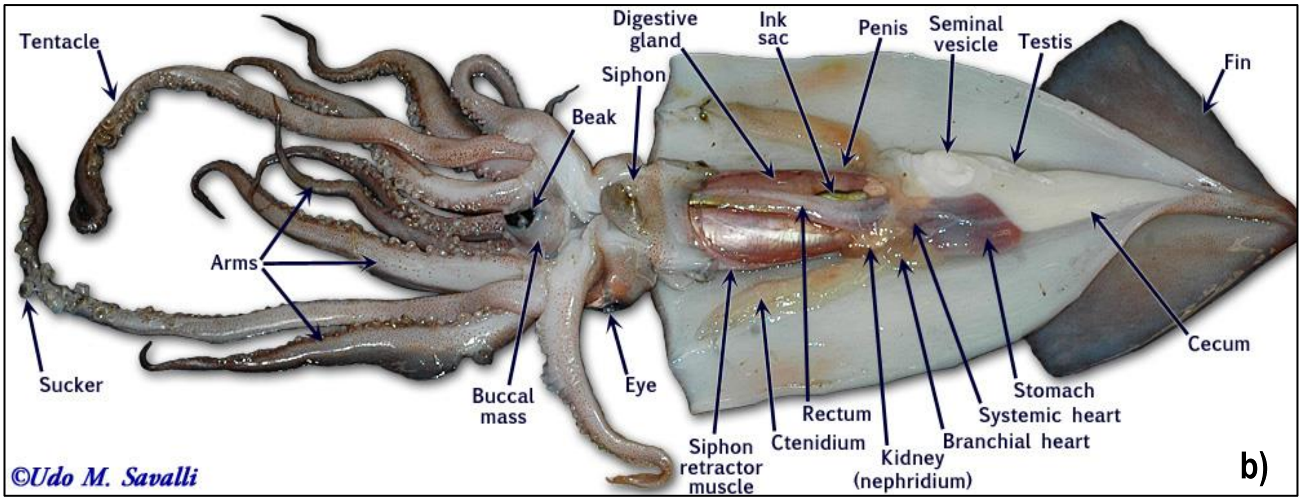


Figure 8.10. Internal anatomy of a female (a) and a male (b) squid.

FOR MORE INFORMATION…

General

- **The University of California Museum of Paleontology – The Mollusca**
  http://www.ucmp.berkeley.edu/taxa/inverts/mollusca/mollusca.php
  Variety of biological facts about mollusks.

- **Virtual Squid Dissection** -
  http://www.biologycorner.com/worksheets/squid_virtual.html
  Although there aren't any great photos here, this site provides a run through of the squid dissection that you might find useful.

- **YouTube Squid Dissections** –
  http://www.youtube.com/watch?v=OueQ9kU36i0
  http://www.youtube.com/watch?v=AaaWXlAGenc
  Here are some videos of squid dissections.

Abalone Declines

- **CA Living Marine Resources: A CA Department of Fish and Game Status Report** - https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=34381&inline=true
  Provides population and other biological information about the five main abalone species found in Caifornia.

- **CA Fish and Game Invertebrate Management Team feature article** -
  https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=31440&inline=true
  Popular press article regarding declining abalone in California.

CHAPTER 9

THE ROUNDWORMS (Phylum Nematoda)

Objectives

You should be able to:

- identify:
  - the level of organization seen in these animals
  - the type of symmetry seen in these animals
  - the number/type of embryonic tissue layers found in these animals
  - the type of skeleton found in these animals
  - whether a coelom is present and, if so, in what form
  - which organ systems are present
- describe the significance of the cuticle in these animals
- indicate if nervous, respiratory, circulatory (open/closed?), osmoregulatory/excretory, or digestive (complete/incomplete?) systems are present and, if so, in what form
- describe the movement in these animals
  - significance of having longitudinal muscles but not circular muscles
- indicate whether these animals are monoecious or dioecious
- describe the types of habitats in which these animals can be found
- describe the kind of lifestyle these animals live

PHYLUM NEMATODA

This phylum of round worms is one of a few phyla whose members are known as **pseudocoelomates** or **blastocoelomates** – they possess an internal body cavity known as a **pseudocoelom** or **blastocoelom**. These animals are not considered to have a full coelom because it is not entirely lined by a mesodermal tissue called the **peritoneum**. The pseudocoelom is derived from the **blastocoel** of these animals' embryonic stages. The cavity is fluid-tilled and serves a very important role as a **hydrostatic skeleton** for the members of this phylum.

As the common name suggests roundworms have an elongate, cylindrical body that is tapered at both ends. Thy also have a well-developed, flexible **cuticle** which is secreted by the epidermis (skin). It serves a protective function as well as a "skeletal" one. Moreover, roundworms use their cuticle for support and leverage as they move. The cuticle is a feature that nematodes share with other ***ecdysozoan*** animals such as arthropods. Ecdysozoans periodically shed their cuticle as they grow.

Internally, underneath the epidermis, are four groups of **longitudinal muscles**; there are no circular muscles. Consequently, the nematode can only bend its body from side to side, but it cannot "crawl" or lift itself. When free-swimming roundworms move, it takes on the appearance of a **thrashing motion**.

ACTIVITY 9-1: Visit the demonstration with the live roundworms of the genus *Turbatrix*, the "vinegar eels". Use your observations to answer the following questions:

- Describe the motion of the animals as they move through the water.

- Make a sketch of *Turbatrix* illustrating how it moves using its contractions of their longitudinal musculature.

- Compare how the movement of these roundworms compares to the movement of the flatworms and annelids.

You can also check out this nematode thrashing motion by checking out this video).

The digestive system is complete but unspecialized – there are no sections of the digestive system that are significantly modified like we see in oligochaetes. In nematodes, the digestive system begins with the **mouth** at the anterior end of the animal, leads to a muscular pumping **pharynx** and into an elongate intestine that exits through an **anus** at the posterior end. This type of arrangement is called a "tube-within-a-tube" body plan, and is the design for all animals with **complete digestive systems**.

Among the multicellular animals the nematodes are probably second only to the insects in numbers of species and individual animals. The majority of nematode species are free-living in almost any habitat, where they may serve as decomposers or predators; but there are also large numbers of **symbiotic** species, some of which are serious parasites of plants, humans and other animals. Most of these species are barely visible to the naked eye, transparent, and have **simple life cycles** ***(What does this mean?).*** The species that live as parasites in vertebrates may attain lengths of up to a meter and have **complex life cycles** ***(How would this compare to roundworms with simple life cycles?).*** The examples of nematodes that we feature in the lab are comprised of both **free-living** and **symbiotic** species.

The large size of *Ascaris*, the intestinal parasite of humans, pigs and other domestic animals, makes it ideal for examination of the relatively simple internal roundworm anatomy (Figure 10.1). These worms have an elongate intestine. As mentioned earlier, these animals are **dioecious** and there are differences between the sexes. The reproductive systems are tubular in shape, extending from a thin gonad (or two in the female) through a sequence of gradually enlarging tubes, finally exiting the body through an opening called the **gonopore**. The female system consists of several structures including the **ovaries**, where the eggs are produced, **oviducts**, **uteri (= uteruses),** a single **vagina** and the **gonopore**. The male system consists of a single **testis**, where the sperm is produced, a **vas deferens**, where the sperm matures, and a **seminal vesicle** in which the sperm is collected before transfer. The **copulatory spicules** are inserted into the female's gonopore, and sperm is transferred into her reproductive tract.

ACTIVITY 9-2: Visit the demonstration with the dissected preserved *Ascaris* roundworm(s):

- Examine the external and internal anatomy of these animals.
- Take note of any differences between male and female *Ascaris*.
- Make note of similarities and differences to what can be found in the other animal groups you have studied thus far.

- Make a sketch or use Figure 9.1 to illustrate all of the external and internal features you have found.
- Take a moment to wash your hands after this dissection.

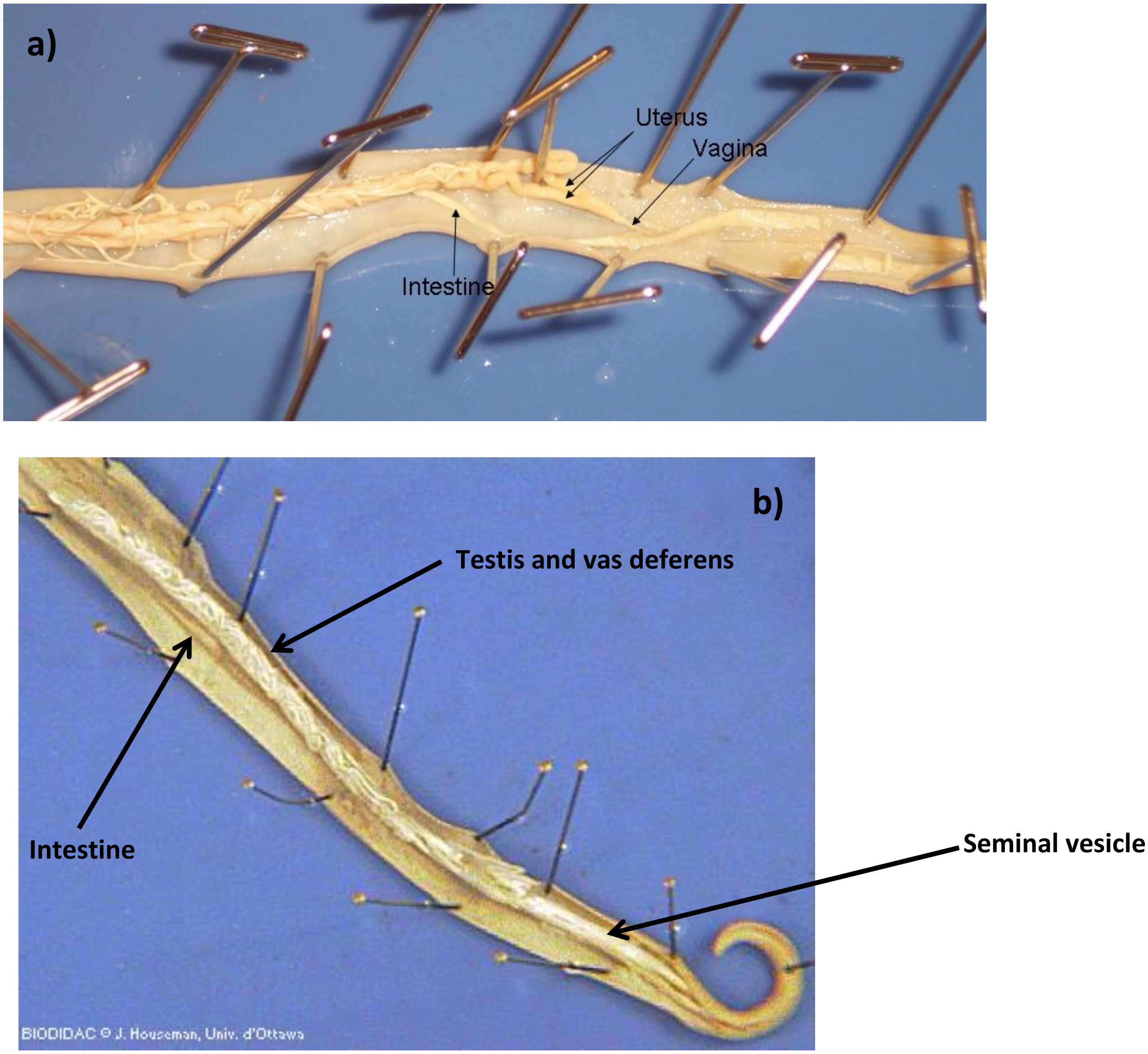


Figure 9.1. Internal anatomy of female (a) and male (b) *Ascaris* roundworms.

Nematodes also have a simple nervous system, the main component of which is the circumpharyngeal (circling the pharynx) ring which comprises the brain. Nerves servicing various sensory structures throughout the body extend from the brain.

Parasitic roundworms, like *Ascaris*, often respire anaerobically (without the use of oxygen) since oxygen is often in limited supply hosts' bodies. If oxygen is present or if the roundworm is free-living with access to oxygen, aerobic (with the use of oxygen) respiration will occur. There are no formal respiratory structures in nematodes; so, they use diffusion in the gas exchange process.

Roundworms do have excretory/osmoregulatory structures. These come in the form of rennet cells.

Another roundworm that has gained considerable attention in recent years is *Caenorhabditis elegans* (= *C. elgans*), a small nematode that is easily cultured and has become a major experimental organism for research in genetics, developmental biology, and cell/molecular biology. In fact, CSUEB Biology's own Dr. Maria Gallegos works with this animal in her genetics/developmental biology lab. *Caenorhabditis elegans* is the first animal for which the complete DNA sequence of its genome has been established.

Two other important nematodes that are parasites of humans are on demonstration in the Biol 1403 lab with supplemental reading material:

- The hookworm *Necator* is an intestinal parasite responsible for a debilitating disease in many infected individuals around the world.
- The worm responsible for the disease known as **trichinosis** infects humans who eat poorly cooked and infected pork products. The genus of this worm is *Trichinella* and humans serve as intermediate hosts for the parasite. The larvae become embedded in our musculature, remaining there for the rest of their lives unless the host is eaten by another carnivore!

ACTIVITY 9-3: Look at the rest of the display items and read through any additional materials on the nematodes, making sure to take note of any important factors that help highlight important phylum and class characteristics.

FOR MORE INFORMATION…

- **YouTube – Ascaris dissection video!** http://www.youtube.com/watch?v=_ybbnPj0t9Y&playnext=1&list=PLBF36765ECE396110&index=18

- **Animal Diversity Web (Nematode write up)** - http://animaldiversity.ummz.umich.edu/accounts/Nematoda/
  You can find a variety of information on the anatomy, natural history and biological significance of nematodes.

- **University of California Museum of Paleontology at U.C. Berkeley** http://www.ucmp.berkeley.edu/phyla/ecdysozoa/nematoda.html
  You will find a variety of facts on the Nematodes at this site.

CHAPTER 10

THE Arthropods (Phylum Arthropoda)

Objectives

You should be able to:

- identify:
    - the <u>level of organization</u> seen in these animals
    - the <u>type of</u> <u>symmetry</u> seen in these animals
    - the number/type of <u>embryonic tissue layers</u> found in these animals
    - the <u>type of skeleton</u> found in these animals
    - whether a <u>coelom is present</u> and, if so, in what form
- indicate if nervous, respiratory, circulatory (open/closed?), osmoregulatory/excretory, or digestive systems (incomplete/complete) are present and, if so, in what form
- indicate whether these animals are <u>monoecious</u> or <u>dioecious</u>
- describe the <u>types of habitats</u> in which these animals can be found
- describe the <u>kind of lifestyle</u> these animals live
- <u>Recognize this phylum</u> and the name and <u>important characteristics of the following suphyla and classes:</u>
    - **Subphylum Trilobitomorpha** = **trilobites**
      You should be able to describe these animals':
        - characteristics
        - lifestyles
        - staus as extinct
    - **Subphylum Crustacea** = **crustaceans**
      You should be able to describe these animals':
        - characteristics
        - lifestyles
        - <u>**Class Malacostraca**</u> = crabs, crayfish, lobsters and relatives; we will only focus on this one of several crustacean classes.
        - <u>function and location of external anatomical characters on the crayfish</u>: *cephalothorax and abdomen;* <u>cephalothorax</u>: *rostrum, carapace, compound eyes, mandibles, 2 pairs of antennae (1 longer pair called antennae & 1 shorter pair called antennules; mouth, 5 pairs of legs (including pincers), gills (inside carapace);* <u>abdomen</u>: *5 pairs of swimmerets, uropods, telson; difference between males versus females.*
    - **Subphylum Hexapoda**
      You should be able to describe these animals':
        - characteristics
        - lifestyle

- **<u>Class Insecta</u>** = the insects
  - have <u>5 primary Orders;</u> you should be able to recognize these:
    - Coleoptera (beetles)
    - Lepidoptera (butterflies & moths)
    - Diptera (flies), Hymenoptera (bees, ants and wasps)
    - Hemiptera (true bugs, scales, aphids, etc.)

- <u>function and location of external anatomical characters on the grasshopper</u>: *head, thorax, abdomen, spiracles, antennae, compound eye, ocelli, mandibles*

- **Subphylum Myriapoda = millipedes and centipedes**
  You should be able to describe these animals':
  - characteristics
  - lifestyles
  - **<u>Class Diplopoda</u> (millipedes)** – circular body in cross section, herbivores, 2 pairs of legs/segment
    <u>Class Chilopoda</u> (centipedes) - dorsoventrally flattened, predators, 1 pair of legs/segment, first pair of legs modified into poison claws (unique)

- **Subphylum Chelicerata = spiders and scorpions**
  You should be able to describe these animals':
  - characteristics
  - lifestyles:
  - **<u>Class Merostomata</u> (horseshoe crabs)** – marine, long telson, ancient group
    <u>Class Arachnida</u> (spiders, scorpions, ticks, mites, etc.) – 4 pairs of legs on cephalothorax (unique), mainly terrestrial predators and parasites

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Phylum Arthropoda

This enormously successful phylum of **<u>ecdysozoan</u>** (see definition in the Chapter 10) animals has in excess of one million species discovered, and many more undiscovered. The arthropods have utilized almost every conceivable habitat throughout the world. They are, by far, the most successful (at least in terms of sheer species numbers) of the terrestrial invertebrates, are extremely abundant in marine and freshwater habitats, and have many **<u>symbiotic</u>** relationships with plants and animals. The relationship humans have with arthropods seems to be one of "love/hate", since they provide us with clothing, food, pollination of our crops, predation on other pests, but at the same time are responsible for the transmission of deadly diseases, destruction of our crops, animals, and structures.

The external features of the arthropods involve a number of characteristics that distinguish the phylum. For example, all arthropods are characterized by the presence of **<u>chitinous exoskeleton</u>** that covers all parts of the body. Often the chitin is supplemented by **<u>calcium carbonate</u>** to provide additional strength to the exoskeleton. Having this kind of exoskeleton means that the appendages must be jointed in order to move (Arthropoda = jointed foot). While in place, the exoskeleton prevents the continuous growth and expansion of the soft tissues of the arthropod body. Consequently, these animals must periodically shed their exoskeleton to grow. They do this through a complex process known as **molting**.

The entire body is divided into a number of segments, but in contrast to the Annelida, **segmentation is heteronomous** (= unequal). Through a process of reduction and fusion various segments evolved to operate as larger units that are referred to as **tagmata**. In the majority of arthropods the body consists of a **head**, **thorax**, and **abdomen** but quite a number of species have a fused head and thorax called the **cephalothorax** or **prosoma**.

Internally the Arthropoda have well-developed organ systems that provide for the variety of functions we generally associate with animals at this evolutionary level. Of particular interest are the **open circulatory system** (the internal cavity is called a **hemocoel**), the **respiratory system** (quite variable, including gills, book lungs, book gills, and trachea), the **digestive system**, the **nervous and sensory system**, and the **endocrine system**.

Our examination of the phylum Arthropoda will consider representatives of the four subphyla, emphasizing the major characteristics of these groups and some of the important classes (and in one case, major orders) within the subphyla.

Subphylum Trilobitomorpha

The members of this group are all extinct and are represented in the laboratory only by fossil specimens. We mention them here, however, because they are very commonly found fossils and are often offered for sale in various venues including gem and mineral shows, souvenir shops and the like.

Trilobites posses many of the external characteristics found in extant (= living) arthropods such as crustaceans and arachnids. This suggests that the trilobites were a pivotal ancestral group in the evolution of the arthropods.

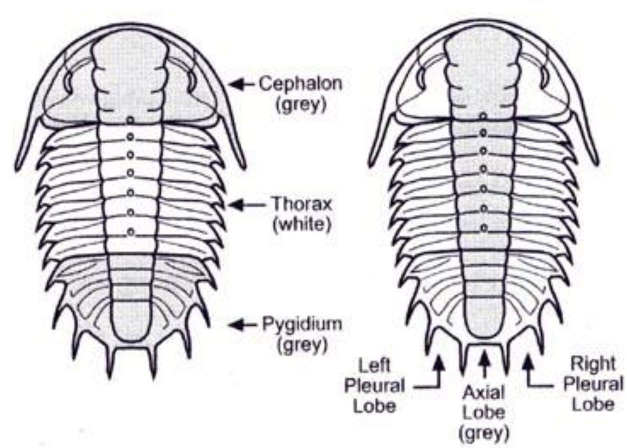


Figure 10.1 The major body segments of trilobites.

ACTIVITY 10-1: **Examine the demonstration fossil specimens and note the division of the body into head, thorax, and abdomen. Each of these units, which are called tagmata, have a number of segments that bear a pair of biramous (two**

branches) appendages. Use Figure 10.1 to help you in your examination of this group.

Subphylum Chelicerata

The chelicerates are characterized by the presence of six pairs of appendages: the anterior-most pair are the **chelicerae**, which used for food capture and manipulation, next are the **pedipalps**, which are also used for food manipulation as well as copulation, and other purposes. There are also **four pairs of walking legs.** The body of these animals is divided into two units, the **prosoma** or **cephalothorax** (fused head and thorax) and the **abdomen**.

There are three classes of the subphylum, two which we will consider in this lab.

Class Merostomata

These unusual arthropods are almost all extinct. The genus *Limulus* found along the eastern and southern coasts of the United States, is the only remaining living group; they have been in existence for over 350 million years. Horseshoe crabs are slow moving animals inhabiting mud and sand fiats and feeding on a variety of invertebrates.

ACTIVITY 10-2: **Visit the horseshoe crab demo. Note the characteristic external features of these unique animals using Figure 10.2 to help you in your examination of this group.**

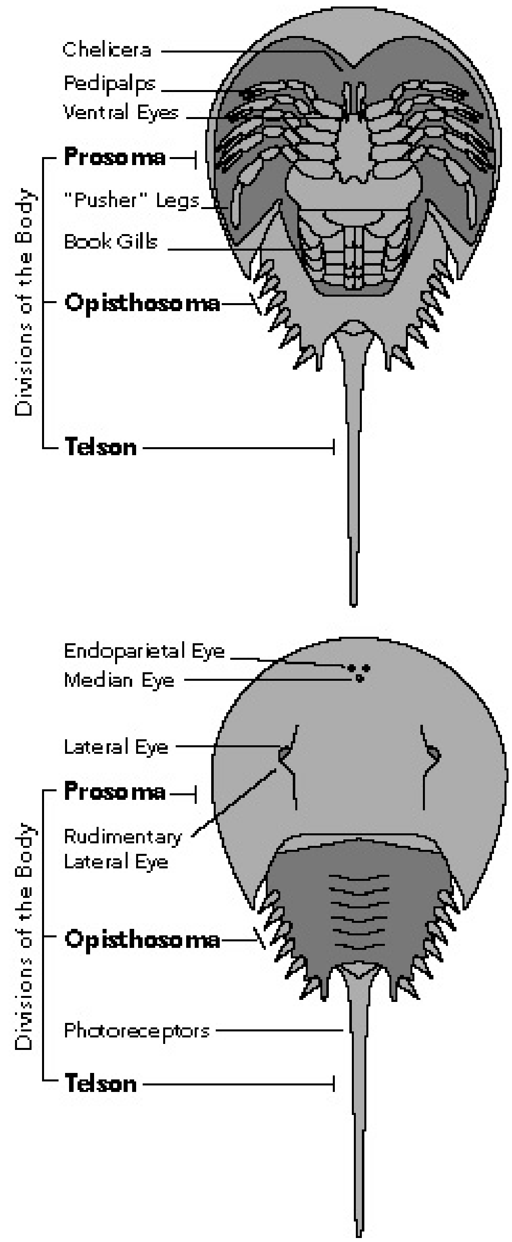


Figure 10.2. External anatomy of *Limulus* sp., the horseshoe crab.

Class Arachnida

Of considerably more importance than the previous class, the arachnids include a variety of animals not well appreciated by humans, though the vast majority have no relationship with us. Mention of scorpions, spiders, mites and ticks is usually enough to cause many of us to run, not walk, in the other direction. This is unfortunate as these arthropods are important and interesting animals.

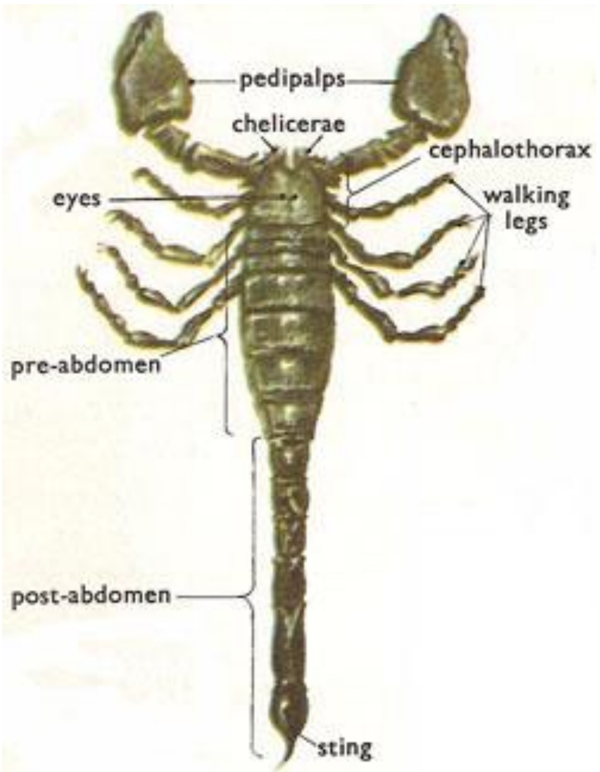


Figure 10.3. Dorsal view of the external anatomy of a scorpion. Note: the pre-abdomen and the post-abdomen collectively make up the opisthosoma.

Scorpions—These terrestrial animals of temperate and tropical regions of the world are characterized by a **prosoma** (= cephalothorax) and an **opisthosoma** (= abdomen). The latter has a **poison gland** and **stinger** at its distal end that is used for food capture and defense. The large pincers are the pedipalps and aid in feeding (Figure 10.3).

Figure 10.4. Dorsal view o f the external anatomy of a spider. Note: the cephalothorax is also known as a prosoma.

Spiders—This is a very large order of chelicerate arthropods of great interest to
zoologists. Spiders have an anterior **prosoma** (= cephalothorax) separated from the posterior **abdomen** by a thin **pedicel**. The **chelicerae** are fang-like and used to inject a toxin into prey. The small **pedipalps** are used by the male for copulation. Four pairs of walking legs are a characteristic feature and may be used to distinguish these animals from the insects. Major structures of spiders are the **silk glands** and **spinnerets** that are utilized to produce a fluid silk that, when extruded through the spinnerets,

hardens on contact with the air to form the characteristic spider webs, draglines, balloons, nests, and cocoons. Respiration occurs primarily through a pair of book lungs located at the anterior end of the abdomen (Figure 10.4). A number of live and preserved specimens of spiders are available in the laboratory for your examination.

<u>Mites and Ticks</u>—These generally small arachnids have a fused prosoma and abdomen and segmentation is not obvious. Many of these animals are serious parasites, causing considerable discomfort and serious medical problems for humans.

Dermacentor, a tick (Figure 10.5) lives on mammals and transmits a number of diseases including Rocky Mountain spotted fever . The hair follicle mite, *Demodex* (Figure 10.6), is a tiny mite which lives in and around mammal (including human) hair follicles. This animal is known to cause certain kinds of mange in dogs.

Figure 10.5. The tick *Dermacentor* sp.

Figure 11.6. The mite *Demodex* sp.

ACTIVITY 11-3: **Visit the Chelicerata demo. Note the characteristic external features of these animals using Figures 10.3-10.6 to help you in your examination of this group.**

<u>Subphylum Crustacea</u>

Crustaceans are primarily found in aquatic habitats and are extremely important members of marine and freshwater food chains. Members of this subphylum include such well-known animals as:

<u>Barnacles</u>—Curious, sessile animals with well-developed calcium carbonate plates surrounding the body. Balanus is found throughout the world.

"Water fleas" —Best represented by the genus Daphnia, a common inhabitant of freshwater ponds and lakes.

Isopods—Dorsoventrally flattened animals found in aquatic and terrestrial habitats. The common pill bug is a member of this order.

Amphipods—Laterally flattened, or curious "stick-figures", these animals art found in the marine and freshwater habitats.

Decapods—The largest order of crustaceans that include the crabs, shrimp, lobster, crayfish and hermit crabs.

Some of the distinctive characteristics of the Subphylum Crustacea include: (1) **biramous** appendages, (2) two pairs of **antennae** on the head, (3) one pair of **mandibles** serving as jaws, (4) two pairs of **maxillae** immediately behind the mandibles that are used for food manipulation, (5) **gills for respiration**, and (6) **exoskeleton frequently hardened with calcium carbonate** and often including a carapace over the **cephalothorax**.

There are a number of classes in this subphylum including Class Malacostraca (isopods, amphipods, krill, crabs, shrimp, etc.), Class Branchiopoda (fairy shrimp, water fleas, etc.) and Class Maxillopoda (ostracods, copepods, barnacles). In this laboratory exercise, we will only focus on one of the crustacean classes – Class Malacostraca.

Class Malacostraca

Malacostracans have a cosmopolitan (i.e., worldwide) range and can be found in most environments, particularly in marine, freshwater, and terrestrial environments. Malacostracans have an **chitinous exoskeleton overlaid by calcium-carbonate**. The body typically described as having a fused head and thorax, called a **cephalothorax**, and an abdomen.

Members of this class also typically exhibit **gills** as their main respiratory organ. In larger animals, a formal circulatory system is typically present and it is open. A fairly **well-developed, centralized nervous system** is present and **excretion of nitrogenous wastes occur across the gills or the body wall**. The **digestive system is complete**, with digestive waste released via an anus on the **telson**. Feeding strategies are varied with predators, herbivores, filter feeders, scavengers, and parasites all represented. Malacostracans are **dioecious** and most have a **larval stage**.

The crayfish, or "crawdad", the genus *Procambarus*, serves as a good introduction to the complexity of the external features of the arthropod body plan and as a good example of the crustacean, specifically the malacostracan, body plan (Figure 10.7). Note that there are two main divisions of the body: the anterior composed of the fused head and thorax, the **cephalothorax**, and a posterior portion, the **abdomen**, with obvious segmentation. A **carapace** covers the cephalothorax, providing protection especially to the gills located on the lateral sides of the body. Projecting from the body are a complex series of appendages that are used for a variety of purposes.

At the anterior portion of the animal you will note two pairs of **antennae**. The smaller, more anterior pair, are the **antennules**, and are followed posteriorly by the **antennae**, elongate appendages that are important chemosensory organs for the crayfish. If there are live crayfish in the lab and you "tickle" their antennae, you may note the great sensitivity of these structures.

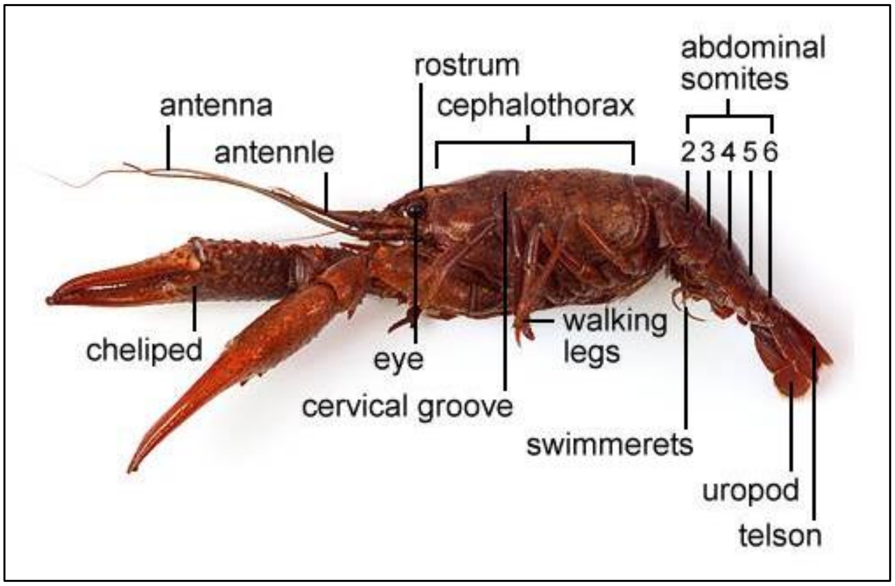


Figure 10.7. Lateral veiw of the external anatomy of *Procambarus* sp., the crayfish.

A pair of stalked **compound eyes** are prominent features of the head. Each eye consists of a large number of separate units, the **ommatidia**, which operate as individual light sensitive units (Figure 10.8). Remove a compound eye and examine it with a dissecting microscope, noting the complexity of this unique structure.

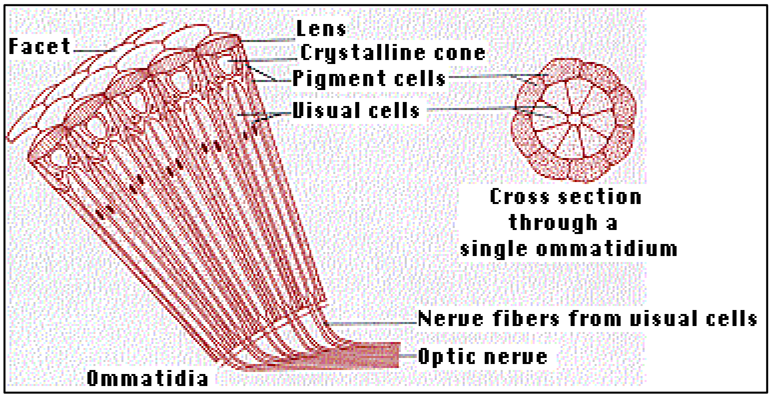


Figure 10.8. A closer look at the anatomy of an ommatidium, the principle structure of the compound eye in many crustaceans.

On the ventral side of the head region are the pair of **mandibles**, and immediately behind them, two pairs of **maxillae**. These are somewhat difficult to see, but with careful probing and dissection the appendages may be identified and removed.The second maxillae have a paddle-like projection, the **bailer**, that is used to pump water through the gill chamber. Along the ventral side of the "thorax" region are eight pairs of appendages. The first three pairs are small units and referred to as the **maxillipeds**. They are used for food manipulation and cleaning of the gill surfaces.

The last five pairs of appendages are called the **walking legs**. The anterior pair have large pinchers, or claws, and are called the **chelipeds**. They are used for food gathering and, obviously, protection! You might examine the defensive behavior of a live crayfish or crab and note how effectively they can use these appendages for protection. The remaining four pairs of walking legs are used for locomotion.

The abdomen is characterized by fan-like and bilobed appendages at the posterior end that are called the **uropods**. Between die uropods is found the last segment of the abdomen, the **telson**. The broad, flat structure of these units makes them particularly useful in swimming and rapid thrusting motions. The appendages on the anterior portion of the abdomen are called the swimmerets. In the male crayfish the two most anterior pairs are modified for sperm transfer during copulation. The remaining **swimmerets** are used for locomotion and water circulation; in the female they are also used to carry die developing eggs and young larval stages.

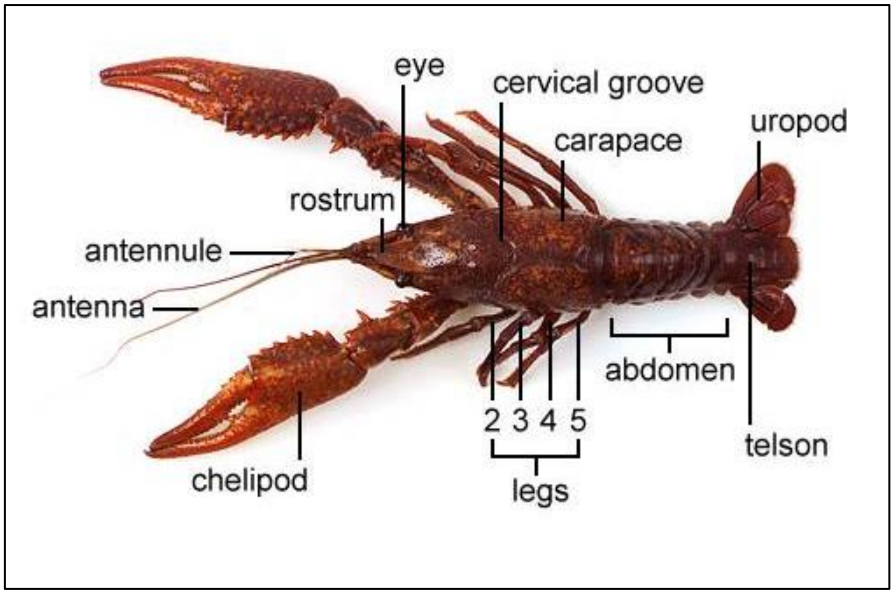


Figure 10.9. Dorsal view of the external anatomy of *Procambarus* sp., the crayfish.

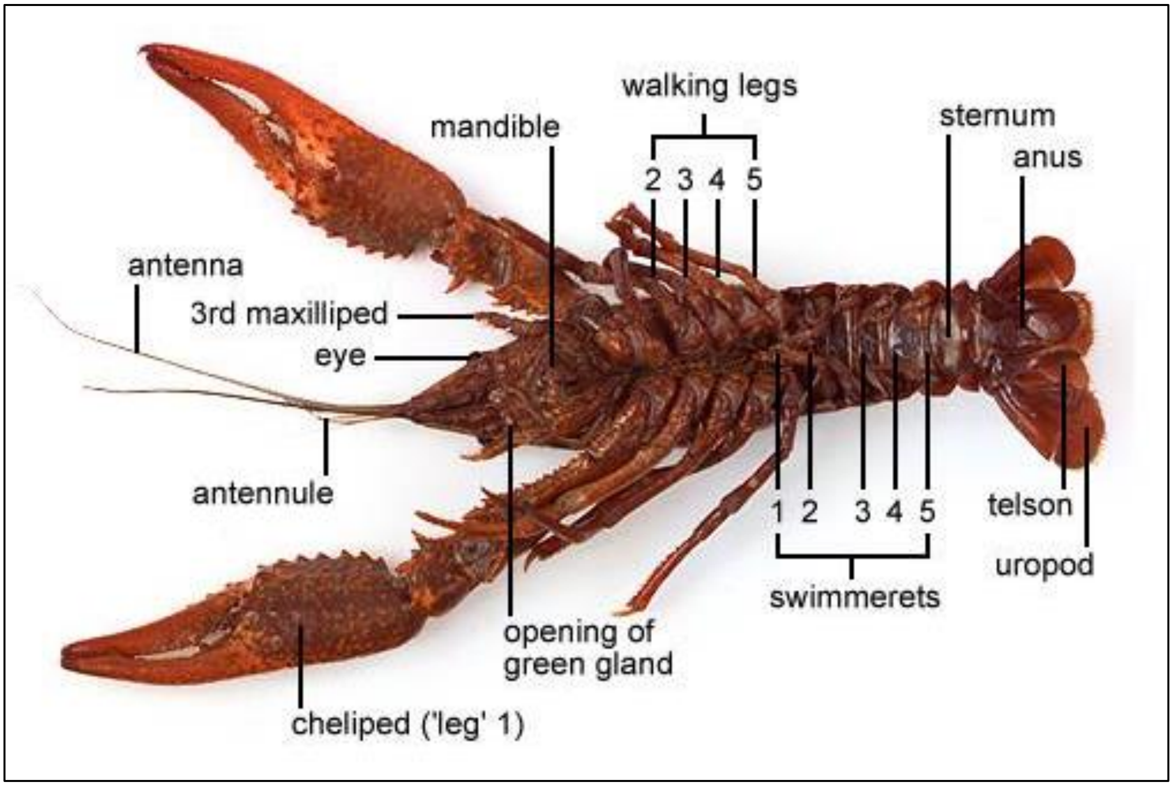


Figure 10.10. Ventral view of the external anatomy of a male crayfish.

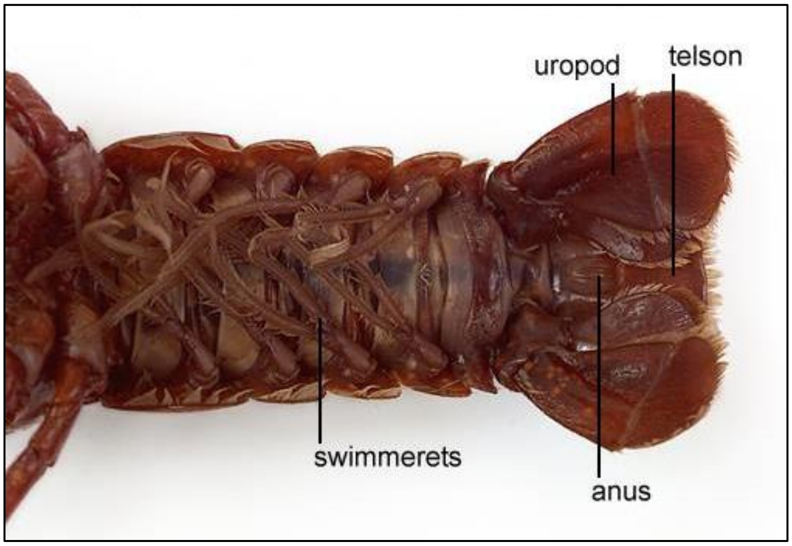


Figure 10.11. Ventral view of the abdominal external anatomy of a female crayfish.

ACTIVITY 10-4: **Visit the crayfish demo. Study the external anatomy of these animals, referring to Figures 10.7, 10.9, 10.10 and 10.11 and the dissection guide at your table to help you in your identification of the structures listed below.** *(Note: Supplementary charts and dissection guides will enable you to identify the main features of internal anatomy).*

Cephalothorax

- **rostrum**
- **carapace**
- **compound eyes**
- **mandibles**
- **2 pairs of antennae (1 longer pair called antennae & 1 shorter pair called antennules)**
- **mouth**
- **5 pairs of legs (including pincers)**
- **gills (inside carapace)**

Abdomen

- **5 pairs of swimmerets**
- **Uropods**
- **Telson**

Gender Differences

Be sure that you are also able to differentiate between males and females:

- **Males' chelipeds are disproportionately larger than females'**
- **The first pair of swimmerets in males are enlarged**

Subphylum Hexapoda

These animals, the insects, used to be included with the Class Crustacea in a subphylum Mandibulata, but the common prevalence of uniramous (unbranched) appendages and a single pair of antennae are considered by most arthropod specialists sufficient evidence to separate them from the crustaceans. Clearly, the most important class within the subphylum is the Class Insecta.

Class Insecta

This enormous class of highly diverse arthropods is the most important group Within the phylum. With regard to total number of species and individuals they clearly are the dominant terrestrial animals on the earth. The success of the insects can be attributed to a number of features such as (1) adaptability to a wide variety of ecological niches, (2) presence of wings for flying, (3) tough, protective exoskeleton, (4) aggressive, yet protective, behavior, and (5) metabolic systems adapted for a wide variety of conditions. Most insects have larval stages different in appearance and requirements of those of the adults. The larvae go through a proa of metamorphosis accompanied by a number of molts to develop into the adults.

Our survey of the Insecta will be necessarily brief, but with use of one common insect and the demonstration material of some of the most important orders ot insects, you should gain some appreciation of the basic organization and diversity of the class. The grasshopper, genus *Romalea*, is an ideal insect for observations of the external and internal anatomy.

The body is covered by a chitinous **exoskeleton** that consists of hardened plates or sclerites separated by thin membranous areas, the suture.The three tagmata of the insect body are the **head**, **thorax**, and **abdomen**, all easy to recognize from each other. On the head of the grasshopper note the one pair of antennae, **one pair of prominent compound eyes**, **three ocelli (simple eyes)** between the compound eyes, and the **chewing mouthparts**. These mouthparts include a dorsal labrum (upper lip), pair of mandibles, pail oi' maxillae, a ventral labium (lower lip), and the hypopharynx (tongue). The **thorax** consists of fused segments, but ma) be general!) divided into a prothorax, mesothorax, and metathorax. Each of these units bears one pair of walking legs. The mesothorax and metathorax each have a pair of wings. Spread the wings out and note the difference in construction between the fore and hind wings. Often in insects the (brewings arc heavier and more protective in nature than the thinner, membranous hiitdwiiigs. There are prominent wing veins formed by thickening of the exoskeletal cuticle around the tracheae, nerves, and blood sinuses.

The three pairs of legs arc used for walking and climbing, but the third pair are also modified lor leaping by increasing the size and musculature of the femur and tibia portions. In male grasshoppers the inner surface of the femur has a row of spines that are rubbed against the forewings to produce sounds.

The abdomen df the grasshopper is more or less cylindrical and consists of eleven segments, the last three of which are modified for copulation and egg laying. Look closely along the lateral sides of the abdominal segments for ten pairs of spiracles, openings lor the tracheal tubes extending into the inner tissues of the body. The first abdominal segment has a pair of tympanic membranes serving as a hearing organ.

ACTIVITY 10-5: **Examination of a preserved specimen of *Romalea* to study the external anatomy of insects. Use Figures 10.12 and 10.13 to aid you in your study).**

External Anatomy

1) In groups of four, obtain a circular wax petri dish.
2) Place your grasshopper in the petri dish.

Examine your specimen and identify the following external characteristics:

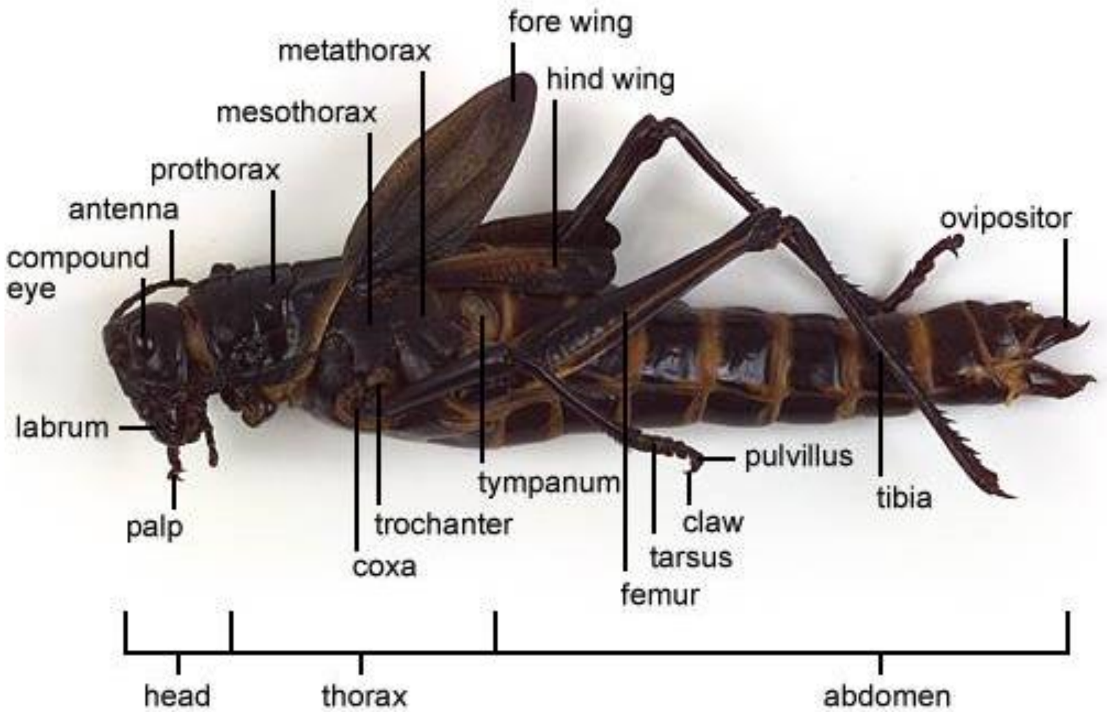


Figure 10.12. The external features of a grasshopper.

- **Head, thorax, and abdomen**

<u>Head section</u>
- **antennae**
- **compound eyes**
- **ocelli**
- **maxilla**
- **mandibles**
- **labrum**
- **labium**

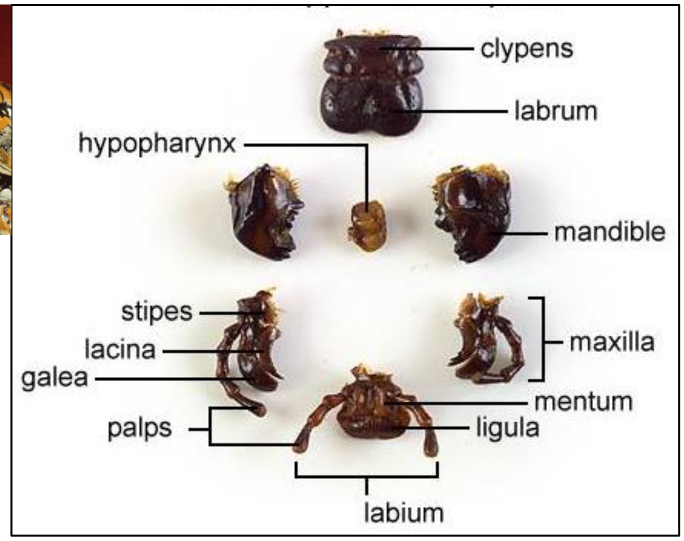


Figure 10.13. The mouthparts of a grasshoper.

<u>Thoracic region</u>
- **prothorax**
- **mesothorax**
- **metathorax**
- **thoracic legs (femur + tibia)**
- **wings (forewings and hindwings)**
- **tympanum**

<u>Abdomen region</u>
- **spiracles**

The internal anatomy of insects is best observed in living or freshly killed specimens such as the American cockroach, *Periplaneta* (Figure 11.14). Although we will not dissect an insect this year, we can use the figures of *Periplaneta* to examine their internal anatomy.

ACTIVITY 10-6: Study Figures 10.14-10.22 as you read through the information on insect internal anatomy below.

The **<u>foregut (= stomodaeum)</u>** consists of the **<u>pharynx</u>**, **<u>esophagus</u>**, **<u>crop</u>** and **<u>proventriculus</u>**. The esophagus and crop form a continuously widening sac with no real division between them. Salivary glands are adpressed to the lateral sides of the crop. The proventriculus is cup-like and at the posterior end of the crop; it serves as the entrance to the midgut. The midgut has eight **<u>gastric caecae</u>** attached to its anterior edge. These are used for temporary storage and digestion. At the posterior end of the midgut in association with the junction to the hind gut are a large number of yellowish **Malpighian tubules** that are used for collection of excretory products from the surrounding hemocoel. Waste products are collected in the tubules and emptied into the hindgut passed out through the anus.

The **hindgut** (= **proctodaeum**) consists of the anterior **intestine** and the **rectum** Both the hindgut and the foregut have a thin lining of exoskeletal material that is lost with each molt and must be replaced along with the new exoskeleton. The intake of oxygen, its distribution to the tissues, and the removal of carbon dioxide are accomplished by means of an intricate system called the **tracheal system**. This tracheal system begins externally with the **spiracles**, which serve to connect the internal part of the system with the outside. The spiracles connect with the **trachea (= trachael tubes)**, the principal tubes of the system. These **trachael tubes** spread by means of finer and finer tubes, the **trachioles**, throughout the tissues. In fresh specimens these tubules appear as fine silver-white structures throughout the body.

The **open circulatory system** of the insects is characterized not only by the **hemocoel**, but a well-developed dorsal vessel consisting of an aorta and hear!. Ii might be possible to find this structure by careful probing along the dorsal midline of your specimen. The **nervous system** is typical of arthropods and consists of a **dorsal brain** followed by a **ventral, longitudinal nerve cord**. The cord contains a pair of ganglia in each segment. It might be possible to see this nervous system if you were particularly careful in opening a specimen from the dorsal side.

The gonads of the **reproductive system** are located in the abdomen, testes in the male and ovaries in the female. The female tract includes a pair of oviducts leading to the vagina that opens to the outside. A spermatheca, for temporary storage of sperm, and other accessory glands are associated with the tract. In the male the testes are followed by the vas deferens which then unite to form an ejaculatory duct leading to the outside through an intromittant organ that is used for sperm transfer to the female.

Figure 10.14. ***Periplaneta americana*** **- Dorsal surface of the American cockroach Showing external features.**

Figure 10.15. ***Periplaneta americana*** **- Ventral surface of the American cockroach showing external features.**

Figure 10.16. ***Periplaneta americana*** **- Detail of the ventral surface of the cockroach head showing the mouthparts, compound eyes and antenna.**

Figure 10.17. Insecta - ***Periplaneta americana*** **- Tip of the female abdomen of the cockroach.**

Figure 10.18. ***Periplaneta americana*** **- Ventral view of the posterior end of the male cockroach – cerci are present**

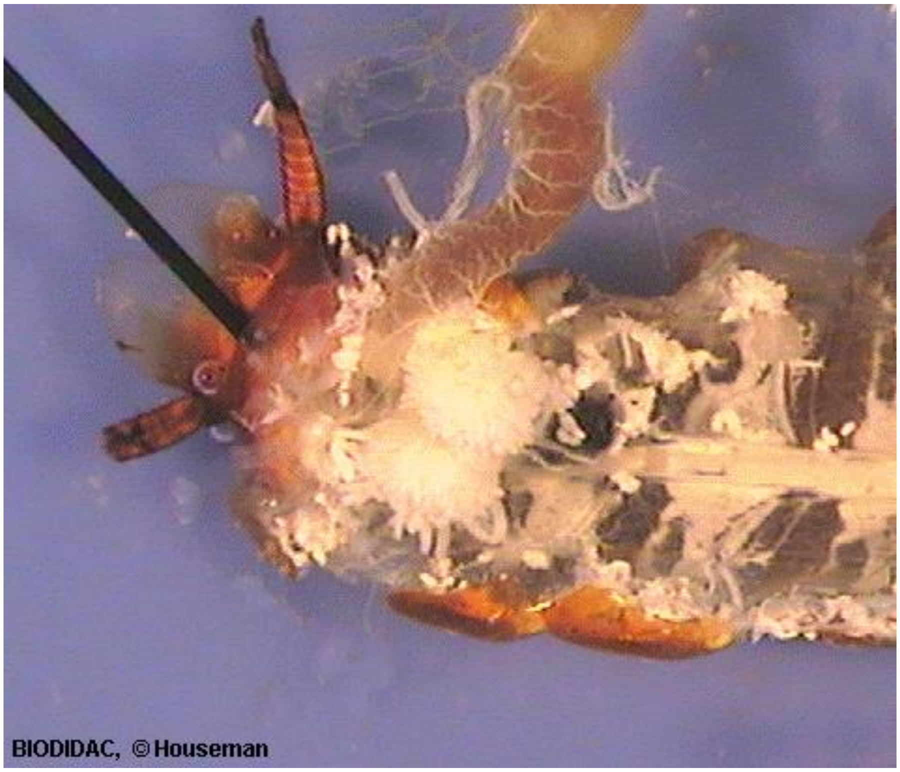


Figure 10.19. ***Periplaneta americana*** **- Dissection of the male cockroach showing the mushroom body. Some of the fat body has been removed to show the nerve cord.**

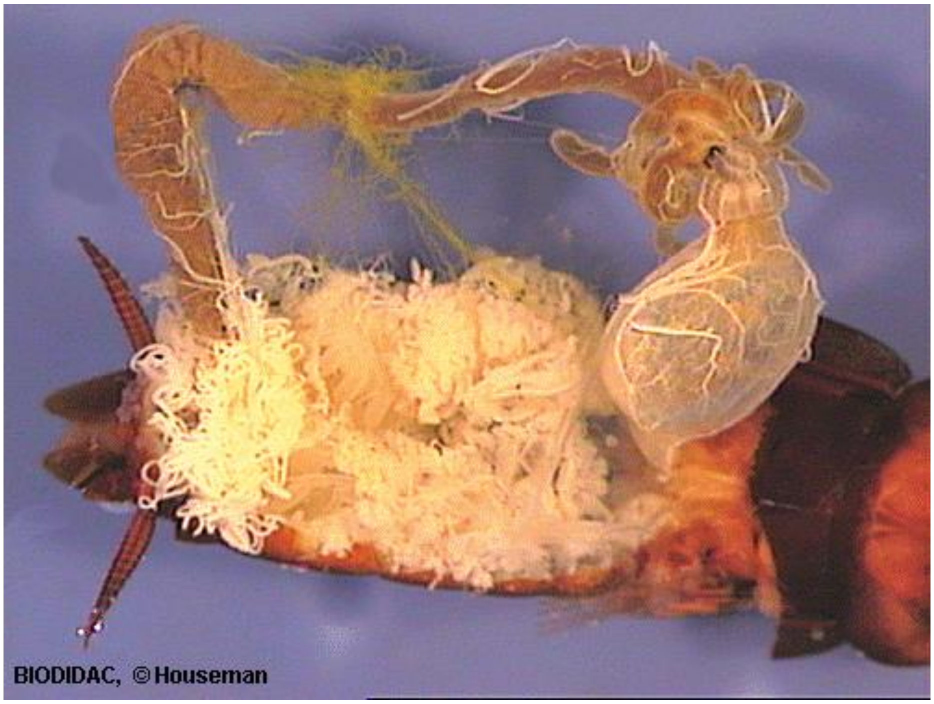


Figure 10.20*.* *Periplaneta americana* - Dissection of the cockroach showing the digestive tact, fat body, ovaries, and female accessory glands – collaterial glands.

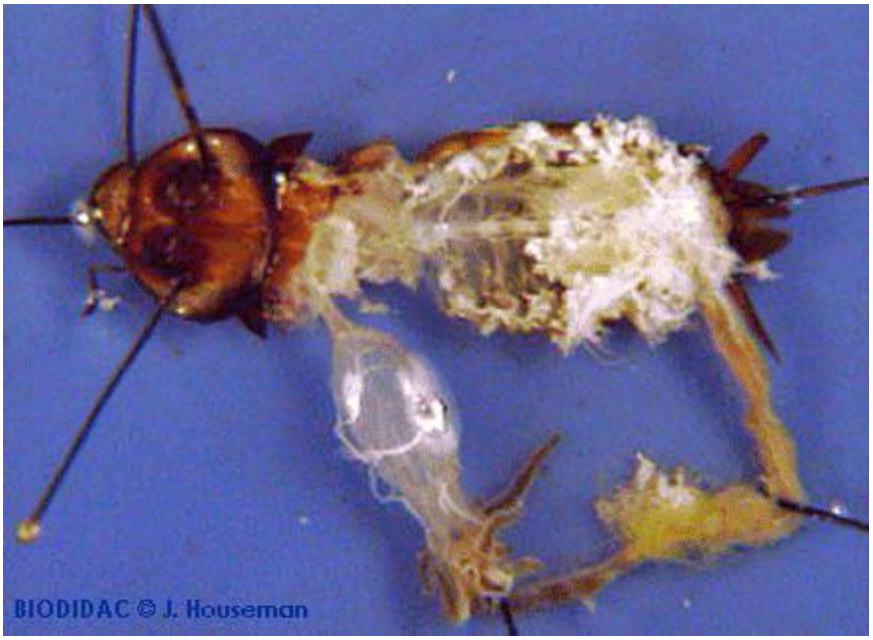


Figure 10.21. ***Periplaneta americana*** **- Dorsal view of the dissected cockroach: nervous system, digestive system, female reproductive system, Malpighian tubules and fat body.**

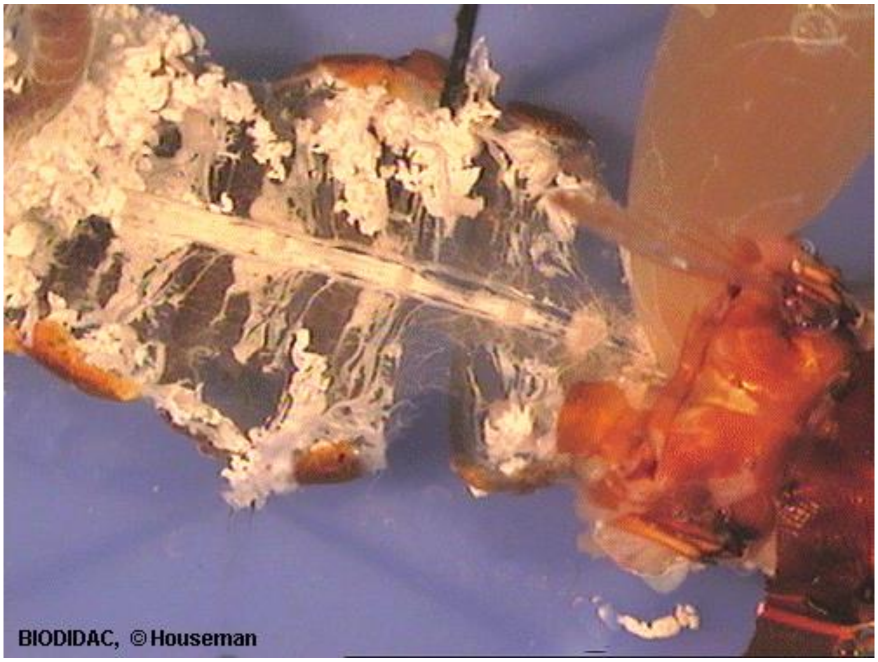


Figure 10.22. ***Periplaneta americana*** **- Abdomen of the cockroach dissected to show the nerve cord and the tracheal trunks.**

Subphylum Myriapoda

Figure 10.23. Centipedes (a) and millipedes (b) are examples of myriapods.

There are approximately 13,000 species of arthropods grouped into subphylum Myriapoda including the centipedes and millipeds (Fig. 10.23). Myriapods, which range in size from nearly microscopic to 30 cm in length, are all terrestrial. All are terrestrial with most living in humid environments. They can be found in soil, in leaf litter, or under items like rocks or pieces of wood. Many species possess **repugnatorial glands**, from which foul-tasing compounds are secreted as a mechanism of defense.

Myriapods, “many legged ones”, have up to 200 pairs of appendages depending on the species. Moreover, similar to insects, with which they were formerly grouped, centipedes, millipedes and their relatives are **uniramous**, meaning they have legs which do not split into two at their posterior end; they have one ramus or branch.

Two period groups of note are the chilopods, the centipedes, and the diplopods, the millipedes:

Class Chilopoda

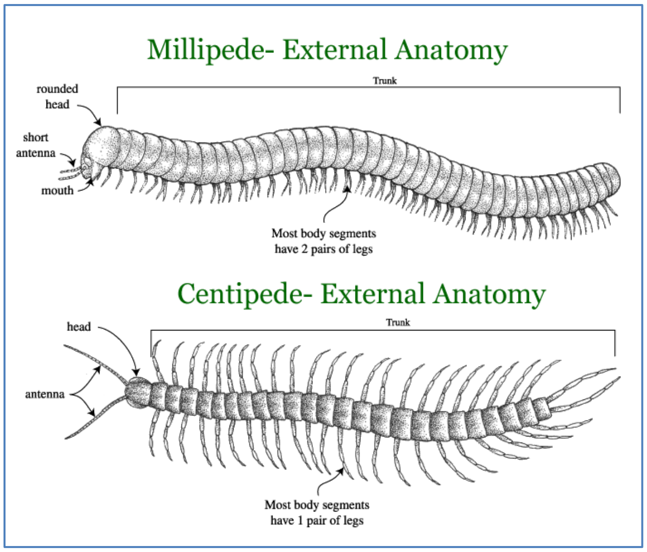


Figure 10.24. External anatomy of a millipede and centipede.

There are approximately 2,500 species of centipedes. Like millipedes, centipedes have bodies that can be separated into a **head** and a **trunk** (see Fig. 10.24). Their bodies are **dorsoventrally flattened** and are made up of a chain of many segments (can be up to/greater than 150). Each segment except the one behind the head and last two bear a single pair of **uniramous legs**. The appendages of the first body segment, the head, have been modified to form large, **fangs** capable of delivering poison and that are used to capture prey. Centipedes tend to be **small in size** although some can get as large as 25 cm (10 in). The larger the centipede, the more likely that its bite would be considered to be painful to a human and even dangerous to a small child.

As implied above, centipedes are **predatory**, feeding on invertebrates that reside in the soil such as earthworms and terrestrial insects. All centipedes dwell in **moist, terrestrial habitats**. Following internal fertilization with use of a spermatophore, centipedes will produce eggs. They have direct development; so when the eggs hatch, the young resemeble disproportionately-shaped adults.

Class Diplopoda

There are approximately 8,000 species are millipedes. Millipedes are cateogorized as diplopods, or "double legs". Like centipedes, they have e**longated bodies** but millipedes have more **rounded trunks** (see Fig. 10.24). Moreover, save for the first four thoracic segments, **each body segment has two pairs of legs**.

Millipedes **live in moist habitats** and many are very proficient burrowers. Most millipedes are **herbivores or detritivores**, feeding on decaying vegetation and animal matter. Unlike centipedes, millipedes do not have “poison claws” and do not bite. Instead, to discourage predators they roll into a defensive ball and many release poisonous or foul-smelling substances.

FOR MORE INFORMATION…

- **The University of California Museum of Paleontology – The Arthropoda**
  http://www.ucmp.berkeley.edu/arthropoda/arthropoda.html
  Variety of biological facts about arthropods.

- **Animal Diversity Web – The Arthropoda**
  http://animaldiversity.ummz.umich.edu/accounts/Arthropoda/
  Variety of biological facts about arthropods.

- **Animal Diversity Web – The Arthropoda**
  http://www.bbc.co.uk/nature/life/Arthropod
  Arthropod videos, news and facts.

CHAPTER 11

SEA STARS AND THEIR RELATIVES (Phylum Echinodermata)

Objectives

You should be able to:

- identify:
  - the level of organization seen in these animals
  - the type of symmetry seen in these animals (larval versus adult stages)
  - the number/type of embryonic tissue layers found in these animals
  - the type of skeleton found in these animals
  - whether a coelom is present and, if so, in what form
- indicate if nervous, respiratory, circulatory (open/closed?), osmoregulatory/excretory, or digestive systems (incomplete/complete) are present and, if so, in what form
- indicate whether these animals are monoecious or dioecious
- describe the types of habitats in which these animals can be found
- describe the kind of lifestyle these animals live
- Recognize this phylum and the name and important characteristics of the following classes:
  - **Class Asteroidea** = **sea stars**
    You should be able to describe these animals':
    - characteristics
    - lifestyle
    - function and location of *external* anatomical characters on the sea star: central disc, arms, aboral and oral sides, spines. ambulacral grooves, madreporite = sieve plate, tube feet, mouth, spines

      function and location of *internal* anatomical characters on the sea star: pyloric caecae (= digestive glands; also function in absorption and storage), cardiac and pyloric stomachs, gonads (in arms), endoskeleton plates, ambulacral plates, radial canal, circular canal = ring canal, lateral canal, ampulla of tube feet

      Also, although you will likely not see these structurs, you should know the general location and function of the following: anus, skin gills, pedicillaria, lateral canal, stone canal
  - **Class Ophiuroidea** = **brittle stars**
    You should be able to describe these animals':
    - characteristics
    - lifestyle

- **Class Echinoidea** = **sea urchins and sand dollars**
  You should be able to describe these animals':
  - characteristics
  - lifestyle

- **Class Holothuroidea** = **sea cucumbers**
  You should be able to describe these animals':
  - characteristics
  - lifestyle

- **Class Crinoidea** = **sea lillies and feather stars**
  You should be able to describe these animals':
  - characteristics
  - lifestyle

Introduction to the Deuterostomic Animals

Members of the deuterostomic animals include both invertebrate and vertebrate organisms and today's laboratory will serve as an introduction to these unique organisms. There are only two major phyla in this line of animal evolution, the Echinodermata and the Chordata, and both phyla contain a diversity of animal species. These animals share a number of embryological characteristics that differentiate them from the protostomic invertebrates. For example, the embryonic mouth forms secondly, after the formation of the anus from the **blastopore**, the first opening of the embryonic gut; hence the term deuterostome (= second mouth). In addition, both phyla have a **coelom which is formed from outpockets of the embryonic gut**, **mesoderm fully lining the coelom**, and an early development pattern in which the **fate of the cells of the blastula is not determined until the gastrulation process begins** (see Figure 11.1). All of these basic developmental and anatomical characteristics are different than those found in almost all other phyla, and thus the echinoderms and chordates occupy a separate major branch of the animal evolutionary tree.

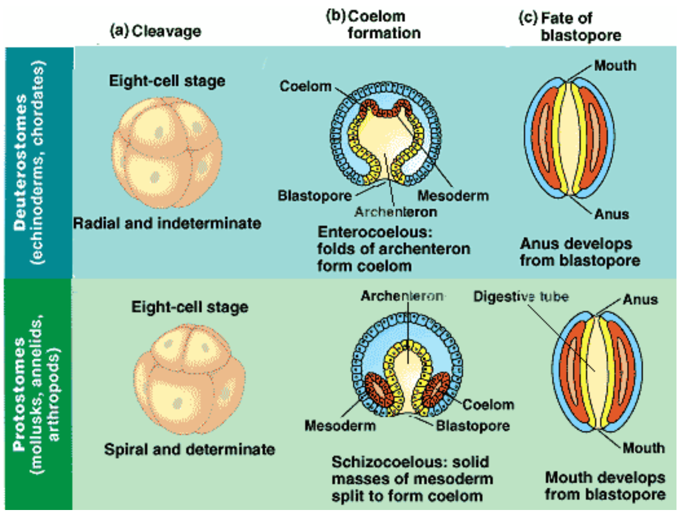


Figure 11.1. Summary of the differences between protostomes and Deuterostomes.

Since we are members of the Phylum Chordata, this has the rather interesting implication that our closest invertebrate relatives are sea stars, sea urchins, and their relativesI It also suggests why the Chordata is of particular interest to us.

Phylum Echinodermata

The spiny-skinned animals of the phylum Echinodermata are considerably different from most of the other members of the animal kingdom. They are members of the **deuterostomic** line of invertebrate evolution, having embryological charac teristics which more closely align them with the Phylum Chordata than the protostomic invertebrates that constitute the majority of higher invertebrates.

The most obvious characteristic of the echinoderms is the presence of a **calcium carbonate endoskeleton** made up of numerous separate **ossicles**. This endoskeleton is manifested externally in the form of spines and tubercles that form the well-known "skin" of the echinoderms. The body of the adult animals is organized around a central axis, a **pentaradial symmetry** built on a plan of five or multiples thereof. Interestingly, the echinoderms have larval stages that are **bilaterally symmetrical**, and when they undergo metamorphosis to the adult stage, the symmetry is changed to pentaradial. The adult symmetry reflects the generally sluggish and/or sessile habits of these marine animals.

A distinctive feature of the echinoderms is the **water vascular system**, a complete network of canals that circulates sea water and body fluids serving primarily to operate the tube feet. These structures, extending out of **ambulacral grooves**, are used for locomotion, food-gathering, and respiration. Most echinodcrms have a complete digestive system (some are herbivores, others carnivores or omnivores), rudimentary circulatory, excretory, respiratory, nervous and sensory systems, and seasonally-developed gonads. They are surprisingly simple animals compared to the other animals considered in this laboratory exercise. Our brief examination of echinoderms will cover the five classes of the phylum, most of which are well-represented in the fauna along the central California coast.

Class Asteroidea

Anyone who has wandered about the tidepools of our coast is aware of the members of this class, the seastars. These distinctive members of rocky intertidal communities are common, colorful and important members of this habitat. Two excellent representatives are *Pisaster*, the ochre-star, and *Asterina*, the bat star, and we will use them to learn a little about this class of echinoderms.

ACTIVITY 11-1: Dissection of a (preserved) seastar. In groups of four, with the aid of Figure 11.2-11.10 and the additional dissecting chart on your table, obtain and dissect a preserved sea star and review and identify the external and internal structures listed below and their function.

External Anatomy

Aboral (=dorsal) Surface

a) In groups of four, obtain a seatar and a dissection pan.
b) Place your sea star in the dissection pan with its dorsal or aboral (top) surface facing upward.
c) Observe the starfish and review its symmetry.
d) Locate the **central disc** in the center of the starfish and the **five arms (= rays)**.
e) Locate the small, round hard plate called the **madreporite** (= **sieve plate**) on top of the central disc.Water enters through this into the **water vascular system**.
f) Feel the upper surface of the starfish for **spines**. These spines protect the sea star and are part of their internal skeleton (= endoskeleton).
g) Look at the tip of each arm and see if you can find the **eyespot**.

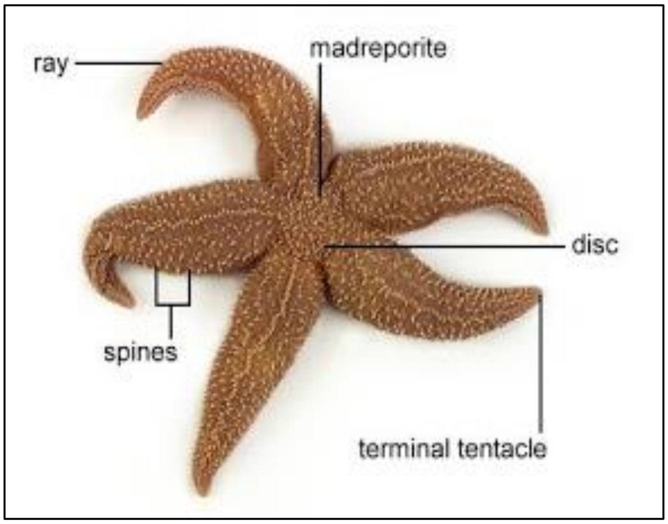


Figure 11.2. Aboral side of a sea star.

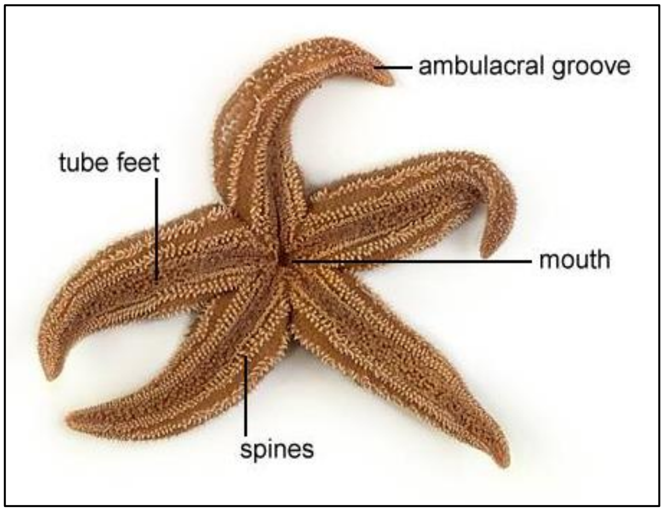


Figure 11.3. Oral side of a sea star.

Oral (=ventral) Surface

h) Turn the starfish over to its **oral** (= ventral or underside) surface.
i) Locate the **mouth** in the center of the **central disc**. Find the ring of **oral spines** surrounding the mouth.
j) Find the groove that extends down the underside of each arm. This is called the **ambulacral groove**.
k) Feel the numerous, soft **tube feet** inside each groove. These are part of the water vascular system and aid in movement and feeding.

Figure 11.4. Close up view of sea star tube feet.

Internal Anatomy

l) With the sea star's aboral surface facing you, cut off the tip of an arm (= ray). Then cut a flap of skin off the top of the arm (see Figure 11.5) and remove this flap of skin.

m) Observe the parts of the **tube feet** as they appear both internally and externally. In addition to feeding and locomotion the tube feet, along with **skin gills** located throughout the aboral side of the animal, function in gas exchange.

n) Find the zipper-like ridge that extends the length of the arm. The tube feet are attached to these.

o) Locate the bulb-like top of a tube foot called the **ampulla**. This sac works like the top of an eyedropper to create suction. The bottom of the tube foot is a sucker.

p) Inside each arm, locate two long digestive glands called the **pyloric caeca** (pyloric caecum = singular). These make enzymes which are sent to the pyloric stomach to aid in digestion of food.

q) Cut a circular flap of skin from the **central disc**. *(You will have to also cut around the madreporite in order to remove this flap).* Observe the **pyloric and cardiac stomachs** *(may be hard to distinguish between the two***)** under the **central disc**.The mouth connects via a short esophagus (will not really be visible here) to a pouch-like **cardiac stomach** which, in turn, opens into the more dorsally/aborally-located **pyloric stomach**. The cardiac stomach can be everted through the mouth to be used to

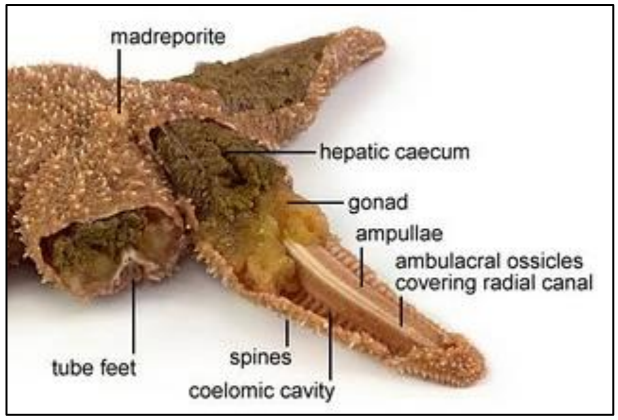


Figure 11.5. Aboral view of the internal anatomy of a sea star.

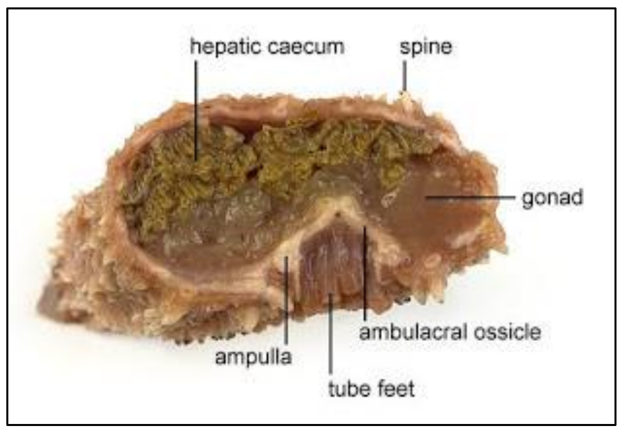


Figure 11.6. Cross section of an arm of a sea star.

Figure 11.7. Aboral view of the internal anatomy of the central disk region of a sea star.

deliver digestive enzymes to prey, such as mussels. Alternatively, the pyloric stomach stays inside of the sea star and, the **pyloric caecae** produce digestive enzymes which are routed to the pyloric stomach to aid in digestion. A short intestine connects the pyloric stomach to the **anus** (hard to see on your preserved animal).

r) Remove the pyloric caeca from the dissected arm. Find the **gonads** *(testes or ovaries)* underneath. These may be small if the starfish is not in breeding season. Sea stars are **dioecious** but males and females are not really distinguishable without microscopic examination. In nature, males and females release sperm and eggs, respectively, into the surrounding seawater environment, where fertilization takes place. The resulting zygotes develop into **bipinnaria larvae** (see Fig. 11.9).

s) Remove the gonads to see the rest **of** the **water vascular system**. Note how the **radial canal** in the arm connects to the **circular canal** **(= ring canal)** in the area of the **central disk** (which you can reveal by removing the structures in that area after you examine them).

t) The nervous system, which you will not be able to see easily in your specimen, consists of a circular **nerve ring** which surrounds the moth, and a radial nerve which runs through each arm and connects with the light sensing **eyespot** at the tip of each arm.

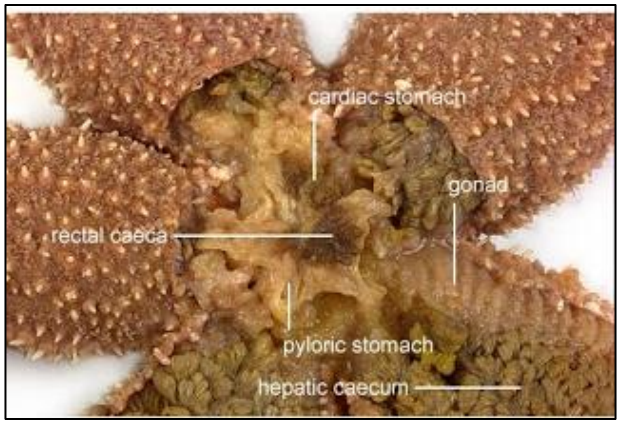


Figure 11.8. Aboral view of the digestive organs of a sea star.

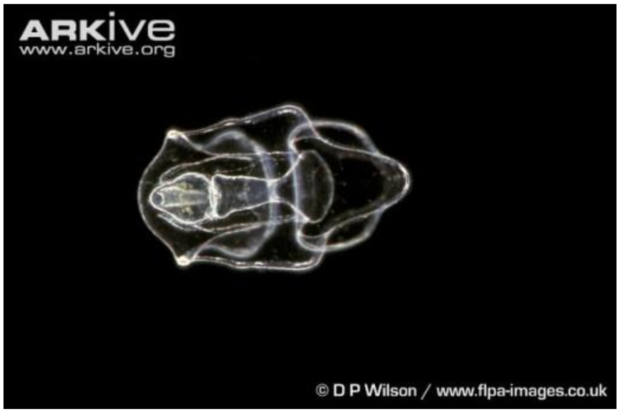


Figure 11.9. Bipinnaria larva, a developmental stage in Asteroid echinoderms.

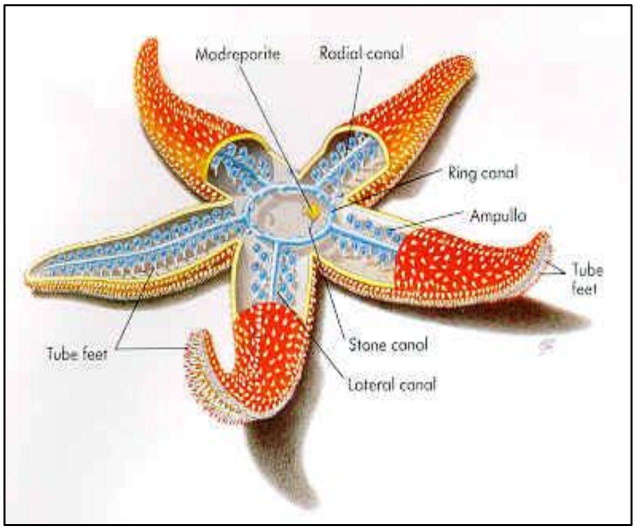


Figure 11.10. The water vascular system and other internal features of a sea stars.

u) Embedded in the soft body wall are skeletal plates called **<u>ossicles</u>**.
v) Running down the center of each arm is a **<u>radial canal</u>** (= **<u>lateral canal</u>;** see Figure 11.10) to which tube feet are attached.
w) In the central disc the five radial canals connect to the **<u>ring canal</u> (= circular canal)**.
x) A short, canal called the **<u>stone canal</u>** leads from the ring canal to the **<u>madreporite</u>** where water enters.
y) After examining the pyloric and cardiac stomachs and the madreporite, remove these structures to reveal the **<u>circular canal</u>** (= **<u>ring canal</u>**) section of the water vascular system. Note how it connects up to the radial canal in the arm from which you removed the gonads and pyloric caeca.

Clean up

z) When you are done reviewing the internal and external features of the sea star, place your sea star in the appropriate biohazard container. Also rinse your dissecting tray and the rest of your tools, and place these materials in their appropriate storage areas.

ACTIVITY 11-2: Other specimens representing Class Asteroidea are available.

1) Visit the preserved specimens on demo and review the characteristic external features of these animals using Figures 11.2-11.10 to help you.
2) <u>View the demo slide</u> of a crossection of a seastar arm. You can use Figure 12.11 as a resource for this task.
3) View the whole mount of a sea star **<u>bipinnaria larva</u>**. The digestive tract including the mouth, esophagus, stomach, intestine and anus should be visible. You can use Figure 11.9 as a resource for this task.

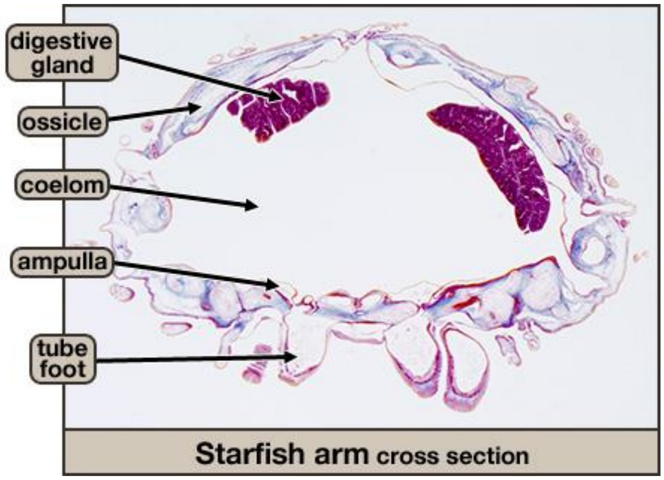


Figure 11.11. Crossection of a sea star arm.

Class Ophiuroidea

Brittle stars (Fig. 11.12) are closely related to the asteroids, which may not be that surprising to you considering their appearance. With that said, brittle stars are placed in a separate taxonimic class because they differ from seastars in a variety of ways including the very narrow arms and the separation of their arms from their central disc.

Figure 11.12. Dorsal and ventral views of a brittle star.

Locomotion is primarily accomplished by the muscular movement of the arms as opposed to the movement of their tube feet. Ophiuroids have an incomplete digestive system; and the tube feet are used for feeding. Brittle stars are found under rocks and vegetation in the rocky intertidal, but larger populations occur in subtidal regions of marine habitats. An unusual group of animals called basket stars are also members of this class. In these animals the arms are divided into numerous subunits forming a complex tangle of arms that arc used for locomotion and feeding.

ACTIVITY 11-3: Specimens representing Class Ophiuroidea are on demonstration. Visit the specimens on demo and review the characteristic external features of these animals.

Class Echinoidea

The echinoids include the sea urchins (Figure 11.13), heart urchins and sand dollars (Figure 11.14). As with other echinodetms they have an endoskeleton composed of ossicles, but in this case the ossicles are fused into a solid unit called the **test** (see Figure 11.15). The spines are attached to the test by means of "ball-and-socket" joints that gives them flexibility.

Figure 11.13. Dorsal view of the external surface of a sea urchin.

In the sea urchins holes in the test along the **ambulacral grooves** provide openings for the elongate tube feet to extend out beyond the spines which enable the urchins to move. Sand dollars and heart urchins use the spines rather than tube feet for locomotion.

Figure 11.14. Dorsal view of a sand dollar.

On our coast the purple urchin, *Strongylocentrotus*, is very characteristic of lower tidepools. It is an herbivore which grazes on attached or drift algae that it catches with its spines and **pediceilaria**. The algae is taken into the digestive system through a complex feeding device called **Aristotle's lantern** (Figure 11.16). External evidence of this can be seen on the oral side where five small calcium carbonate teeth extend outward through the mouth.

Figure 11.15. Sea urchin test.

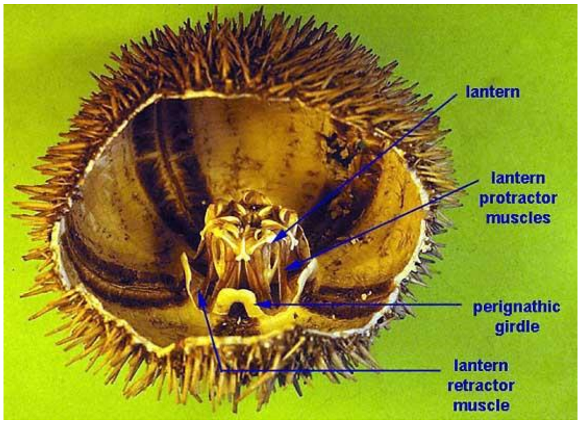


Figure 11.16. Cutaway of a sea urchin body to reveal its Aristotle's lantern (Source: The Full Wiki, http://www.thefullwiki.org/Aristotle's_lantern.

ACTIVITY 11-4: Specimens representing Class Echinoidea are on demonstration. Visit the specimens on demo and review the characteristic external features of these animals using Figures 11.13-11.16 to help you.

Class Holothuroidea

Perhaps the most unusual of the echinoderms are the sea cucumbers (Fig. 11.17), which are members of the Class Holothuroidea. They are found in most marine environments, but are most diverse on tropical shallow-water coral reefs. They range from the intertidal, where they may be exposed briefly at low tide, to the floor of the deepest oceanic trenches. They are found primarily in subtidal habitats, however.

These animals have elongate, cylindrical bodies with tough, flexible body walls. The endoskeleton is reduced to microscopic **ossicles** embedded in the wall. The oral side of the animal is at one end of the body. The mouth is surrounded by **tentacles** that are used for feeding, either by filtering water or by transferring quantities of bottom detritus into the mouth.

Figure 11.17. A sea cucumber.

ACTIVITY 11- 5: Specimens representing Class Holothuroidea are on demonstration. Visit the specimens on demo and review the characteristic external features of these animals.

Class Crinoidea

Living crinoids (Figure 11.18) mostly inhabit deep water.They superficially resemble sea stars, but with the mouth facing upwards.These animals represent the most "primitive" (i.e., least highly derived) of the echinoderm classes. In fact, they have been referred to as a **"living fossil"** since they appear to look the same today as they did hundreds of millions of years ago when they first came on the evolutionary scene. With their five arms (or more, but usually in multiples of five) crinoids are unusual looking animals because they look more like plants than animals, hence the name "sea lilies". But they are not plants; crinoids have muscles, nerves, a gut, a reproductive system, and other features of "advanced" animals even if it does not superficially look like it.

Figure 11.18. A yellow crinoid. Philippine Islands, Occidental Mindoro, Apo Reef.

It turns out scientists believe that crinoids evolved a plant-like morphology so that they could remain attached to the seafloor while they spread their arms to catch food.

Stalked crinoids, or "sea lilies", lived attached to the bottom, and filter plankton from the from the currents flowing past them.The sea lilies and feather stars swim by gracefully moving the arms up and down. These animals (see photographs in lab) are not commonly found in California waters.

ACTIVITY 11-6: Specimens (well, photographs) representing Class Crionoidea are on demonstration. Visit the specimens on demo and review the characteristic external features of these animals.

FOR MORE INFORMATION…

- **The University of California Museum of Paleontology – the Echinodermata**
  http://www.ucmp.berkeley.edu/echinodermata/echinodermata.html
  Variety of biological facts about echinoderms.

- **Tree of Life Project - Echinodermata**
  http://tolweb.org/Echinodermata
  Variety of biological facts about echinoderms.

CHAPTER 12

THE Chordates (Phylum Chordata) – Part I

Objectives

You should be able to:

- identify:
    - the level of organization seen in these animals
    - the type of symmetry seen in these animals (larval versus adult stages)
    - the number/type of embryonic tissue layers found in these animals
    - the type of skeleton found in these animals
    - whether a coelom is present and, if so, in what form
- indicate if nervous, respiratory, circulatory (open/closed?), osmoregulatory/excretory, or digestive systems (incomplete/complete) are present and, if so, in what form
- indicate whether these animals are monoecious or dioecious
- describe the types of habitats in which these animals can be found
- describe the kind of lifestyle these animals live
- Recognize this phylum and the name and important characteristics of the following Subphyla and Classes:
    - **Subpylum Urochordata – the tunicates or sea squirts**
      You should be able to describe these animals':
        - characteristics
        - lifestyle
    - **Subpylum Cephalochordata – the lancelets**
      You should be able to describe these animals':
        - characteristics
        - lifestyle
    - **Subphylum Vertebrata – the vertebrates**
      You should be able to describe these animals':
        - characteristics
        - lifestyle
        - important classes:
            - ✓ **Class Myxini** = the **hagfish**
            - ✓ **Class Cephalospidomorphi = the lampreys**
            - ✓ **Class Chondrichthyes = the sharks, skates and rays**
                - location of *external* anatomical characters on the shark: *nostrils, eyes, lateral line, paired fins (pectoral, anal, pelvic), dorsal fins, caudal (tail) fin, homocercal tail, scales, spiracles, gill slits*
            - ✓ **Class Actinopterygii = the bony ray-finned fishes**
                - function and location of *external* anatomical characters on the perch: *nostrils, eyes, lateral line, paired fins (pectoral, anal, pelvic), dorsal fins, caudal (tail) fin, homocercal tail, scales*

Phylum Chordata

The Phylum Chordata includes the well-known vertebrates (fishes, amphibians, reptiles, birds, mammals). The vertebrates and the hagfishes, which do not have even rudimentary cartilaginous vertebral structures and, thus, cannot be called a true vertebrate, together comprise the taxon **Craniata**. The remaining extant (= living) chordates are the tunicates (Urochordata), lancelets (Cephalochordata). With some exceptions, chordates are active animals with **bilaterally symmetric** bodies that typically are arranged into a body form comprised of a head, trunk and tail. The most distinctive and unifying morphological features of chordates are the:

- **notochord**
- **nerve cord**
- **pharyngeal slits** (a.k.a. visceral clefts and arches or gill slits)
- **post-anal tail**

All chordates, at least sometime in their developmental lifetime, exhibit these four characteristics.

The **notochord** is an elongate, rod-like, skeletal structure located dorsal to the digestive tract but ventral to the nerve cord. It appears early in embryogeny and, in most adult chordates, it disappears or becomes highly modified. For example, in higher vertebrates, it is largely replaced by a bony vetebral column with remnants serving as cartilaginous, intervetebral discs. In some non-vertebrate chordates and fishes the notochord persists as a laterally flexible but incompressible skeletal rod which supports body structure during swimming.

The **nerve cord** is a hollow tub located dorsal to the notochord. In most chordate species it becomes the central nervous system (CNS) – the brain and the spinal cord.

The pharyngela slits are located in the pharyngeal part of the body (hence the name) posterior to the oral cavity and anterior to the esophagus. These pharyngeal slits take the form of several pairs of pouches that push outward from the side of the pharynx, connecting with the surface. These structures, are thus, continuous, slit-like passages connecting the pharynx to the external environment. The soft and skeletal tissues between adjacent slits are the **visceral arches**. The embryonic fate of the slits varies greatly depending on the taxon. In many of the non-vertebrate chordates, such as tunicates and cephalochordates, they serve as part of the filter feeding apparatus, used to strain plankton from the surrounding aquatic environment. In most fishes and juvenile amphibians, they develop into gills. In adult amphibians and the **amniote** tetrapods (= reptiles, including birds, and mammals) the anteriormost slit becomes the Eustachian (auditory) tube and middle ear chamber, and the other slits disappear. In some adult vertebrates, the skeleton and muscles of the visceral arches become jaw and facial muscles.

The **post-anal tail** is present in most chordates and is typically referred to as a “tail” or caudal or tail fin. Depending on the species, this structure is used for locomotion, balance, defense, communication, parental care, and reproduction among other things.

Chordates other than craniates include entirely aquatic forms. As a whole, however, chordates can be found in terrestrial habitats as well as freshwater and terrestrial ones from the Equator to the high northern and southern latitudes. The smallest chordates (e.g. some of the tunicates and gobioid fishes) are mature at a length of about 1 cm, whereas the largest animals that have ever existed are chordates: some sauropod dinosaurs reached more than 20 m and living blue whales grow to about 30 m.

Subphylum Urochordata

The most “primitive” or least highly derived chordates are the tunicates or sea squirts. The adult is a sessile organism and remains attached to the intertidal substrate throughout its life (Figure 12.1). It feeds by pumping water into a large pharynx its incurrent siphon. They are filter feeders and feed on plankton, which are trapped in the pharynx and transported to the digestive tract.The water minus the suspended plankton passes on through gill slits in the pharynx and out through the excurrent siphon. On the way it picks up waste products from the intestine and. if the individual is in reproductively active, either eggs or sperm from the gonads.

This sessile, filter-feeding way of life is very similar to that seen in a number of invertebrate species you have already studied.

Q. What other invertebrate groups have exhibited a similar sessile, filter-feeding lifestyle? Do you see any evidence of convergent evolution/analogous structures between the urochordates and these other invertebrate groups?

Now if tunicates are invertebrates no matter what angle we view it from why, then, is this group of animals considered a member of "our" phylum, Phylum Chordata? The reason lies in an understanding of its larval form.

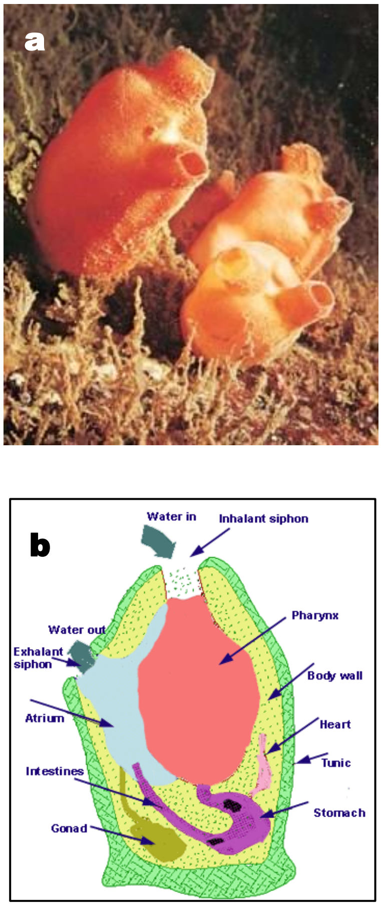


Figure 12.1. a) Adult form of a tunicate a) and b) labeled diagram of a tunicate.

The larval stage is free-swimming and exhibits all of the chordate characteristics: a notochord, a dorsal nerve cord, pharyngeal slits, and a post-anal tail. The gill slits persist in the adult form, but the notochord and the dorsal nerve cord are resorbed with the rest of the tail during metamorphosis.

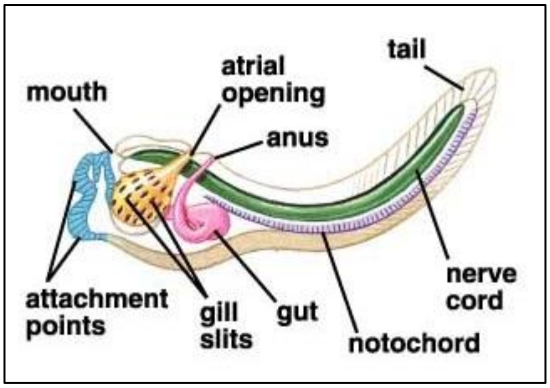


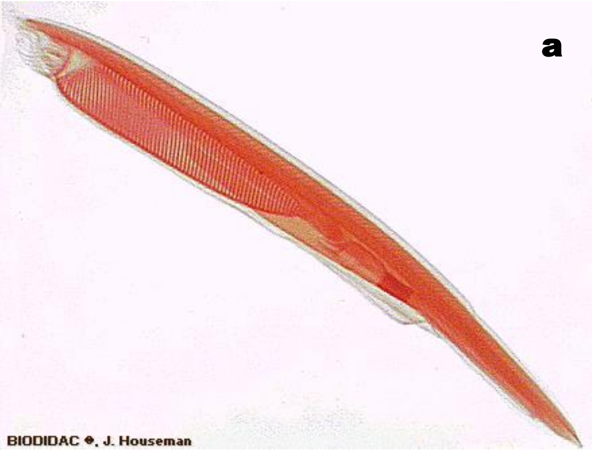
Figure 12.2. Larval tunicate.

The tadpole-like larva is mobile and can swim. In many tunicates, it eventually attaches to a hard substrate, it loses its tail and ability to move, and its nervous system largely disintegrates. Some tunicates are entirely pelagic; known as salps, they typically have barrel-shaped bodies and may be extremely abundant in the open ocean.

ACTIVITY 12-1: Specimens, including live ones, representing Subphylum Urochordata are on demonstration. Visit the specimens on demo and review the characteristic features of these animals using Figures 12.1-12.2 to help you.

Subphylum Cephalochordata

This subphylum is represented by approximately 25 species of small swimming and burrowing shallow tropical and temperate ocean =dwelling animals known as lancelets or amphioxus (Fig. 12.3a). These anaimals resemble an enlarged, streamlined version of the tunicate larva. These small, eel-like, animals spend much of their time buried in sand, with only their heads exposed. Like tunicates, they are filter feeders and, in that position, they filter feed plankton from their surrounding environment, using **tentacles** (= **oral cirri**) surrounding their mouth to help guide food in. The sexes are separate in this group, and both males and females have multiple paired gonads. Eggs are fertilized externally, and develop into free-swimming, fishlike larvae (Fig. 12.3b).



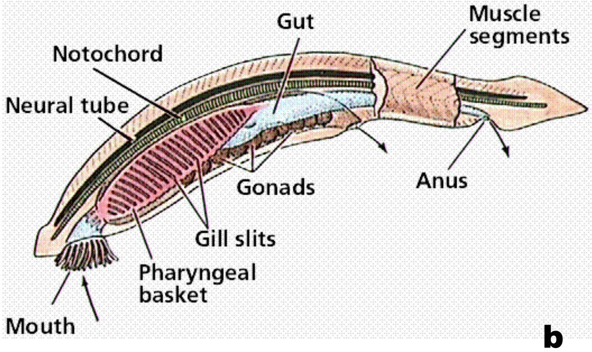


Figure 12.3. Photograph (a) and labeled drawing (b) of a lancelet.

Cephalochordates have all of the typical chordate characteristics. The **dorsal nerve cord** is supported longitudinally by a muscularized **notochord**. The pharynx is perforated by over 100 **<u>pharyngeal slits</u>** or "gill slits", which are used to strain food particles out of the water. The musculature of the body is divided up into chevron (= v-shaped) blocks, or **<u>myomeres</u>**, and there is a **<u>post-anal tail</u>**. Cephalochordates are separated from the true vertebrates, howeveer, in that they have a very small, poorly developed brain, poorly-developed sense organs, and there are no true **<u>vertebrae</u>**.

Scientists believe that the cephalochordates may have evolved from a tunicate tadpole-like larval ancestor through a process called **<u>neoteny</u>**. "Neoteny" occurs when a larval form acquires sexual maturity while still retaining its larval characteristics. It then goes on to reproduce more larval forms which may also be neotenic. If there are factors which provide the larval life form greater fitness than that of the adult, natural selection may ultimately result in the loss of the adult form altogether.

ACTIVITY 12-2:

a) Specimens representing Subphylum Cephalochordata are on demonstration. Visit the specimens on demo and review the characteristic features of these animals using Figure 12.2 to help you. Note that these animals again have the four primary chordate features: notochord, dorsal nerve cord, gill slits, and post-anal tail. Unlike with the tunicate larvae, the Amphioxus nerve cord and notochord extend far anterior through the head, hence the name cephalo- or "head" chordate.

b) Examine the following slides as part of your review of the cephalochordate anatomy:

a) <u>Student table slide</u>: whole mount, preserved lancelet

b) <u>Student table slide</u>: crossection, preserved lancelet (an examination of a cross-section slide of amphioxus provides a good view of the structural relationships between the notochord, dorsal nerve cord, muscle tissue and the pharyngeal gills; *see Figure 12.4 for reference*).

c<u>) Slides</u>: cross-section and location of gills

d) <u>Slide</u>:notochord and hollow dorsal nerve cord.

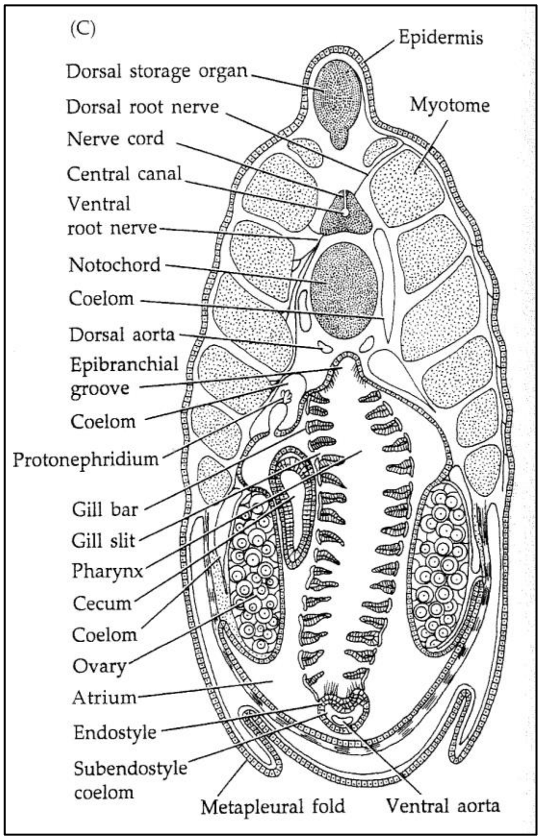


Figure 12.4. Crossection through a lancelet body.

Members of the Subphylum Cephalochordata exemplify the ideal chordate body plan. However, we will see that, in the third and last chordate subphylum, Vertebrata, this idealized chordate body plan has undergone a series of modifications.

Subphylum Vertebrata

The vertebrates are distinguished from other chordates by the addition of cartilaginous or bony reinforcements around the notochord called vertebrae. These vertebral additions become so prominent in the development of most vertebrate species that they completely replace the notochord as the central supporting structure of the body. The anterior end of the dorsal nerve cord enlarges in the vertebrates and is protected by a new cartilaginous or bony structure, the **cranium**.

THE JAWLESS FISHES: Class Myxini and Class Cephalospidomorphi

These two classes are collectively known as the **agnathans** (translation: "without jaws"). This group was originally represented by a now extinct group of small fish-like species called ostracoderms ("bone-like skin"). Today, only a small group of agnathans persist. These are the hagfish (Class Myxini) and the lampreys (Class Cephalospidomorphi).

The hagfish (Fig 12.5) are **elongated, pinkish marine fish** which are found in cold waters in both the northern and southern hemispheres. Hagfish are almost blind, but have well developed senses of touch and smell. They tend to be found benthically, burrow for invertebrates, particularly poloychaete worms, and/or eat dead or dying fish through which they burrow as they feed. They have four pairs of **tentacles** surrounding their mouth and two pairs of tooth-like rasps on the top of a tongue-like projection in their jawless mouths. These aid them in tearing into the flesh of their prey. Unlike many other fish, hagfish exhibit **direct development**, with no larval stage. Hagfish are probably best known for the large quantities of sticky **slime** which they can produce relatively quickly. This ability can be use as a form of self-defense as a potential predator may end up with a mouthful of slime rather than hagfish.

Figure 12.5. A hagfish.

There are approximately 50 species of lampreys (see Fig. 12.6), found in temperate rivers and coastal oceans. Some species live in fresh water for their entire lives while others are **anadromous**. That is, they are hatched and grow in freshwater, migrate to the ocean to mature, and then return to fresh water to spawn. These **elongated, jawless fishes** have a **larval stage**, which are referred to as **ammocoetes** (see Figure 12.7).

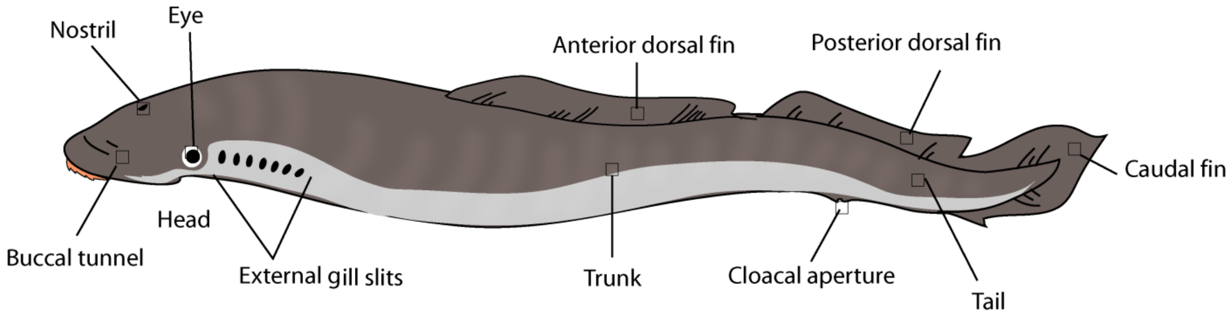


Figure 12.6. The external anatomy of a lamprey.

Adults lampreys have seven gill openings located anteriolaterally and have a **cartilaginous endoskeleton**. Unlike hagfishes, with which they were once classified, lampreys have a complete braincase and rudimentary true vertebrae. They also have a **single "nostril" on the dorsal side of the head**.

Lampreys are known for their **round, suckerlike, jawless mouth** filled with rows of **horny (i.e., well-keratinized) teeth**, and a **rasplike "tongue"** (see Figure 12.8). Lampreys sometimes prey on small invertebrates, but they are often fish **ectoparasite**. They can use their sucker-like mouth to rasp onto the flesh of another fish and feed on their body fluids through the wound that they make.

Lampreys have made an infamous name for themselves in the Great Lakes area of the United States and Canada. For more information on this, check out the citation at the end of this chapter.

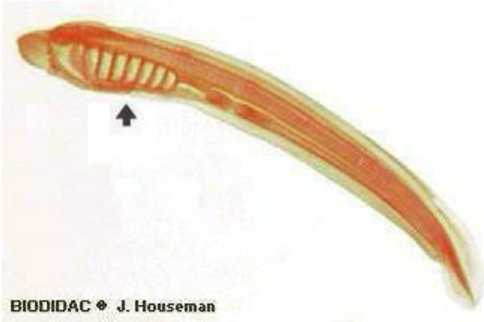


Figure 12.7. Ammocoete larva.

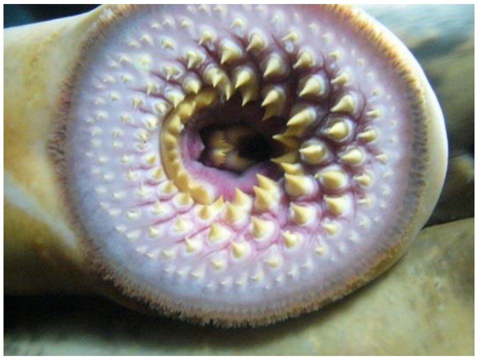


Figure 12.8. A lamprey mouth.

ACTIVITY 12-3:

a) Specimens representing Class Myxini are on demonstration. Visit the specimens on demo and review the characteristic external features of these animals.

b) Specimens representing Class Petromyzontida are on demonstration. Visit the specimens on demo and review the characteristic features of these animals. Note particularly their:
   - round, jawless mouth with teeth for rasping
   - mouth modified into a sucker
     - rows of teeth in the mouth
   - single nostril on dorsal side of the head
   - paired gill slits along the anterior lateral side of the body
   - cartilaginous skeleton
   - no jaws = agnathan
   - no scales
   - no paired fins, but have dorsal fins and tail (caudal) fin
   - external gill slits

THE JAWED FISHES:

Scientists believe that the first vertebrates to evolve jaws and paired appendages were the Placoderms, which were heavily armored fishes that lived approximately 425 million years ago. Today, there are four classes of extant (living) jawed fishes:

- the lobe-finned fishes (e.g., coelacanths**,** lungfish) ***(Class Sarcopterygii)***
- the sharks, skates, and rays ***(Class Chondricthyes)***
- the bony fishes ***(Class Actinopterygii)***

Although all three groups are worthy of discussion, because of the limited amount of time that we have in the quarter, we will only consider the last two groups.

Class Chondricthyes

Class Chondrichthyes, which contain the sharks, rays and skates, is the smaller of the two classes, containing about 900+ living species. They are covered with small, tooth-like scales called **placoid scales**.They have an **endoskeleton composed of cartilage,** and there is no operculum covering their gill slits.

These animals, particularly the sharks, tend to have a **heterocercal tail,** meaning that the lobes (i.e., tips) of the tail are differently shaped and/or sized. This helps provide them powerful thrust upward which is leveled off by their relatively stationary pectoral fins. These fishes do not possess a swim bladder, like the Actinopterygiians, for buoyancy. Instead, depending on the species, they use **regulation of oils in their liver** (some sharks) or they do not have a specific organ that aids in buoyancy.

Most members of this class are **viviparous** (= they bear their young alive), and fertilization is internal, achieved by **claspers** in males. In addition, these mostly carnivorous fish have well developed systems relative to the invertebrates we have been assessing throughout the quarter. This includes formal circulatory, respiratory, excretory/osmoregulatory, digestive and nervous systems. This has afforded them the ability to function effectively efficiently and effectively enough to be able to detect, pursue, secure, and consume larger and more active prey.

ACTIVITY 12-4: The external anatomy of a (preserved) shark, known as the Spiny Dogfish, on demo. Review the external anatomy of the preserved shark using Figure 12.9. The anatomical features and their functions that you should review are described below:

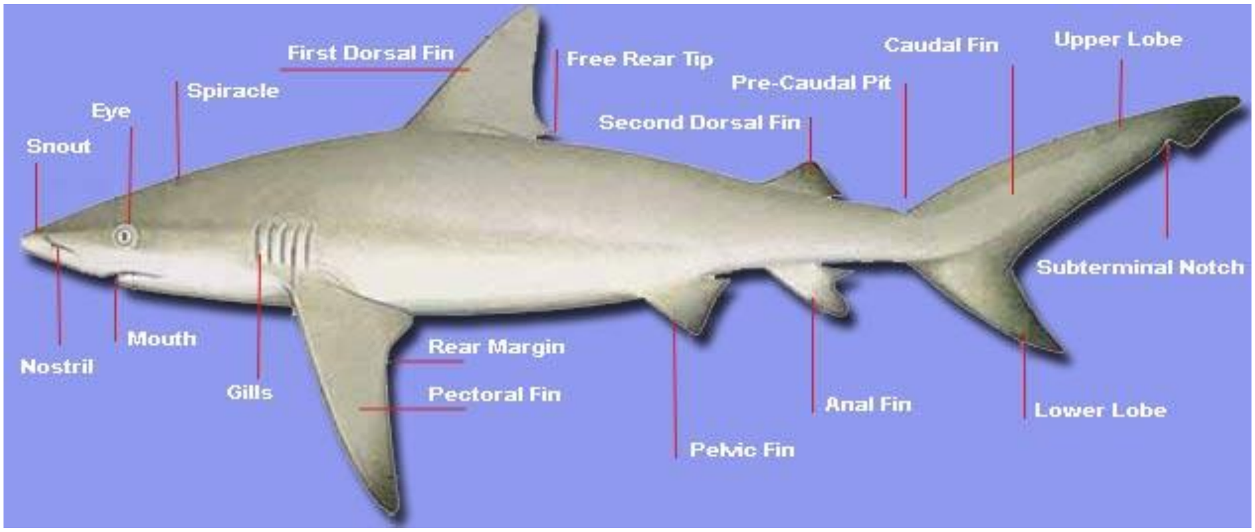


Figure 12.9. The external anatomy of a shark.

a) The shark has a graceful and **streamlined body shape** built for fast, long distance swimming. Examine the fish's body and note the division into the **head**, **trunk**, and **tail**. Note that the shark's body is dark gray above and almost white below.
b) Observe that along the sides of the body is a light-colored horizontal stripe called the **lateral line**. The line is made up of a series of tiny pores that lead to receptors that are sensitive to the mechanical movement of water and sudden changes of pressure.
c) The spiny dogfish has a **double dorsal fin**. Observe that the **anterior dorsal fin** is larger than the **posterior dorsal fin**. The spiny dogfish has two spines, one immediately in front of each dorsal fin. The spines carry a poison secreted by glands at their base.
d) Note that the **caudal fin** is divided into two lobes: a **larger dorsal lobe** and a **smaller ventral lobe**. This type of tail is known as a **heterocercal tail**.

e) Find the **cloacal opening**, which is located on the ventral surface between the pelvic fins. It receives the products of the intestine, the urinary and the genital ducts. The name cloaca, meaning sewer, seems quite appropriate.

f) The **paired pectoral fins** act like an airplane's wings to provide the lift needed to keep the shark from sinking.

g) The **paired pelvic fins** are located on either side of the cloacal aperture (= the cloacal opening). They are different in males and females. Males have grooved copulatory organs called **claspers** on the inner side of their pelvic fins. Fertilization in the dogfish shark is internal. During copulation, one of the claspers is inserted into the oviduct orifice of the female. The sperm proceed from the cloaca of the male along the groove on the dorsal surface of the clasper into the female.

h) Find the shark's **rostrum** which is the pointed snout at the anterior end of the animal. This tapered tip at the anterior end helps overcome water resistance in swimming.

i) Find the shark's **eyes**. They are prominent in sharks and are very similar to the eyes of man. A transparent **cornea** covers and protects the eye. A darkly pigmented **iris** can be seen below the cornea with the pupil at its center. Upper and lower eyelids protect the eye. Just inside the lower lid is a membrane, called the **nictitating membrane**, that extends over the surface of the eye to cover the cornea. This is particularly helpful to the shark when attacking potential prey, which could potentially injure the shark's eyes.

j) The opening to the **mouth** of sharks is always on the underside. The teeth are sharp and pointed. There are **several rows of flattened teeth lying behind the upright set** ready to replace them when worn out or lost.

k) The **nares** or external nostrils are located on the underside (ventral surface) of the rostrum anterior to the jaws. A nasal flap separates the incurrent from the excurrent opening. Water passes into and out of the olfactory sac, permitting the shark to detect the odors of the water.

l) The patches of pores on the head in the areas of the eyes, snout, and nostrils are the openings of the **ampullae of Lorenzini**. These sense organs are sensitive to changes in temperature, water pressure, electrical fields, and salinity.

m) The line of sensory structures runnng the length of the shark on both sides are collectively referred to as the **lateral line**. Together, these mechanorecepter-based structures assist sharks with detecting movement and changes in pressure in the surrounding water.

n) Find the large **spiracle openings**, located posterior and dorsal to the eyes. A spiracular valve, permits the opening and closing of the external spiracular pore. The spiracle is an incurrent water passageway leading into the mouth for respiration.

o) Most sharks have five **external gill slits** located on thire sides behind the mouth and in front of the pectoral fins. Water taken in by the mouth and spiracles is passed over the internal gills and forced out by way of the gill slits.

ACTIVITY 12-5: Specimens representing Class Chondrichthyes are on demonstration. Visit the specimens on demo and review the characteristic features of these animals.

Class Actinopterygii

In contrast, there are many more species in the class Actinopterygii. Indeed, about one-half of all vertebrate species (30,000 +) belong to this class. This class is characterized by at least a partially **bony endoskeleton** and a body covering of either **large, flat scales or, in some species, no scales**. These **scales are bony** but thinner and this shift from the rougher, placoid scales in the Chondrichthyes has afforded these fishes more flexibility. A **swim bladder** is present in most species (with it being reduced or absent in many benthic species). These fish have a flexible, bony covering, known as an **operculum**, over their gill slits.

The dominant form of reproduction involves **oviparity** (= egg laying), although there are a number of **viviiparous** (= live bearing) groups within the Class. Like chondricthyians, these fish have well developed systems relative to the invertebrates we have been assessing throughout the quarter. This includes formal circulatory, respiratory, excretory/osmoregulatory, digestive and nervous systems.

ACTIVITY 12-6: Review of the external anatomy of a (preserved) perch. In groups of four, and with the aid of Figure 12.10 and the additional dissecting chart on your table, obtain and review the external anatomy of a preserved perch. The anatomical features and their functions that you should review are listed below.

a) In groups of four, obtain a perch and a dissection pan.
b) Place your perch in the dissection pan.

Q. We encourage you to draw the perch (in your lab notebook) and indicate the following:

a. Anterior end
b. Posterior end
c. Dorsal side
d. Ventral side
e. Lateral sides

c) Open the perch's **mouth** and observe its **bony jaws**.
d) Feel the inside of the mouth for the **teeth** and locate the **tongue**.
e) Open the mouth wider and use a blunt probe to reach back to the **gill chamber**.

f) Locate the **nares** (nostrils). There are two and they connect up with the **olfactory sacs**, providing these animals with a sense of smell. Label these on your "Notes" fish figure.

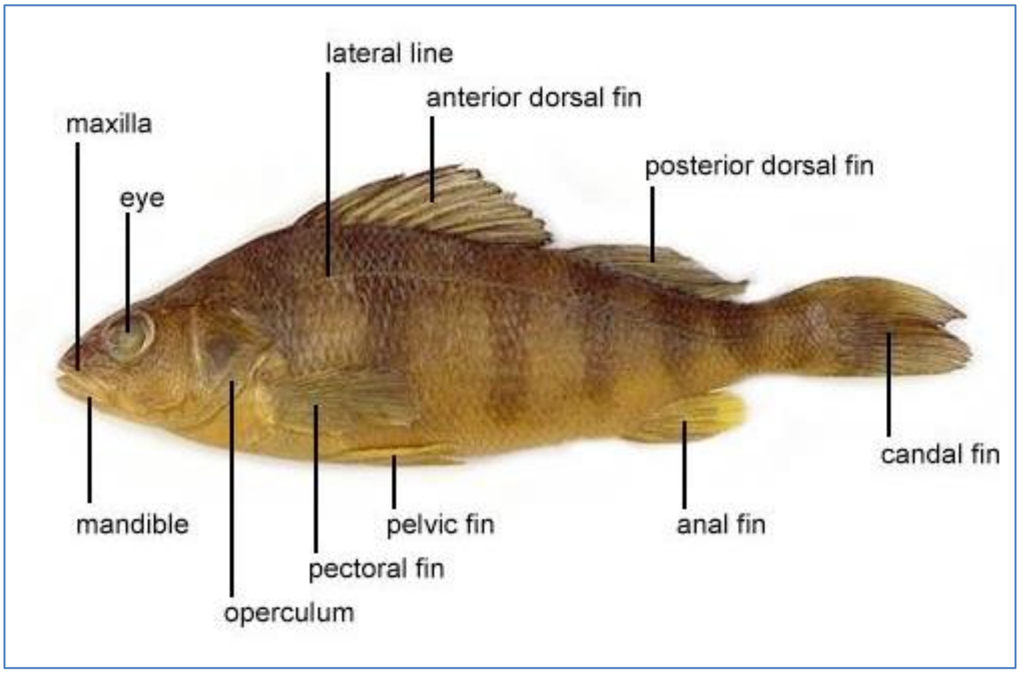


Figure 12.10. External anatomy of the perch.

g) Locate and note the location of the **eyes**, which have no eylids as is the case with sharks. and label these on the figure in your Notes.

h) Find the bony covering on each side of the fish's head called the **operculum**. The opercula cover and protect the gills.

i) Use a probe to lift the operculum and observe the **gills**. Note their color.

j) Observe and identify the different fins on the perch.

- **Dorsal fins** – there is a spiny dorsal fin located anterior to a soft dorsal fin.
- **Pectoral fins** – are paired
- **Pelvic fins** – are paired
- **Anal fin** – unpaired, lcoated behind the anus
- **Caudal fin** – also known as the tail fin; is unpaired; consists of dorsal and ventral lobes of approximately equal size.

m) Locate the **anus** on the perch anterior to the anal fin. In the female, the anus is in front of the **genital pore**, and the **urinary pore** is located behind the genital pore. The male has only one pore (urogenital pore) behind the anus. Determine the sex of your perch.

n) Find the **lateral line** on the side of your perch. The line is made up of a series of tiny pores that lead to receptors that are sensitive to the mechanical movement of water and sudden changes of pressure.Label this structure on the figure in your notes.

o) Examine the fish’s scales using a magnifying glass or a dissecting scope.

ACTIVITY 12-7: Specimens representing Class Actinopterygii are on demonstration. Visit the specimens on demo and review the characteristic features of these animals.

FOR MORE INFORMATION…

- **University of California Museum of Paleontology: Introduction to the Chordata** - http://www.ucmp.berkeley.edu/chordata/chordata.html

- **Tree of Life: Chordata** - http://tolweb.org/Chordata/2499

- **Shape of Life Website: Phylum Chordata** http://www.pbs.org/kcet/shapeoflife/animals/chordates.html

- **Monterey Bay Aquarium - Fishes Animal Guide**: http://www.montereybayaquarium.org/animals/AnimalList.aspx?a=Fishes

- **Steinhart Aquarium (California Academy of Sciences)** – http://www.calacademy.org/academy/exhibits/aquarium/

- **Virtual Shark Dissection**: http://www.pc.maricopa.edu/Biology/ppepe/BIO145/lab04.html

- **Shark Dissection Webcast** – http://aquarium.ucsd.edu/Education/Learning_Resources/Shark_Dissection_Webcast/

- **Dissection of a Yellow Perch (YouTube video)** – http://www.youtube.com/watch?v=7SkzwTMcVC8

- **Australian Museum: Dissection of a Blue Mackerel** – http://australianmuseum.net.au/Dissection-of-a-Blue-Mackerel-Scomber-australasicus

CHAPTER 13

THE Chordates (Phylum Chordata) – Part II

Objectives

You should be able to:

- identify:
    - the <u>level of organization</u> seen in these animals
    - the <u>type of</u> <u>symmetry</u> seen in these animals (larval versus adult stages)
    - the number/type of <u>embryonic tissue layers</u> found in these animals
    - the <u>type of skeleton</u> found in these animals
    - whether a <u>coelom is present</u> and, if so, in what form
- indicate if nervous, respiratory, circulatory (open/closed?), osmoregulatory/excretory, or digestive systems (incomplete/complete) are present and, if so, in what form
- indicate whether these animals are <u>monoecious</u> or <u>dioecious</u>
- describe the <u>types of habitats</u> in which these animals can be found
- describe the <u>kind of lifestyle</u> these animals live
- <u>Recognize this phylum</u> and the name and <u>important characteristics of the following Subphylum and Classes:</u>
    - **Subphylum Vertebrata – the vertebrates**
      You should be able to describe these animals':
        - characteristics
        - lifestyle
        - important classes:
            - ✓ **Class Amphibia = frogs, salamanders, and caecilians**
                - location and function of *external* and *interna*l anatomical characters on the frog (see characteristics in pages below).
            - ✓ **Class Reptilia = turtles, lizards, snakes, and alligators and birds**
            - ✓ **Class Mammalia = platypuses, marsupials, ungulates, carnivores, rodents, bats, shrews,**
                - Location and function of *external* and *internal* anatomical characters of the fetal pig (see characteristics in pages below).

Phylum Chordata

Class Amphibia

The amphibians, which include approximately 6,700 speices, are comprised of three orders: Order Anura (the frogs including toads), Order Caudata (the salamanders including newts) and Order Apoda (the caecilians) (see Figure 13.1). In many ways this is the most diverse of the vertebrates classes. In their evolutionary transition from the water to land, they have produced a wide variety of forms adapted to both types of environment. Most amphibians have a separate, aquatic larval stage (called **tadpoles** in frogs and **larvae** in salamanders) and a terrestrial, semiaquatic or aquatic adult stage. The larvae of most amphibians rely on **lungs for respiration** and have a strong, broad tail for swimming. Alternatively, the adults rely on **lungs** (terrestrial and semiaquatic) or **gills** (aquatic) for approximately 35-40% of their respiration and their **moist**, **highly, vascularized skin** for 60-65% of their respiration.

Figure 13.1. Three extant (living) and one extinct amphibian group.

Several species of eastern North American salamanders never metamorphose into an adult land form but instead live an aquatic existence all their life. In contrast to this situation, the largest group of North American salamanders, Family Plethodontidae, has evolved a lifestyle which does not require that their eggs be laid in an aquatic environment in order to develop, nor do they have a larval stage. Instead there is **direct development** where the embryo passes through a larval-like stage within the egg and hatches as a fully functional miniature adult. Members of this family also have no lungs and respire entirely through their skin.

Frogs and salamanders differ in many ways. For example, while salamanders have a head, trunk and tail with four even-sized legs, frogs lack of a tail and have greatly enlarged hind legs designed for jumping. The aquatic larval stage is also quite different. **Larval salamanders** have **external gills**, **legs during most of their larval life**, and a **large mouth** which serves their **carnivorous feeding habit** while, in contrast, the anuran larva or **tadpole** has **internal gills** (i.e., gills covered by a fleshy operculum), has **no legs until just before metamorphosis,** and has a **small scraping mouth** which allows it to **feed on algae**, Dunng metamorphosis the herbivorous anuran larva undergoes a complete redesign of its digestive system to fit the adult carnivorous feeding plan.

***ACTIVITY 13.1:* Review of the external anatomy of a (preserved) frog.**
In groups of four, and with the aid of Figure 13.2 and the additional dissecting chart on your table, obtain and review the external and internal anatomy of a preserved frog.

External Anatomy

a) Place the frog in a dissecting pan.
b) Identify the **eyes**, which have a non-moveable upper and lower lid, but can be covered with a **nictitating membrane** which serves to moisten the eye.

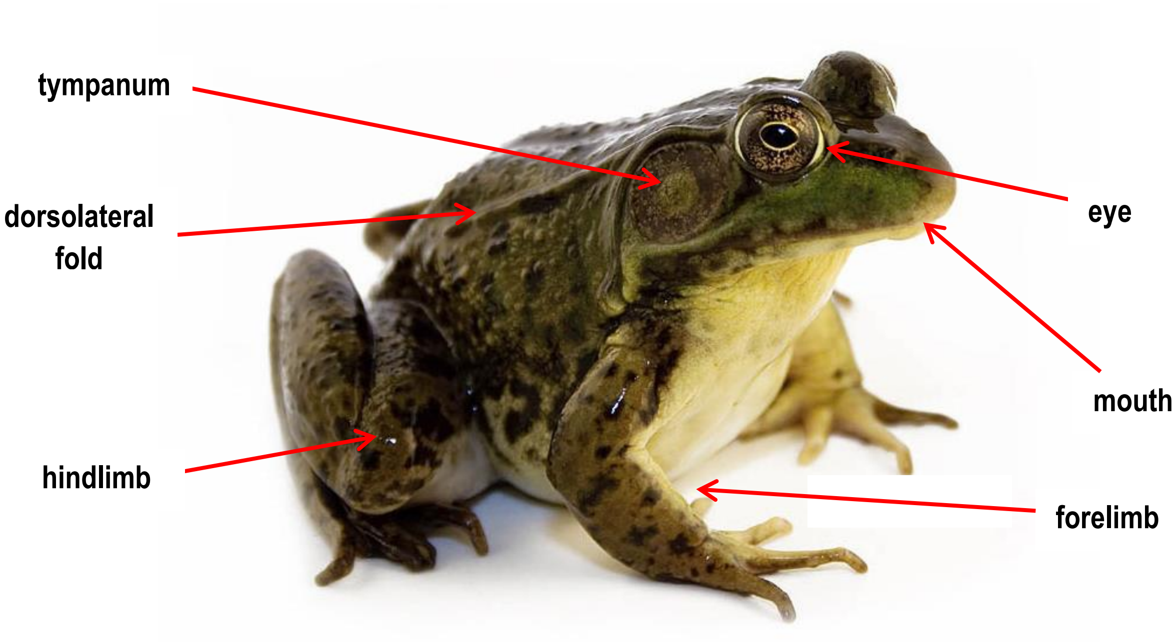


Figure 13.2. External anatomy of the bullfrog

.
c) Examine the **external nares** (nostrils). Insert a probe into the external nares and note that it protrudes from one of the paired small openings, the internal nares, inside the mouth cavity.

d) Locate the circular **typanum** – there is one on each side of the head just behind the ***eye***. This structure represents the outer wall of the middle ear. There is no external ear. *NOTE: one way to sex your frog externally is by the size of the tympanum. These are larger in males compared to females.*

e) Identify the **paired appendages**. The short **forelimb** consists of an ***upper arm, forearm***, *wrist* and ***palm***. The palm has four digits and a rudimentary vestigial thumb. The **hind limb** consists of a ***thigh***, ***shank***, ***ankle***, and ***foot***. The foot has five digits and a rudimentary sixth digit.*NOTE: Another way to sex your frog is by the size of the thumb. Male frogs have enlarged thumbs, known as **nuptial pads**, which aid them in holding onto females during reproductive periods (Figure 13.3).*

Figure13.3. The enlarged thumb of a male common frog illustrating one way by which you might sex a frog.

f) Note the **skin without scales, fur or feathers**. Amphibian skin is semipermeable and must be kept moist to facilitate gas exchange.

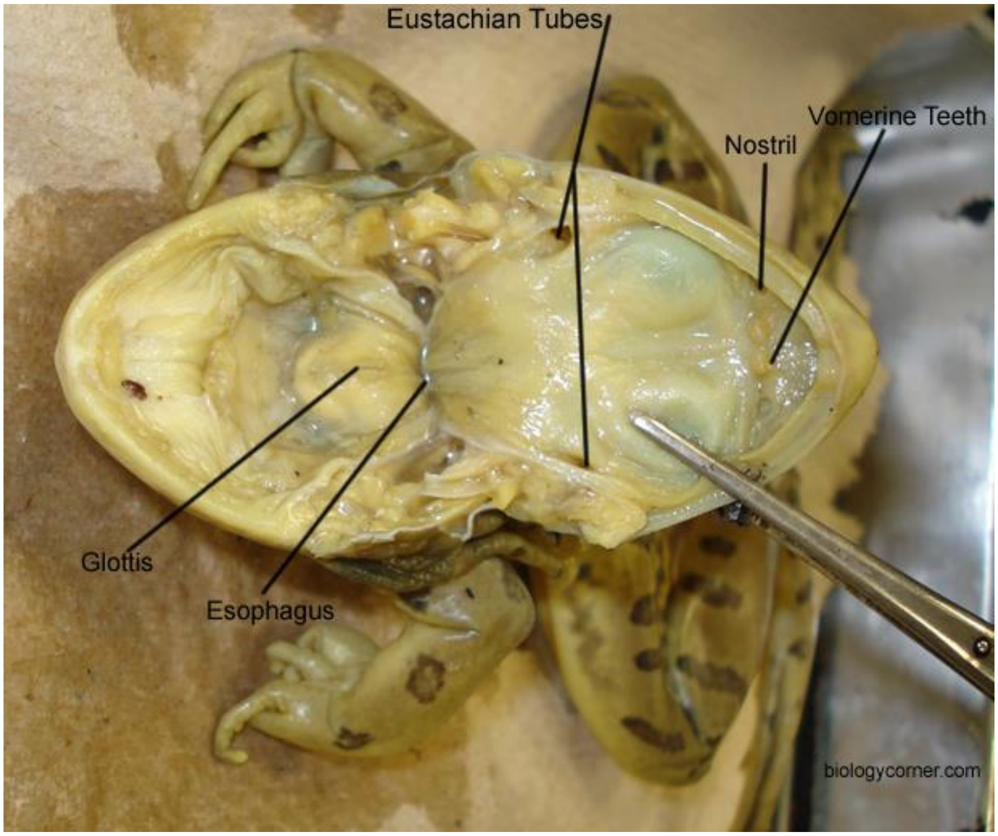


Figure 13.4.. Structures inside the oral cavity of the frog.

g) Open your frog's mouth very wide, cutting the angles of the jaw if necessary. Use Figure 13.4 and the dissecting chart at your table to examine the next several characteristics.

h) Identify the **tongue** attached to the lower jaw's anterior end.

i) Find the **Eustachian tube** opening into the angle of the jaws. These tubes lead to the ears. Eustachian tubes equalize air pressure in the ears.

j) Examine the *maxillary teeth* located along the rim of the upper jaw. Another set of teeth, the *vomerine teeth*, is present just behind the mid portion of the upper jaw.

j) Locate the **glottis**, a slit through which air passes in and out of the **trachea**, the short tube from the glottis to the ***lungs***.

k) Identify the **esophagus**. which lies dorsal and posterior to the glottis and leads to the stomach.

Internal Anatomy

l) Place the frog in the dissecting pan ventral side up.

m) Pin the frog for dissection by securing each of the four limbs to the pan. Place the pins through the hands and feet to secure them to the pan.

n) Use scissors to lift the abdominal muscles away from the body cavity and cut along the midline of the body from the pelvic to the pectoral girdle (see Figure 13.5). Be very careful not to cut too deeply so as to prevent damage to the organs.

o) This is very important. When you reach a point just below the front legs, make a transverse (horizontal) cut in either direction. (see Fig. 13.5). To do this, turn the scissors blades sideways to cut through the bones in the chest. This should prevent damage to the heart or other internal organs.

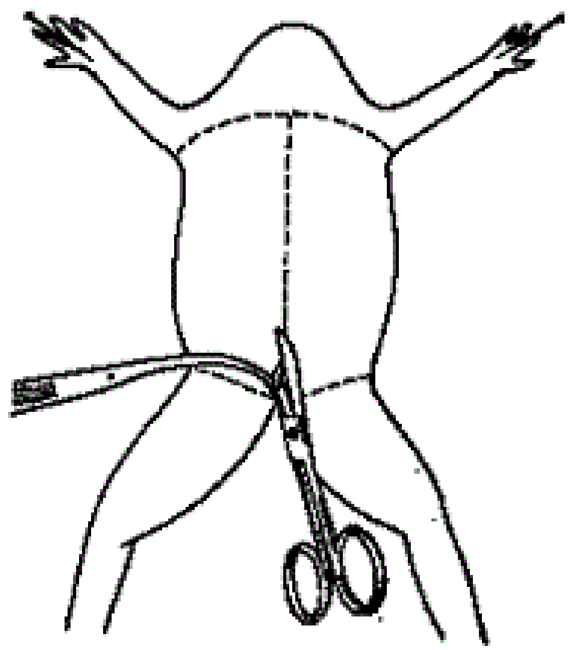


Figure 13.5. A guide for making your incisions for the frog dissection.

p) Make transverse (horizontal) cuts just above the rear legs as well (see Fig. 13.5)

q) Pin back the skin/muscle flaps. This will allow easy access to the frog's internal organs. *NOTE: If your specimen is a female, the body may be filled with eggs and an enlarged ovary. You may need to remove these eggs to view the organs.*

r) Using Figures 13.2-13.4, 13.6-13.13 and the dissecting guide on the table, identify the structures below, making sure to take note of their form and function:

Digestive Structures – Amphibians, like all chordates, have a **complete digestive system*.*** The digestive system consists of the organs of the digestive tract, or food tube, and the digestive glands. After bringing food into its mouth using its tongue, the food moves from the **esophagus**, into the **stomach** and then into the **small intestine**. Digestive secretions from the **pancreas** and the **gallbladder**

low into the **small intestine** via the **common bile duct.** Use Figures 13.4 ,13.6-13.7, and the dissection chart on the table to study the following structures:

- **Mouth**
- **Tongue**
- **Esophagus** – Open the frogs mouth and find the esophagus, poke your probe into it and see where it leads. If you have a hard time locating this, locate the stomach and follow it upward; where it gets smaller is the beginning of the esophagus. The esophagus is the short tube that leads from the frog's ***mouth*** to its stomach.
- **Stomach** - Curving from underneath the ***liver*** is the whitish, j-shaped stomach. It connects with the ***esophagus*** anteriorly and with the small intestine posteriorly. The stomach is the first major site of chemical digestion. Frogs swallow their meals whole. Follow the stomach to where it turns into the small intestine. The ***pyloric sphincter valve*** regulates the exit of digested food from the stomach to the small **intestine**.

  Cut the stomach out of the frog and open it up. You may find the remains of the frog's last meal in there. Look at the texture of the stomach on the inside. It illustrates the secretory nature of the organ.

- **Small intestine** – Where most of the digestion and absorption of food into the bloodstream takes place. Leading from the stomach, the first straight portion of the small intestine is called the **duodenum**, the curled portion is the **ileum**. The ileum is held together by a membrane called the **mesentery**. Note the blood vessels running through the mesentery; they will carry absorbed nutrients away from the intestine.

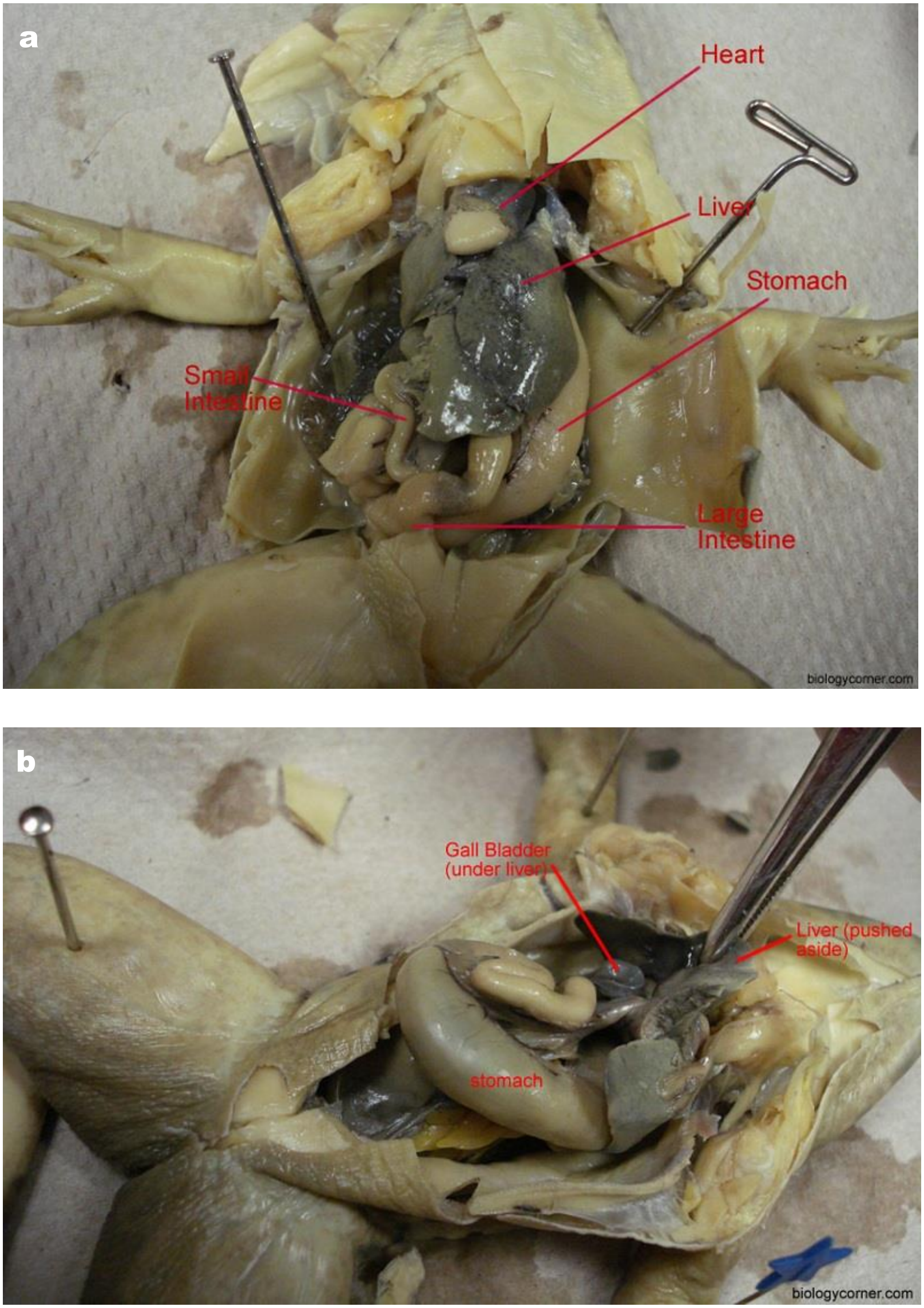


Figure 13.6. Internal anatomy of the frog, including organs of the digestive system. Note that the liver has been removed from the specimen in (b).

- **<u>Liver</u>** - The largest structure of the body cavity. This brown colored organ is composed of three parts, or lobes. The right lobe, the left anterior lobe, and the left posterior lobe. Although the liver is not primarily an organ of digestion, it does secrete a digestive juice called ***bile***. Bile is needed for the proper digestion of fats.

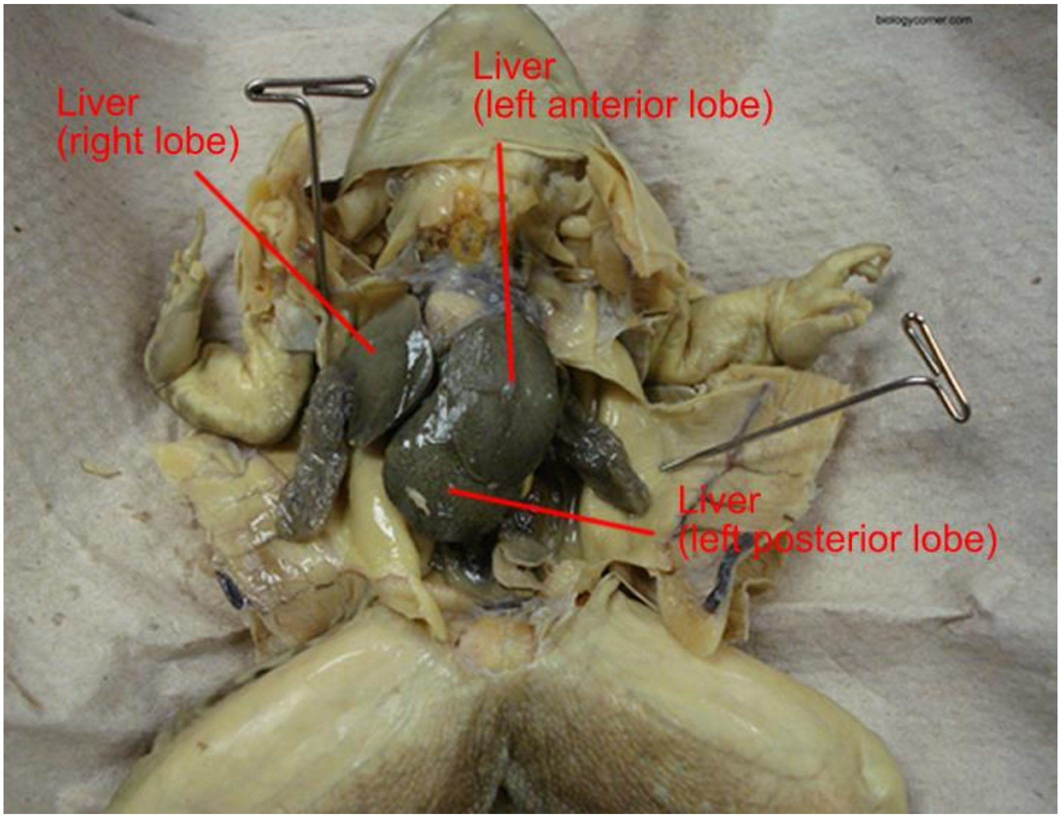


Figure 13.7. Lobes of the frog liver.

- **<u>Gall bladder</u>** - Lift the lobes of the liver; there will be a small green sac under it. This is the gall bladder, which stores ***bile***. Bile is a digestive juice made by the liver and stored in the gallbladder. Bile flows into a tube called the **common bile duct**, into which secretions from the **pancreas** also flow. The contents of this duct flow to the **small intestine**.
- **<u>Pancreas</u>** – As you lift the **small intestine** you will see the pancreas, a thin, yellowish ribbon, between the small intestine and the stomach. Produces pancreatic juice, a digestive juice, which flows into the small intestine via the ***common bile duct***.
- **<u>Spleen</u>** - Within the folds of the mesentery, you will find a dark red spherical object – the spleen. This organ serves as a holding area for blood.
- **<u>Large intestine</u> -** As you follow the ***small intestine*** down, it will widen into the large intestine terminating in the.anus.
- **<u>Anus</u>**

- **Cloaca -** common exit for the urogenital and digestive systems. Urine, sperm and eggs, and digestive wastes exit here. It opens to the outside by way of the anus. Trace the path of food in the digestive tract from the mouth to the cloaca.

Urogenital Structures *- The frog's reproductive and excretory system is combined into one system called the urogenital system. You will need to know the structures for both the male and female frog. Use Figures 13.8-13.10 and the dissection chart on the table to study these structures.*

Reproductive Structures – *Amphibians, like all vertebrates, are* **dioecious.**

- **Fat Bodies** – Spaghetti-shaped structures that have a bright orange or yellow color. These can be found in both males and females and serve as an energy source. These become more prominent during the breeding season. The fat bodies are usually located just on the inside of the abdominal wall.If you have a particularly "fat" frog, the fat bodies may need to be removed to see the other structures.
- **Cloaca** – common exit for the urogenital and digestive systems. Urine, sperm and eggs, and digestive wastes exit here.
- ***(Males)* Testes** - in male frogs, these yellow or tan-colored, bean-shaped organs are located at the top of the ***kidneys***. Several small ducts, the *vasa efferentia,* carry sperm into the kidney ducts that also carry urine from the kidneys. Fat bodies are attached to the testes.
- ***(Females)* Oviducts** - females do not have testes. However, you may notice a "curly-q" type structure around the outside of the kidney. These are the oviducts. **Oviducts** are where eggs are produced. Males can have structures that look similar, but serve no actual purpose. These would be called vestigial oviducts.

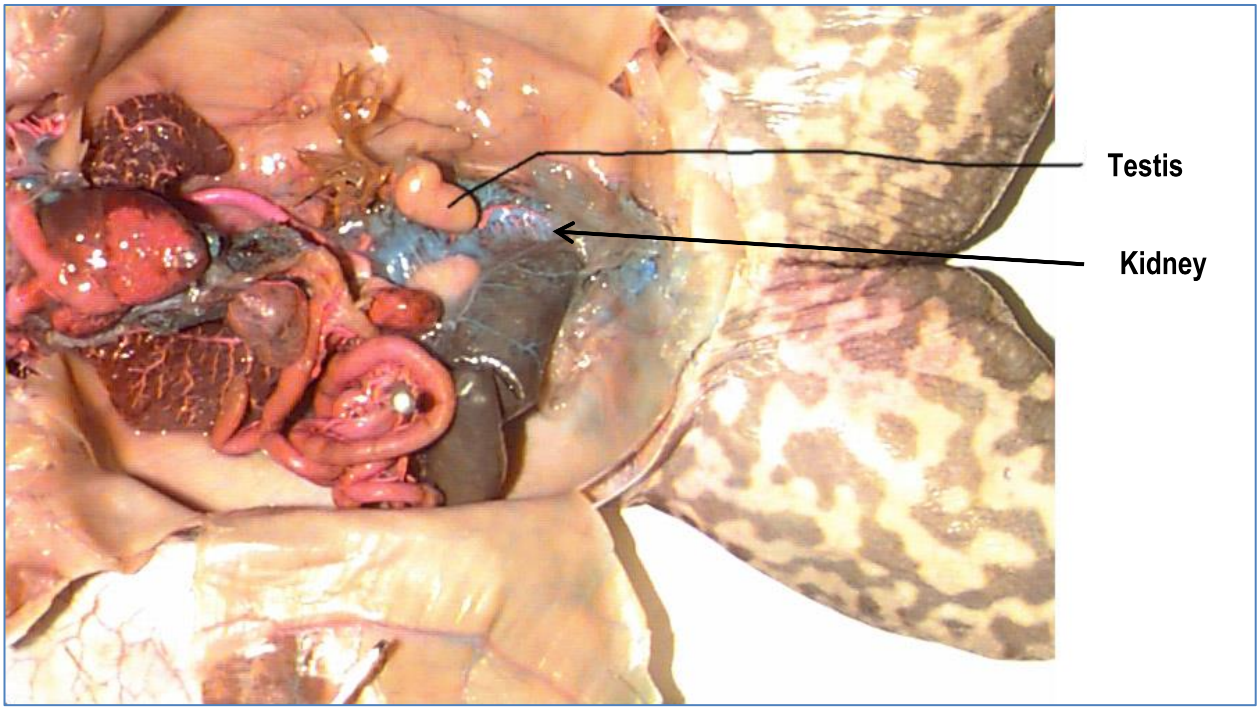


Figure 13.8. Internal anatomy of a male frog, including structures of the urogenital system. Note: the liver was removed so that the underlying structures could be observed.

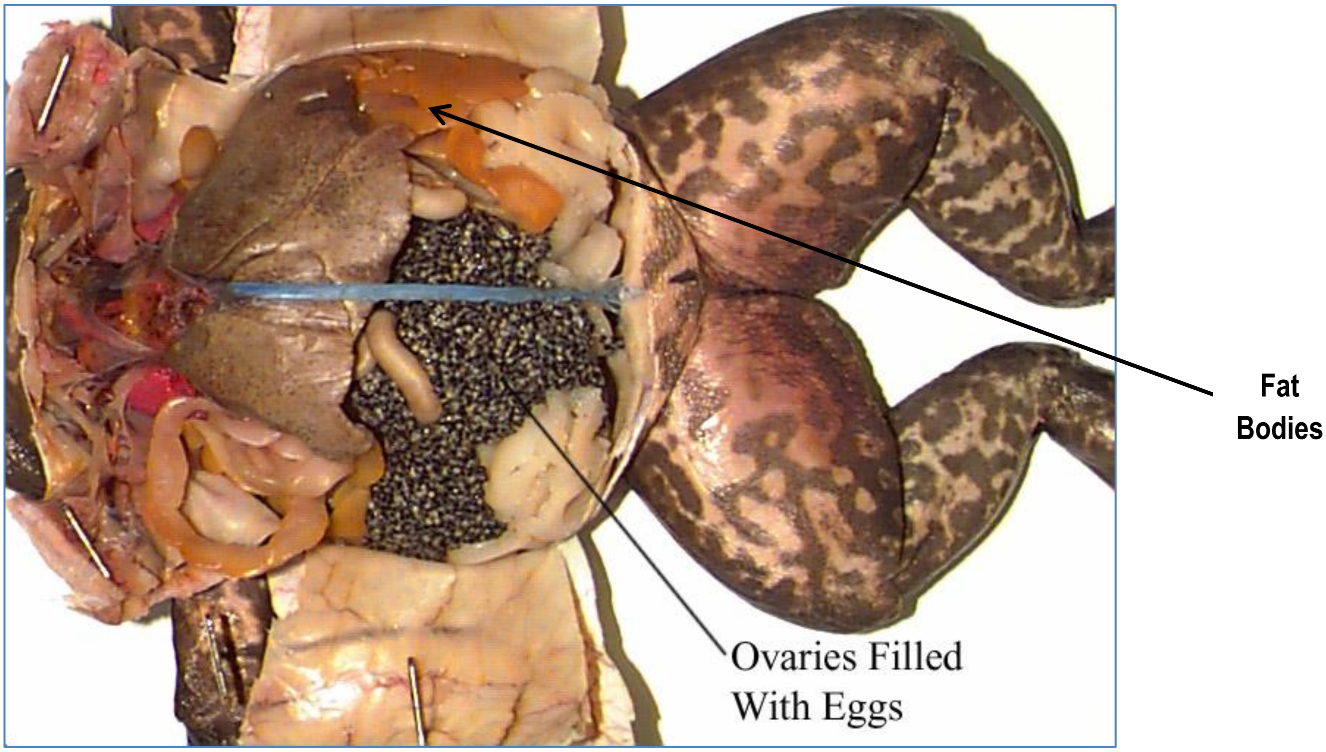


Figure 13.9. Internal anatomy of a female frog, featuring urogenital structures.

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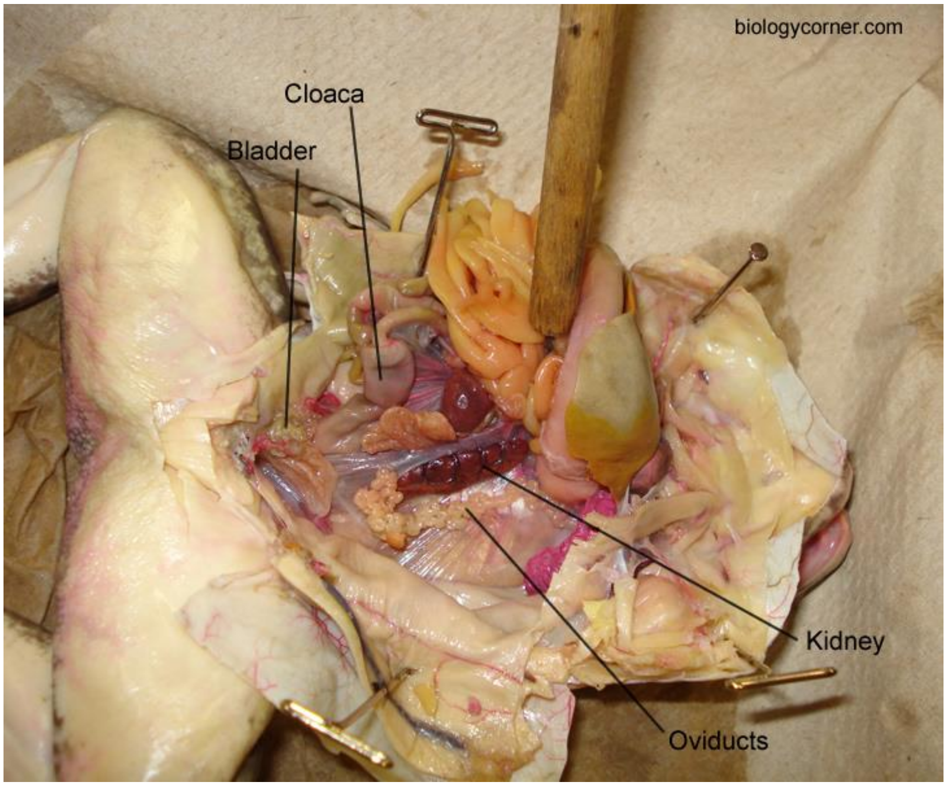

Figure 13.10. Another view of the the internal anatomy of a female frog, featuring the urogenital structures. NOTE: the head has been removed in this photograph.

Excretory Structures

- **<u>Kidneys</u>** - flattened bean shaped organs located at the lower back of the frog, near the spine. They are often a dark color and they typically have yellowish stringy fat bodies attached at their anterior ends.The kidneys filter wastes from the blood and ultimately release it in what we commonly call ***urine***. Connected to each kidney is a **<u>ureter</u>**, a tube through which urine passes into the **<u>urinary bladder</u>**.
- **<u>Urinary bladder</u>** - An empty sac located at the lowest part of the body cavity, attached to the ventral wall of the cloaca. The bladder stores urine until it passes out of the body through the cloaca.

Circulatory Structures – *Amphibians, like most reptiles, technically have a three-chambered heart. Use Figures 13.11-13.12 and the dissection chart on the table to* ***study these structures****,*

The frog circulatory system consists of the heart, blood vessels, and blood. The heart has **two atria**,which essentially serve as "receiving chambers", and **one** **ventricle**, which serves as a "sending chamber". Deoxygenated blood is carried to the right side of the heart in vessels called ***veins***. Veins from different parts of the body enter the **right and left atria**. Blood from both atria flows into the single **ventricle** and is then pumped into the ***arteries***, which are blood vessels that typically carry oxygenated blood away from the heart and to the rest of the body.

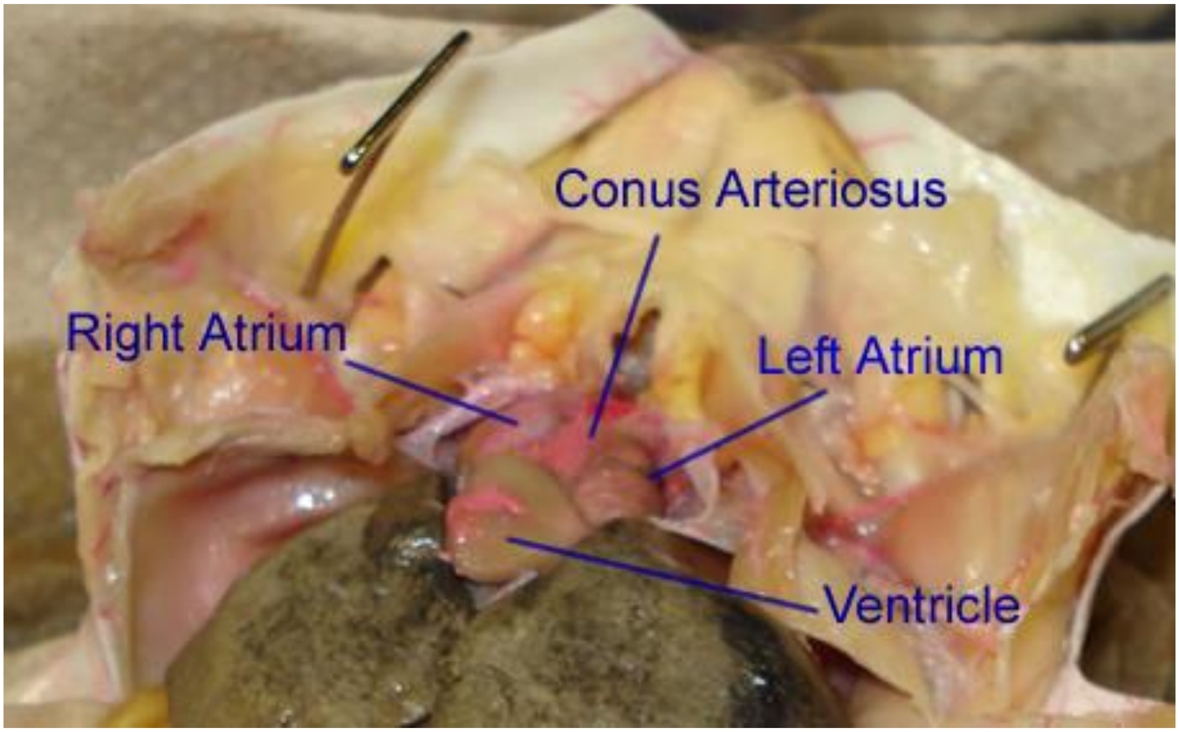

Figure 13.11. Structure of the frog heart.

- **Pericardium** – Membranous covering surrounding the heart.

  With forceps, lift the covering, and gently slit it open.

- **Heart** - at the top of the liver, the heart is a triangular structure. The amphibian heart technically has three chambers. The thin- walled **left and right atria** can be found at the top of the heart. A **single, thick-walled ventricle** is located at the bottom of the heart.

- Locate the three large veins that join together beneath the heart to form the **sinus venosus**. *(To lift the heart, you may have to snip the slender strand of tissue that connects the atria to the **pericardium**).* Blood from the sinus venosus enters the **right atrium**. The **left atrium** receives blood from the lungs and skin (= collectively known as the **pulmocutaneous circuit**).
- **Conus arteriosus** - The large vessel extending out from the heart. It is a single, wide arterial vessel leaving the ventricle and passing ventrally over the right atrium. It ultimately splits into the *right and left **truncus arteriosus***.
- **Truncus arteriosus** – paired arterial blood blood vessels leading out from the ***conus arteriosus***. Split into three branches on each side: ***carotid arches***, ***aortic/systemic arches***, and ***pulmocutaneous arches*****.**
- **Pulmocutaneous arches** – first pair of blood vessels leaving the ***truncus arteriosus***. The ***pulmonary and cutaneous arteries*** bring deoxygenated blood to the lungs or gills and skin to pick up oxygen; the *left and right pulmonary veins* bring oxygenated blood back to the ***left atrium***.

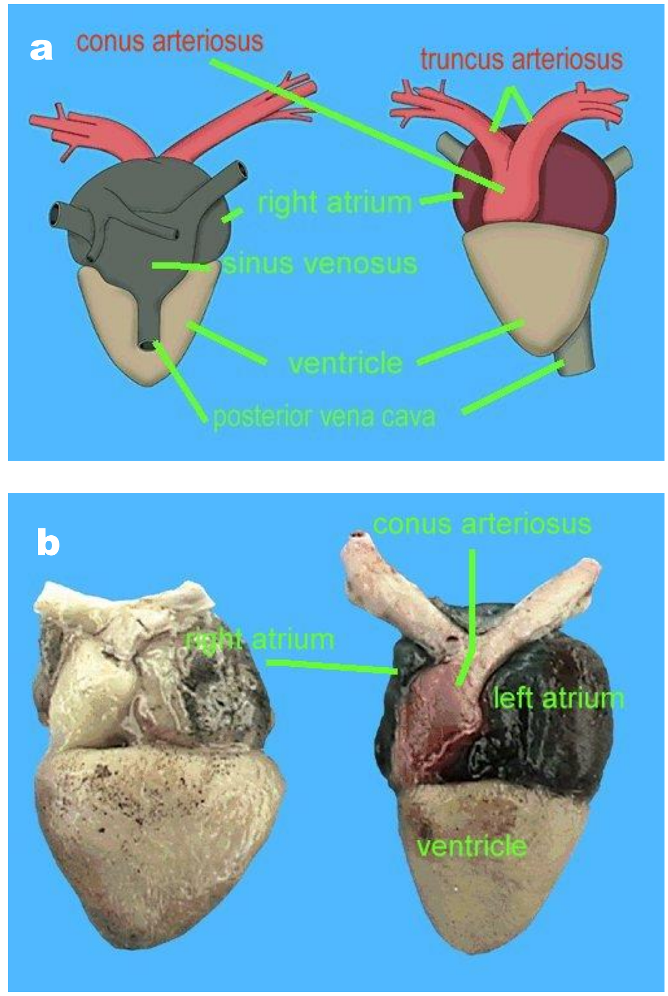

Figure 14.12. Drawing (a) and photograph (b) of the dorsal and ventral sides of the frog heart.

- **Carotid arches** – branch off of the systemic arches; carotid arteries supply the head region with oxygenated blood.
- **Aortic/systemic arches** – the second pair of vessels branching from the ***truncus arteriosus***; they fuse behind the heart to form the **dorsal aorta**. The systemic arches and then *dorsal aorta* transport oxygenated blood to the rest of the body (i.e., besides the head).
- **Dorsal aorta** – major blood vessel leaving out of the left side of the ventricle of the frog heart; formed by the fusion of the ***systemic arches*** along the

dorsal body wall in mid abdomen; carries oxygenated blood posteriorly to the lower portion of the body. One set of branches off of this major blood vessel are the ***common iliac arteries***.

- **Common iliac arteries** – the left and right lliac arteries branch off from the ***dorsal aorta****;* carry oxygenated blood from the dorsal aorta to the legs.
- **Superior/anterior vena cava –** carries deoxygenated blood from the head to the ***right atrium*** of the heart.
- **Inferior/posterior vena cava -** begins between the ***two kidneys*** and returns blood to the *sinus venosus*; carries deoxygenated blood from the posterior portion of the body to the ***right atrium*** of the heart.
- **Left and right pulmocutaneous arches** – the first pair of vessels branching off the ***trucus arteriosus***; carries blood to the lungs and skin (= collectively knowns as the pulmocutaneous circuit).

Respiratory Structures – Use Figure 13.13 and the dissection chart on the table to study these structures.

Amphibians carry out a majority of their respiration through their skin. However, they typically have a secondary organ – either lungs or gills. Air enters the body via the ***nares****. It then is pushed through the* ***glottis*** *and into the* ***larynx****. The air then travels down the* ***left and right bronchi*** *which are hollow tubes that open into the* ***left and right lungs****, hollow sacs with thin walls. The walls of the lungs are filled with* ***capillaries****, which are microscopic blood vessels through which materials pass into and out from the blood.*

- **Nose/snout**
- **Nares/Nostrils**
- **Glottis** – opening at the back of the mouth that leads to the respiratory track.
- **Pharynx** – the throat area.
- **Left and right bronchi** – tubes that connect the pharynx to the left and right lungs, respectively.
- **Left and right lungs** – are two small sacs on either side of the midline, partially hidden under the liver’ used for respiration.

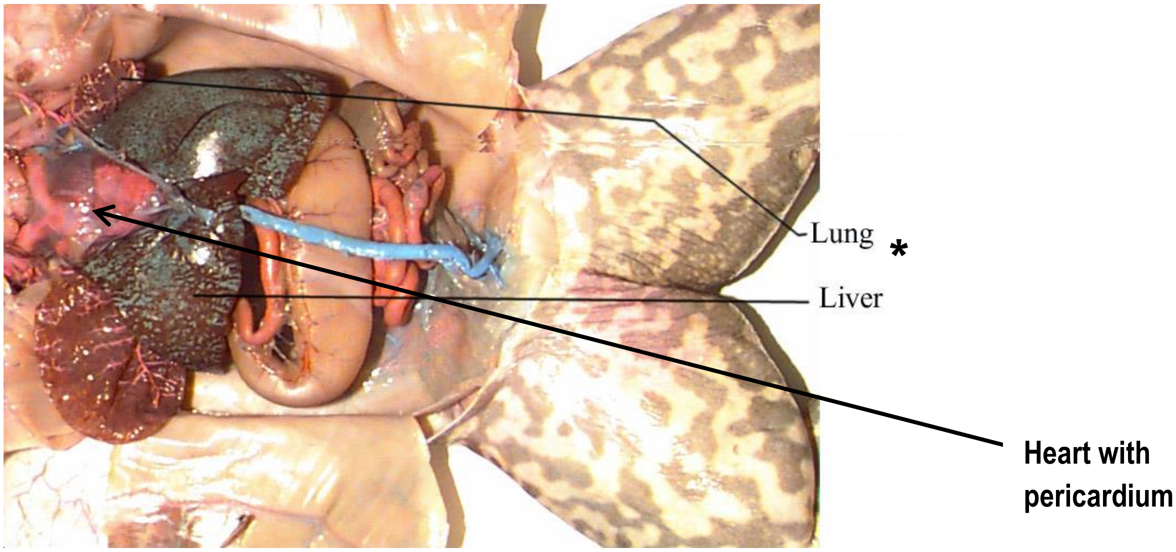

Figure 13.13. Internal anatomy of the frog, featuring the lungs, which are part most terrestrial frogs' respiratory anatomy.

Cleanup

t) Properly dispose of your frog specimen by placing it in the biohazard container. Do not leave any of parts in the trash cans or sink.

u) Rinse and dry all equipment used, including the dissecting pan.

ACTIVITY 13.2: Various specimens representing Class Amphibia are on demonstration. Visit the specimens on demo and review the characteristic features of these animals using Figures 13.1-13.13 to help you.

Class Reptilia

Figure 14.14 The four major orders of reptiles.

Members of the Class Reptilia traditionally include the lizards, snakes, turtles (including tortoises) and crocodiles and alligators (see Fig. 13.14). Modern scence suggests, however, that this group should also include birds (see further discussion on this issue below).

In general, reptiles exhibit a lifestyle that represents a complete break from the water-dependency as is exhibited by amphibians. With reptiles, we see the evolution of the **amniotic egg** (which possess an ***amnion***, a fluid-filled sac surrounding the developing embryo), lungs (rather than skin) as the major respiratory organ, a **three-chambered heart** (complete with an intraventricular septum for the partitioning of oxygenated and deoxygenated blood in the ventricle), protective **epidermal scales or plates**, and water-conserving **uric acid** as the nitrogenous waste product (with fish, it is typically ammonia and with amphibians it is typically urea).

With the characteristics described above, this taxon set the basic biological design for the birds and mammals to which it gave rise. The on-going exploration of dinosaur fossil remains continues to demonstrate just how successful the reptile lineage once was. Indeed, it was this group of reptiles which initially filled most of the vertebrate primary consumer (= herbivore) niches on Earth. The only other vertebrate class to do so has been the mammals, but their time in this role has as yet been much shorter than that of the extinct large reptiles. Only evolutionary time will tell which of these two vertebrate taxa will have been the most successful.

Figure 13.15. Bird diversity.

The Taxon formerly known as "Class Aves"

The birds, formerly categorized in a separate Class Aves, began their evolutionary journey about 160 million years ago as a lineage of small, dinosaur-like reptiles in the Jurassic period. Currently, this group contains more species than any other vertebrate class (10,000; see Figure 13.15) except Actinopterygii (25,000).

If one had to point to a single feature which has accounted for the success of the birds, it would be **flight**. Flight has arisen independently several times during the evolution of life on Earth: in the insects (most species), reptiles (Pterosaurs and birds - almost all species), and mammals (bats). In addition to **feathers**, birds have evolved a number of characteristics associated with flight including **light, hollow bones**, the **absence of teeth**, **oviparity**, and **massive flight muscles** on a reinforced (i.e., through fusion of bones as in the :wishbone") skeletal structure.

Besides the flight-related characteristics listed above, birds also have a **horny (keratin-based) beak** and **parental care (**not commonly exhibited in most amphibians or non-avian reptiles; exceptions include crocodiles, alligators and dinosaurs). In addition, the modern birds, along with mammals, represent the only two **endothermic** vertebrate taxa with a high and constant metabolism.

ACTIVITY 13.3: Specimens representing Class Reptilia, including the birds, are on demonstration. Visit the specimens on demo and review the characteristic features of these animals.

Class Mammalia

Class Mammalia includes approximately 5,000 species of animals divided into three main suborders: the ***monotremes*** (the platypuses and their relatives), the ***marsupials*** (opossums, kangaroos, the Tasmanian devil and their relatives) and the ***placental mammals*** (most mammals including rodents, ungulates, bats, shrews, carnivores and their relatives) (see Fig. 13.16).

All mammals share at least three characteristics not found in other animals: 1) hair/fur, 2) three middle ear bones, and 3) milk production by modified sweat glands called **mammary glands**. In addition to these characteristics mammals, like birds, are **endothermic** and have **heterodont dentition.**

The two living species of monotremes, the platypus and the spiny echidna, exhibit a clear link to mammals' reptilian ancestry with their **oviparous** (egg-laying) nature. However, it has been the evolution of **mammary glands** which function in the nourishment of the young during extended post-birth periods which, perhaps, accounts for much of their success. Although mammals tend to have fewer offspring relative to fishes or frogs, they tend to provide much more in the way of parental attention which has likely influenced increased rates of survivorship to adulthood. **Fur** and/or **subcutaneous fat insulation** allow mammalian species to thrive in nearly all habitats on earth, a distinction which they share only with their "warm blooded" relatives, the birds.

Figure 13.16. Mammalian diversity.

ACTIVITY 13.4: Review of the external and internal anatomy of a (preserved) fetal pig.

In groups of four, and with the aid of Figures 13.17-13.31 below and the additional dissecting chart on your table, obtain and review the external and internal anatomy of a preserved fetal pig.

External Anatomy

a) Obtain a fetal pig, a dissecting tray and some string. Place the pig in the dissecting pan. You will use the string momentarily to secure your specimen to the dissecting tray.

b) In preparation for your examination of the fetal pig anatomy, be sure that your recognize the location of the ***anterior, posterior, dorsal***, and ***ventral*** sides of the animal. In addition, make sure that you can identify the ***medial*** (toward the midline or middle of the body), ***lateral*** (toward the outside of the body), ***proximal*** (close to a point of reference) and ***distal*** (farther from a point of reference) aspects of the specimen. Familiarity with these terms will be important as you navigate through the directives listed below and in other resources you use today.

- To test yourself, label the figure of the fetal pig in your Notes section with these terms listed above.

c) Determine the sex of your pig by identifying the placement of the <u>**urogenital opening**</u>. The urogenital opening is a pathway for both the urinary and reproductive systems. On females, this opening is located near the <u>**anus**</u>. On males, the opening is located near the ***umbilical cord*** (see Figure 13.17).

- If your pig is female, you should also note that a <u>**urogenital papilla**</u> is present near the genital opening. The urogenital papilla is a triangular flap of tissue that covers the opening of the urogenital tract. It is found just ventral to the **anus**, beneath the tail. Males do not have urogenital papilla.

- Both males and females have an <u>**umbilical cord**</u> and <u>**two rows of nipples**</u>,
  - *Two umbilical arteries* carry blood from the fetal pig to the placenta, and a *single umbilical vein* delivers nutrient-rich blood back to the fetal pig.
  - Mammary glands will later develop only in maturing females.

Q. What sex is your pig? ______________________

d) Locate these additional external features, using Figure 13.18 and the dissecting guide at your table as a resource:

- **Eyes**
- **Tail**
- **Limbs:**
  - **Forelimbs: shouldter, elbow, wrist, hoof with digits**
  - **Hindlimbs: hip, knee, ankle, hoof with digits**
- **Pinnae (= external ears)**
- **Snout with nares**

Q. How many toes are on the feet?_______________

Q. Are there an odd or even number of toes? ______________

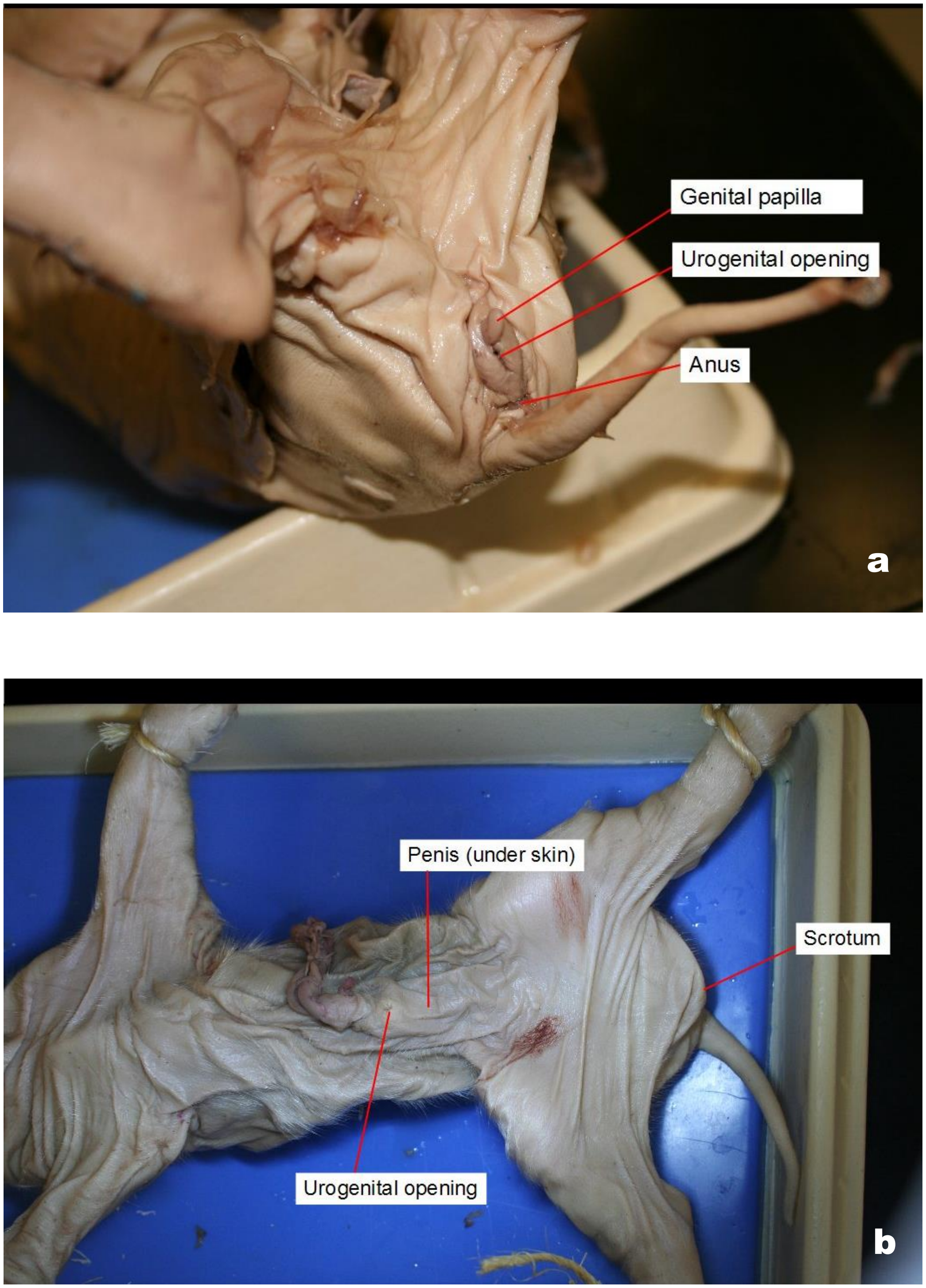

Figure 13.17. Posterior, ventral view of a female fetal pig (a) and ventral view of a male fetal pig (b). Location of the urogenital opening and presence of a penis and scrotum in males and the urogenital papilla in females can be used to sex your specimen.

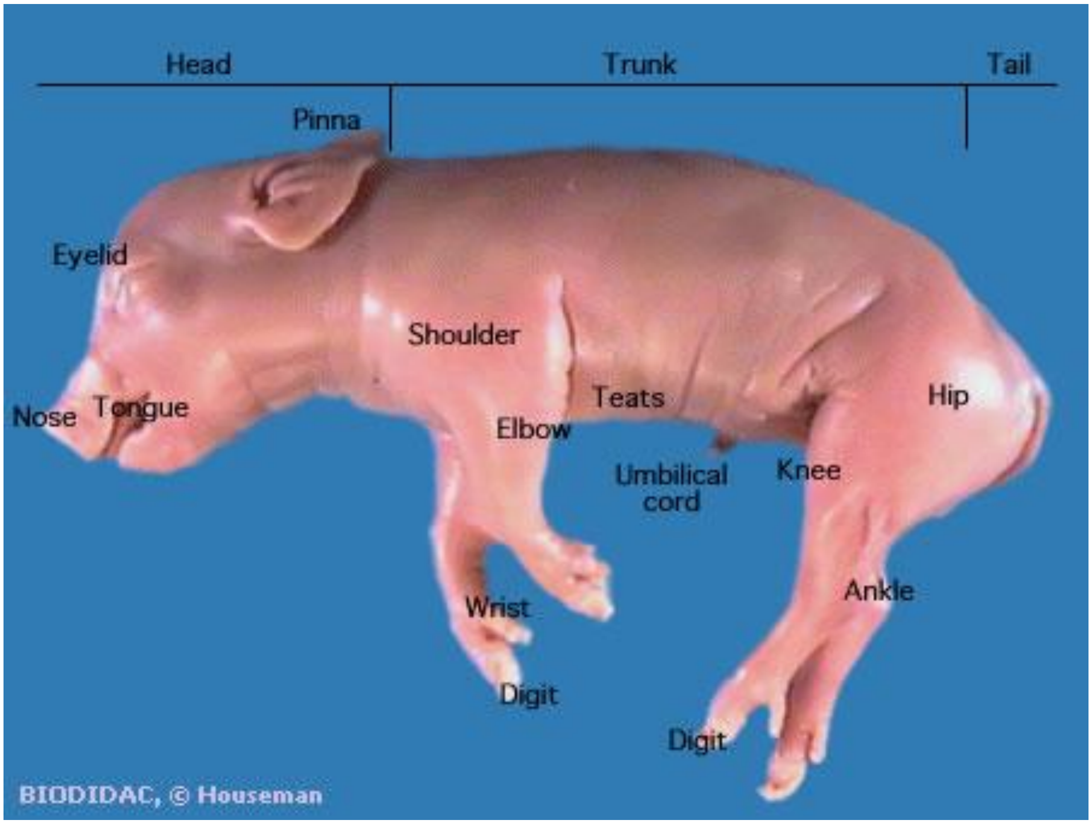

Figure 13.18. External anatomy of a fetal pig.

<u>Internal Anatomy</u>

e) Position your fetal pig on your dissecting tray ventral side up. Use the string you have to tie the right hind leg around the ankle. Then run the string under the tray and around to the other side where the left hind leg is and, leaving no slack, tie the other end of the string around the left hind ankle. Repeat this with the forelimbs.

Using the figures below and the dissecting guide on the table, identify the structures below, making sure to take note of their form and function:

Digestive Structures – *Pigs, like all chordates, have a* ***<u>complete digestive system</u>.*** *The digestive system consists of the organs of the digestive tract, or food* ***t****ube, and the digestive glands. Use Figures 13.19-13.22 below and the dissection chart on the table to study the following structures.*

- To expose the structures of the **<u>mouth</u>** and **<u>pharynx</u>**, insert a pair of scissors in the angle of the lips on one side of the head and cut posteriorly through the cheek. Open the mouth as you make your cut and follow the curvature of the tongue to avoid cutting the roof of the mouth.

- The **<u>pharynx,</u>** <u>also known as the throat,</u> is the cavity in the back of the mouth which serves as the junction for the pathways leading to the digestive system (via the **<u>esophagus</u>**) and the respiratory system via the **<u>larynx</u>**).
- Locate the **<u>glottis</u>**, the opening to the ***larynx*** and the rest of the respiratory system. Associated with the ***glottis*** is the **<u>epiglottis</u>**, a small, cartilaginous flap which covers the glottis when the pig swallows.
- Hold down the **<u>epiglottis</u>** and surrounding tissue and continue your incision dorsal to it and on into the opening of the **<u>esophagus</u>**. Next, repeat the procedure on the other side so that the lower jaw can be pulled down to expose the structures within the ***mouth*** and ***pharynx*** as shown in Figure 13.19

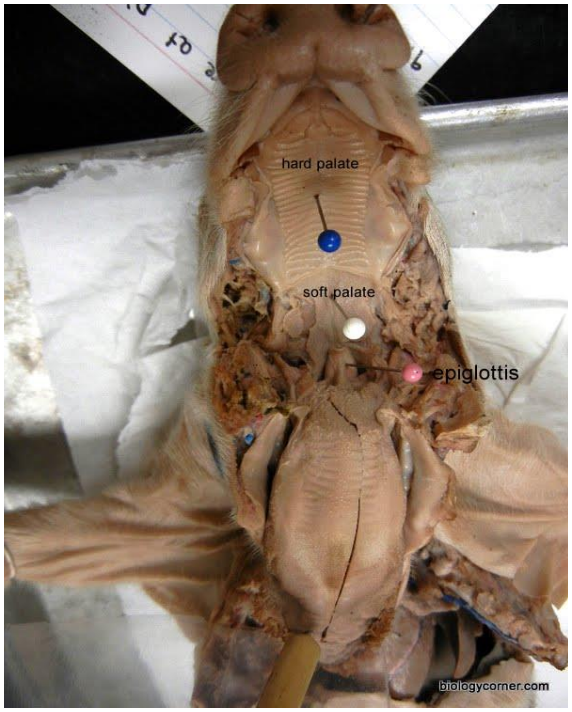

Figure 13.19. Inside the oral cavity of a fetal pig.

- Locate the **<u>hard and soft palate</u>** on the roof of the mouth. The hard palate is the hard bony part in the front of the roof of the mouth, while the soft palate is the soft tissue part in the back of the roof of the mouth. The soft palate is responsible for the shutting off of the nasal passages during swallowing.

Q. Can you feel your own hard and soft palates with your tongue?

- Note the taste buds (also known as **<u>sensory papillae</u>**) on the side of the tongue. Feel the edge of the mouth for teeth.

Q. Does the fetal pig have teeth? ____________________

Q. Are humans born with teeth? _____________________

- At this time, you need to further dissect the animal so that you may examine the internal organs. Use a scalpel and/or dissecting scissors to cut through the skin and muscles according to Figure 13.20. Do not remove the umbilical cord. In the first section, you will only examine the abdominal cavity (the area below the ribcage).
- After completing the cuts, locate ***the umbilical vein*** that leads from the **umbilical cord** to the **liver**. You will need to cut this vein in order to open up the abdominal cavity.

  NOTE: If your pig is filled with water and/or preservatives, drain it over the sink if necessary and rinse the organs.

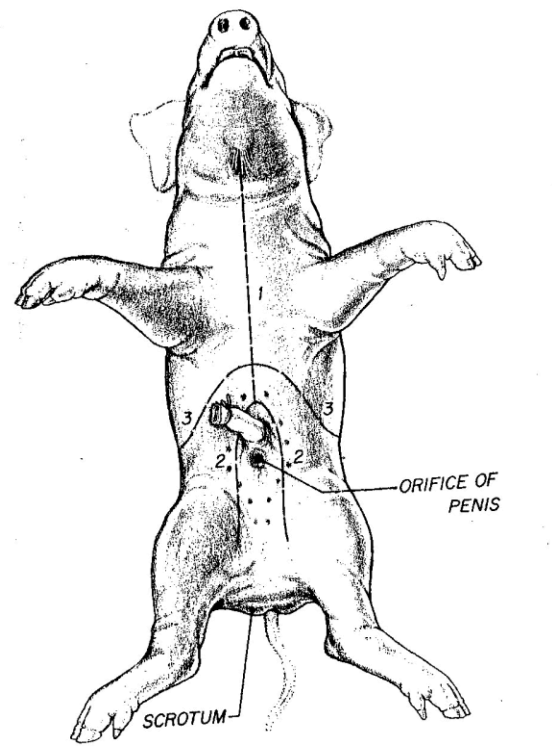

Figure 13.20. How to make your incision in your fetal pig. For males, make cuts 1and 2; for females, make the 1 and 3 cuts.

- After cutting, reflecting back and/or removing the skin and muscles from the ventral neck area.probe the area dorsal to the trachea and find the **esophagus**. The esophagus is a flexible walled tube composed of connective tissue and smooth muscle. Note that the esophagus runs parallel to but dorsal to the **trachea**.

  Q. Why are the respective designs of these two passageways very complementary to their functions?

- Now proceed to the **peritoneal cavity (cavity = space), located** below the ***diaphragm***. The first organ encountered is the massive **live**r.
  - **Liver** - This structure is lobed and is the largest organ in the body. The liver is responsible for making **bile** for digestion.
- Carefully push and pin the liver to one side, noting the **gall bladder** on its underside as you do so.

Q. What is the functional relationship between the liver and the gall bladder?

- **Gall bladder** -This greenish organ is located underneath the ***liver***; the ***bile duct*** attaches the ***gall bladder*** to the ***duodenum*** **(the first section of the small intestine)**. The gall bladder stores bile and sends it to the duodenum, via the bile duct..

- Next locate the "U" shaped **stomach** and note the entrance of the **esophagus** at its anterior end. Trace the stomach to its narrow posterior end where it joins with the ***small intestine***.
  - **Stomach** - A pouch shaped organ that rests just underneath and to the pig's left. At the top or anterior portion of the stomach, you'll find the ***esophagus***. The stomach is responsible for breaking down food. View the inside of the ***stomach*** by slicing it open lengthwise.
  - The constriction between the ***stomach*** and ***small intestine*** is called the **pylorus**, and passage of material from stomach to small intestine is controlled by a ***pyloric sphincter valve***. At the esophagus there is a ***cardiac sphincter valve***.
- **Small intestine** -The stomach leads to the ***small intestine***, which is composed of the ***duodenum*** (straight portion just after the stomach), the ***jejunim*** (the middle portion) and the ***ileum*** (the last, curly part). At the end of the ileum, where it widens to become the ***large intestine***, a "dead-end" branch is visible. This is the ***cecum***. The cecum contains a special collection of bacteria which helps the pig (and mammals in general) digest plant material.
- **Mesentery** - The ileum is held together by ***mesentery***. In the small intestine, further digestion occurs and nutrients are absorbed through the arteries in the mesentery. These arteries are called ***mesenteric arteries***.
- As you begin tracing the **small intestine**, look carefully for a small cluster of spongy tissue attached to the thin, transparent mesentery which spans the first bend in the small intestine. This material is the **pancreas**.
  - **Pancreas** - a bumpy or spongy organ located along the underside of the stomach. The pancreas secretes special ***digestive enzymes*** which are dumped into the the duodenum via a duct. The pancreas also makes ***insulin***, which is necessary for the proper uptake of sugars from the blood.
- **Rectum** - the large intestine can be traced to the ***rectum***. The rectum lies toward the back of the pig and will not be moveable. The rectum opens to the outside of the pig through an opening we call the ***anus***.

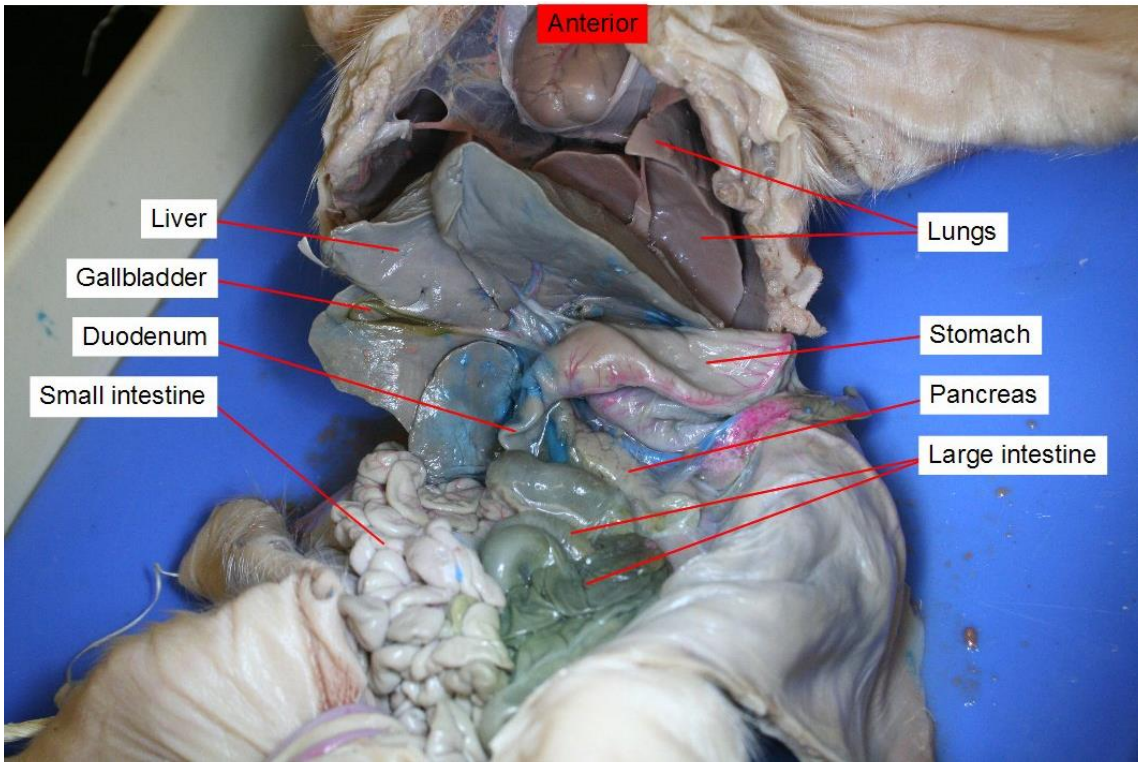

Figure 13.21. Digestive system of the fetal pig.

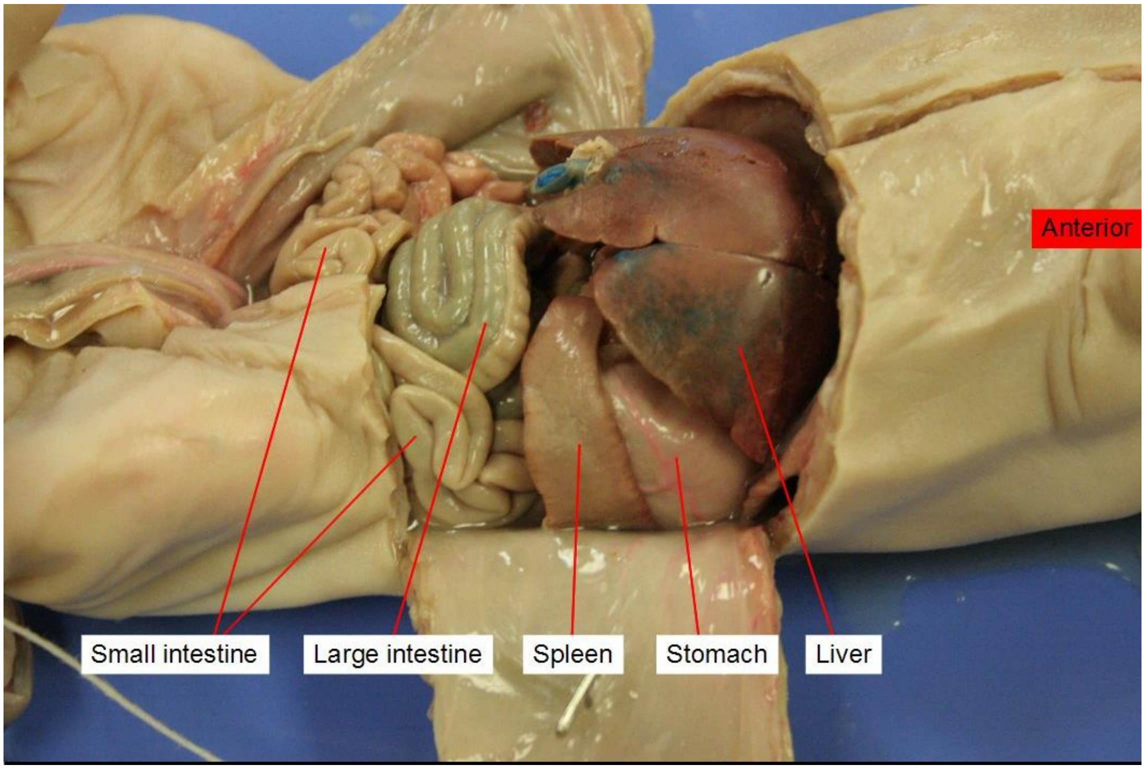

Figure 13.22. Organs of the digestive system of the fetal pig, including the spleen.

Urogenital Structures –You will need to know the structures associated with the male versus female excretory and reproductuve systems for the pig. Use Figures 13.23-13.26 below and the dissection chart on the table to study these structures.

- Fold back the intestines and pin it out of the way so that the organs on the dorsal aspect of the peritoneal cavity may be easily seen.

Reproductive Structures **-** *Pigs, like all vertebrates, are* ***dioecious.***

(Male)

- Find the **scrotal sacs** at the posterior end of the pig (between the legs, just below the **anus**); a **testis** is located in each sac.
- Carefully cut through the wall of one of the sacs and locate the **testis** and a mass of highly coiled small tubes, the **epididymis**, in which the spermatozoa are stored. Sperm cells produced in the testes pass through the epididymis and into a tube called the **vas deferens** (in humans, a vasectomy involves cutting this tube).
- The **penis** can be located by cutting away the skin on the flap near the umbilical cord. This tube-like structure eventually exits out the urogenital opening, also known as the ***urethra***.

(Female)

- In the female pig, locate two bean shaped **ovaries** located just posterior to the ***kidneys*** and connected to the curly **oviducts**.
- Trace the oviducts posteriorly to visualize how they merge at the **uterus**. Trace the uterus to the **vagina**. The vagina will actually will appear as a continuation of the uterus.

Excretory Structures

- Locate the **kidneys** on either side of the vertebral column. The tubes leading from the kidneys that carry urine are the **ureters**. The **ureters** carry urine to the **urinary bladder** - located between the umbilical vessels (contained together in the structure known as the **umbilical cord**).
- Lift the bladder to locate the **urethra**, the tube that carries urine out of the body. In a female fetal pig, the urethra empties into the distal portion of the ***vagina***. In a male mammal, it travels the length of the ***penis*** and opens at its tip.
- Note the vessels that attach to the ***kidney*** - these are the **renal vessels** (i.e., renal veins and renal arteries).

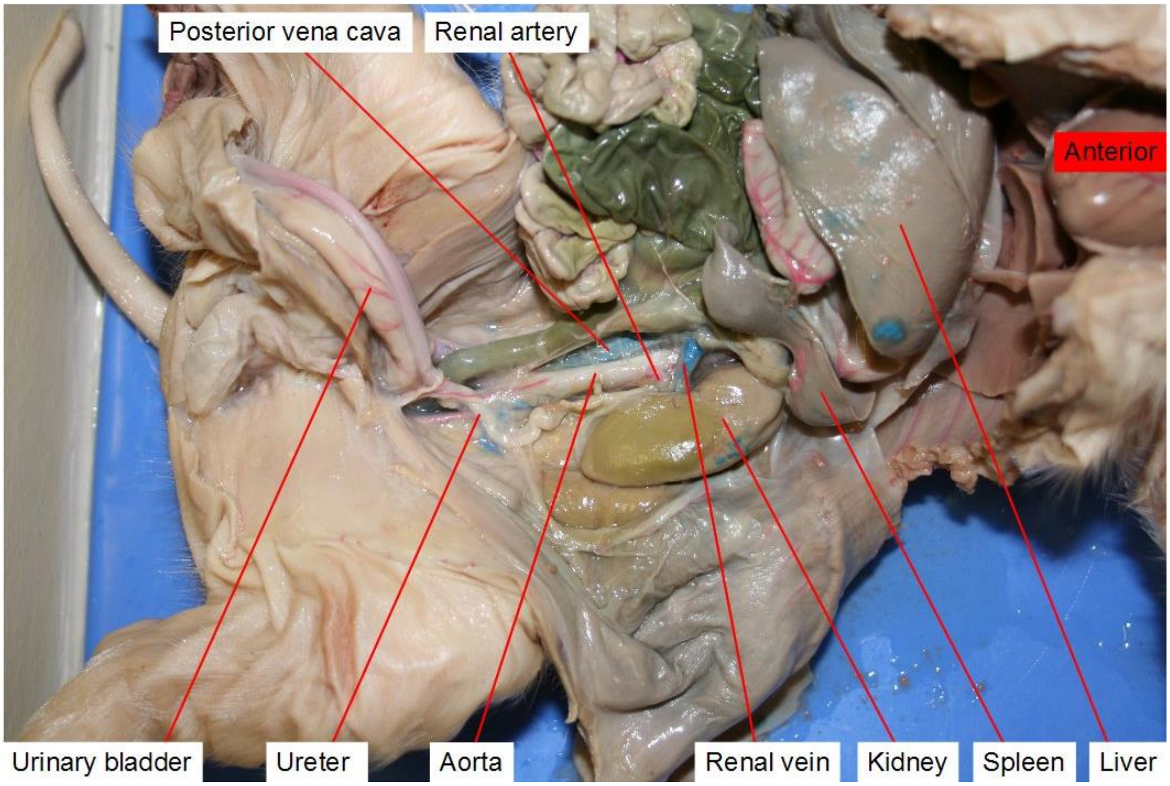

Figure 13.23. Organs associated with the excretory system of the fetal pig.

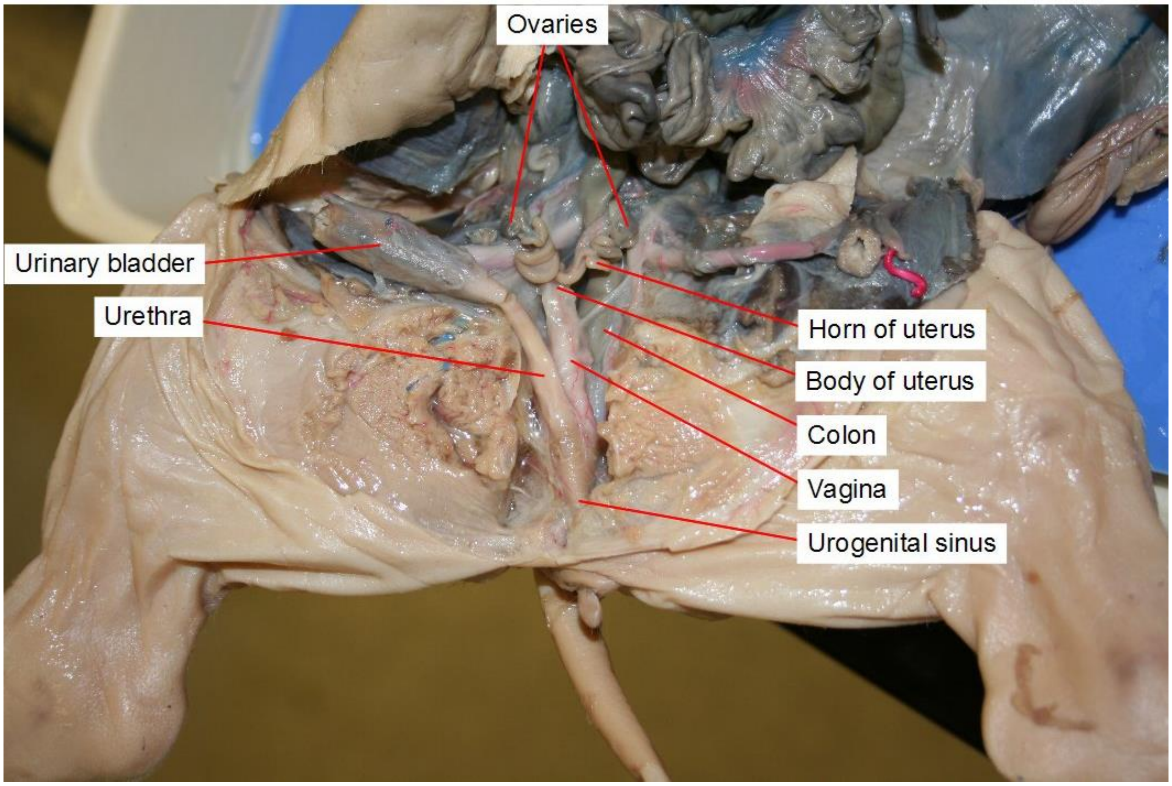

Figure 13.24. The urogenital system of a female fetal pig.

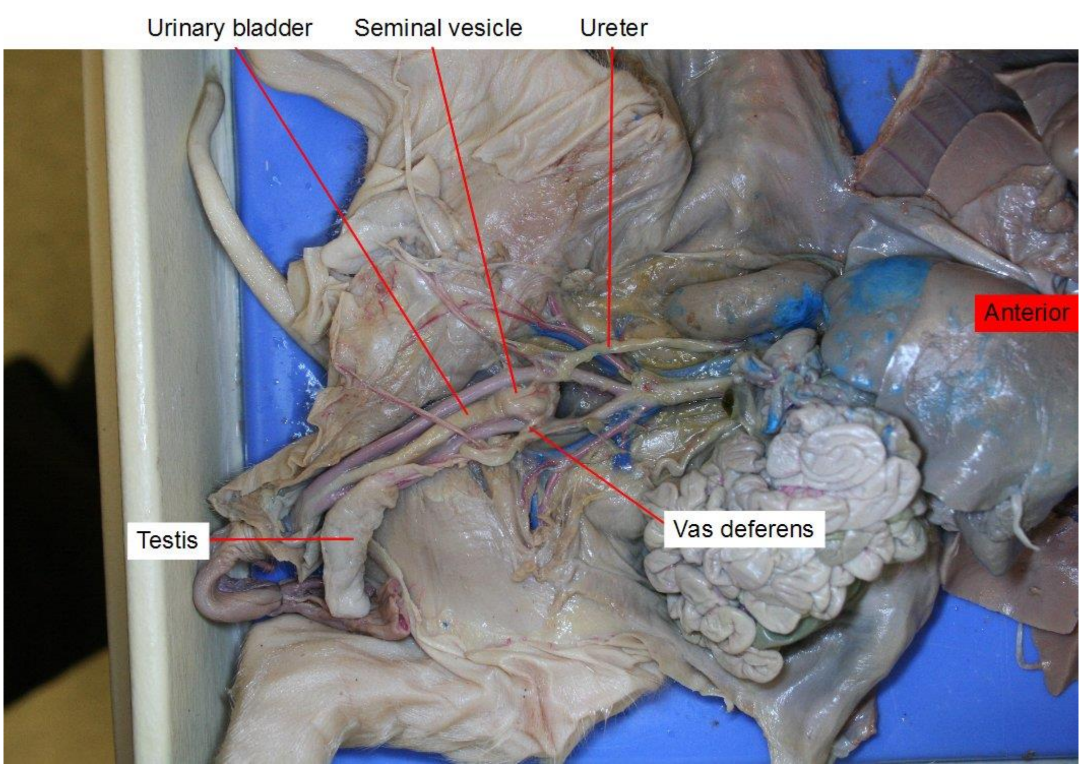

Figure 13.25. Urogenital system of a male fetal pig.

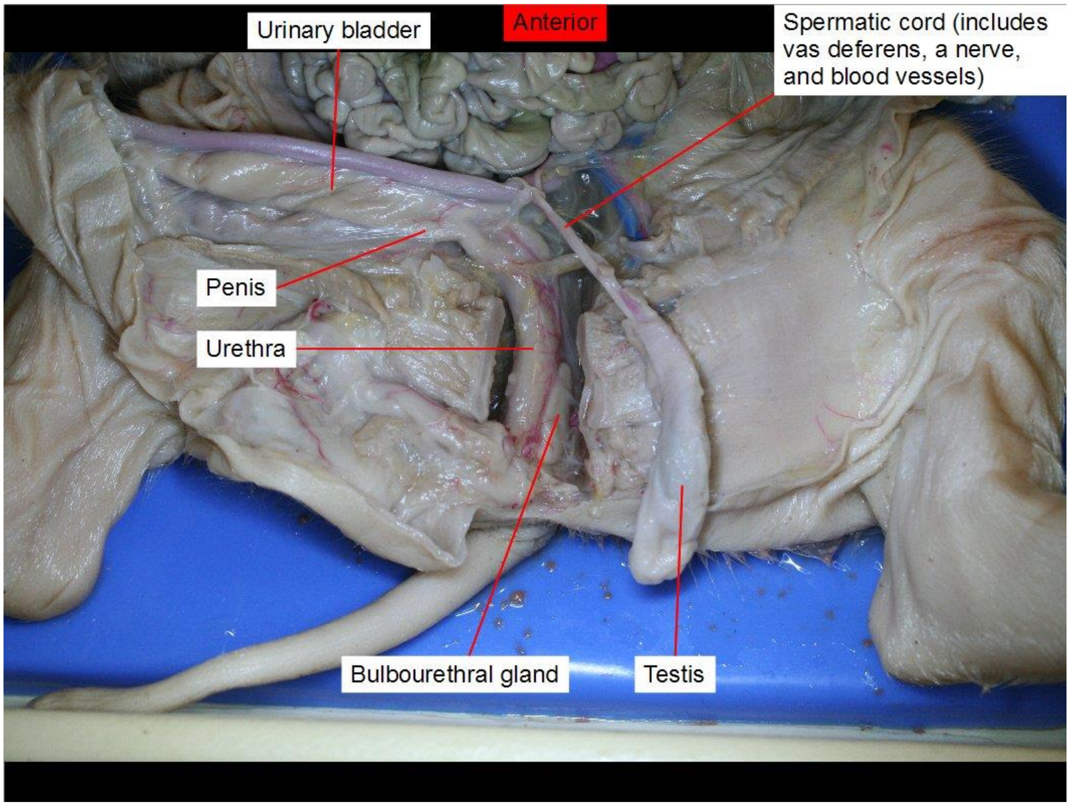

Figure. 13.26. Another view of the urogenital system of a male fetal pig.

Circulatory Structures – Pigs like most reptiles, technically have a four-chambered heart. Using Figures 13.27-13.30 below and the dissection chart on the table to study these structures.

- Find the **diaphragm**, which separates the ***abdominal cavity*** from the ***thoracic cavity***. Above the diaphragm, in the center of chest, is the **heart**.
- **Heart** – mammals have a *four-chambered heart*.
  - in mammals is comprised of a **right** and **left atrium and a right** and **left ventricle,**
  - while it can be observed from the outside that there are ***two atria***, it is not obvious from the outside that there are ***two ventricles***.
- **Pericardium** – is a thin membrane that surrounds the heart. Sits within its own ***pericardial cavity***. This is a separate body compartment and it contains ***pericardial fluid*** which cushions the heart.

Cut through the pericardium and examine the heart as it lies in its natural position within this mammalian body.

- **Pulmonary trunk** - is the most obvious vessel on the front of the heart. It curves upward and joins the ***aorta***. *NOTE: The term "trunk" in cardiovascular anatomy refers to a base vessel which, like the trunk of a tree, will soon give rise to several smaller branches.*
    - The large artery leaving the ***right ventricle*** is the **pulmonary artery** which soon splits into a left and right branch. Note that just before the left branch there is a short vessel which connects the ***pulmonary artery*** to the ***dorsal aorta***. This is the **ductus arteriosus** *(see more on this structure below).*
- **Aorta** - this vessel arches from the heart and curves around to go to the lower part of the body where it is called the dorsal (abdominal) aorta. The aorta supplies the body with oxygenated blood after it leaves the left side of the heart. The aorta will curve back and then branch in two spots - the ***right brachiocephalic*** and the ***left subclavian***. The ***right brachiocephalic*** then branches into arteries - the ***common carotid*** and the ***right subclavian***. The subclavians supply blood to the arms and follow the clavicle bone.
    - The ***right subclavian*** next splits into more branches distally.
    - The ***arch of the aorta*** continues to bend posteriorly and gives rise to the ***left subclavian*** which, like its right counterpart, gives rise to several additional arteries which supply the shoulder and forelimb region.
    - The ***aorta*** now proceeds posteriorly just under the *vertebral column* and gives rise to a number of arteries named for the organs which they supply. their respective organs.
    - The ***dorsal aorta*** eventually ends by dividing into paired ***umbilical arteries*** just after it gives rise to ***paired external iliac arteries*** connecting with the hind limbs. You can trace the ***umbilical arteries*** through the ***umbilical cord***. In the normal fetal state they would terminate in a dense capillary complex in the ***placenta***.
- **Common carotid** - the common carotid branches into the ***left and right carotid arteries***. The carotid arteries supply blood to the head and neck.
- **Coronary vessels** - observe the coronary vessels on the outside of the heart. These vessels supply blood to the heart muscle.
- **Anterior and posterior vena cava** – if you lift the heart to look on its dorsal side (toward the back), you should be able to see the anterior and posterior vena cava, which brings blood from the body back to the right side of the heart. In addition, you should also be able to find the ***left and right jugular*** veins that drain blood from the head and run parallel to the carotids.
- On the greater curvature of the ***stomach*** lies the dark-red **spleen**. This is a flattened organ that lies across the ***stomach*** and toward the extreme left side of the pig. The spleen stores blood and is the main site of red blood cell production

in this fetal mammal; it gives over this latter function to the bone marrow in early post-natal life.

- A NOTE ABOUT FETAL CIRCULATORY ANATOMY: In fetal mammals, it is important to begin tracing the venous system from the ***placenta*** or ***umbilical cord*** region where the single ***umbilical vein*** is found. This begins in small ***venules*** in the placenta and carries freshly oxygenated blood from the placental capillary bed. You can trace it anteriorly to where it joins the large ***posterior vena cava*** via a short branch, the **ductus venosus.** At the point where the ***umbilical vein*** joins the ***ductus venosus***, the ***hepatic portal vein*** joins it carrying blood back to the heart from the ***liver*** and most other major body organs. Additional veins from the liver, the ***hepatic veins***, join the ***posterior vena cava*** just anterior to the junction with the ***ductus venosus***.

  You can trace the ***posterior vena cava*** on to the right side of the ***heart*** and then find the large ***anterior vena cava*** as it enters the ***right atrium***. As this large vein courses anteriorly, it branches into the ***left and right subclavian veins***, and the ***left and right jugular trunks*** which then branch into the ***right and left internal and external jugular veins***.

- **A NOTE ABOUT FETAL CIRCULATION**: We know that in the post-natal mammal, blood is oxygenated in the ***lungs***, then travels back to the left side of the heart where it is pumped under high pressure to all cells of the body via the ***arterial system***. After servicing the cells through the ***capillary bed***, it is collected in small ***venules*** which then pass the now deoxygenated blood on to the larger ***veins***. The latter all connect with either the ***anterior or posterior vena cava*** which in turn return the deoxygenated blood to the right side of the heart for pumping to the ***lungs*** where it will again be oxygenated.

  Now, if we try to apply this post-natal circulatory scheme to the fetus, one initial problem is apparent: the ***lungs*** are not functional. Instead, the organ of oxygenation is the ***placenta*** where the fetus receives oxygen and nutrients from the maternal circulation and also gives up waste products . Thus the most highly oxygenated blood in the fetal mammal is found in the ***umbilical vein*** (remember, a vein is any vessel which carries blood back to the ***heart***, NOT a vessel which carries deoxygenated blood). When the ***umbilical vein*** joins the ***posterior vena cava*** via the ***ductus venosus***, it mixes with deoxygenated blood returning from the posterior body area. Further mixing takes place when the ***posterior vena cava*** joins the ***anterior vena cava*** at the ***right atrium***. Thus a mixture of oxygenated and deoxygenated blood enters the right side of the heart and then is pumped by the right ventricle into the base of the **pulmonary artery** or ***pulmonary trunk***.

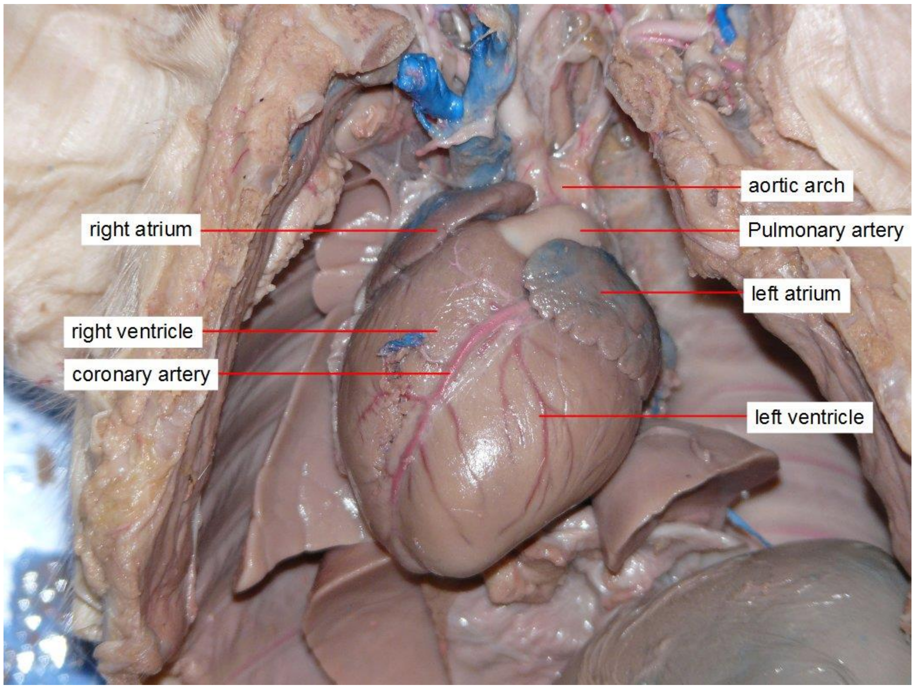

Figure 13.27. Close up view of the heart of a fetal pig

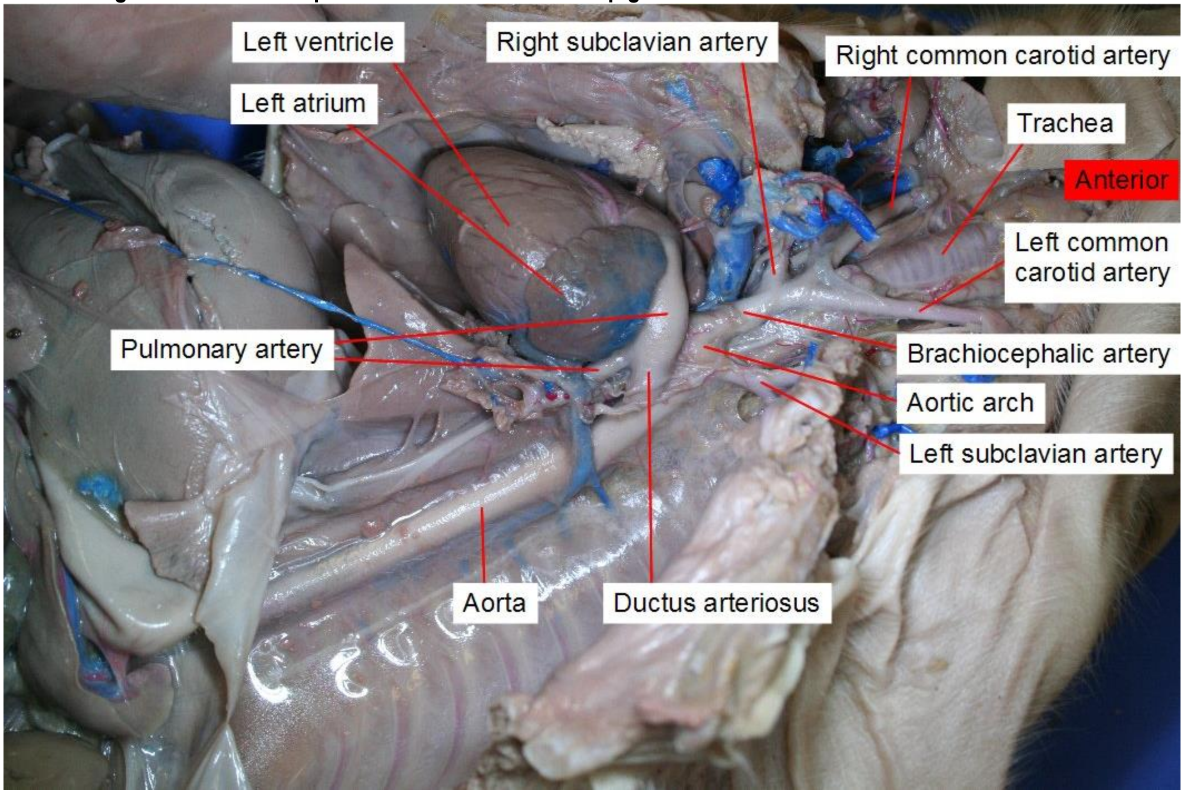

Figure 13.28. View of the heart and major blood vessels of a fetal pig.

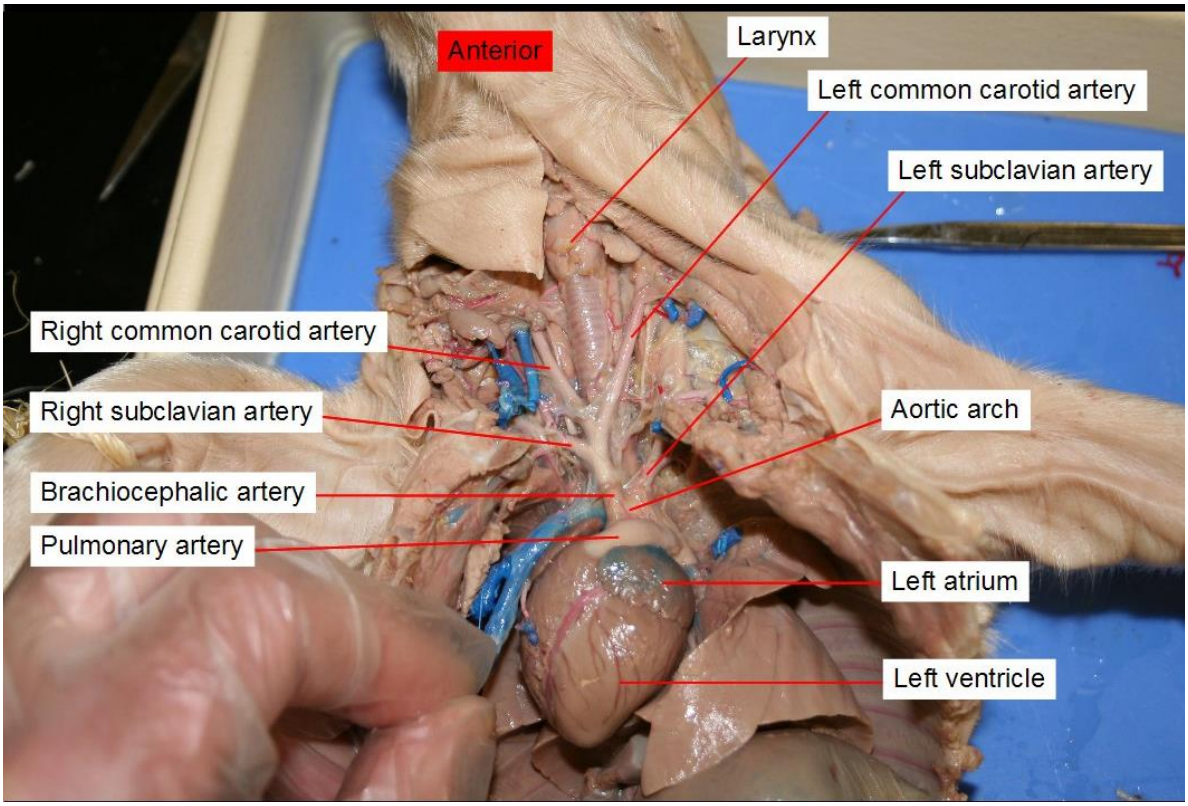

Figure 13.29. Another view of the heart and major blood vessels of a fetal pig.

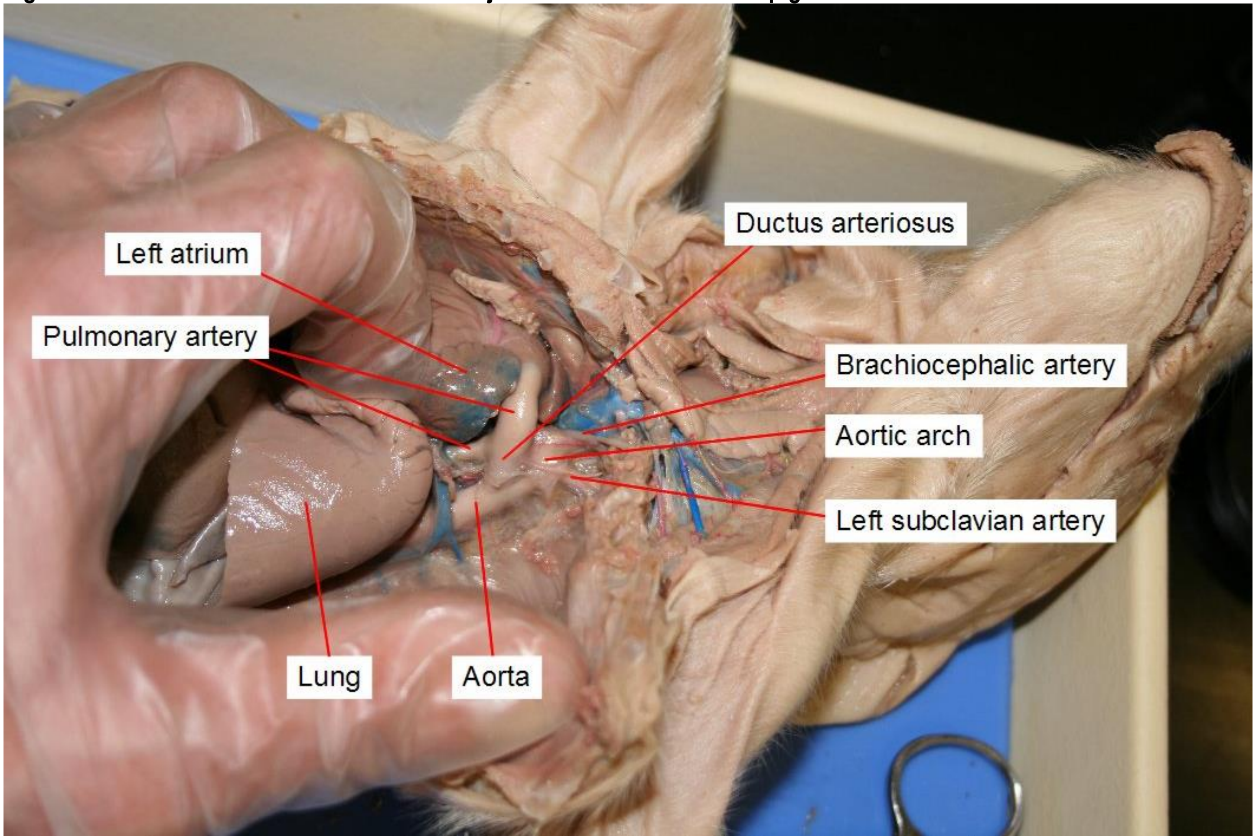

Figure 13.30. A view of the ductus arteriosus in the circulatory system of a fetal pig.

Respiratory Structures – Use Figure 13.31 below and the dissection chart on the table to study these structures.

- Proceed to the ***pleural cavity***. This is a separate body compartment bounded by the ribs, the sternum, the vertebral column, and the **diaphragm**. It defines the region containing the **lungs**.
- Carefully examine the **diaphragm** and its position in the body. This muscle divides the ***thoracic*** and ***abdominal cavities*** and is located near the ribcage. The diaphragm aids in the mammalian negative-pressure breathing. Contraction of the diaphragm, causes the volume of the pleural cavity to increase and, thus, draws air into the lungs, while relaxation of the diaphragm decreases the volume of the pleural cavity and forces air out of the lungs.

  Q. Which way does it move during an inhalation? How about during exhalation?

- **Trachea** - The trachea is easy to identify due to the cartilaginous rings, which makes it appear somewhat like a small vacuum hose. These cartilaginous rings help keep the trachea from collapsing as the animal inhales and exhales. The trachea should be located in the chin area above the heart. It runs parallel but ventral to the ***esophagus***.
  - Next carefully probe dorsally towards the trachea. While doing so, your probe will pass through the large **thymus gland** which overlies the trachea. The thymus gland helps form part of the immue system.
  - Lying atop (ventral to) the ***trachea*** and just under the ***thymus gland***, locate the much smaller, pinkish-brown, V shaped structure called the **thyroid gland**. This gland secretes hormones that control growth and metabolism.

  NOTE: The thymus and thyroid glands are not part of the respiratory system; they are better categorized within the endocrine system. However, since we are not covering the endocrine system during this lab activity and because of the location of these glands relative to certain respiratory structures, these glands are mentioned here.

- **Larynx** - at the anterior (toward head) of the ***trachea***, you can find the hard light colored larynx (or voice box). Is composed of cartilage and contains the vocal cords. The larynx allows the pig to produce sounds - grunts and oinks.

- **<u>Lungs</u>** - push the heart to the side to locate two spongy lungs located to the left and right side. The lungs are connected to ***bronchial tubes*** (not visible) which connect to the trachea (forming a Y).
- **<u>Bronchi</u>** - the ***trachea*** branches to form the two primary bronchi. *(Note: these structures should be readily visible if the heart is removed; if/when this is done dissect away connective tissue as needed).*
- **<u>Vocal cords</u>** - view on each side after making a mid-central incision in ***larynx***.
- **<u>Bronchioles</u>** - dissect along a ***bronchus*** to view branching as it enters ***lung***.

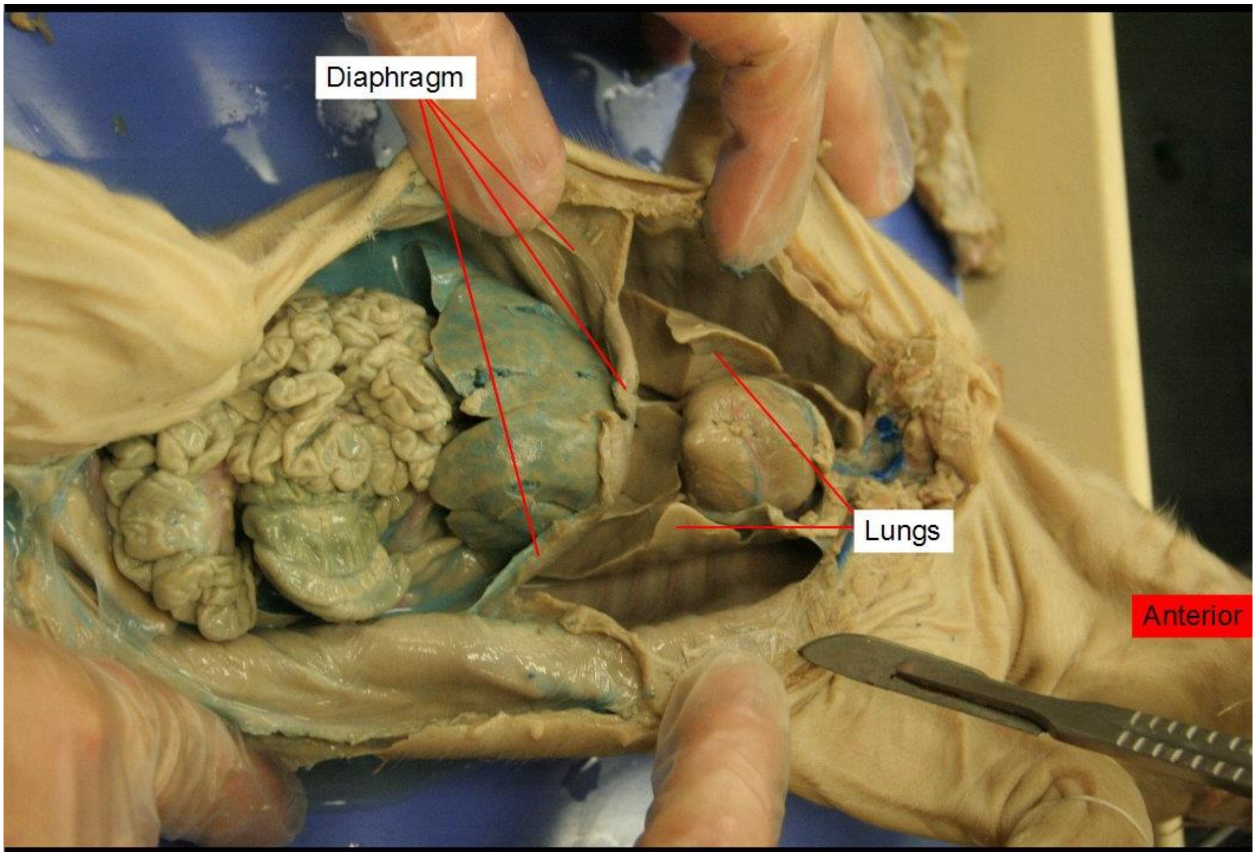

Figure 13.31. Lungs and diaphragm within a fetal pig.

Cleanup

h) Dispose of your specimens properly in the biohazard container.Do not leave any parts in the trash cans or sink.

i) Rinse and dry all equipment used, including the dissecting pan.

ACTIVITY 13.5: Specimens representing Class Mammalia, are on demonstration. Visit the specimens on demo and review the characteristic features of these animals.

FOR MORE INFORMATION…

- **University of California Museum of Paleontology: Introduction to the Chordata** - http://www.ucmp.berkeley.edu/chordata/chordata.html

- **Tree of Life: Chordata** - http://tolweb.org/Chordata/2499

- **Shape of Life Website: Phylum Chordata**
http://www.pbs.org/kcet/shapeoflife/animals/chordates.html

- **California Herps: Reptiles and Amphibians of the San Francisco Bay Area**
http://www.californiaherps.com/identification/bayareaherps.html

- **Bullfrog Dissection Information**
http://biologycorner.com/worksheets/bullfrog/index.html

- **Frog Anatomy Review Resources**
http://www.biologycorner.com/worksheets/frog_review.html

- **Frog Anatomy Review Resources**
http://www.biologycorner.com/worksheets/frog_review.html

- **Virtual Frog Dissections**
http://www.altoona.psu.edu/academics/www/mns/bioal/Frog/setup.htm
http://www.biologyjunction.com/frog_dissection.htm

- **University of California Museum of Paleontology – Introduction to Aves**
http://www.ucmp.berkeley.edu/diapsids/birds/birdintro.html

- **University of California Museum of Paleontology - Bird as Dinosaurs**
http://www.ucmp.berkeley.edu/diapsids/avians.html

- **Animal Diversity Web:**
Mammaliahttp://animaldiversity.ummz.umich.edu/accounts/Mammalia/

- **Virtual Fetal Pig Dissections**
http://faculty.clintoncc.suny.edu/faculty/michael.gregory/files/bio%20102/bio%20102%20laboratory/fetal%20pig/fetal%20pig.htm

http://biology.uco.edu/animalbiology/pigweb/pig.html

http://www.biologyjunction.com/fetal_pig_dissection.htm