The Diversification of Life

Examining the Tree of Life

Objectives

1. Improve ability to use a compound light microscope. Be able to track moving organisms under microscope.
2. Recognize single cells, colonies and filaments.
3. Know at least two mechanisms of motility of microscopic organisms.
4. Be able to draw (and recognize from drawings) important characteristics of microorganisms under the microscope.
5. View example animals from all three domains, and many branches of the phylogenetic tree of life.

Taxonomy is the branch of biology concerned with naming and classifying organisms. In the past, classification of organisms was based on physical appearance and shared characteristics. Since the advent of our ability to read the genetic code of organisms, biologists have been reassessing the relationships of organisms and are currently redrawing the phylogenetic tree of life.

In today's lab, we will try to give you a brief outline of all life on earth, with the current genetic relationships as represented by a **phylogenetic tree**. The tree of life describes the evolutionary relationships between species. The phylogenetic tree diagram works like a diagram of a family tree; close branches represent groups that share a recent common ancestor, further branches indicate further common ancestors. You will see a few examples of a few of the major lineages in the tree of life.

Ultimately, today's lab should help you to further develop your microscope skills, while increasing your knowledge of the difference between prokaryotic and eukaryotic organisms. You will examine some organisms from different branches of the phylogenetic tree of life. Hopefully, this lab will show you a few of the wide range of organisms you have been living with, some which you may have never noticed or thought about, that exist in our world.

What are we doing today? **Specifically**, in this lab you will examine some prokaryotic and eukaryotic organisms, representing the major lineages on the tree of life. You will create scientifically accurate drawings of the microorganisms to enable you to learn about the microorganisms' structures and functions.

History / Background

You are probably accustomed to the traditional Linnaean system of classification. It assigns organisms to set levels of organization, and many people use a mnemonic to remember the order:

Domain	**Kingdom**	**Phylum**	**Class**	**Order**	**Family**	**Genus**	**Species**
Dashing	King	Philip	Came	Over	For	Grandma's	Soup

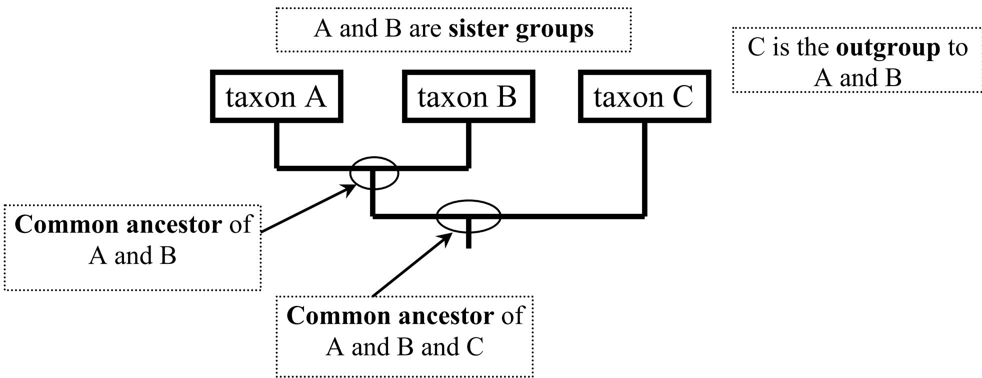
Over the last twenty years, there has been a dramatic change in the way organisms are classified. Since the early 1990s, biologists have truly embraced the classification of organisms using **PHYLOGENETIC TREES**. The change to using tree diagrams for classification is occurring as biologists desire to use a system that does not rely on strict ranks (e.g. class, order, family) but instead portrays the evolutionary history in the classification system. Phylogenetic tree diagrams are more useful to evolutionary biologists than the Linnaean classification system from several important reasons:

1. Tree diagrams depict relationships in organisms based on shared traits or characters.

2. Tree diagrams depict degree of relatedness by branch differences (further separated braches represent more evolutionary separation.)

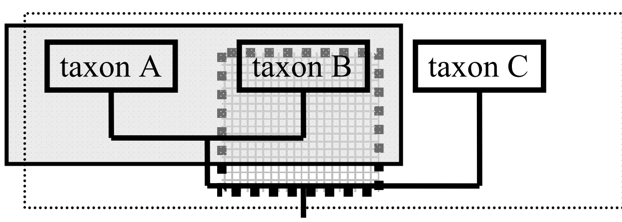
3. Tree diagrams do not rely on set ranks; more (or less) breaks in a tree diagram can show more (or less) changes in characteristics between the groups shown.

Example of a phylogenetic tree:



This phylogenetic tree shows the relatedness of the three taxa, A, B, and C. The branches in the diagram show that taxon A and B are more closely related than Taxon C. These trees are very useful to evolutionary biologists, and currently the relatedness of different taxa is still being discussed and investigated.

Instead of using the ranks assigned by Linnaeus, these groups are called **clades**, and this diagram is called a **cladogram**. All the groups in the boxes below represent different clades. You can think of clades as branches on the tree of life.



This clade contains taxa A, B, & C.

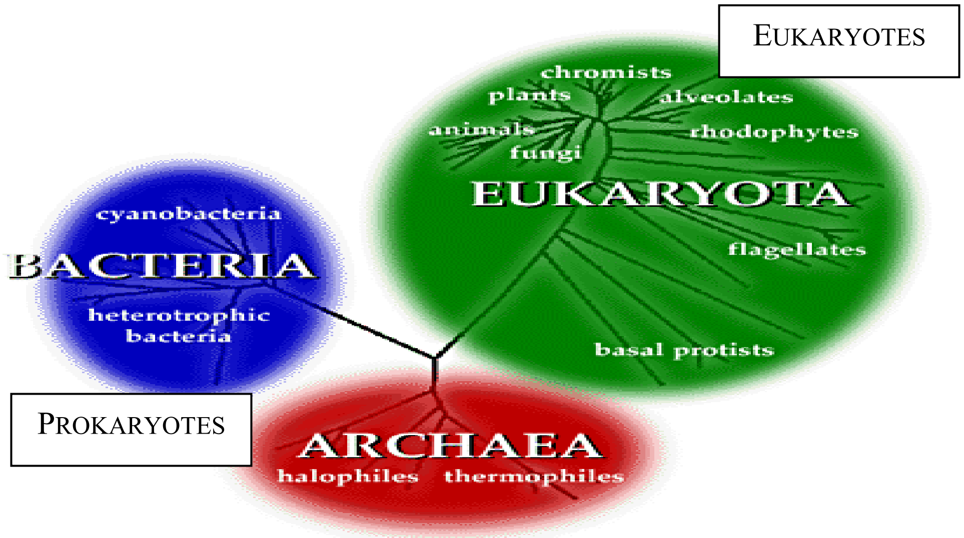
This clade contains taxa A & B.

This clade contains only taxon B.

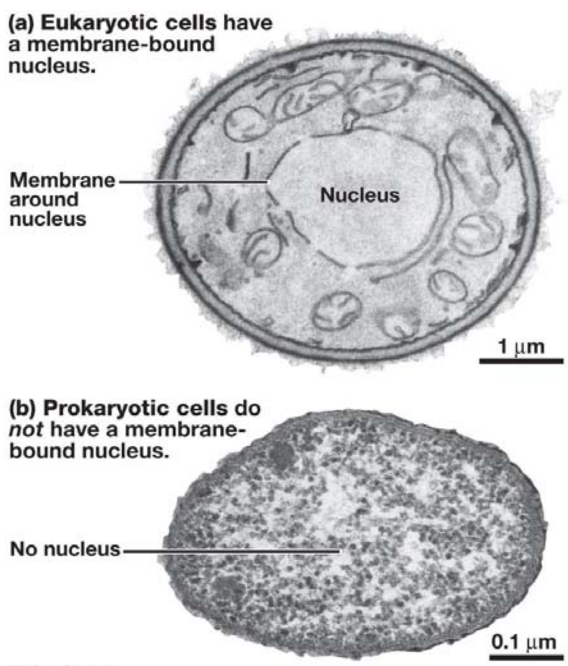
Examining and drawing organisms from all three domains in the tree of life

All of life on earth can be described by the most simplistic phylogenetic tree. This tree shows the relationship of the three domains: Bacteria, Archae, and Eukarya.

As you can see from the tree of life, cellular organisms can be **Prokaryotes** , organisms with cells that lack membrane-bound organelles, and are unicellular, **which are contained in the domains Bacteria and Archaea.** All other organisms have membrane-bound organelles, and are called **Eukaryotes, which are contained in the domain eukaryota**. Eukaryotes are generally multi-cellular and are the organisms you are probably more familiar with, including plants, animals, fungi, protists, and algae. In this lab we will examine organisms from all three domains.



Picture of molecular tree of life from: www.ucmp.berkeley.edu/alllife/threedomains.html



This picture on the left from your Freeman textbook demonstrates the two main differences between eukaryotic and prokaryotic cells. First, note the membrane bound nucleus in the eukaryote and the lack of nucleus in the prokaryotic cell. Secondly, note the difference in size between the two cells; generally eukaryotic cells are 10x larger than prokaryotic cells.

What organisms will we see?

The domain **Archaea** (pronounced ar-KAY-ah) are perhaps the least familiar to most people, but include some very important organisms. Two of the best studied groups of Archae are the thermophiles and the halophiles. The **thermophiles** (temperature loving) can survive extreme temperatures. One example you are now familiar with was used in our PCR lab; we used an enzyme from the thermophile *Thermus aquatic.* We call this enzyme Taq polymerase. A second well-studied group of Archaea, called **halophiles**, is found in extremely high salt environments such as salt ponds, where salt concentrations range from 15 to 30 percent; this high concentration is roughly four to nine times the salinity of sea water (3.5 percent). The optimum growth condition for these halophile (salt loving) archaea is 20-30 percent salinity. They cannot survive if the salt concentration drops much below 12 percent.

In today's lab, you will examine a culture of the Archaea halophile, **Halobacteria**. This organism normally lives in a salt pond, but here is grown on a high salt concentration agar plate.

The domain **Bacteria** are familiar to many people as we notice them when they make us sick: strep throat, tuberculosis, and Lyme disease are all caused by bacteria. However, of the hundreds or thousands of bacterial species living in or on your body, only a small fraction is harmful. In lab today, we will examine two of the many groups of bacteria. We will examine **heterotrophic** ("other-feeding") bacteria and **cyanobacteria**.

You will see two examples of **heterotrophic** bacteria: 1) some helpful, "probiotic" heterotrophic bacterial cultures, bacteria normally found in human gastro-intestinal tract, **Lactobacillus acidophilus**, and 2) a harmful heterotrophic bacteria, **Streptococcus pneumoniae**, the bacterium that causes pneumonia. You will also see two examples of **photosynthetic autotrophic cyanobacteria**: **Anabaena** and **Spirulina**. Cyanobacteria capture the sun's energy through photosynthesis, so they are **autotrophic** (self-feeding).

The third domain, **Eukarya**, includes all organisms with a true, membrane-bound nucleus. And within the Eukarya, all organisms are protists except for the fungi, animals and land plants. So the remaining organisms you see in lab today will be mainly protists.

Amoeba – tan or clear in color, move and feed with pseudopodia false-foot like projections. Cytoplasmic streaming (movement of cytoplasm) into pseudopods is apparent.

Physarum – a plasmodial slime mold, bright yellow color. This organism is made of several single cells, each with thousands of nuclei. These cells are formed when individual flagellated cells swarm together and fuse, resulting in one large bag of cytoplasm with many diploid nuclei.

rotifers -- are multicellular animals with specialized organ systems and a complete digestive tract. Most species of rotifers are about 200 to 500 micrometers long. Rotifers are thus multicellular creatures who make make their living at the scale of unicellular protists. The name "rotifer" is derived from the Latin word meaning "wheel-bearer"; this makes reference to the crown of cilia around the mouth of the rotifer. The rapid movement of the cilia in some species makes them appear to whirl like a wheel.

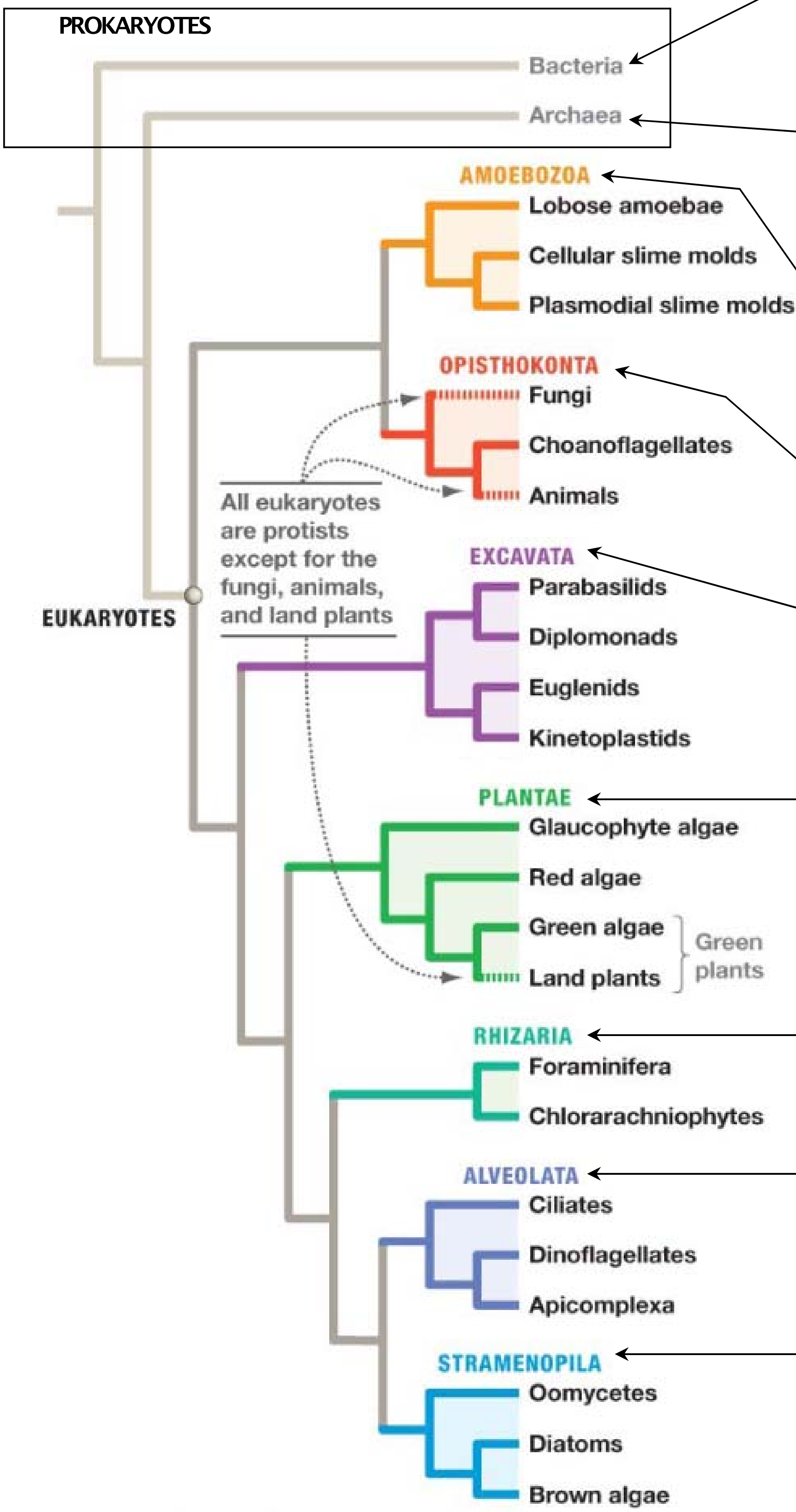
Euglena-- 1/3 of Euglena species have chloroplasts, 2/3 of species do not.
Have chloroplasts (chlorophyll bearing structures), and so are photosynthetic. It can also ingest food through phagocytosis. No cell wall. It uses flagellum or body distortion for movement. This body distortion is called Euglenoid motion. Note reddish stigma (spot), near the base of the flagellum: it is a light detector which enables phototaxis (movement of an organism in response to light). Unicellular.

Volvox -- Green algae/plant. Colonial flagellates. The colony is comprised of many single, bi-flagellated cells connected together. It forms a hollow, green sphere. Individual cells have a red eyespot and, with chloroplasts, can make food from sunlight. Daughter colonies grow within this main colony and eventually break free and develop as a new parent colony. Small animals like rotifers prey on the Volvox. Unicellular, but living in colonies.

Paramecium – Footprint-shaped. Often tan or clear, but internal organelles apparent. Covered with cilia. Cilia beat, driving food into oral opening. Unicellular.

Stentor -- Trumpet shaped when extended, blue to blue-green ciliate with a complex nucleus that looks like a string of beads (dark connected dots on the left). It has a crown of structures at top (buccal membranelles), beat in a rhythm creating a vortex which draws food into "funnel"/ mouth. It can contract into a ball, and may swim freely, extended or contracted. Unicellular, but one of the largest unicellular organisms.

Blepharisma -- Elongated and roughly egg-shaped. Typically, they are pigmented with some shade of red or pink. The anterior pole is bluntly pointed, the posterior pole is blunted. The body is noncontractile, but exact form may vary within one species and even within the same culture. Unicellular.



DOMAIN BACTERIA:

-**Lactobacillus acidophyllus**
-**Streptococcus pneumonia**
Cyanobacteria –**Anabaena**
- **Spirulina**

DOMAIN ARCHAEA:

- **Halobacterium**

DOMAIN EUKARYA:

Amoebozoa -
Plasmodial slime mold
- Physarum
Cellular slime mold
- **Amoeba**

Opisthokonta
Fungi
Animals - **rotifers**

Excavata
- **Euglena**

Plantae
Red Algae
Green Algae/Plant
- **Volvox**
- **Chlamydomonas**

Rhizaria
Foraminifera

Alveolata
Ciliates – **Paramecium**
Stentor
Blepharisma

Stramenopila
Diatoms
Brown algae

Summary Chart Comparing Micro-organisms

Fill in this chart with your TA in lab or at home using your textbook and/or reliable internet sources. (If using the internet, document your sources.) You are responsible for this information.

Organism	**Pro-** or **Eu-karyote**	**Domain**	**Uni-or Multi-cellular Colonial Filament-ous**	**Move-ment**	**Feeding method**	**Drawing & Notes**
Lactobacillus acidophilus						
Streptococcus pneumoniae						
Anabaena						
Spirulina						
Halobacteria						
Physarum						
Amoeba						
rotifer						
Euglena						
Volvox						
Chlamydomonas						
foraminifera						
Paramecium						
Stentor						
Blepharisma						
diatom						

Taxonomy –
The Description and Classification of Living Organisms

Objectives

1. Students will learn to use a dichotomous key.
2. Students will key out a variety of invertebrate and vertebrate animals

Using a dichotomous key to identify animals

When organisms are placed into their domains and into more specific, smaller phylogenetic groups, organisms are grouped together based on their shared evolutionary history. This shared history is determined by examination of their physical characteristics and by their genetic code. In order to identify species using their genetic code, part of the organism must be collected and sequenced in a lab. Although it would be cool (and efficient!) to sequence organisms in the field with tiny computers, we do not currently have that type of technology.

Currently, when a biologist working in the field finds an organism that needs to be counted or described, biologists use a taxonomic key. Most taxonomic keys are **dichotomous keys** (keys having two branches) and use a succession of paired, mutually exclusive choices, to enable the key user to identify the organism.

Taxonomic keys are not meant to be read from start to finish. Instead, you should read the choices, determine which best applies to the organism you are studying, and then skip ahead to the number listed, skipping the non-applicable steps along the way.

Also, taxonomic keys are not written to describe the evolutionary history or relatedness of organisms. They are written so that scientists can differentiate between different organisms and be able to accurately identify the organism they are examining. However, as you might expect, closely related organisms look very similar and have many similarities in their genetic code, so often organisms of the same phylogenetic branch of the tree of life are close to each other in a taxonomic key.

You will see that the dichotomous key we use in class has many of the same names traditionally used by Linnean classification. As biologists change to using phylogenetic trees and de-emphasizing classification by rank, the familiar names of groups that have been used for hundreds of years are still used by biologists. These names are now reassigned to branches on the phylogenetic tree.

Ultimately, today’s lab is also designed to help you learn to use a taxonomic key and to become familiar with the most common scientific names and groupings of organisms. Hopefully, this lab will show you a few of the wide range of organisms you have been living with, some which you may have never noticed or thought about, that exist in our world.

What are we doing today? **Specifically**, in this lab, using a dichotomous key, you will key out some of the many different animals displayed on the laboratory tables. The dichotomous key and a description of how it is used will be given to you by your TA. If you have questions about certain characteristics of any of the micro- or macro-organisms, ask your laboratory TA for assistance. However, first try to make your own determinations without any outside help.

While we would really like to give you the chance to look at more examples of the many types of life on earth, but we are limited in time. Take this opportunity to look at as many examples as possible.

How do taxonomic keys work? If you were to make a dichotomous key for the students in our lab, you would want to list some of the characteristics shared by members of the group, such as gender, hair color, hair length, height, eyeglasses, and so forth. You would then construct your key by setting up a series of bifurcating characteristics, starting with the most general characters and moving to the most specific such that, in the end, each member of the group can be clearly identified. For example:

1.	Gender: female	2
	Gender: male	5
2.	Hair color red	Ashley
	Hair color not red	3
3.	Hair color blonde/brown	Jessica
	Hair color black	4
4.	Glasses worn	Sarah
	Glasses not worn	Brittany
5.	Shoes high-top sneakers	Christopher
	Shoes not high-tops	6
6.	Hair color blonde/brown	Michael
	Hair color black	Jacob

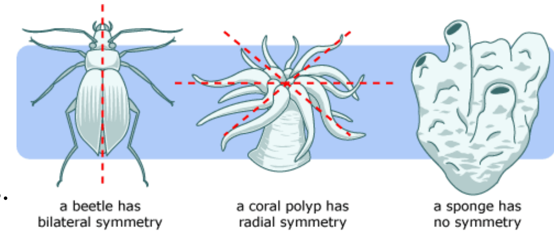
Thus if we are looking at a male student with brown hair wearing cowboy boots we would start at step 1. Because he is male, we would be instructed to go to point 5. At point 5 we would establish that his shoes are not high-tops, and so be directed to step 6, where the fact that our specimen has black hair would allow us to determine that we are looking at Jacob.

You can see from this simple taxonomic key example, that the key does not represent relatedness but is used to identify specific organisms to the correct identification.

What are we doing today? Specifically, in today's lab, there are about twenty different animals displayed on the laboratory tables. Each specimen is identified by a number. Either individually or in pairs, you will carefully examine the animals on display and identify them as far as the key indicates. An answer sheet is provided and before leaving you will complete it with appropriate determinations. A simplified key is supplied to assist you in your identifications. The use of the key will be explained by your TA. If you have questions about certain characteristics of any of the organisms, ask your laboratory TA for assistance. However, first try to make your own determinations without any outside help.

Where are the plants? In Bio101 Lab, we focus on the Animalia. While we may have some organisms from the Plantae, Fungi, Protista, Bacteria and Archaea in our course, we generally save the exciting world of plants for Bio 102 labs. Today, we will examine some organisms from different clades, but mostly focus on the Animals, of which 90% of the animal species are invertebrates. In fact, half of all the animal species are arthropods!

Today we will show a bias and examine more vertebrates than we should; they tend to be easy to key out. The true hope is that this lab topic will whet your appetite for future studies of animals of all kinds. There is a wide variety of amazing organisms on display today, so look, learn and enjoy!



Picture from http://evolution.berkeley.edu

Vocabulary for Dichotomous Key

asymmetry – Having no symmetry.

bilateral symmetry – Having a body displaying two similar halves.

radial symmetry – Having similar parts radiating from a central point.

pentaramous symmetry – Divided into five even parts.

appendages – Any part of an animal coming from the main body, trunk, such as arms, legs, antennae

colonial – A group of organisms of the same species living together.

digits – A finger or toe.

dorsoventrally – From back to front.

endoderm – The innermost, of the three layers, of the skin.

epiderm – The outermost, of the three layers, of the skin.

exoskeleton – An external skeleton, shell.

flagellum – A long, threadlike appendage, especially a whip-like extension of certain cells or unicellular organisms that functions as an organ of locomotion.

gelatinous – Looks like jelly.

integument – Skin.

mesoderm – The middle, of the three layers, of the skin.

nematocyst – The stinging barb of coelentrates.

pseudopodia – "False feet", temporary projections of eukaryotic cells.

porous – Full of tiny holes.

radula – A tongue-like toothed structure used in chewing and rasping.

segmented – The division of the body into similar parts.

sessile – Attached to one place.

siphon – An extension of the mantle in molluscs for drawing water into the mantle cavity.

solitary – By oneself.

tentacles – Long cylindrical tubes for sensory reception or food capture.

Name: ________________________________ TA: _____________________ Sect: ____

Number	Common Name	Phylum	Clade
1			
2			
3			
4			
5a			
5b			
5c			
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