

MARINE BIOLOGY LABORATORY



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Marine Biology

Laboratory

By

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Detailed Licensing

Licensing

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1: Laboratory Etiquette and Safety

LIFE SCIENCE LABORATORY ETIQUETTE

GENERAL

1. **Work is permitted in the laboratory only when there is an instructor or lab manager in charge.** Consult your instructor if you want to work in the laboratory at other times.
2. **Follow directions carefully. This is important for your own safety and the safety of others.**

SAFETY AND FIRST AID

1. **If you get chemicals in your eyes, flush your eyes out immediately with one of the emergency eyewashes at either end of the lab. Notify your instructor and rinse your eyes for a FULL FIFTEEN MINUTES.** Hold eyelids open with a thumb and forefinger and roll eyes while rinsing. Have another person help you keep track of the time to ensure full rinsing.
2. Familiarize yourself with the **locations of fire extinguishers, eyewashes, first aid kits, and spill kits.**
3. If you have long hair, you should tie it back. Hair burns easily.
4. Wear long pants and closed shoes to the lab at all times. Long sleeves are also recommended.
5. **Avoid direct contact with all chemicals.** Disposable gloves are available.
6. If you spill a chemical, notify your instructor, who will advise you on how to clean up the spill.
7. **Do not put food or drinks on the laboratory tables (this includes water bottles).** Please store food/drink storage at the front of the room in the cubbies if available (No cubbies in LS104).
8. **In case of fire to clothing, use a fire extinguisher.**
9. **In case of fire in containers or on the bench, step back, warn your instructor and others, and allow your instructor to take the appropriate action.** There are fire extinguishers available.
10. **Report all accidents, including all cuts and burns, promptly to your instructor or lab manager.**

CLEANLINESS

1. Wash your equipment as soon as you finish using it.
2. **It is your responsibility to immediately clean up any chemicals you spill in the lab.** If you are not certain how to do this, consult your instructor.
3. **Dispose of waste in the appropriate place.**
 - a. **WASTE BASKET:** for **paper and gloves only, no glass or liquids.**
 - b. **SINK:** Only water-soluble, nontoxic substances. **NO SOLIDS!!!** Flush with tap water.
 - c. **SPECIAL DISPOSAL CONTAINERS:** Your instructor will tell you which substances to place here.
 - d. **GLASS DISPOSAL CONTAINER:** For **all glass waste**, including Pasteur pipettes. No trash here!
 - e. **RECYCLING:** Dispose of your recyclable materials in the proper container in the front of the lab.
4. Before leaving the laboratory, **wash and dry your bench top. Please also see that you have not misappropriated any equipment that should have been returned [in good condition] to its original location.**

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2: Physical Oceanography- Measurement, Density, and Buoyancy

Physical Oceanography- Measurement, Density, and Buoyancy

Purpose:

Explore many of the tools and techniques used to study and measure the physical world. You will learn about taking multiple samples and the importance of averages and error in data collection. We will explore the concepts of salinity, temperature, and density, and how they interact in the lives of sea creatures.

Tasks:

1. Practice using several different tools and record your results in the lab manual.
2. Create three water layers with density differences significant enough to allow for separation and no mixing.
3. Lastly, you will try to build a model of a plankton that sinks as slowly as possible through the water.

Criteria:

Your recorded numbers will be shared in class so we can talk about class averages and the pros and cons of different tools. Your water layers will be examined in class and shared with other groups. Your plankton will compete with other plankton to see who sinks slowest. A homework assignment will be turned in next week that explores the idea of density and buoyancy in greater detail with three specific examples.

Introduction

Why do we measure things? This course looks at the marine realm through the eyes of ecology. **Ecology** is the scientific study of the interactions between **organisms** and their **environment**. This endeavor is **empirical**, dependent on evidence observable by the senses. This evidence can include purely descriptive data, but more often it tries to make sense of the world through the collection of **numerical, quantitative data** vs. **qualitative** descriptions that just use words.

We can describe things using numerical, quantitative data or qualitative descriptions. Being able to say a snail was 4.2 cm long is much more informative than saying it is “small”, or stating that the water is 30°C and has a salinity of 33 is much more helpful than saying that the water is “cold and salty.”

What can we measure?

List some ideas of what can be measured from:

Living Things	Non-living Things

There are two main components studied in ecology: the **biotic**, or living world, and the **abiotic**, or non-living world. These components are quite different, and likewise so are the methods and tools that allow us to collect empirical, numerical data on these two areas. Within the biotic realm, we often concern ourselves with measures of an organism's **abundance**, **density**, and **spacing**. We will learn about these techniques and tools in later labs. In addition, we often try to quantify predation, competition, and other biotic factors like behavior (which are often not easily done!). Abiotic factors can include both **physical** and **chemical** factors, such as location, temperature, light, pH, wave force, wind, rock, sand, etc. The almost endless list of abiotic factors that a scientist could think to measure is measured by a large variety of different tools, many of which can measure the same thing in many different ways, with sometimes different units. A trend in recent years with the miniaturization of sensors, probes, and computer technology is the creation of multipurpose tools, which can measure many different abiotic factors, sometimes all at once. Using some of these tools, we will get some hands-on experience measuring common abiotic factors and practice graphing the results!

pH determination

1. You will spend time examining pH, a measure of the acidity of a solution in terms of the proportion of hydrogen ions (H⁺).

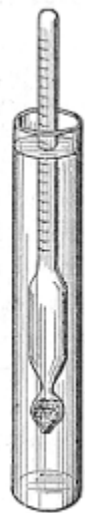
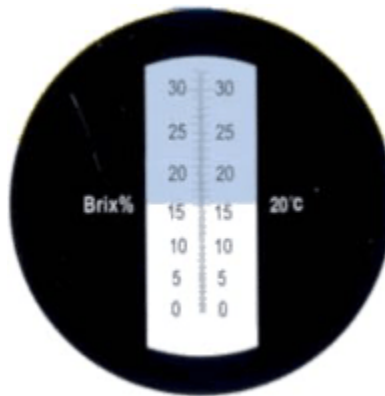
- Record the pH values of the three solutions A, B, and C using the pH paper and the digital pH meter. Do the values agree?

Solution	pH Paper	pH Meter
Solution "A"		
Solution "B"		

Salinity

There are several different methods of testing the amount of dissolved solids, or salinity, in solutions. You can determine salinity using the difference in the refraction of light through a sample. You can also measure the density of the solution with a floating hydrometer. Electrical conductance is also commonly used; the higher the salinity in the water, the more easily current can flow. Salinity is usually measured in "parts per thousand (‰).

- Using the hand-held refractometer, determine the salinity of the three solutions. Place a drop of the solution on the glass plate and put the cover down on the drop. While holding it up to the light, look in the scope, and you should see a shadow line, which is where you read the sample. Make sure you read the number from the right side of the meter (‰).
- Using the digital conductivity meter, measure the salinity of the three samples again. How do the three values compare? Note: you need to pay close attention to the flashing lights and green button! The instructor will explain.
- Take a look at the glass, floating hydrometer. Your instructor will demonstrate how to use the device by letting it float until still and then reading the measurement off the scale inside the glass. You don't need to do this yourself.



Refractometer View inside Hydrometer Pasco unit

Solution	Refractometer (‰)	Conductivity Meter
Tap Water		
Sea Water		

Temperature

Several different temperature measuring devices have been put into two beakers of liquid.

1. Record the temperature on each device for each liquid. Which device is most accurate? How do you know?

Solution	Lab (glass)	Digital	Pasco
Beaker 1			
Beaker 2			

Density

One of the most fundamental abiotic properties of water is its density. The density of water is mainly determined by two things: salinity and temperature. The formula for density is:

$$D=M/V$$

Where: D is the object's density (measured in kilograms per cubic meter), M is the object's total mass (measured in kilograms), V is the object's total volume (measured in cubic meters)

For a given volume of water, the only things that determine density right now are the mass (M) and volume (V), and the two things that do that are temperature and salinity.

Lowering the temperature squeezes the same number of water molecules into a smaller volume (they are closer together), thereby increasing the density. Raising the temperature does the opposite.

So: Colder Temp = Lower Volume = Higher Density

Salinity adds dissolved salts into the volume of water, raising the mass, but doesn't add as much to the volume, and therefore the density will go up as the salinity increases.

So: Higher Salt = Higher Mass = Higher Density

In this lab, we will investigate the density of liquid layers and how they interact (or don't) by carefully combining a few different liquids in two different experiments. Using any combination of salinity (fresh water all the way to super-saturated with salt), temperature (very cold to very hot), and some food coloring, you will mix up and dye water 'layers' that will interact when you put them into a small plastic tub. If you are careful about not mixing the water layers (don't pour them roughly into the tank, etc.), you can expect your water layers to sit on top of each other, depending on their density. See if you can make a three-layered ocean in your tub and experiment with making waves on the surface and in the lower layers by blowing with a straw. Additional instructions and tips will be provided during the lab.

Here is a good website to calculate Density with Salinity and Temperature: <http://www.csgnetwork.com/h2odenscalc.html>

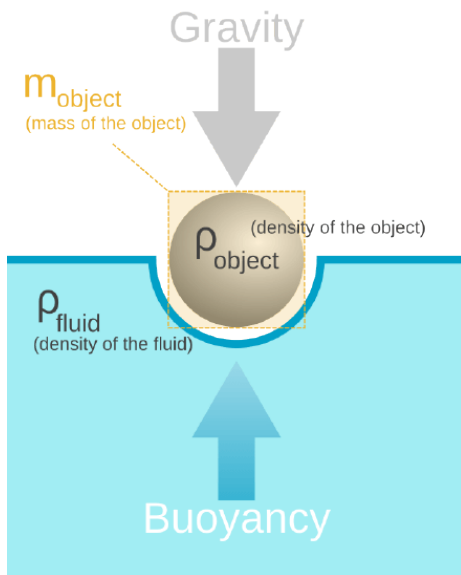
Buoyancy

Plankton are organisms that drift; they cannot swim against a current any stronger than about 1 knot (1.15 miles/hour). Usually, plankton are very small, microscopic organisms, but some larger animals, like certain jellyfish, are also considered plankton. Plankton are divided into two groups: plant-like (**phytoplankton**) and animal-like (**zooplankton**). Phytoplankton make their food through **photosynthesis** using sunlight to combine carbon dioxide and water into sugar. Creatures that make their own food are called **autotrophs** (*self-feeders*). Zooplankton must ingest, or eat, food made by other creatures, so they are **heterotrophs** (*other-feeding*). Plankton are usually heavier than water. This is important because if a planktonic organism just floated on the

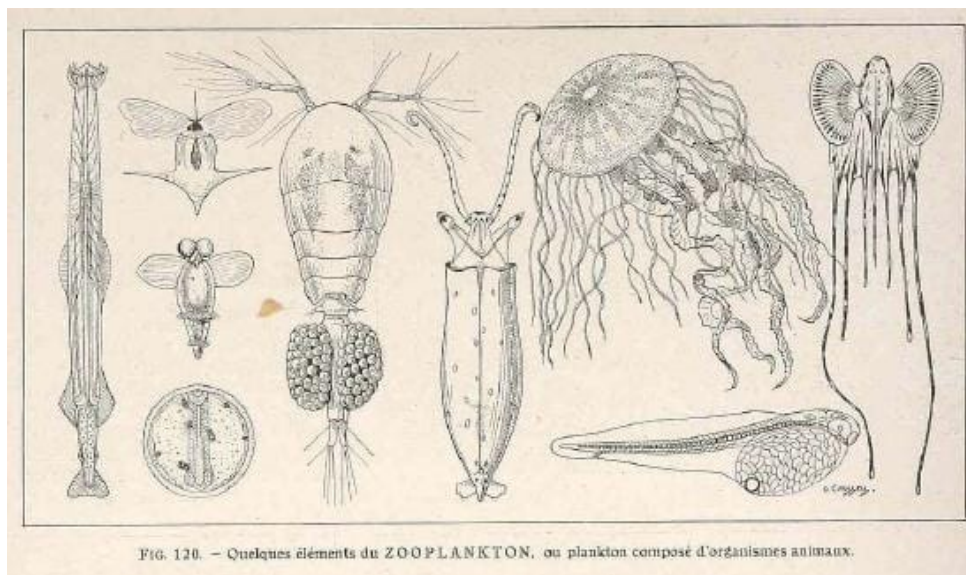
surface of the water, it might not be able to get to food sources below it, or it might get too warm or too much light from the sun (even phytoplankton can be "burnt" by the sun!). So, plankton will tend to sink in the water column. But phytoplankton do need to stay where sunlight penetrates in the ocean. Zooplankton feed on phytoplankton, so the zooplankton want to stay where the phytoplankton are in the water column. One important note is that zooplankton are usually able to swim upward in the water column very slowly to maintain their position. But if they sink too quickly or are too heavy, they will go straight to the bottom of the ocean and not be able to get back up! Therefore, planktonic organisms will have adaptations that prevent them from sinking too quickly.

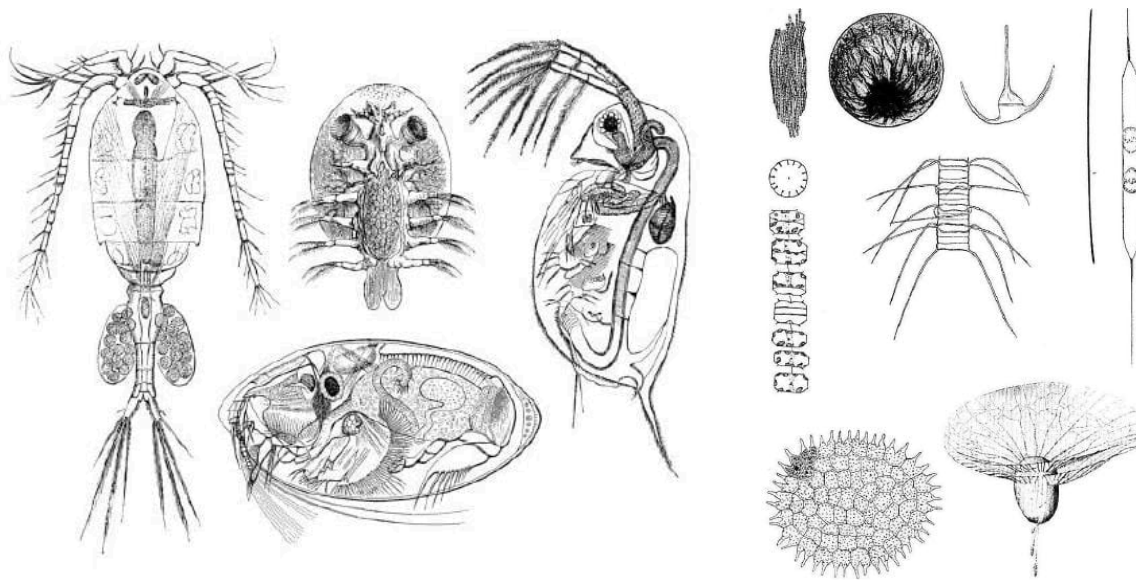
These adaptations include the following:

- 1) small size (small things sink more slowly than large things)
- 2) long spines or projections that increase drag (drag is sort of like friction)
- 3) long, thin, or flattened shape - also increases drag
- 4) contain small amounts of oil (which is lighter than water)



The density of the object and the density of the fluid determine whether it is buoyant or not. If the overall density is less than water, it will float; if it is greater than water, it will sink.





Various plankton groups showing a wide range of size and shape.

The Great Plankton Race

Start to think about how you would build a plankton (smaller than 3 inches across). What would you try to do to minimize its sinking? Using random stuff around your house, try to build a plankton that sinks, but sinks as slowly as possible. The “perfect” plankton would drop down under the surface and then remain motionless. That is VERY hard to make! Use a large, clear container of some sort with at least a foot of water depth to be your test tank. Water pitchers are often good.

The rules are simple:

- 1) You need to start 1 cm below the water’s surface.
- 2) If it floats up to the surface, it is disqualified.
- 3) We will time how long it takes to hit the bottom of the container.

Laboratory Write-up Instructions

All organisms in the aquatic environment must deal with the challenges of having their living tissues and their cells be denser than the surrounding water. Proteins, organelles, muscle tissue, and most other things inside cells are denser than the surrounding fluid (seawater). We’ll see later in the lecture that this difference between the insides of organisms and the outside environment is quite important on all sorts of levels, but for now, let’s limit our attention to the issues of density, sinking, and adaptations that creatures might have to deal with this challenge. Many creatures must remain in a specific area of the ocean to be successful and can’t just sink into the deep ocean or float at the surface.

For this lab write-up, you are to investigate the strategies used by three different organisms that live out at sea in the water (not living on the bottom) and explain their adaptations and/or behaviors used in dealing with the specific problem of buoyancy. The three organisms will cover a wide size range, as the strategies involved tend to be quite different depending on the organism’s size! Use any combination of the book, lectures, web, or other sources.

Your three organisms will fall into each of the following three size classes:

1. Smaller than 1 cm in length
2. Between 1 cm and 10 cm
3. Bigger than 10 cm

Please write up one paragraph on each of the organisms. Include the following information in each paragraph:

1. Define the species’ particular challenges as they relate to buoyancy.
2. Explain how its shape, size, insides, and/or behavior might be used to deal with the problem of sinking or floating.
3. List the sources you used using a full citation format (do a [web search for MLA](#) for examples of what to include).

Please turn this in ONLINE, typed, next week before the beginning of the next lab.

Thumbnail: “[Moving waters](#)” by [Ishrona](#), [CC BY 2.0](#)

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3: Marine Habitats- the Monterey Bay Aquarium

Monterey Bay Habitats

An organism must deal with several outside influences in its daily life and the evolution of its species. We often want to examine these influences and ponder how they affect the characteristics and behaviors of the organism. However, the ocean is a hard place to study! It is usually covered with water, hard to get to, cold, and we can't hold our breath very long. So today we are going to spend some time looking at artificial, simplified habitats at the Monterey Bay Aquarium. Although not "natural" and not filled with all the animal and algal life you would expect if you were to go scuba diving in the bay, they are quite well done on many levels and do have a good representation of many of the species we would see in the wild. We can also look at them without getting cold and wet, which has a lot of obvious benefits. So, using the habitat areas around the aquarium, you will investigate several aspects of biological, physical, and evolutionary forces that impact the organisms you see.

Assignment:

Working with a partner, you will visit 3 different habitats as depicted in the aquarium (such as the open ocean, rocky intertidal, shallow subtidal, estuaries, etc.).

In each of these three habitats, I would like you to do the following:

1. **Food Web:** Identify the significant species (plural, as in many) found in the habitat (these could be specific individual species (like Blue Fin Tuna) or more general higher taxonomic levels (such as "jellyfish", or "phytoplankton"). You should include several species at the top of the food web (i.e., top consumers/predators), several that are at the bottom of the food web (i.e., algae), and some in the middle that connect the bottom and top. At the bottom of all your webs should be the ultimate source of energy, the Sun! All organisms need to connect to the sun through some path. Draw a rudimentary food web that shows the relationships between your organisms. You can do this by hand or using a computer (Google Slides, etc.)
2. **Physical Environment:** Identify the main physical factors (non-living, such as "rock" or "temperature") that are important and unique to that particular habitat. We want the habitat's characteristics, not the animal's physical characteristics. This is about what makes these environments different from one another.
3. **Evolutionary Adaptations:** Identify some of the defensive strategies available to these organisms. How do they keep from being eaten? What strategies are unique to their particular habitat? Focus on what makes surviving in a particular habitat different from another. Describe how the organisms found in the habitat deal with these unique physical challenges. In other words, how are the organisms specifically adapted to their physical surroundings? Pay attention to both the top and the bottom of the food chain.

Due Next Week: Turn in a typed write-up of the three habitats with **each** habitat having a food web (#1) and two short paragraphs that address questions #2 & #3 above. So, you will do questions 1, 2, and 3 for each of your three habitats. Turn them in at the beginning of next week's lab on Canvas.

Thumbnail image: “[Monterey Aquarium Window](#)” by [Liz Lawley](#), CC BY-SA 2.0

4: Estuaries- Elkhorn Slough



Background:

Today, we will investigate our largest local estuary, Elkhorn Slough. An estuary is a place where seawater meets freshwater, and often some sort of embayment forms at the mouth of the river. As we will discuss, there are several different types of estuaries and different ways they can be formed. Estuaries play many important roles, including providing a large 'nursery' for many marine organisms, water purification, sediment catchment, and wildlife utilization.

The history of Elkhorn Slough is long and very colorful, with use by humans stretching back thousands of years. The Slough has been changed considerably by human use and the natural cycle of coastal processes. From pre-historical times, the Ohlone Indians used the area for food, resources, and dwellings. The infiltration of the Spanish missions and Mexican cattle ranchers drastically changed the nature of the Slough and began a long period of large modifications, including the filling in of some areas and changes to the flow of water. During the 1700s, the Russian Sea Otter trade flourished and brought the near extinction of the species. In 1811 alone, over 9,000 otters were killed in Elkhorn Slough! Hunting, logging, whaling, farming, and aquaculture were all large industries in the area and brought with them many important changes to the Slough, including many invasive species both on land and at sea. More modern uses of the Slough include the railroad, a hunting club, and large dairies, all of which still

show their scars on the Slough's fragile ecosystem.

Of all of these changes, one of the biggest was a natural event. A large storm in 1908 broke the Salinas River through the dunes at its current location between Marina and Castroville and thereby cut off the main source of freshwater flowing into the Slough. At this point, the Slough changed from a full-time estuary to a seasonal estuary, only getting large amounts of freshwater during the rainy months.

In the 1950s, the power plant and refractories were built, both of which used large amounts of seawater. The Moss Landing Harbor was constructed in 1946 and has drastically changed the flow patterns of the Slough, causing some areas of the Slough to fill in with sediment and other areas to be scoured away.

Field Explorations:

We are going to examine two different areas of Elkhorn Slough and assess the biological and physical characteristics at each location. Our first visit will be at the estuary mouth near the Hwy 1 bridge in Moss Landing at the floating boat launch to talk about the physical and biological properties of estuaries and sloughs. These include: types of estuaries, plant systems, animal systems, soft-bottom communities, and salt/fresh issues. We will examine land use, watershed factors, and the history of the Elkhorn Slough.

Access the Elkhorn Slough Data Table [here](#). (Instructors: Go to "File" and "Make a copy" to create a version you can type into)

Site 1: Harbor Mouth

We will start by collecting some information on the physical and biological characteristics of this location.

1. We will record the Depth, Turbidity, Temperature, Salinity, Dissolved Oxygen, Phosphate levels, and pH from the floating boat launch and then compare these with the same measurements from a second location inside the slough.

We will use several different digital sensors to collect most of the data. We practiced using most of these during the first lab of the semester, so most will be familiar to you. A new tool is called a Secchi disc, used to examine water clarity. A Secchi disk is an 8-inch (20 cm) disk with alternating black and white quadrants (sometimes all white). It is lowered into the water until it can no longer be seen by the observer. This depth of disappearance, called the Secchi depth, is a measure of the transparency of the water. Transparency can be affected by the color of the water, algae concentration, and suspended sediments.

2. Next, we will try to assess what animal and algal life may be in the area. Start by looking at the animals and algae found on the sides of the dock. This is a good indication of what might be found in other areas of the harbor. We will also use a plankton net and a bottom grab to see what is in the water and on the sea floor in this location. We can see how deep it is at this location, what the bottom is made of, and what larger animals we might find. We'll take the grab and empty it into the sieve and see what we can find. If the tide is out, we will also look for organisms in the mud.

Site 2: South Slough

Lastly, we will visit the South Slough area, where the old Salinas River drained into the Slough before 1908, and look at the biological and physical environment of this back-slough area and compare it with the harbor mouth. Examine the life on the sides of the shoreline. What types of animals and plants do you see? What types do you not see?

1. Redo the profiles of Depth, Turbidity, Temp, Salinity, DO, Phosphate, etc., from both the North and the South sides of the bridge.
2. Compare how the values were similar or different between the three locations.
3. If time and tide allow, we will also attempt to examine the densities of an invasive species, the Japanese mud snail.

Assignment:

The assignment is to choose **3 different physical measurements** (like temperature, salinity, and phosphate) and compare them between all three of the sites to analyze and "tell a story" about the numbers. How did things change from one site to another? Why do you hypothesize that might have been?

1. In your analysis, use **graphs** to help tell a story with the numbers and look for patterns.
2. **Write** a short **paragraph** that explains what the numbers are showing and why you think the data shows what it does.

Put the graph and paragraph together into a document, and then turn that in here.

If you need some help getting started on how to make your graphs, check out [this video](#).

Lab Thumbnail image: “[Elkhorn Slough](#)” by [Brad Parrett](#), CC BY-ND 2.0

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5: Photosynthesis and the Algae

Introduction

Photosynthesis is probably the single most important living process on Earth. Without photosynthesis, life would be limited to single-celled bacteria. It is through this process that all the life forms we are familiar with get their food and energy. Chemically, photosynthesis is the conversion of light energy into chemical energy. The raw materials are carbon dioxide and water, the energy source is sunlight, and the end-products include glucose (a sugar) and oxygen.



While you're probably most familiar with this process as it relates to land plants, it is the same process as we see in the Algae. **Algae** come in multiple forms, from large, familiar multicellular organisms like kelp to microscopic, single-celled organisms, which are the most important photosynthetic group in the ocean. The production of energy-rich organic compounds (like sugar) from carbon dioxide and water, through the process of photosynthesis, is called **primary production**. Almost all life on Earth is directly or indirectly reliant on primary production for its food. The organisms responsible for primary production are known as **primary producers** or **autotrophs** (a *self-feeder*), and form the base of the food chain.

Activity 1. Photosynthetic Rate

When studying photosynthesis, often the thing we are most interested in is the **rate** or speed at which it is happening. This is a measure of how much sugar, energy, or oxygen is being produced over time. We could do this by keeping track of any one of the items in the equation above. Knowing any one, we could calculate how fast the process is happening. We typically do this by measuring the amount of oxygen being produced over time or the amount of CO_2 that is being used. This gives us a rate of photosynthesis. Observe the Pasco oxygen and CO_2 demonstrations, which will explore the amount of dissolved oxygen in two different samples of algae-filled water at different light intensities. What would you predict would happen to the photosynthetic rate with no light, low light, and high light? Do the data support your hypothesis?

Activity 2. Understanding Net Production

In biology, especially in studies involving ecosystems or photosynthesis, we use the following formula:

$$\text{Gross Production} - \text{Respiration} = \text{Net Production}$$

Let's break this down:

- **Gross Production (GP):** This is the total amount of energy or biomass produced by an organism (like a plant) through **photosynthesis**. It includes all the energy captured from sunlight and converted into chemical energy.
- **Respiration (R):** Organisms use some of this energy for their own life processes (like growth, repair, and reproduction). This energy use is called **respiration**, and it reduces the amount of energy available for growth or for the next level in a food chain.
- **Net Production (NP):** This is the energy or biomass **left over after respiration**. It represents the amount of energy that can be passed on to consumers (like herbivores) or stored in the organism for growth.

Why It Matters:

When measuring productivity in ecosystems (like a pond or plant experiment), calculating **net production** helps us understand how much energy is actually available to support other organisms. It's an important part of the energy flow in ecological studies.

Activity 3. Taxonomy and the Groups of Algae

Taxonomy (from Ancient Greek: *taxís*, "arrangement," and *-nomia*, "method") is the science of defining groups of biological organisms on the basis of shared characteristics and giving names to those groups. A related discipline is **Systematics**, which studies identification and taxonomy with regard to the evolution of groups. There are several different taxonomic systems, but

by far the most common is one that was developed in 1735 by Swedish botanist Carl Linnaeus. To do this, it uses taxonomic ranks, including, among others (in order from most inclusive to most specific): **Domain, Kingdom, Phylum, Class, Order, Family, Genus, and Species**. The historical way to form these taxonomic groups was by looking for similarities and differences in the morphology (appearance) of the organisms. Things that are more similar are more closely grouped, and those that are very different are more distantly grouped.

In the algae, there are three main **Divisions** (same as Phylum above), the green (**Chlorophyta**), brown (**Phaeophyta**), and red (**Rhodophyta**). These three groups are quite different from each other, evolutionarily speaking, and do not have a recent common ancestor, but the groups can look very similar to each other!

1. Working within a group, you will try to form a taxonomic grouping for the various algae. Start by trying to figure out which are the greens, browns, and reds.
2. Once you have them all separated by Division, try to find other, smaller groupings all the way down to the species. What characteristics do you use to group and separate?
3. Using the provided books, keys, and lists, you will try to identify as many of the common species of marine algae as time allows. Write their common and scientific name in pencil on a small piece of paper and put them on top of the specimens once you have a good guess.
4. This exercise is about careful observation and stopping to look at this amazing and often overlooked group of organisms. To aid in your observations and study, you will be making presses of some of the species as well.

Activity 4. Algae Pressing

Algae pressing is very similar to the techniques used to press flowers, and is used widely by scientists as a means of preserving algal specimens and observing their features. Using the printed instructions and directions from the instructor, you'll make an artistic, permanent press of representative algae from the lab. Work slowly and carefully, and you'll be surprised how informative (and cool) they will be.

How to Press Algae

1. Obtain a seaweed specimen, remove debris and epiphytes, and blot mostly dry.
2. Get a dry piece of herbarium paper, write your name and any other text in pencil on the dry paper. Writing notes about the collection date, location, etc., is also a good idea.
3. Get your paper wet and carefully lay out your specimen, spreading out the parts carefully so that they are visible and flat. Choose a specimen that is large enough to easily identify, but thin enough that when compressed into a two-dimensional shape, it does not become a shapeless blob. Thus, "bush-like" algae should be thinned (analogous to pruning) to one branch layer thick before pressing. With delicate, finely branched seaweeds, first float the sample in a little water over your paper and then gently lift it out of the water, or gently tilt the paper so the water runs off and the sample stays behind. This technique helps to prevent the branches from clumping together. You can also separate branches with a paintbrush or toothpick.
4. Bring your work to the instructor to be put into the press.
5. Remove the pressed specimen from the press and carefully peel off the waxed paper. If the specimen comes loose from the paper you pressed it onto, you can secure it with a small drop of glue.

Some Common Algae from Monterey Bay

Chlorophyta

Cladophora sp.- Green pin-cushion alga

Ulva (old *Enteromorpha*) intestinalis

Ulva spp.- Sea lettuce

Codium fragile- Dead man's fingers

Acrosiphonia sp.- green ponytail

Bryopsis sp.- green hair

Phaeophyta

Cystoseira sp.- small floats

Egregia menziesii- feather boa kelp

Fucus gardneri- rockweed, with midrib

Laminaria spp.

Macrocystis pyrifera- giant kelp

Nereocystis luetkeana- bull kelp

Pelvetiopsis limitata- rockweed w/out midrib

Postelsia palmaeformis-sea palm

Silvetia compressa- rockweed- long and slender (30 cm)

Pteryogophora californica- Stalked kelp

Rhodophyta

Porphyra spp.-nori

Bossiella spp.- geniculate coralline-thick

Corallina spp.- geniculate coralline-fine

Endocladia muricata- Scouring pad algae

Chondracanthus spp.- Turkish towel

Gracilariopsis sp.- Red sand Spaghetti

Lithothamnion sp.- nongeniculate coralline, crustose

Mastocarpus spp.- bumpy/frilly red

Mazzaella splendens- Iridescent dark-purple

Mazzaella spp.- red dichotomous with frills

Prionitis sp.- dark brown with bladelets

Botryocladia sp.- Sea grapes

Microcladia sp.- Fine branching pattern

Gelidium sp.- Highly branched, sometimes thick, used to make agar.

Faucea sp.- very flat, iridescent.

Anthophyta (flowering plants)

Phyllospadix spp.- surfgrass (thin blades)

Zostera spp.- eelgrass (broad blades)

Thumbnail image: “Bubbles” by [Brad Smith](#), CC BY-NC 2.0

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6: Plankton and Microscopes

Background

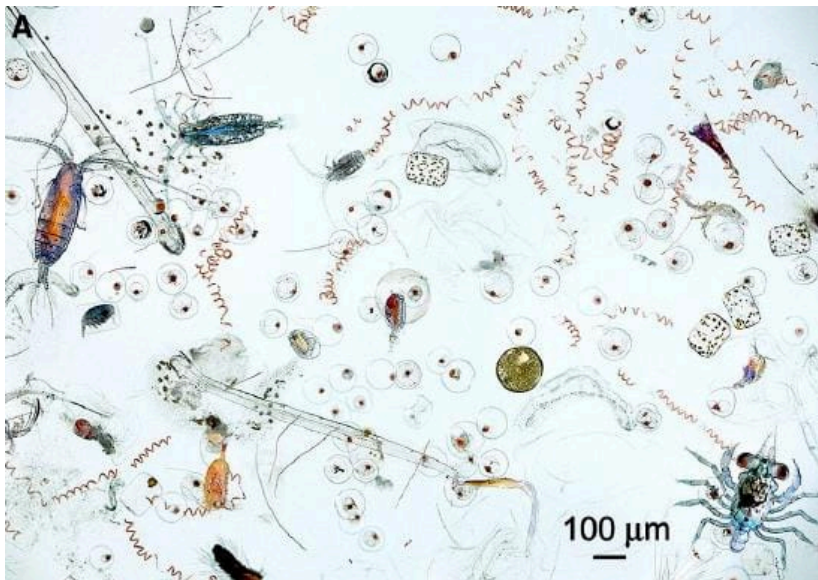
The name plankton means "wanderer" or "drifter". While some forms of plankton are capable of movement and can swim up to several hundred meters up and down in a single day (a behavior called *diel*, or daily, vertical migration), their horizontal position in the water is mostly determined by currents in the body of water they inhabit. By definition, organisms classified as plankton are unable to resist ocean currents. This is in contrast to nekton, which are organisms that can swim against the flow of their water environment and control their position (e.g., squid, fish, and marine mammals). Within the plankton, there are two main types. Holoplankton are those organisms that spend their entire life cycle as part of the plankton (e.g., most phytoplankton, copepods, salps, and jellyfish). By contrast, meroplankton are those organisms that are only planktonic for part of their lives (usually their early larval stages), and then graduate to either the nekton or a benthic (sea floor) existence. Examples of meroplankton include the larvae of sea urchins, starfish, crabs, marine worms, and most fish.

Plankton are primarily divided into 3 broad functional (or trophic level) groups:

Phytoplankton: autotrophic prokaryotic or eukaryotic algae that live near the water surface where there is sufficient light to support photosynthesis. Among the more important groups are the diatoms, cyanobacteria, and dinoflagellates.

Zooplankton: small protozoans or animals that feed on other plankton. Some of the eggs and larvae of larger animals, such as fish, crustaceans, and worms, are included here too.

Bacterioplankton: bacteria and archaea, prokaryotic cells that play very important roles in the water column.



Jay Nadeau, Chris Lindensmith, Jody W. Deming, Vicente I. Fernandez, and Roman Stocker. Image courtesy of David Liittschwager., CC BY-SA 4.0.

Plankton size classes: There are several size classes of plankton.

Group	Size range	Major organisms
Megaplankton	(20+ cm)	jellies, kelp
Macroplankton	(2-20 cm)	krill, chaetognaths
Mesoplankton	(0.2mm-2 cm)	Copepods, etc
Microplankton	(20-200 μ m)	large protists, diatoms, juvenile/small metazoans
Nanoplankton	(2-20 μ m)	small eukaryotic protists
Picoplankton	(0.2-2 μ m)	bacteria, small eukaryotic protists
Femtoplankton	(< 0.2 μ m)	marine viruses and ???

The samples of plankton today will go across many of the size ranges above, so you will need to use different types of observation tools to see the different planktonic groups.

Dissection and Compound Microscopy

Instrumentation is all about expanding our senses in order to more precisely describe the world around us. In the biology lab, light microscopes enable us to peer into the cells, tissues, and organs of living things and see a world that is all but lost to our naked eye. In this lab, you will become familiar with two types of light microscopes, the compound microscope and the dissection microscope. These are each capable of magnifying within very different ranges, up to 1000X for the compound scope and only about 35X for the dissection scope, and so the resolution (amount of detail you can see with each) varies accordingly. Nevertheless, each has its purpose in the biology lab; the former as a tool for studying cells and very small specimens, and the latter during delicate dissections or examining larger specimens.

Microscopic Terms

To get the most out of your microscope, it is worthwhile to take a moment to review the three principles that govern its use as an investigative tool. These are magnification, resolution, and contrast:

Magnification is the factor by which the image of an object is increased in size relative to the actual size of the object (when held from a specified distance). While most people believe that the purpose of the microscope is to magnify, in fact, this is only partly true. Magnification is a necessary step that enables us to see details that are normally lost to our eyes. But the real purpose of the microscope is to increase resolution, which is accomplished by making the object appear larger and clearer.

Resolution can be defined as the smallest distance between two points when they can still be seen as being separate. While increasing the virtual size of the object does increase our ability to resolve some details, recognize that this process has its limitations, just as infinitely zooming in on a photograph will not enable you to see infinite amounts of detail. The limit of resolution is set by, among other things, the nature of the imaging source, which in this case is visible light. The third parameter that influences your ability to study a specimen with the microscope is contrast.

Contrast is the degree to which the image of an object stands out relative to the background. This can be how a cell is revealed relative to the surrounding cells, or how some transparent creature is shown against a background. To enhance contrast, microscopists can treat the specimens they are observing with chemical dyes or stains. These are pigments that, due to their chemical properties, preferentially bind to certain parts of the specimen, making them appear more prominent relative to those areas that don't take up the stain. In marine biology, we are often working with living organisms, so adding chemicals to increase contrast often is not possible, but with *different lighting*, we can change the contrast as well.

Dissection Microscope

Although of much lower magnification than the compound microscopes, dissection scopes are incredibly useful because of the large working distance between the subject and the microscope head and the fact that we can look at thick, opaque objects. This allows us to look at large, still living organisms, and even allows us to do things like dissect and manipulate the specimens with probes, etc. The new Leica EZ4 dissection microscopes have a 3-way incident light feature using three different sets of LEDs, which can be switched individually, dimmed, and combined with transmitted light from underneath the subject. The switch for the scope is on the back, and the lights are controlled by switches on the top of the stage. Dissecting microscopes always have two objective lenses and two oculars. This arrangement provides a three-dimensional image with a large depth of field, two features that are essential to the kinds of activities performed with a stereoscope.

Activity

1. Take a coin (or some other object) you have in your pocket and place it on the stage of the microscope. Adjust the ocular lens distance so that when you look into the scope, you see only one circle of light when viewed with both eyes at the same time. Make sure the zoom is on its lowest setting and then, while looking in the scope, focus on the object with the large knob.
2. Play around with the different lighting controls and see what a difference the direction of light plays in how the object looks and on the contrast.
3. Get comfortable with the scope and practice zooming in and out of the object. Do you need to re-focus the scope after zooming?
4. Draw the object under the scope in the first plankton "box" (see last page). Using the ruler, measure the size of the object under the scope to the nearest millimeter (mm).
5. After your work is done (at the end of the lab), *carefully* wipe down any drops of water from the scope! Seawater is very harmful to the microscopes and will do a lot of damage if not cleaned up. If you had a lot of seawater on the stage, wipe it down with freshwater, then dry it with a towel.

YouTube Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

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Dissection Microscope. Image by Kevin Raskoff. CC BY-SA 4.0.

The Compound Microscope

Biologists of all types use microscopes as a principal investigative tool. From genetics, molecular, and cell biology all the way to evolution and ecology, this instrument provides useful and often critical information relating to the action of genes, the structure of cells, the presence of particular tiny adaptations that are key to an organism's survival. The microscope consists of a lens system, a controllable light source, and a geared mechanism for focusing the specimen by adjusting the distance between the lens system and the specimen or object being observed. The light on compound scopes always comes from behind (transmitted) the objects, so they must be either very small, transparent, or very thin to see through.

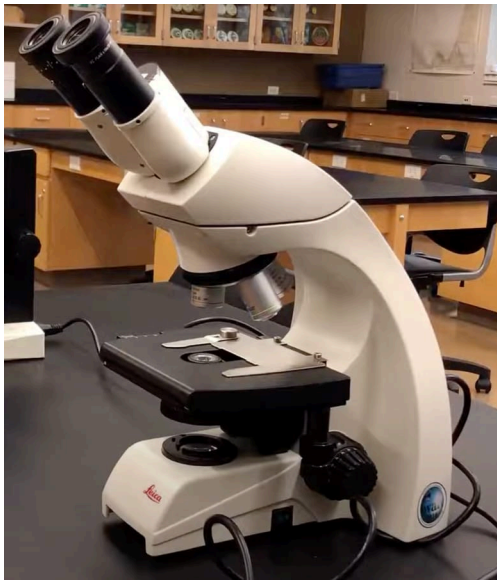
Lens and magnification: The magnification achieved by a compound microscope is the result of two systems of lenses: the objective lens, nearest the specimen, and the ocular, or eyepiece lens, at the upper end of the instrument. To achieve different degrees of magnification, three or four objective lenses are provided. These are attached to the nosepiece, which revolves around an axis above the specimen, enabling you to gradually increase the magnification by simply rotating from the shortest lens in the active position, in sequence, to the longest objective. The magnification of each objective is indicated on its side and can be specified from the shortest to the longest, as follows: Scanning objective (4X), low power (10X), high dry objective (40X), and the optional oil immersion lens (100X). To determine the total magnification of your image, it is necessary to multiply the magnification of the objective lens you are using by the magnification of the ocular, which is fixed at 10X. So, for example, if the specimen is being viewed with the 40X objective, multiply 40 by 10 to get a total magnification of 400X.

YouTube Video

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Compound Microscope. Image by Kevin Raskoff. CC BY-SA 4.0.

Activity

Making a Wet Mount: Wet mounts are used to study fresh, living material. They can be used only for a little while because they will soon dry out. They are useful for observing qualities such as natural color, movement, or behavior that cannot be observed on dead, fixed, and stained material.

1. Obtain a clean slide and coverslip from the supply counter. If the slides and/or coverslip are not clean, wipe them gently with a Kimwipe or get a new one.
2. Place a drop of the living material (plankton) on your slide with the bulb pipette.
3. Touch the edge of the coverslip to the drop of water on the slide and gently lower the coverslip onto the slide. If you have been careful, the slide will not have any bubbles. If not, you will see the air bubbles as circles of various sizes with very dark edges when you look at your slide with the microscope.
4. Click the scanning objective lens into position. The scanning lens is the shortest lens and has a magnification, by itself, of 4X.
5. Using the coarse focus knob, lower the stage as far as possible.
6. Place the slide on the stage and position the cover slip directly over the hole in the center of the stage.
7. Now, looking from the side and using the coarse focus knob, bring the scanning lens as close to the slide as it will go.
8. Look into the microscope and slowly turn the coarse focus knob so that the scanning lens is moving away from the slide. Continue looking and turning until the plankton comes into focus. Fine-tune the image with the fine focus.
9. Using the travel knobs on the mechanical stage, move the slide away from you and note what happens to the image. Does the image move in the same direction? Move the slide to your left, then to your right. What does the image do when you make these movements?
10. Note that the inverted image always moves in the direction opposite to the direction in which the slide is moved.
11. Now, switch the objective lens to low power. The low-power lens is a bit longer than the scanning lens and has a magnification by itself of 10X. Since these lenses are “parfocal”, you will only have to slightly adjust the fine focus. If you do not see the plankton any longer, it is probably because you did not center the image in the scanning field before switching to the 10X lens.
12. Once again, center the image in the middle of the low-power field of view.
13. Move the high-power objective lens (40X) into position, making certain that it clicks in correctly. You may have to fine-tune the image with the fine focus knob. **DO NOT USE THE COARSE FOCUS KNOB WHILE UNDER HIGH POWER**, it can easily break the lens and the slide!
14. Observe the slide and wonder at the magnificent things to be seen in this microscopic world! *Imagine what it must have been like for the first microscopists to look into a drop of pond water and see all these amazing creatures!*
15. After your work with all the slides has been done, carefully wipe down any and all drops of water from the scope! Seawater is very harmful to the microscopes and will do much damage if not cleaned up.

Measuring things with the microscope

If you have a microscope with a reticle in the ocular lens (a small ruler-like scale), then measuring the sizes of things under the scope is easy. Using the scale, you just need to measure your object and then multiply the number of units by a conversion factor. The scale doesn't know what magnification you are on, so you need to use that information to find out the true size of the object. If an object were 23 units long under a magnification of 25x, then the size would be: $23 \times 40 \mu\text{m} = 920 \mu\text{m}$ (or .92 mm).

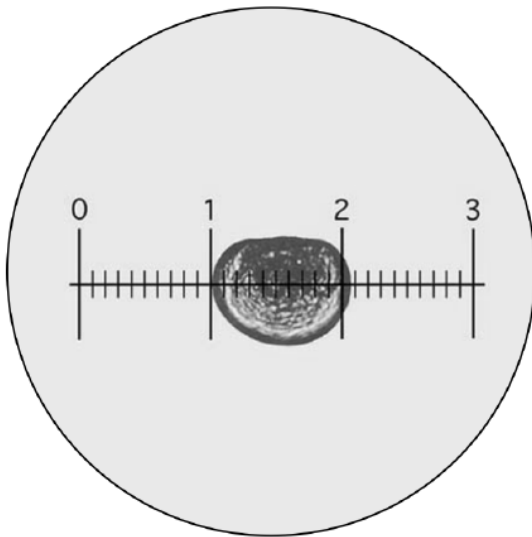
Dissection Scope Reticle Scale

Magnification	Unit Measure (μm)
8	125
10	100
12.5	80
16	62.5
20	50
25	40
30	33
35	29

Equation is: $1000/\text{Mag}=\text{Unit}$

Compound Scope Scale

Using the reticle, you can see this object is 10 units long (pay attention to the littlest lines, not the bigger ones). If this were viewed under 400x magnification, then the size would be: $10 \times 2.5 \mu\text{m} = 25 \mu\text{m}$.



Magnification (total)	Unit Measure (μm)
40	25
100	10
400	2.5

Activity

Drawing Plankton: Using several different samples of the plankton in both the dissection and compound microscopes, you will draw and try to identify several groups of plankton. Using the techniques outlined above and the books and guides provided, carefully examine the specimens and draw their details on the plankton observation pages provided. Use the magnification and microscope best suited to the organism under study, and use the entire circle of the drawing area to represent the field of view of the microscope.

For each drawing of a plankton, try to list the following items:

1. Common Name:
2. Scientific Name (Genus and species):
3. Phylum:
4. Class:
5. Which Microscope?
6. Size of creature in micrometers (μm)
7. Other notes on its behavior or look

7: The Common Invertebrate Phyla

Introduction

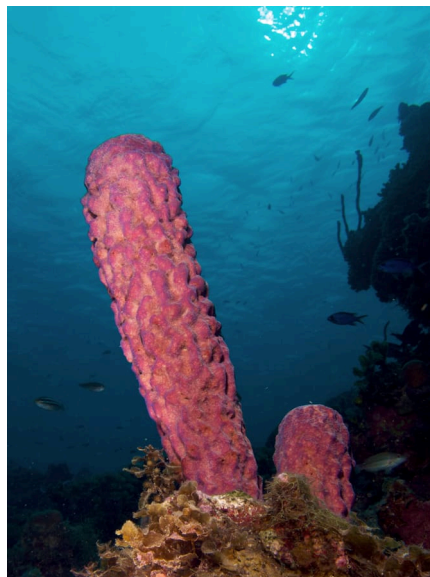
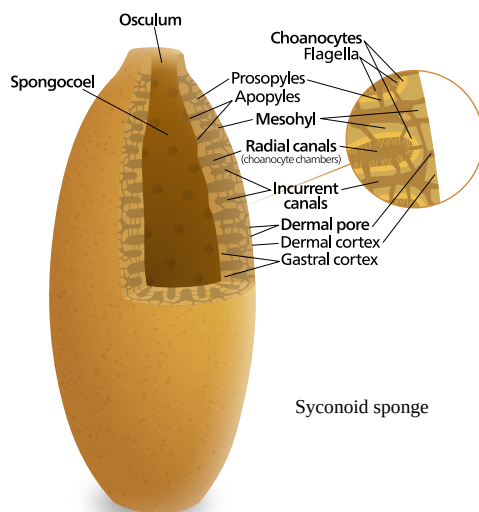
The animals “without backbones” is a common way to describe the invertebrates, but we will see that it is much more interesting (and instructive) to see what these incredible groups of animals do have, as opposed to what they lack. When we examine the invertebrates, we see more than simply a bunch of animals with which we may or may not be familiar. What we can observe if we look carefully is the evolution of the animals as a whole. Over 95% of species on the planet “lack a backbone”, so get ready to meet not only your ancestors, but the rulers of the planet, both on land and in the sea.

Activity

Using the guidebooks and key, you will examine members of every phylum and class listed below. Explore the living specimens in the seawater tables and the preserved and dried specimens on the side and back of the lab. Get to know the unique characters of each phylum and spend time looking at the animals with your own eyes and using the microscopes. Try to draw as many as you can to practice your observation skills. At the end of the lab, you should not only be familiar with each phylum but also know the main characteristics of the groups.

Major Animal Phyla

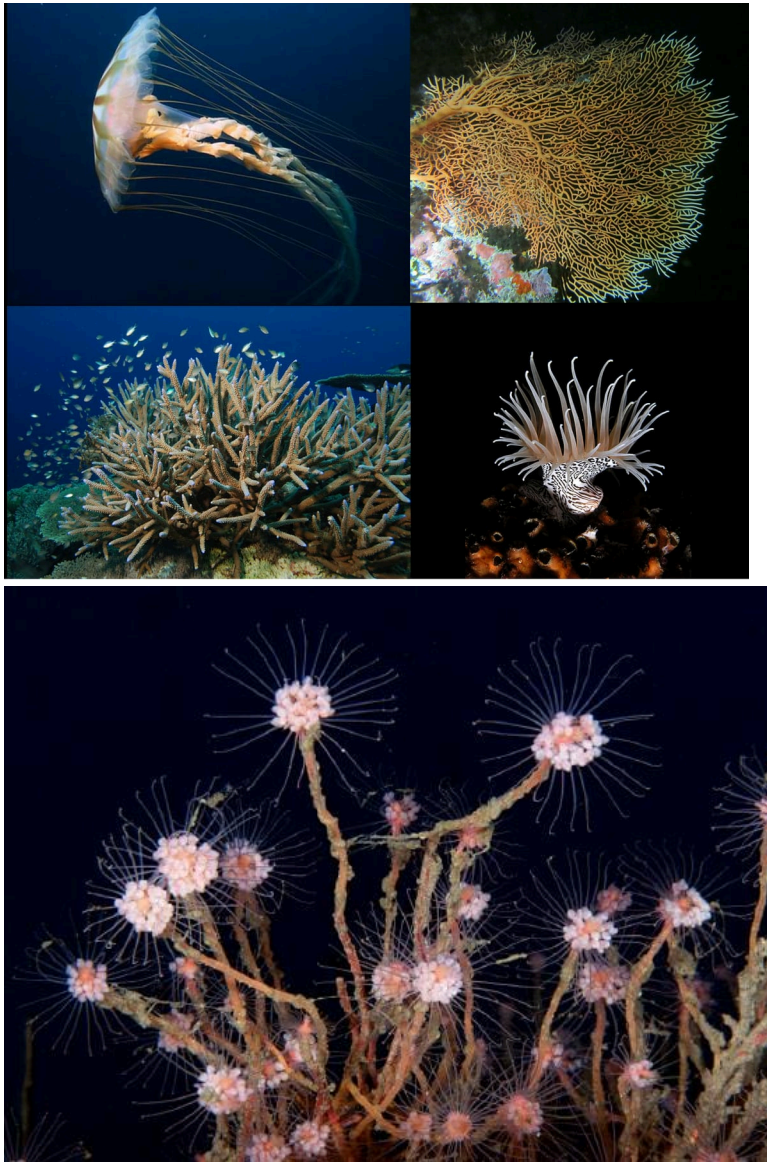
Phylum Porifera. The primitive nature of sponges is evident in their body plan, which lacks tissues or organs. The basic body plan of sponges consists of two layers of cells supported by fibers and secreted mineral elements that form a middle layer, called the mesohyl, between the cell layers. These cells and their products form the body wall of the sponge and are organized around a central cavity called a spongocoel. This space is neither a digestive tract nor a body cavity; rather it is simply part of a system of passageways that allow water, drawn across the wall of the sponge to move toward an opening near the top of the sponge, the osculum, thus enabling filter feeding. Special cells, called choanocytes, pump and filter the water of food while also exchanging gases and wastes.



A- Kelvin Song; B- Nick Hobgood. Both CC BY-SA 3.0 <<https://creativecommons.org/licenses/by-sa/3.0/>>, via Wikimedia Commons

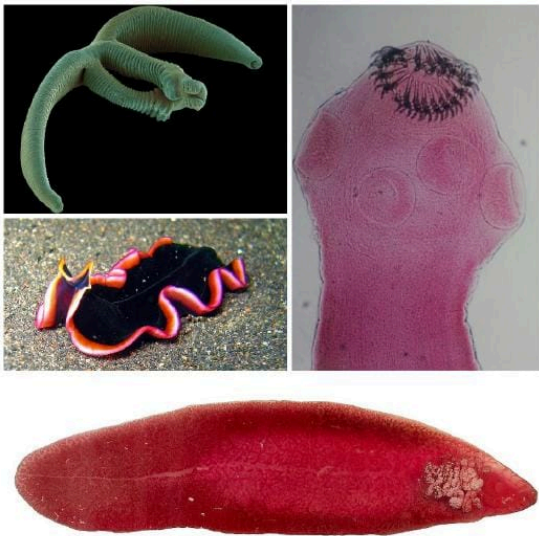
Phylum Cnidaria This phylum includes anemones, corals, jellies and box jellies, which until recently were thought to be only slightly more advanced than sponges; but given the presence of tissues, they are classified among the metazoans—animals with

well-defined tissues and organ systems. This view was developed on the basis of their body plan, which exhibits a tissue level of organization but lacks the organs seen among all remaining animal phyla. Two radially symmetric body forms are seen among most cnidarians: the sessile, cylindrical polyp form characteristic of anemones and corals, and the umbrella-like medusa, a free-swimming form, common to jellies. Among the cells making up the epidermis are specialized stinging cells called cnidocytes, which contain a stinging organelle, called a **nematocyst**. When stimulated, the nematocyst will evert from the cnidocyte, stinging its prey and, in many cases, delivering immobilizing toxins. These stinging cells are a distinguishing feature of Cnidarians.



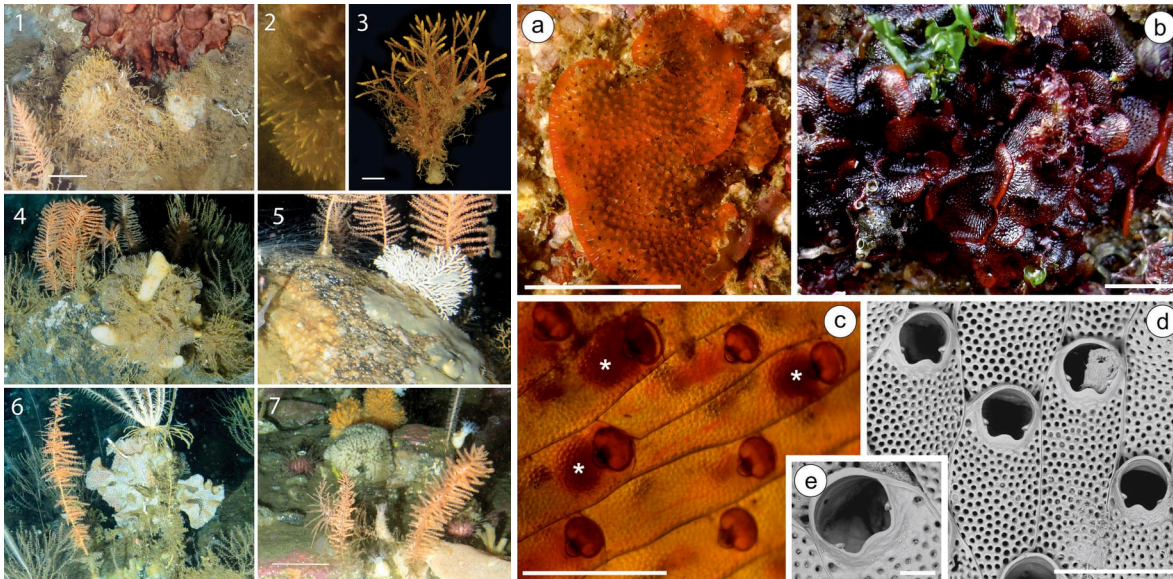
Jellyfish by Kevin Raskoff. Collage by Frédéric Ducarme, CC BY-SA 4.0 <<https://creativecommons.org/licenses/by-sa/4.0/>>, via Wikimedia Commons. Hydroid by Bernard Picton, CC BY-SA 4.0 <<https://creativecommons.org/licenses/by-sa/4.0/>>, via Wikimedia Commons.

Phylum Platyhelminthes includes the flatworms. They are all quite flat (most less than 1 mm thick) and come in many wonderful colors. They often have eye spots and can be seen “gliding” around, as opposed to wriggling about. They glide around on mucus and cilia and can have very fine control over where they are going. These are the first animals with heads and are efficient hunters. They do not have a complete gut, so that food goes in and undigested material comes back out the same opening, which is usually found on the belly on the worm.



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Phylum Bryozoa and three other small phyla have a feeding structure called a lophophore, consisting of a set of horseshoe-shaped or circular ciliated tentacles surrounding the mouth. The cilia create currents of water that pass over the tentacles, where they can trap food particles. They usually live in large colonies made up of very small individuals, like small apartments in a big complex.



A- Cecchetto M, Lombardi C, Canese S, Cocito S, Kuklinski P, Mazzoli C, Schiaparelli S (2019) The Bryozoa collection of the Italian National Antarctic Museum, with an updated checklist from Terra Nova Bay, Ross Sea. ZooKeys 812: 1-22. <https://doi.org/10.3897/zookeys.812.26964>, CC BY 4.0 <<https://creativecommons.org/licenses/by/4.0/>>, via Wikimedia Commons. B- Reverter-Gil, O., Souto, J. 2019. Watersiporidae (Bryozoa) in Iberian waters: an update on alien and native species. Marine biodiversity. 49: 2735–2752. DOI: 10.1007/s12526-019-01003-4, CC BY 4.0 <<https://creativecommons.org/licenses/by/4.0/>>, via Wikimedia Commons.

Phylum Annelida consists of worms, but this group has one very obvious difference: their bodies are segmented, both internally and externally. Annelids evolved to burrow into the oceanic sediments where they could ingest the substrate and digest the organic detritus that had accumulated there. In general, annelids are elongate, protostomous, schizocoelous, worm-shaped animals divided into a series of similar segments. They have the tube-within-a-tube body plan where each segment has a well-developed coelom, digestive, circulatory, excretory and nervous system. There are three classes of annelids, broadly distinguished

by their respective habitats. Free-living marine annelids exhibit the greatest diversity; however, freshwater and terrestrial classes are also well represented. Very few are parasitic.

Class Polychaeta - Annelids with distinct heads bearing sensory organs and a pair of lateral flap-like extensions of the body wall called parapodia bearing many bristles (setae) on each body segment that are involved in locomotion and gas exchange.



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Phylum Mollusca is a big group of bilaterally symmetric, soft-bodied animals. Molluscs have well-developed organ systems for feeding, digestion, circulation, respiration, excretion, movement, nervous coordination, and reproduction. The molluscan body plan has large anatomical regions: a head, a muscular foot, a visceral mass, which is covered by a mantle that may secrete a calcareous shell. Among the unique and defining features of all molluscan classes, except the bivalves, is the presence of a feeding structure known as the radula; this structure takes on many different forms according to the feeding strategies of each group.

Class Polyplacophora - These are chitons, molluscs with somewhat dorso-ventrally flattened bodies with a reduced head and the shell divided into eight valves which lie dorsally. The chitons are entirely marine and live in intertidal areas that are subject to wave action and alternate drying and submerging caused by tides.

Class Gastropoda - Commonly known as snails, limpets, conchs, and whelks, the gastropods are the largest class in the phylum. Most shelled gastropods undergo torsion and spiraling during embryonic development; this 180-degree rotation of the visceral mass results in the digestive and nervous systems having roughly a U-shape. Spiraling involves the coiling of the visceral mass inside the shell so that the anus and mantle cavity lie in the anterior end at the opening of the shell.

Class Bivalvia - This group includes clams, oysters, mussels, and scallops. They are sedentary, filter feeders characterized by a laterally compressed body surrounded by a two-piece shell consisting of right and left valves. The shell is lined by the mantle and the head is indistinct. A large, muscular foot can be extended and is used in burrowing.

Class Cephalopoda - Commonly known as nautilus, squids, and octopuses, these animals are active marine predators. Nautilus has an external shell, but in the others, the shell is internal or absent. The muscular foot has grown up around the head and developed into eight or more long, prehensile tentacles. The well-developed head has accommodating, image-forming eyes.



PaleoNeolithic, CC BY 4.0 <<https://creativecommons.org/licenses/by/4.0>>, via Wikimedia Commons.

Phylum Nematoda are very small (usually) cylindrical worms that lack any distinct head or other body parts. They don't have fine control over their movements and are usually seen thrashing about. They have a complete gut and eat just about everything. What they lack in size and complexity, they make up for in numbers. On just about every living thing and drop of dirt, there are nematodes





Bob Goldstein, UNC Chapel Hill <http://bio.unc.edu/people/faculty/goldstein/>, CC BY-SA 3.0 <<https://creativecommons.org/licenses/by-sa/3.0/>>, via Wikimedia Commons; CSIRO, CC BY 3.0 <<https://creativecommons.org/licenses/by/3.0/>>, via Wikimedia Commons.

Phylum Arthropoda is the largest group of animals on earth, with features such as jointed, hard exoskeletons, with segmentation, and many paired appendages. All members have exoskeletons and grow by the process of ecdysis, or molting. They usually have distinct body regions, such as a head, thorax, and abdomen. This body plan affords the members of this phylum with a tremendous potential to evolve because its simplicity is easily adaptable to gathering food, feeding, locomotion, and sensing. Furthermore, the exoskeleton—formed from a chitinous cuticle and then calcified in aquatic arthropods—provides protection. Soft, pliable regions of the exoskeleton form the basis for jointed appendages, allowing movement.

Subphylum Crustacea – About 40,000 species of lobsters, crabs, shrimps, barnacles, and water fleas. Mostly aquatic arthropods, except pill bugs (terrestrial), in which the body is segmented into two or three parts with biramous (branching), paired appendages that are often highly specialized. The head has well-developed paired appendages, including two pairs of sensory antennae (anteriormost), followed by three or more pairs of mouthparts, including hardened jaws (mandibles). Walking legs are present on the thorax, and, unlike insects, crustaceans have appendages on the abdomen.



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Phylum Echinodermata This phylum includes about 7,000 species of slow moving or sessile marine animals exhibiting spiny skin. They are voracious feeders and the adult bodies exhibit secondary, pentamerous radial symmetry, meaning that the body is arranged into five (or multiples of five) repeating units radiating from a central area. The use of the term secondary in this context arises from the fact that the larval stage of these organisms is bilaterally symmetric. The adults have a calcareous endoskeleton composed of bone-like flat plates (ossicles) from which spines emerge, with their bases articulating with the ossicles. Echinoderms have a unique physiological system called a water vascular system that serves a variety of functions, the most prominent being locomotion whereby the system ends in a number of tube feet. They have a complete tubular digestive system, and the body surface (along with some surface specializations) serves as a site for the exchange of respiratory gases and nitrogenous wastes since they lack any other specialized organs to perform these functions.

Class Asteroidea – Sea Stars

Echinoderms are flattened and starlike with arms bearing grooves and tube feet on the oral surface.

Class Ophiuroidea – Brittle Stars and Basket Stars

Echinoderms with stellate bodies that are flattened with long, thin, flexible arms sharply set off from the central disc. Tube feet are present but lack suckers.

Class Echinoidea – Sea Urchins and Sand Dollars

Echinoderms with globular or disc-like bodies in which the ossicles are fused to form a solid endoskeleton (test). All have many movable spines and tube feet.

Class Holothuroidea – Sea Cucumbers

Echinoderms with soft bodies that have become elongate (sausage-shaped) in the oral-aboral axis and the mouth is surrounded by feathery tentacles. There are five rows of tube feet, and the ossicles are greatly reduced.

Class Crinoidea – Sea Lilies and Feather Stars

Echinoderms are characterized by having each arm is divided into two or more long, flexible extensions. Sea lilies have a stalked body and are sessile, while feather stars can swim freely.



PbsouthwoodShokaG.P. Schmah, Sanctuary Superintendent. Credit: NOAA/NOS/NMS/FGBNMS; National Marine Sanctuaries Media Library, Sharon Mooney (see User:Edwardtbabinski) Daniel Herschman from Federal Way, US © Hans Hillewaert / CC-BY-SA-3.0 Michael Wolf Derivate Author: Veronidae, CC BY-SA 2.5 <<https://creativecommons.org/licenses/by-sa/2.5>>, via Wikimedia Commons.

Phylum Chordata Chordates include about 50,000 species of animals ranging from simple invertebrates, such as sea squirts, to relatively complex animals like birds and mammals. All members of the phylum share the following characteristics at some time in their life cycle:

1. All have a notochord at some stage in their development

2. All have a **dorsal hollow nerve cord** at some stage in development
3. **Pharyngeal gill slits** appear during development or in adults
4. All have a **post anal tail**

The **phylum Chordata** is split into three subphyla: the **Urochordata** (about 3,000 species of tunicates and salps), **Cephalochordata** (23 species of lancelets), and **Vertebrata** (about 47,000 species of fish, amphibians, reptiles, birds, and mammals). The first two subphyla contain animals that lack a backbone, but have notochords to provide some support. They are the invertebrate members of the phylum. In many respects, they more closely resemble the organisms we have studied thus far, even though they are much more closely related to the vertebrates with which we are more familiar. In vertebrates, a segmented column of bones, the vertebral column, replaces the notochord.

Subphylum Urochordata (or Tunicata) “Sea Squirts and Salps”.

Depending on the species, these marine invertebrates are sessile filter feeders (sea squirts) or drifting, pelagic filter feeders (salps and larvaceans) that may form colonies several meters long. The nerve cord and notochord are present only in the tail of the tadpole-like larvae and disappear in the adult.



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Taxonomic Key to the Major Invertebrate Phyla

Most taxonomic keys are “dichotomous” (two branches), which is to say they are written with a series of two choices to be made about the anatomy of an animal you are looking at. Keys are not made to be read from start to finish like a book or a poem. In each numbered question, you should read both choices, determine which choice best applies to the specimen you are looking at, then go where the key tells you to go, often skipping other steps in between that don’t apply.

1. Radial symmetry or.....2
Bilateral symmetry.....4
2. Highly porous surface, not true tissues.....**Phylum Porifera**
Surface is not highly porous, true tissues present.....3
3. Exhibits pentamerous symmetry and tube feet.....**Phylum Echinodermata**
Lacks pentamerous symmetry and tube feet, possesses tentacles
with nematocysts**Phylum Cnidaria**
4. Macroscopic colony of sessile, microscopic individuals, individuals
small in individual boxes.....**Phylum Bryozoa**
Solitary or colonial in form, individuals of the colony > 0.5 mm in size.....5
5. Gelatinous.....6
Not gelatinous.....7
6. Solitary individuals with 8 rows of comb plates.....**Phylum Ctenophora**
Solitary and/or colonial with incurrent and excurrent siphons, and a
gelatinous exterior called a tunic.....**Phylum Chordata**
7. Possesses segmentation.....8
Lacks segmentation.....9
8. Exoskeleton with jointed appendages.....**Phylum Arthropoda**
No exoskeleton, appendages, if present, not jointed, segmented, worm-like
body, possibly in a tube (if in a tube, may have tentacles).....**Phylum Annelida**
9. Possesses a foot, radula, arms and/or shell.....**Phylum Mollusca**
Lacking all of above, dorso-ventrally flattened or round in cross section.....10
10. Dorso-ventrally flattened to a thickness of less than 1mm ...**Phylum Platyhelminthes**
Round in cross section, worms, usually very small, some large.....**Phylum Nematoda**

VOCABULARY for INVERTEBRATE KEY

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

asymmetry Having no symmetry

bilateral symmetry Having a body displaying two similar halves.

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

dorsoventrally From back to front.

exoskeleton An external skeleton, shell.

gelatinous Looks like jelly.

nematocyst The stinging “cells” of cnidarians.

pentamerous symmetry Divided into five parts.

porous Full of tiny holes.

radial symmetry Having similar parts radiating from a central point.

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.

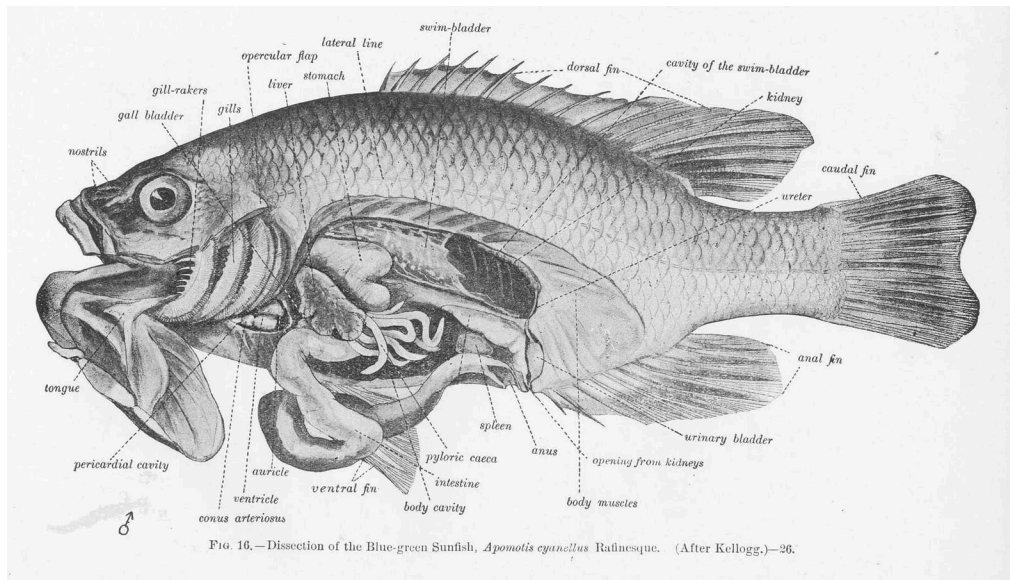
tentacles Long cylindrical tubes for sensory reception or food capture.

8: Fish Anatomy and Dissection

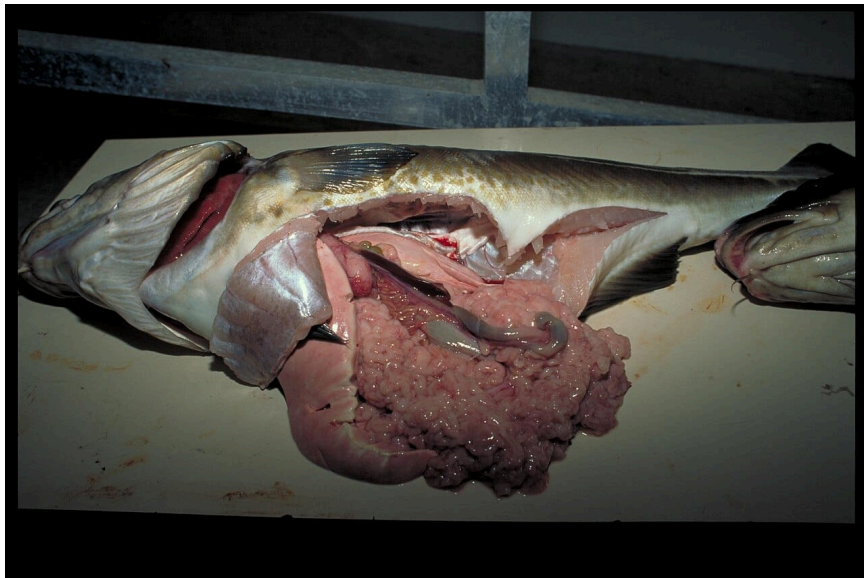
Fish Anatomy and Dissection

Use the guidebooks in the classroom to dissect the various fresh fishes that are available.

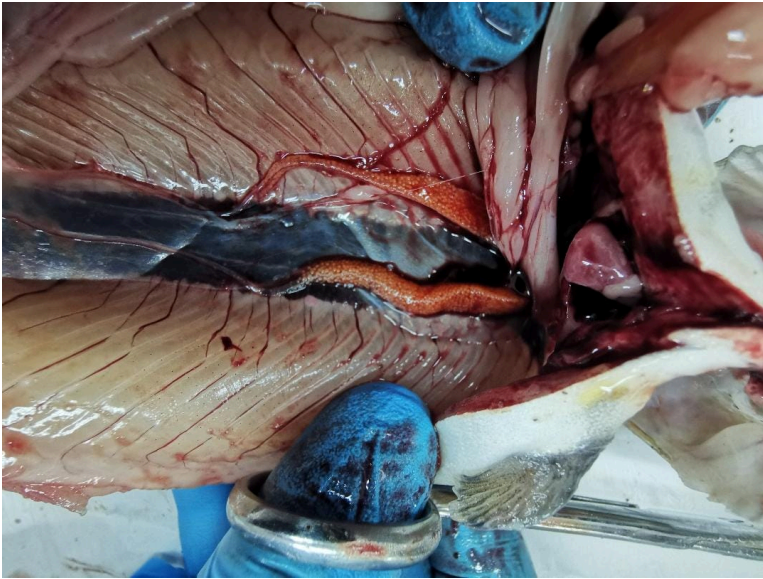
You can use these images for additional resources.



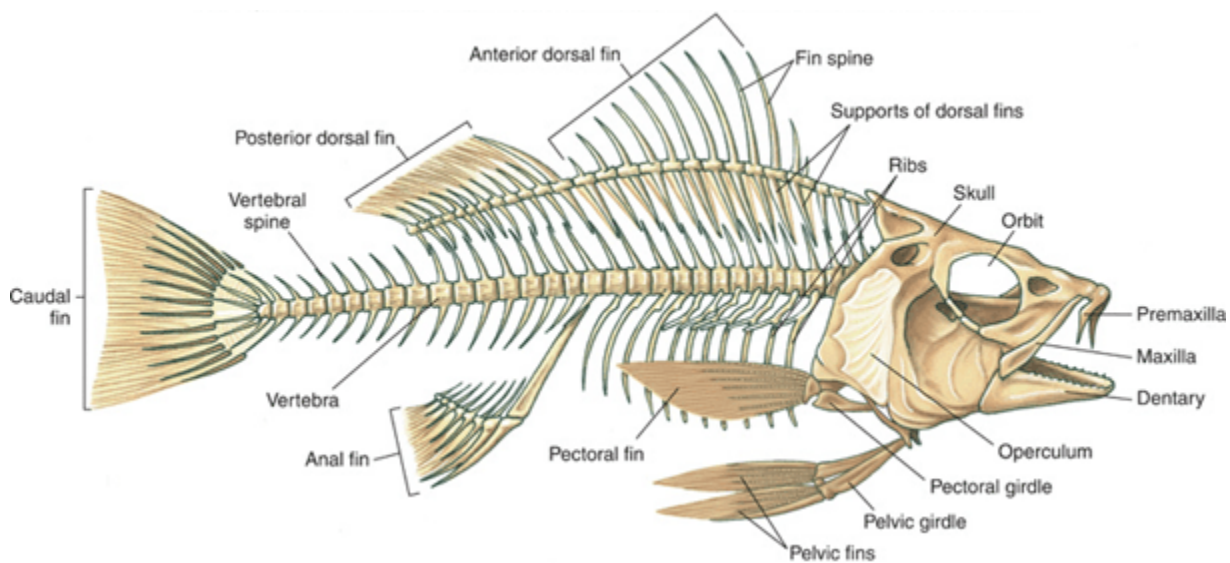
Dissection of the Blue-green sunfish. (1907)



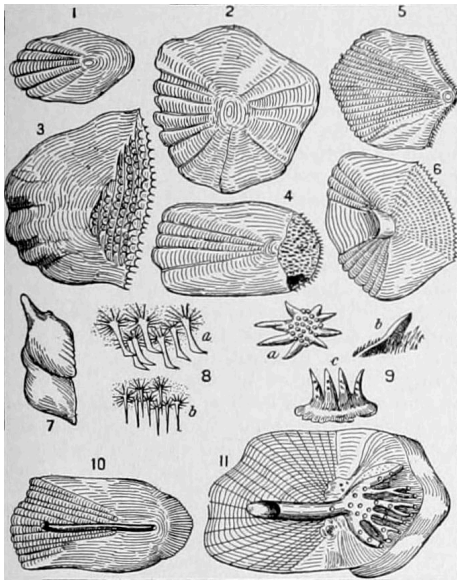
Dissected fish. Stephane Lesbats (IFREMER, Pôle Images, Centre Bretagne - ZI de la Pointe du Diable - CS 10070 - 29280 Plouzané, France), CC BY 4.0 <<https://creativecommons.org/licenses/by/4.0/>>, via Wikimedia Commons.



View of Kidney (dark stripe) and Gonads. Dijana Blazekovic, CC BY-SA 4.0 <<https://creativecommons.org/licenses/by-sa/4.0/>>, via Wikimedia Commons



Skeleton of a fish. Content from African Digital Schools Initiative (ADSI), CC BY-SA 4.0 <<https://creativecommons.org/licenses/by-sa/4.0/>>, via Wikimedia Commons



Fish Scales. unknown artist; article is by Ernest Ingersoll and Charles B. Davenport, Public domain, via Wikimedia Commons.

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Kindey and gonads: Dijana Blazekovic, CC BY-SA 4.0 <<https://creativecommons.org/licenses/by-sa/4.0/>>, via Wikimedia Commons

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9: Marine Mammal Behavior and Population Census

Introduction

If ecology is the study of organisms and their environment, then the study of **animal behavior** can be thought of as how and why animals interact with their environment. This can be with **conspecifics** (others of their own species), with other species, or with the physical environment. By studying animals and their behaviors, we can learn about the relationships between animals, the physiological processes that determine their behavior, and perhaps the ultimate reasons for their evolutionary success. **Niko Tinbergen**, one of the fathers of **ethology**, stated that we should pay attention to four kinds of explanations in any instance of behavior: 1. **Causation**: what are the stimuli that elicit a response, and how has it been modified by recent learning? 2. **Development**: How does the behavior change with age, and what early experiences are necessary for the behavior to be shown? 3. **Evolutionary History**: How does the behavior compare with similar behavior in related species, and how might it have arisen? 4. **Function**: How does the behavior impact the animal's chances of survival and reproduction?

To understand behaviors and the (potential) meanings behind them, the first step is to have a compilation and inventory of the behavior performed by animals of the same species under investigation. This inventory of behavior is an **ethogram**. Behaviors can be divided into several broad **categories**, such as courtship, sleeping, aggression, feeding, etc. Each of these broad categories would then likely be reduced to more specific behaviors. This ethogram is the starting point for asking Tinbergen's questions.

We are all familiar with watching animals every day (especially our own species). **Observing** behavior is more than just watching; it involves the systematic **recording** of the activities of the animal, often with particular questions in mind. One issue we need to be careful with is the quality of the data generated from this type of observational study. **Interobserver reliability** is the agreement between the data recorded by two or more people on the same animal(s). In other words, observation can be somewhat subjective, and two people might 'see' different things, or interpret them differently. Another issue we should be conscious of is the **temporal limitations** (timing) of our observations. How long would it take to generate a complete ethogram of an animal? Would you expect to see all the behaviors of an animal in 30 minutes? What about during day vs. night, during a season, or a year, or a lifetime? What would aliens learn about you if they observed you from 3-5 am, as opposed to 3-5 pm?

Activities

Part 1. Ethogram and Behavior

At the US Coast Guard pier in Monterey, we will observe the behaviors of a large marine mammal, the California Sea Lion (*Zalophus californianus*). California sea lion lives mainly around the waters of California. It also lives around Oregon, Washington, and British Columbia to the north and Mexico and the Galápagos Islands to the south. Adult male California sea lions measure up to 8 feet in length and weigh an average of 800 pounds, while adult females measure an average of five feet in length and weigh 200 pounds. At around five years of age, males develop a bony bump on top of their skull called a sagittal crest as they reach sexual maturity, and it is this that gives the animal its generic name (loph = "crest"). Females are lighter in color than males. California sea lions are opportunistic eaters, feeding on squid, octopus, herring, rockfish, mackerel, and small sharks. In turn, sea lions are preyed upon by Orcas (killer whales) and great white sharks. They are a highly social species that often occur in large groups and breed around May to June. Most pups are born in June or July and weigh 13-20 lbs. (6-9 kg). They nurse for at least five to six months and sometimes over a year. The males usually leave for feeding grounds during the winter, leaving the females and young pups. Most pups are born in the Channel Islands off Santa Barbara. Most of the small sea lions you see in the Monterey area are already weaned pups or yearlings. CA Sea Lions stay with their mothers for 6-9 months on average. Adult females tend not to migrate as far as the males and primarily stick around Southern CA. During the fall, it would be somewhat rare to see adult females in the Monterey area as they would still have dependent pups at that time of year. It would be safe to say that the majority of the sea lions in the Monterey area during the fall are probably young males.



Alexdi at English Wikipedia, CC BY 3.0 <<https://creativecommons.org/licenses/by/3.0/>>, via Wikimedia Commons. Rhododendrites, CC BY-SA 4.0 <<https://creativecommons.org/licenses/by-sa/4.0/>>, via Wikimedia Commons. David Merrett from Daventry, England, CC BY 2.0

Sea Lion Ethogram:

1. You and a partner will team up and observe the animals for a period of time and then try to formulate a list of behaviors that would create a comprehensive ethogram for the species. How long this will take would depend on what things you are looking for, what assumptions you make, and how active the animals are.
2. After you come up with your list, you will then set a specific time frame to observe a single individual or a small group. You could try to keep a running record of behavior, but this is often difficult to do. A more commonly used strategy is to record what an animal is doing at predetermined timed increments, such as every 30 sec, minutes, hours, etc. By keeping track of how often an animal does a particular behavior, you will be able to analyze how the species as a whole spends their time and energy. Since we won't have much time, this period will need to be short, but it should give you a window into the behavior of the species.
3. Both you and your partner will independently record the behaviors of the same animal(s) over the time span of the systematic observation.

Analysis and Write-up: Part 1

- 1. After the lab, combine your data and generate an average number from the two sets. This will help resolve differences in observer interpretation.
- 2. Construct a graph that shows the amount of time the individuals spent performing the specific behaviors. Hand in this graph and a typed list of your ethogram next week.
- 3. Write one detailed paragraph explaining the methods you used to collect your data.

Part 2. Marine Mammal Population Census

A census is an important process in estimating the population of a species. However, the problems of observing animals for a census are compounded by the fact that most species need to be secretive to survive, either to avoid predation or to be effective predators themselves. They often live in areas that are difficult to access and might be scared away by our approach. There are also important differences in population from season to season or even day to day based on mating, feeding, or other patterns that can shift quickly. They are also often non-randomly distributed because they may favor some specific habitat. Being widely distributed or clumped in groups both offer different challenges for the researcher.

Many methods exist to aid the researcher in their observation, including the use of spotting scopes, binoculars, photographic

surveys, infrared and night-vision cameras, aerial counts and photography, pole cameras, balloons and kites with cameras, various marking methods, and statistical analyses that aid in the estimation of a population from a sample observed. Indirect methods can also be used, such as prints, fecal material, fur clumps, etc.

A census works best if it is repeated in a systematic way over time, so you have a long-term data set that can show changes in the population. Since the animals are alive and in the wild, they can be challenging to see and count. They can remain hidden, or move around, and could be erroneously counted more than once. To help with the accuracy of the data, we will average team member data (for the same reasons as above) and also combine the data of all teams into class averages (perhaps others saw something you didn't).

- Starting at Section A of the Lovers Pt.-Hopkins area (see map), you will partner with another student and survey each of the seven areas (A-G) for marine mammals.
 - You will need to:
 - Correctly identify target species in the field
 - Obtain accurate counts of individuals
 - Identify and record the behaviors of the individuals
 - Analyze the data after the lab and prepare a census count of the target animals within the survey area.
 - You are trying to observe all individuals of the species, so try to find appropriate vantage points from the shore that allow you to see a wide area. Using your binoculars, carefully survey each of the seven areas.
 - You will likely need to move to several different locations within each area to adequately cover the whole area.
 - Note the locations of kelp beds and other important structures that may influence the animal's location and activities.
 - Note the behavior of the individuals as you perform the survey. You won't be able to spend much time with any one individual, so it will need to be a quick determination. However, when looking back at your data of all the observations, you may find you have noted several different behaviors.

Analysis and write-up: Part 2

- 1. Calculate the number of each species observed in each area from your team data.
 2. Plot your team data for each species (see below).
 3. Calculate the total population of each species along the entire study area and compare that to your classmates. What is the average?
 4. Write a one-paragraph figure legend summarizing the methods, results, and conclusion. Imagine giving the graph to someone not in the class- what information would they need to know to understand the figure and its implications?

Graphing hints:

I have recorded a short video showing you how to graph the data from the marine mammal lab and post it on YouTube, or find a link on Canvas. It addresses one of the important problems people often have, which is adding a secondary axis to deal with the drastically unbalanced data from section A compared to the others.

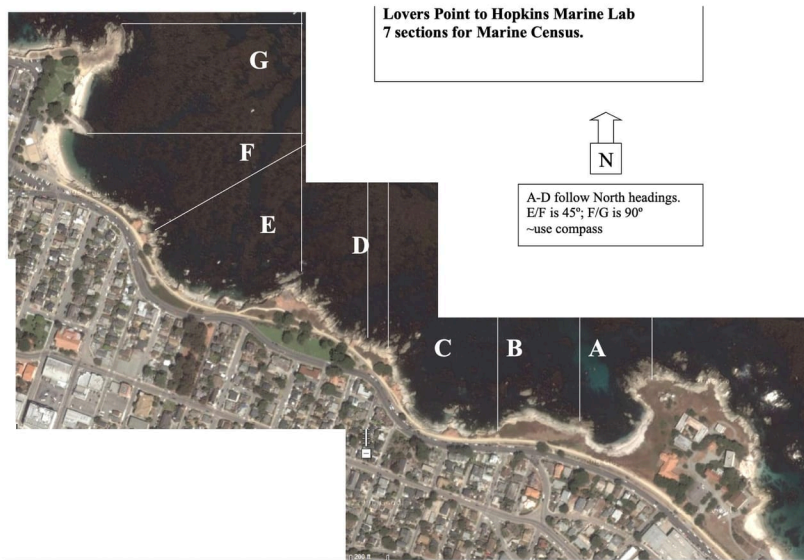
YouTube Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

[View this YouTube Video online](#)



Map of Survey Area



Thumbnail image: “[Sea Lion](#)” by [Adam Rauckhorst](#), CC BY-ND 2.0

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10: The Sandy Intertidal- the microscopic Meiofauna

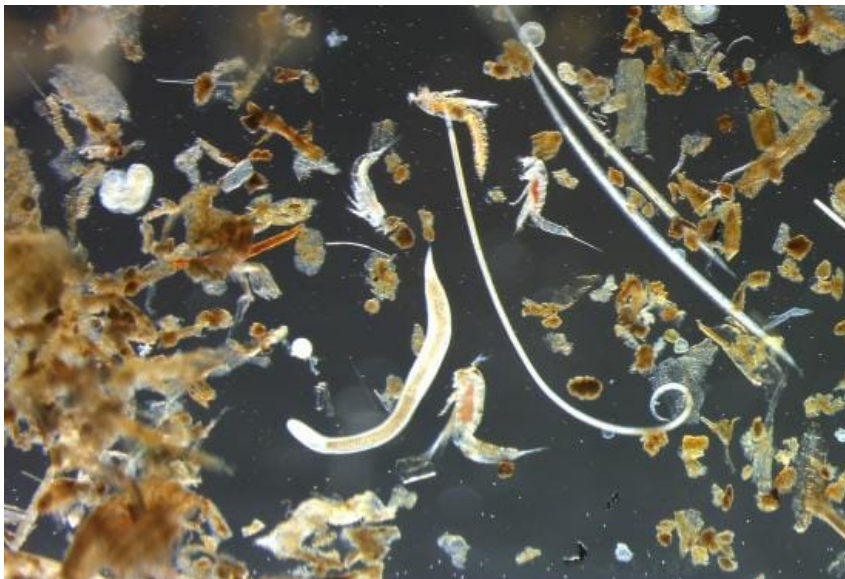
The Meiofauna

Today's lab will sample a region of Monterey Beach, from the water's edge up the beach some appropriate distance (~10 meters). You will examine two different regions of the beach and at two different depths. You will then assess the biodiversity of each location and depth.

Your instructor will find a suitable site and lay down the transect tape. One sample site will be at the water's edge, the other some distance up the beach. Start by getting a temperature profile from the surface down to the maximum depth of the thermometer. At each site, you will sample the surface sand (0-10 cm) and deeper sand (10-20 cm). Each sample will be a 200 ml sample of sand collected and then specially rinsed to get the meiofauna off the sand.

They don't want to leave the sand grains and will actively hold on, so we need to shock them off with a quick rinse in freshwater. After about 5-10 seconds in freshwater, you'll pour the water, which now contains the organisms, through a very small sieve (44- μ m mesh) that will trap them on the mesh. Using seawater, quickly give them a gentle rinse to help them survive. Repeat the osmotic shock 2 more times for each sample to get all the organisms off. Then give a final rinse of the sieve with sea water and then carefully rinse the sample into white 125 ml sample bottles. Carefully label all bottles with the site and depth. Once you have taken your first samples from your site and each depth, try to take another sample from right next to the first as a replicate. This will allow you to compare the two samples and get an average, as well as compare the sites and depths.

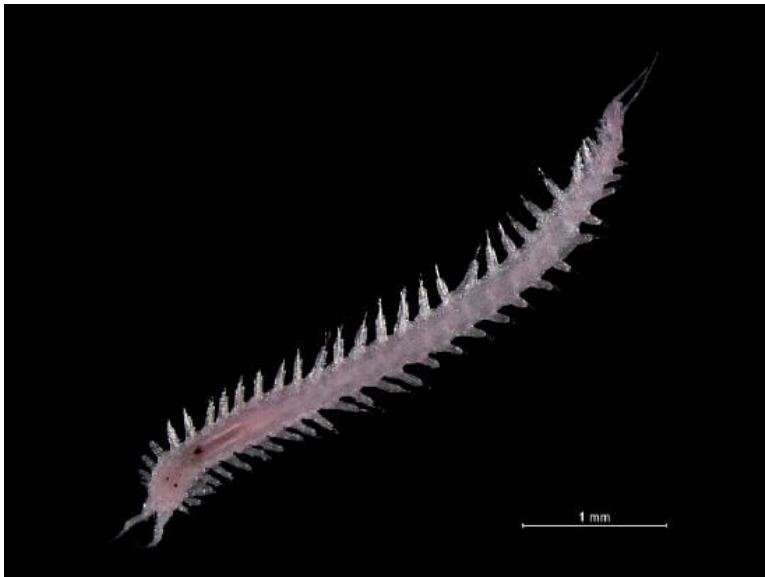
Back in the lab, we will use the dissection and compound microscopes to examine and count the organisms found in the various samples. You will use some biotic measurements, such as density or frequency, to describe and analyze your data, and we will add in **species richness** and **evenness**, which combine to form the very useful **Biodiversity Index**. Calculating biodiversity is not difficult, but like most statistics, it can be very tedious and error-prone, so I recommend using a computerized Excel-based calculator that I have developed and is posted on the class website. This will not only easily determine the biodiversity of an area, but can also statistically compare two different areas and help determine if one area has a higher biodiversity than the other. Just looking at the two numbers can't tell you if one number is higher than the other is truly significant, but the statistical test can.



Mixed meiofauna creatures. Image courtesy of Jeroen Ingels, FSUCML. NOAA. <https://oceanexplorer.noaa.gov/facts...cope-hires.jpg>



Flatworms





Polychaete Worms. Segmented worms that often have small setae or bristles on each segment.



Foraminifera shells. Single-celled amoebas that live inside shells.



Nematode Worms. These "round worms" are some of the more common creatures in the meiofauna.



Copepods are some of the most common arthropods in the water and the meiofauna.



A **gastrotrich** worm. They usually have two "toes" on the posterior end.



Tardigrade, or "water bears".

Estimation Methods and Subsampling

We often have to come up with methods to get good estimates of populations. As we talked about in our statistics lab, if we design our study well, a carefully collected **sample** of the **population** should hopefully be able to help us answer our question. When counting microscopic organisms, we often find we can't even count everything from the sample we took! What we need is a reasonable method for **subsampling** our sample. We are going to take a small, countable portion of our sample, and then use simple math to help us get an estimate of the total sample count. One of the most important issues is making sure any subsample you take is a **representative subsample** of the whole sample. For instance, if you had a lot of animals that settled to the bottom of your sample jar, you would want to make sure you suspended them in the sample before subsampling. A few gentle swirls or inversions of the jar are often all you need to mix the sample back up. You also need to know exactly how much sample you are working with, so your first goal will be to measure all the sample volumes with a graduated cylinder.

Splitting samples

For example, let's say we collected 40 ml of sample from our sand sampling for a site. The first option might be to put it all into a petri dish and see what we can see, but you might find out that that is too much liquid for one dish, or that there are too many creatures in the sample to count. We can subsample that 40 ml by splitting the sample into two 20 ml samples. If you then count 14 worms in your subsample, you can estimate there are $2 \times 14 = 28$ worms in your whole sample of 40 ml (two 20 ml samples $\times$ 14 estimated worms in each). It is not exact, but often good enough to detect differences in samples.

Subsampling the subsample

Let's say you can't even count a whole subsample: you look into the dissection scope and see that you can only count a few fields of view before becoming overwhelmed. You can see how many fields of view would make up a whole dish at a particular magnification, then just look at a few and multiply. For example, let's say you find that the 16x zoom is a good magnification for seeing your creatures. At 16x, each circular field of view is 145.2 of the standard, large petri dish. So, if you counted 27 dinoflagellates, then you could estimate that there were $27 \times 45.2 = 1220$ dinoflagellates in the entire petri dish

Leica EZ4

Magnification	Field Diameter (mm)	Radius	Field Area (mm ²)	Ratio of LARGE petri (84mm)	Ratio of SMALL petri (25mm)
8	25	12.5	490.9	11.3	4.0
16	12.5	6.25	122.7	45.2	16.0
25	8	4	50.3	110.3	39.1
35	6	3	28.3	196.0	69.4

MPC's Leica dissection microscope estimation factors for different magnifications.

The more fields of view you count, the more accurate the estimation will be, so try to count as many as time will allow. The table on the next page has the multiplication values to use with 3, 5, or 10 counted fields of view.

Leica EZ4	Large Petri			Small Petri		
Magnification	3 Fields (large petri)	5 Fields (large petri)	10 Fields (large petri)	3 Fields (small petri)	5 Fields (small petri)	10 Fields (small petri)
8	3.8	2.3	1.1	1.3	-	-
16	15.1	9.0	4.5	5.3	3.2	1.6
25	36.8	22.1	11.0	13.0	7.8	3.9
35	65.3	39.2	19.6	23.1	13.9	6.9

MPC's Leica dissection microscope estimation factors for different numbers of counts at different magnifications.

Using drops as a subsample on a compound microscope

If you need to make compound microscope slides to count very small samples, you can think of a slide as a subsample. A standard drop is 1/20th of a ml (0.05 drops per ml). If you had 53 ml of sample, and made one slide it would represent 1/1,060th of your whole sample ($53 \times 20 = 1,060$). For example, if you counted 43 diatoms in one slide, your estimate would be $43 \times 53 \times 20 = 45,580$ diatoms in your whole sample! These estimates are obviously very sensitive to the numbers you count, as you can end up multiplying them by huge factors. Careful counting of **several replicates** can give you **average estimates** that can moderate the

lows and highs of one or two subsamples.

The Assignment:

1. Using the class data posted on Canvas, calculate the **average** number of each type of creature for those that had more than one number in the box.
2. Once you have the average number of each creature in each of the four sample locations (Beach Surface, Beach Deep, Ocean Surface, Ocean Deep), count the number of different creatures found in each location. This is called the **Species Richness** and is simply a count of the number of different things. So you should have a Richness # for all four sample locations.
3. **GRAPH** the Species Richness numbers on a graph, so that the x-axis is the four locations and the y-axis is the richness value.
OR
4. **GRAPH** the total number of each creature found in the locations so that the x-axis is the four locations and the y-axis is the total number of each creature. (Bar or column graphs are best)
5. What was your original hypothesis about which area you thought would have the highest biodiversity? Was it supported or refuted by the data?
6. After looking at the data results, what is an interesting question that now comes to mind that you could research as a next step, if we were going to do a second experiment?

You will turn in your answers for the items above on Canvas in one document (Google or Word doc).

Data Table

Count and record the number of individuals of the different groups.

Site _____ Depth _____

Sand Sample size _____

Taxa Count Total per 200 ml

Polychaete worms		
Nematodes		
Rotifers		
Dinoflagellates		
Copepods		
Flatworms		
Foraminifera		
Protists		

Collembola		
Microplastics		
Tardigrades		
Mites		

Images:

Thumbnail image: “Syllidae ANN_GUAOFF13_Meiofauna” by INVEMAR_BEM, CC BY-NC-SA 2.0

Polychaete Worm: © Hans Hillewaert "Creative Commons">Creative Commons Attribution-Share Alike 4.0 International

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11: The Rocky Intertidal- Organism Exploration

Background

The purpose of the lab is twofold. First, we will become acquainted with many of the algae and animals that we will learn more about in future lectures and labs. Seeing them in their natural habitat, with their usual neighbors, will allow us to get a much more realistic idea of the local rocky habitat and the community structure of the area. Secondly, we will try to begin using scientific methods to understand the distribution of creatures and how that might be related to the physical environment around them. Using our eyes and cameras, we will investigate the common organisms in the intertidal and start to look for patterns.

Photographs and Photoquadrats

Taking photographs of the creatures that you see out in the intertidal will be an important part of learning who is who, as well as collecting valuable data.

Photographs

Using your camera or smartphone, document at least 10 different types of creatures from your area. Try to have at least three of them be algae and the rest animals.

Photoquadrats

You will place quadrats out in the field and then take a photograph of each one directly over the top. These photoquadrats can then be the source of important data for future questions.

The Write-up: (This will be done individually)

1. Create a Google Slides presentation.
2. Make a page each for your favorite 10-12 species of algae and animals.
 1. Include a few **images** of each creature that you took yourself and of others from the web if needed.
 2. One short paragraph listing:
 1. The **name** of the species (Scientific Name and Common Name.)
 2. A little bit about its **natural history** (where it lives, what it eats, who eats it, and other interesting facts).
 3. Use the [intertidal guidebooks](#) and other [websites](#) to help research these things.
3. Include a few of the photoquadrats on their own slide pages.
 1. Explain **where** the quadrats were from in the intertidal and what **question** you were trying to answer.
 2. Count the total number (or % cover) of a few species in the quadrats. See if you can count the same things in the different quadrats and compare their numbers from one location to the next.
4. What **patterns** did you notice among the species you observed in your different quadrats, and were you able to answer your question?

Turn in your personal slideshow to Canvas next week.

Thumbnail image: “tide pools” by [Mookie Forcella](#), CC BY-NC 2.0

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12: The Rocky Intertidal- Group Project

Summary

The purpose of the lab is twofold. First, we will become more acquainted with many of the algae and animals that we will learn more about in future lectures and labs. Seeing them in their natural habitat, with their usual neighbors, will allow us to get a much more realistic idea of the local rocky habitat and the community structure of the area. Secondly, we will try to begin using scientific methods to understand the distribution of creatures and how that might be related to the physical environment around them.

Background

The rocky intertidal zone is perhaps the harshest environment in which an organism can be found. The high-energy, wave-swept area is constantly being bombarded with crashing **waves**. Any organisms in this area must be able to deal with tremendous pressures and mechanical **stress**. The tidal cycles also expose these marine organisms to anything from concentrated **salinities** to completely fresh water. Evaporation can bring tide pools up to a very **hypersaline** level (100 ppt), about 3x as salty as normal seawater, while rain or river run-off can instantly plunge the area into **hyposaline**, or **fresh** water. The timing of the **tidal cycle** can also drastically alter the **temperature** of the intertidal region. A low tide on a sunny day can elevate the tide pools to well over 38°C (over 100°F), while a low tide during a snowstorm can drop the temperature well below freezing. These incredible physical variations make the intertidal region a difficult place for life, but life abounds! The algae, plants, and animals of the intertidal have a wide assortment of **physiological** and **behavioral adaptations**, which enable them to thrive in this seemingly inhospitable region. Algae, for example, can settle in **microhabitats** that are, on a very fine scale, protected and less harsh, or they can tolerate the extreme physical stress of direct wave action. Some algae species can lose as much as 90% of their cellular water to evaporation during a low tide and still survive! Animal adaptations follow the same sorts of examples as the algae: those that use microscale habitats and those that can tolerate tremendous water loss and wave action.

The rocky intertidal is the **best-studied** marine ecosystem. This is partly due to the fact that many biologists don't like to get wet! Due to the tidal cycle, for roughly half of a 24-hour period, the intertidal, or **littoral** zone, is not covered by water. Because of this **emersion**, the algae, plants, and animals of the littoral region are easily viewed and studied. Another important aspect of the temporary lack of water in this aquatic system is that many of the sampling techniques that were designed for terrestrial ecology can be used in the intertidal zones with ease. However, what we see during the low tide is essentially a habitat in hibernation until the next flooding tide, or **immersion**. Most of the organisms in the intertidal do not do much during the low tide. They are typically **sessile**, or **benthic** forms, and are active only during the high tides, so what we learn about the intertidal during low tide is only half of the story. During the high tide, larger, **mobile aquatic predators**, such as fish, are common; later, they follow the water out with the receding tide. In contrast, during low tide, other **terrestrial** and **aerial predators** are common in the exposed littoral areas. These include many insects, mammals, and birds, all of which are important predators of intertidal algae and animals.

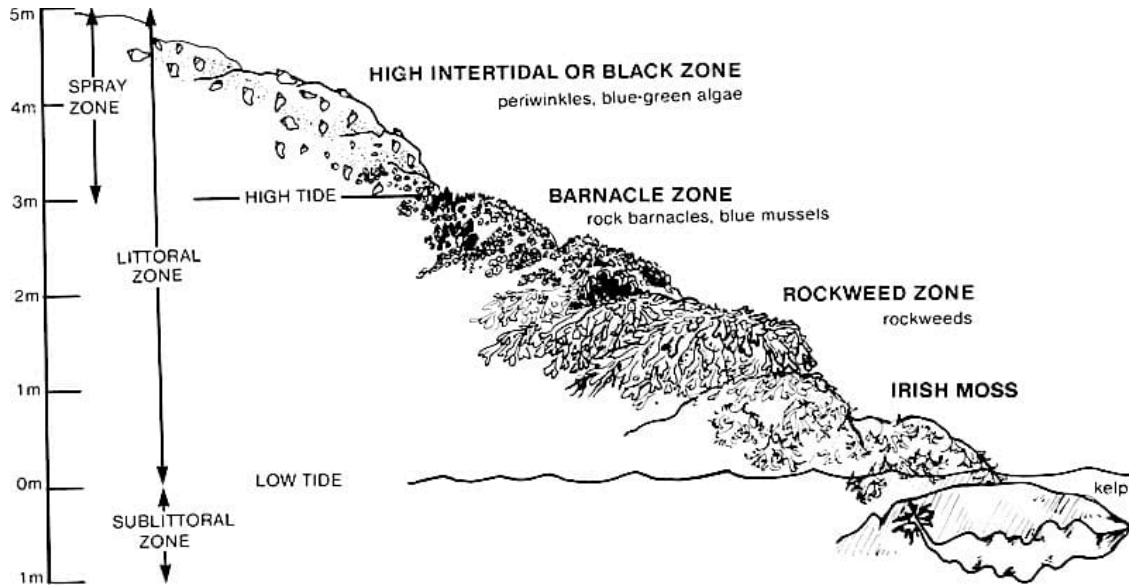
Zonation

One of the first ecological questions ever addressed in the marine ecosystem involved an often observed, but poorly understood, tendency for algae and animals to be found in distinct bands, or zones, in the intertidal. These patterns of **zonation** were noticed all around the globe, in just about every intertidal habitat. But the exact reasons for these patterns were not known. A husband and wife team, Thomas and Anne **Stephenson**, first published the idea of intertidal "zonation" in 1949, and it took over 10 years for the groundbreaking work of Joe **Connell** to finally begin to answer the question of zonation in 1961. This paper is widely regarded as the birth of marine ecology...and it was only around 60 years ago!

What causes this biological zonation in the littoral zones? There are two main answers. **Physical factors**, such as tidal height, spray zone, maximum exposure time, and maximum temperature, generally seem to determine the **upper limits** of organisms, i.e., how high in the intertidal they are found. While mostly **biological interactions** between organisms, such as predation, competition, grazing, and larval recruitment, set the **lower limits** of the zonation of organisms.

Even with what we have learned in the last 60 years about this area of the ocean, which is best understood, we realize that the ecological changes that occur once the water covers the intertidal remain almost totally unstudied. The intertidal habitat still has

a lot of mysteries and questions left unanswered.



(A) Image from page 107 of "An ecological characterization of Coastal Maine (north and east of Cape Elizabeth)" (1980) by Internet Archive Book Images, Public Domain Dedication (CC0). (B) "Zonation on a rocky shore" by Ria Tan, CC BY-NC-ND 2.0

Quadrats

You will place quadrats out in the field, and they will be the source of your data to try to answer your question. You will compare the biodiversity or % cover of your different areas and see what patterns can be discovered. To do this, you will use your data to count the number of creatures inside the quadrat or estimate the % of the quadrat that is covered by species if you are unable to count individuals. Work as a team to count the creatures and get your data.



Each Group will turn in one assignment. Only one person in the group needs to turn it in, but make sure every student's name is clearly listed on the first page.

Activities

- You and your group (maximum of 4 people) will set out to describe both the physical world and the biological components of one of the microhabitats or zones in the intertidal area. Examples of these include: the upper, mid, and lower zones, low energy inshore protected areas, shallow cracks/crevasses, deep tide pools, higher energy outer areas, front of boulders, backs of boulders, etc.
- Each group should clearly decide what the hypothesis that they are testing will be.
- Your group will pick one of these locations, and you will design a rapid sampling strategy utilizing some combination of line transects and/or quadrat sampling techniques. This will not only provide some good information about the habitat in question but will also allow you to take a close look at many of the algae and animals of the intertidal area.
- When designing your sampling protocol, make sure to address the need for replicates. If you are running a line transect with quadrats, how many separate quadrats will you need to make sure you are allowing for the natural variation in the habitat and organisms? How do you also deal with the limited amount of time available to you, both within the lab, but also limited by the tide itself?

Check out this video to get some help graphing your data

Guides of Intertidal Creatures:

- [Northern California Tide Pool Creatures](#)- Short picture guide of some of the common animals and algae.
- <https://seanet.stanford.edu>- A great website made by researchers at Hopkins with lots of good photos and information about the animals and algae.
- [Common creatures](#) previously found at Hopkins.

The Write-up:

1. List of all Group Members and which sections of the write-up they worked on.
2. A map of the study location (use lines, arrows, etc., to show where you were in the field).
3. One short paragraph explaining the observations you made that led to your question. What things do you notice about the distribution of algae and animals that led you to your question?
4. What were the questions and hypotheses that your group decided to research?
5. One short paragraph and graph reviewing any abiotic (physical, like temperature or pH) measurements you took in your areas. This can include actual measurements (temperature, pH, salinity data), visual, weather, tide, historical data, etc. This can also include a simple graph of the data.
6. A graph of the organism data (either bar graphs or pie charts, depending on your data) that shows the results of your samples.

Use averages for your graphs by taking the averages of the replicates at your locations.

7. What was the answer to your question? Was the data you collected able to answer your group's question?
 8. All Group Members: What would be your next question based on what you learned? What challenges did you find? What would you do differently next time? All group members should contribute to this section.
-

Thumbnail image: “Rocky intertidal surveys” by [USFWS Pacific Southwest Region](#), [CC BY 2.0](#)

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13: ROV Lab 1- Practice and Mission planning

Research Proposal For Next Week in the Field

1. **Who is on your team? List the full names of all team members.**
2. **What questions do you want to ask (think of at least three)?**
3. **What are your hypotheses?**
4. **What data do you need to collect to answer your research questions?**
5. **How will you collect this data? Video recording, Live data collection in the field, and still images?**
6. **How many replicates? What sample size is needed?**
7. **How will you analyze your data?**

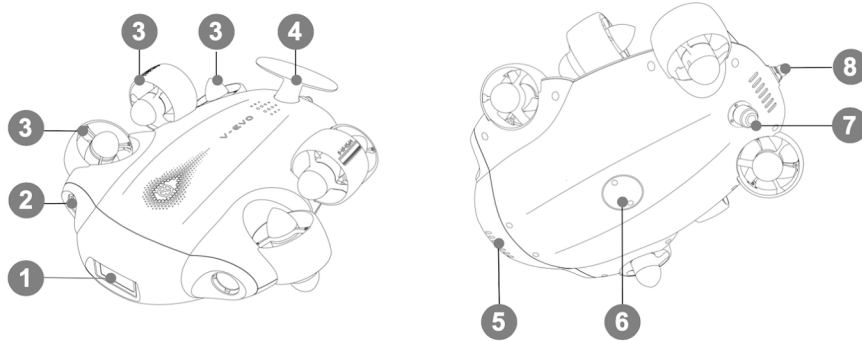
ROVs and Ocean Technology

This week we are practicing with our MPC MiniROVs, and you will develop a research proposal for next week's lab at the ocean. Remotely Operated Vehicles (ROVs) are an important part of ocean science and have been used for several decades for ocean exploration, especially in the deep sea, where safety and costs limit our ability to visit and explore. They are underwater drones that are connected to and controlled by the pilot. Unlike in air, wireless communication doesn't work well in water, so we need to have wires to bring back high-resolution video and other data.



Our ROVs have a 100m tether, and the control and video screen use a tablet or phone. Up to two screens can be connected at once to each ROV. The app needed to connect to the ROVs is for Apple or Android and is called "FIFISH" by Qysea.

ROV (Remotely Operated underwater Vehicle)



1. 4K Underwater Camera
2. 2,500 lumens LED × 2
3. Thrusters × 6
4. Rear Wing^{1,2}

5. Vent Holes
6. Mounting Port
7. Q-interface
8. ROV Tether Port

ROV Operation Team

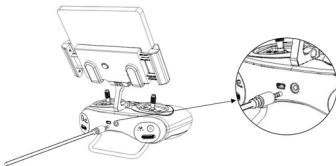
The safe operation of the ROVs will take many people working in a team with good communication. There will be a few different roles and responsibilities, and once we have things working smoothly, the roles can be switched so that everyone has a chance to try out all the jobs.

The roles are as follows:

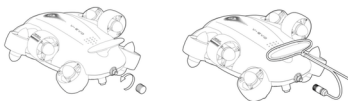
- **Pilot**- Controlling the ROV and listening to other team members
- **Navigator**- Keeping track of where your ROV is and avoiding obstacles.
- **Safety**- Watch all deck operations and confirm all people and equipment are safe. This requires looking at the dock area as well as the ocean for boats, etc.
- **Tether control**- Let out and reel in the tether to minimize the amount of free-floating tether.
- **Science Party**- Observe and document scientific findings and direct the pilot.

Setting up the ROV, Tether, and Controller

A. Plug the tether (3.5 mm head) into remote controller



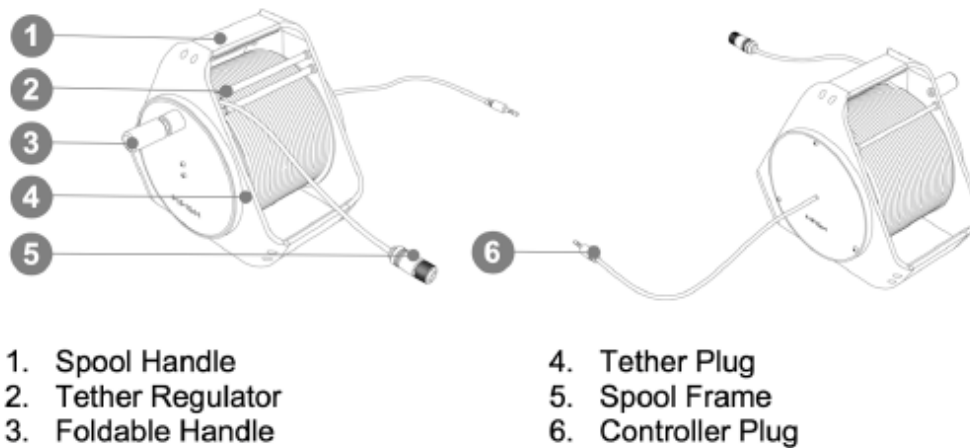
B. Take off the protect cap, tie the knot around the rear wing



C. Plug the tether (ROV end) into the ROV, the ROV will automatically turn on. The music will play 5 chimes: (Do, Re, Mi, Do, Mi)

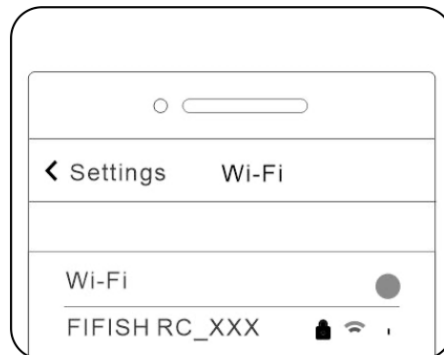


Spool and Tether



3. Software connection

- A. Connect with the RC's Wi-Fi**
 Find the Wi-Fi network name "FIFISHRC_xxxx"
 The password is "1234567890"



Make sure the **switch on the LEFT handle is on the "A" setting**. The switch on the right handle controls the lights.

IMPORTANT SAFETY NOTES:

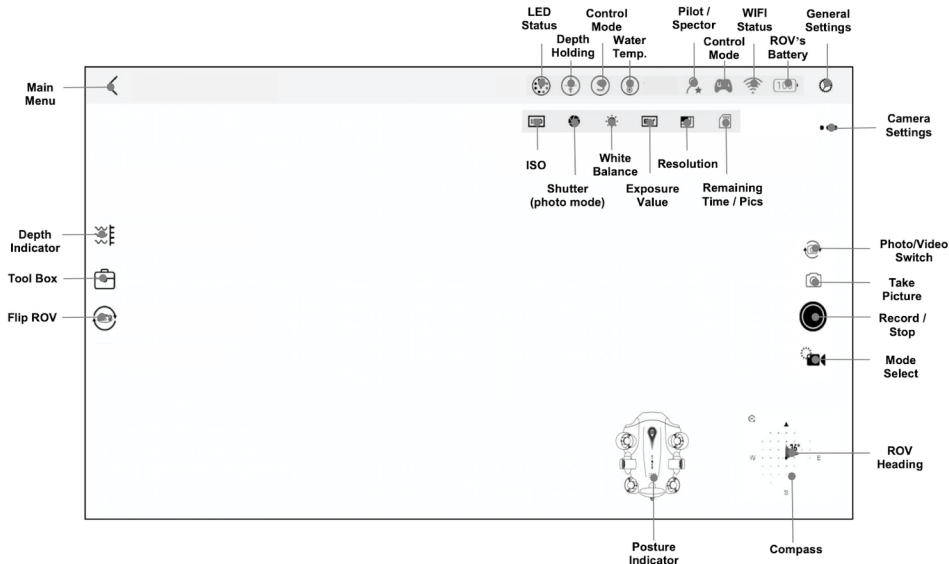
- All wire connections will be made by your instructor or the TA.
- The thrusters must remain **LOCKED** until in the water (button #2).
- The thrusters must be **LOCKED** before you remove the ROV from the water.

Tether Handling

A critical role is making sure that the tether unrolls and rerolls safely and properly. When bringing the tether back onto the spool, you need to maintain a little bit of tension on the wire so that there is no loose wire. Keep a little tension on the wire and slowly turn the handle to spool the wire back onto the reel without any loops, twists, or knots. The wire should be moved back and forth inside the two silver bars to keep an even wrap of wire on all parts of the spool. If any algae or other debris is on the wire, please remove it before wrapping it on the spool.

Control Screen

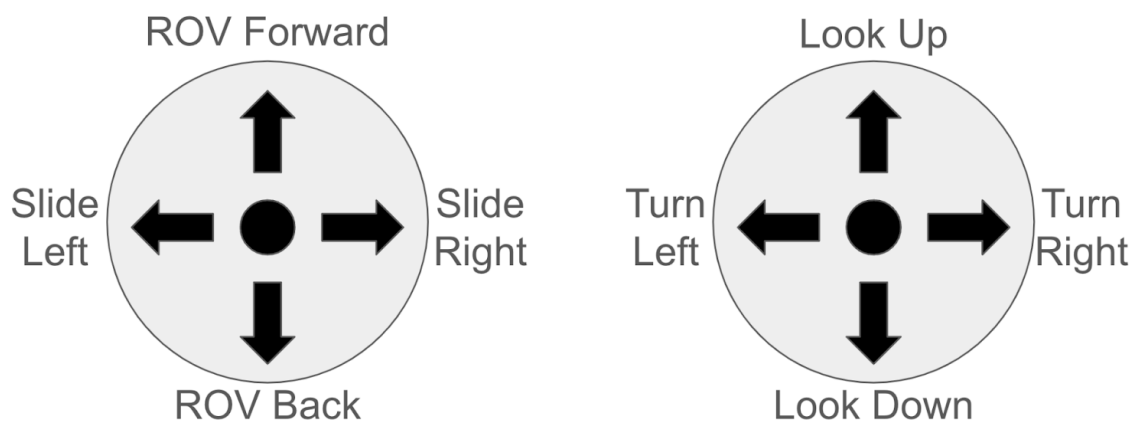
The controller's screen will look like this when you are connected to the ROV. It will show a lot of different information, as well as the live video from the ROV's camera.



To connect to the ROV

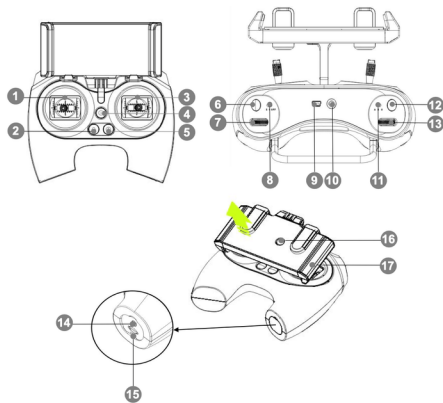
You will need to connect to the specific WiFi signal from the controller of the ROV you are using. Each ROV will have a different WiFi address, and you need to be sure you are connected to the right one! The WiFi address is on the bottom of the controller and will begin with **"FIFISHRC_63xx"** and will have two numbers or letters that are specific to your ROV. Select the correct WiFi from the list and use the password to connect. **The password is "1234567890"**

IMPORTANT! Your instructor or the TA will double-check all connections and settings before the ROV goes into the water. Do not put anything in the water without getting cleared.



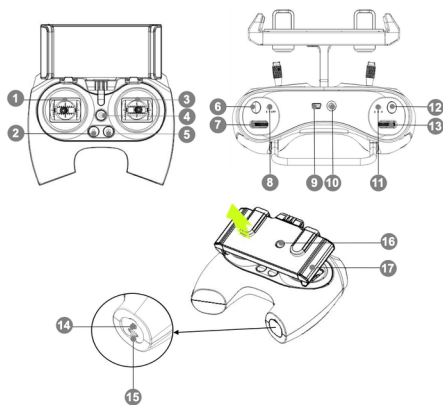
ROV Control Layout: The right controller turns the ROV in place, the Left controller moves the ROV

RC (Remote Controller)



- | | |
|-------------------------------|---|
| 1. Left Control Stick | 10. Tether Port (3.5 mm head port) |
| 2. Thrusters LOCK/UNLOCK | 11. Control Mode (Attitude / Sport / Combine) |
| 3. Right Control Stick | 12. Video Record/Stop |
| 4. ON/OFF | 13. Left Wheel |
| 5. Depth Holding (ON/OFF) | 14. Charging Port |
| 6. Take Picture | 15. Micro SD Slot |
| 7. Right Wheel | 16. Clamp Release Button |
| 8. LED Brightness (OFF, 1, 2) | 17. Clamp for Smart Device |
| 9. Ethernet port | |

RC (Remote Controller)



- | | |
|-------------------------------|---|
| 1. Left Control Stick | 10. Tether Port (3.5 mm head port) |
| 2. Thrusters LOCK/UNLOCK | 11. Control Mode (Attitude / Sport / Combine) |
| 3. Right Control Stick | 12. Video Record/Stop |
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| 6. Take Picture | 15. Micro SD Slot |
| 7. Right Wheel | 16. Clamp Release Button |
| 8. LED Brightness (OFF, 1, 2) | 17. Clamp for Smart Device |
| 9. Ethernet port | |

Moving up and Down: The wheel on the left of the controller will descend (move it right) and ascend (move it left).

Turning the ROV

The joystick on the right will tilt up and down, or rotate left or right. The joystick on the left will move the ROV forward or back, and slide the ROV to the left or right.

Research Proposal For Next Week in the Field

1. **Who is on your team? List the full names of all team members.**
2. **What questions do you want to ask (think of at least three)?**
3. **What are your hypotheses?**
4. **What data do you need to collect to answer your research questions?**
5. **How will you collect this data? Video recording, Live data collection in the field, and still images?**
6. **How many replicates? What sample size is needed?**
7. **How will you analyze your data?**

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14: ROV Lab 2- Ocean Operations

ROV Results

For the second part of the ROV Labs, you will do your best to pull some information out of the photos, videos, and other observations you made during your ocean dives.

Presentation

Create a brief **presentation** with Google Slides that outlines the following:

1. The names of all the team members in your group who participated in the day at the ocean.
2. Summary of the information from your proposals (questions, hypotheses, etc)
3. Mention any changes you needed to make to your plan on the day of the ocean dives.
4. Include images and/or videos that show us what your data collection looked like, as well as any other notable observations. Uploading your video to YouTube and then linking the video to Google Slides is usually the easiest way to do this.
5. Collect some numerical data from your images and video that helps to answer your question, and then try to graph it. This doesn't need to be complicated, but try to have some sort of visualization of the data (bar graph, pie graph, etc)
6. Using your data, reflect on your hypothesis and tell us if it was supported or not and why.
7. If you were to try this experiment again, what would you do differently next time, knowing what you know now?
8. Upload your slides on Canvas when finished (only one person from your group needs to do this).

Remember, use the images and video you collected to help tell your story!

15: MBARI and Marine Technology



President of MBARI

CONGRATULATIONS! You have just been given the job of CEO of [MBARI](http://www.mbari.org) for a few weeks! You have all the funds, personnel, and resources at your disposal for that period. Using what you learned during our tour and what you will read on their website (www.mbari.org), design a large-scale and difficult-to-answer question that can be solvable in the time frame of a few weeks, but utilizes the vast resources of MBARI well. Think big and grand...but make sure it is doable.

Turn in your proposal with the following information (One page, typed):

1. A statement of the question(s) being asked and the reason it is of such importance and interest (hey, even CEOs need to answer to the Board of Directors)
2. List the resources, both people and equipment, that you will need to do this work.
3. Explain the experimental methods you would utilize to answer your question and what it would take to make sense of the data you collect (just collecting data isn't enough, you need to figure out what it all means)

Write up the proposal like you were presenting the idea to the board of directors, and show that you have thought it through. You could easily spend a few million dollars in a few weeks, so you'd better make sure it is worth it!

Thumbnail image: "[MBARI - Ventana-Midwater-Recovery Vehicle](#)" by [kqedquest](#), [CC BY-NC 2.0](#)

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16: Peer-Reviewed Library Research

Library Research Assignment

As we have seen during our field trip, many interesting things are being studied at the lab, encompassing just about every area of marine science, both biological and physical. Scientists of course make their own discoveries and observations, but the major first step of science is **observation**, and becoming educated on what we already know about a subject is a major part of this step. Science “stands on the shoulders” of the scientists who came before us, so that we don’t reinvent the wheel and instead move science forward.

There are many different types of library resources out there that you can utilize for class projects, research, etc., but it is important to realize what you can and can’t get online. Many electronic journal holdings don’t go back more than 25 years, and you typically need to access the article from an institution that pays large sums of money to have total access to the material. Even if you can’t get to the full article, you can usually get the table of contents and often even the summary (or abstract) of the article.

[Google Scholar](#) is a good source for searching for reviewed, scholarly articles, but again, you won’t always be able to get the full text. It can, however, be a great (and free) way to search for things. One problem is that you don’t know what journals/sources Google is searching, so it is hard to know how complete the results will be. But in general, they are pretty good and worth a try. If you are savvy, you can restrict your search to PDF file type by including “filetype:pdf” in your search. At MPC, we have access to specialized search tools with many very good journals that offer full-text articles online.

How to find articles on the MPC Library Website

Go to the [MPC Library website](#)

1. Click on “[Databases](#).”

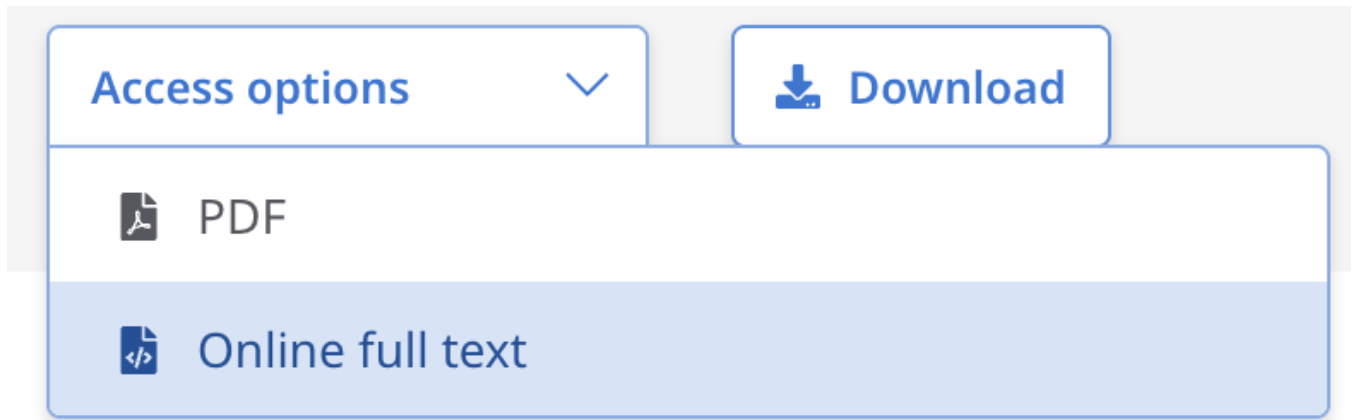
Limit your results (2)

☒ Full Text

☒ Peer Reviewed

☐ References Available

2. Next, select “[Academic Search Complete](#).”



3. You will then type in keywords to search for. These can be particular species, taxonomic groups, geographic areas, science terms, or any combination. When you start to type, suggestions will start to pop up that might help you refine your search.
4. Before you hit “Search”, go down the page and check the boxes for “Full Text” and “Peer Reviewed.” This will only bring back results from scientific publications that have been reviewed by other scientists.
5. Now go back up and click the “Search” button and try to find something interesting. When you select a paper, you should find a drop-down menu below the title that will let you read or download the article.

What if you find a great article, but MPC doesn't subscribe, and you can't get the full text? The library can often get a copy of the article or book for you through Inter-Library Loan (ILL). You can request almost anything from the reference librarian through ILL, and it will be here for you in around a week! It is a great service, but it might not be fast enough for this assignment. But it is a great resource!

Library Research Assignment:

You will choose a specific topic of interest that you learned about during the tour of the marine lab. This could be either biological or physical.

You will:

1. List your topic and summarize what you remember or know about it already.
2. Formulate one question that you would like to research to better understand your topic.
3. Find one article (or more) from academic, peer-reviewed journals that might help answer your question.
4. Provide the full citation for the article (see below for examples).
5. Find and read the full text of the article and write a one-paragraph summary of the main points of the article. Don't just copy parts of the abstract. Put things into your own words!
6. Personally reflect with one short paragraph on how hard or easy it was to understand what you read. Were you able to understand the main points and conclusions, even if you couldn't follow everything? Did the figures and graphs help? Was the abstract a good summary of the whole paper?

Citation Examples

Full citations need to include all the specific information about the publication and article, in a particular order. Below is an example, and others can be found with the web link.

The basic format and information needed are:

Author; Year; Title; Journal; Issue/Number; Pages, DOI web address.

For example, here is one of mine (if you click on the PDF link, you can read it):

Raskoff, K.A. (2010) *Bathychorus bouilloni*: a new genus and species of deep-sea jellyfish from the Arctic Ocean (Hydrozoa, Narcomedusae, Aeginidae). Zootaxa, 2361: 57–67. <https://doi.org/10.11646/zootaxa.2361.1.5>



Kevin Raskoff, Public domain, via Wikimedia Commons.

[Other citation examples found here](#)

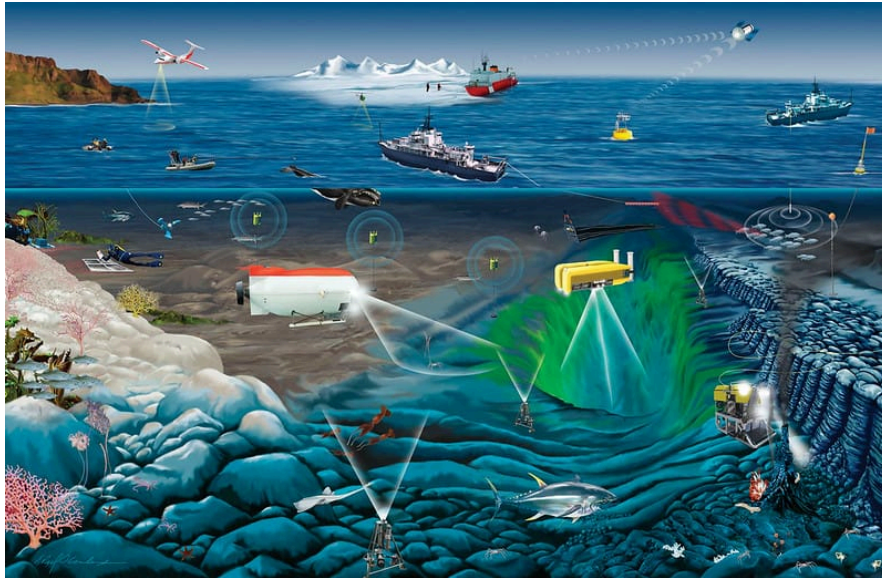
Bathykoros bouilloni from the Arctic Ocean.

Thumbnail image: “[Moss Landing Marine Laboratories and Power Plant](#)” by [Steve Ryan](#), CC BY-SA 2.0

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17: Ocean Databases

Ocean Databases and Marine Data Research



Ocean science is extremely broad and literally covers the whole Earth. The amount of information and data science that has been collected over the centuries is overwhelming and often spread out and isolated in various labs, notebooks, and computers. How do we access all this data? Online biological databases to the rescue! They bring amazing amounts of information easily available to anyone with a computer. Many groups of marine animals have their own database, which are added to by scientists around the globe. FishBase was one of the first, but now there are many more, such as:

[World Register of Marine Species \(WoRMS\)](#)

[Encyclopedia of Life \(EOL\)](#)

The [World Ocean Database \(WOD\)](#)

NASA's [Earthdata Ocean](#)

and many more...including some databases which will tie into all the others, for example:

The [Ocean Biogeographic Information System \(OBIS\)](#) has over 161 million records of marine life.

Your job will be to explore, have fun, and learn not only about a few species of animals, but about biological databases too.

For this lab, you will research **3 species of fishes**. You'll use [FishBase](#) to find out some reliable and scientifically correct information on their lifestyle, habits, etc. Then you'll use [OBIS](#) to search out where these species are found in the world (or at least what has been put into the database so far).

1. Go to **Fishbase** and look up the information available for three different fishes. If it is very rare, there might not be a lot put into the database yet, so try to use more common species. If you can't think of any species to look up, you can try looking up some of the common species of fish on the Monterey Bay Aquarium's website, or even use the Seafood Watch list (<http://www.mbayaq.org/cr/seafoodwatch.asp>).
2. Now, go to **Ocean Biogeographic Information System** (www.iobis.org) and look up the same three species using their scientific names and find out where they have been reported worldwide. Sometimes you will need to close the search box to see the map behind it. Realize that this will only give you info from studies that have been put into the database so far, most

are still not there since it is a big job!

3. Once you have found and read about your three species, you will need to summarize, in your own words, the most interesting facts about each that you read, such as:
 1. In what habitat is it found?
 2. At what depths does it live?
 3. What does it eat?
 4. What are its main predators?
 5. What are two interesting adaptations that allow it to be so successful?
 6. Are there any ways in which humans are harming their population?
 7. Include at least two images of each fish (drawings or photographs).

You can present this as a document or a short slideshow.

Due at the beginning of the next lab.

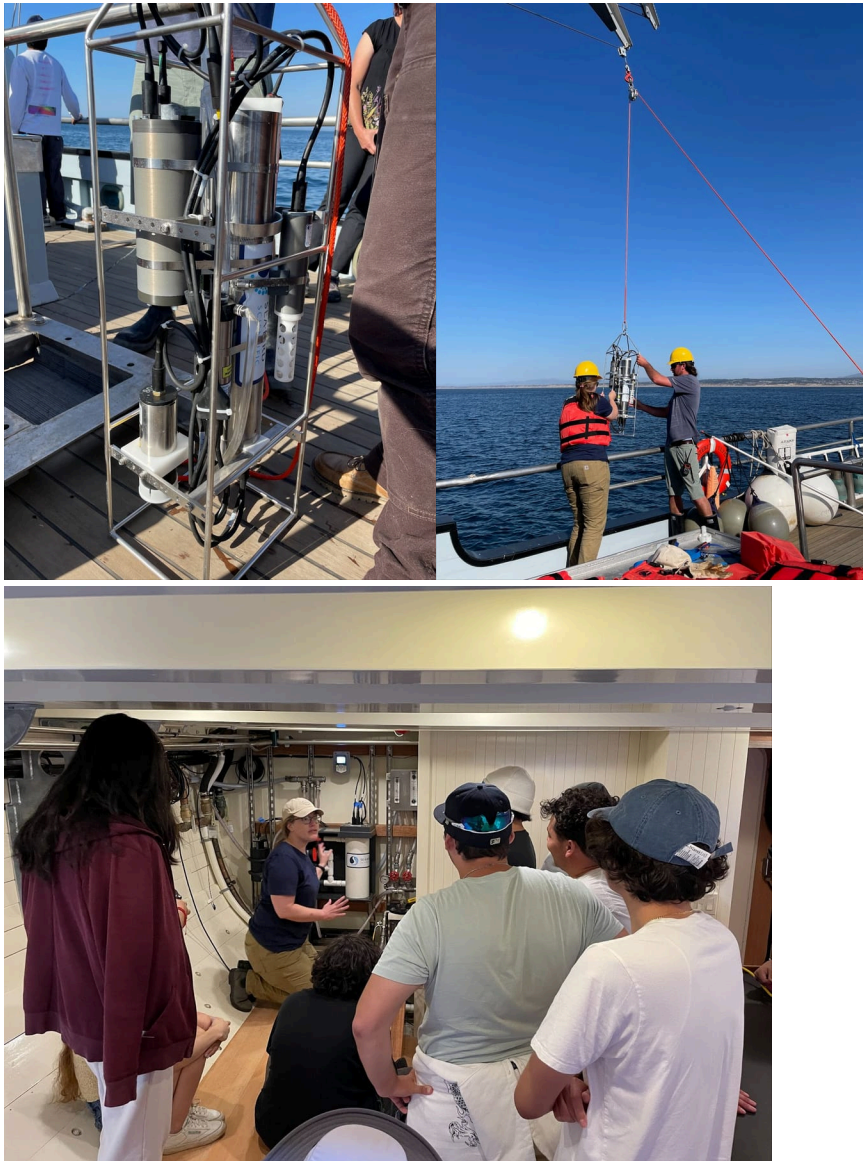
Lab thumbnail image: “[Collecting Multibeam Sonar Data](#)” by NOAA's National Ocean Service, CC BY 2.0

Image at top of page: “[OAWRSfinal1](#)” by Census of Marine Life E&O, CC BY-NC-SA 2.0

18: The Western Flyer

Western Flyer Ocean Data Lab

On our Western Flyer trip, one of the things we got to do was investigate the water chemistry and properties. We did this with two devices: a CTD (Conductivity, Temperature, and Depth) sensor and the flow-through water system down in the lab that measures the seawater flowing into and out of the boat as we sail. The CTD measures the water from the surface to the bottom in one spot as we drop it down, while the flow-through system shows what the water is like at the surface all along the path the boat sails.

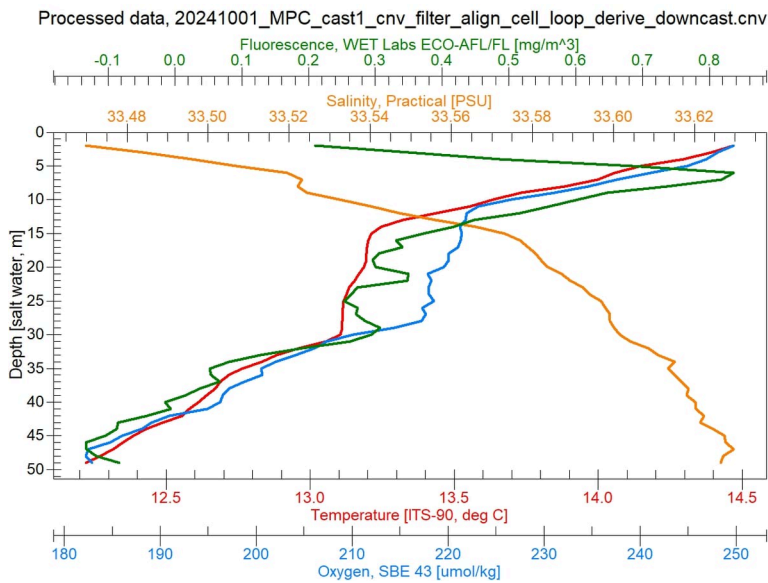


CTD on deck before deployment. CTD going over the side of the boat. Staff showing us the flow-through water system in the lab. All photos by Kevin Raskoff.

The results of both of these sensors were really interesting and can tell us a lot about what is going on in the ocean and its biology. The graph below shows the CTD data. It is a complicated graph but not scary once you understand it. The Y-axis, on the left side, is depth, from the surface (0) down to the bottom (50 meters). The graph has four different things shown on top of each other: fluorescence (green), salinity (orange), temperature (red), and Oxygen (blue). Notice how things change as we drop from the

surface down to the bottom. Fluorescence is a measure of chlorophyll, so it is a measure of the amount of phytoplankton in the water.

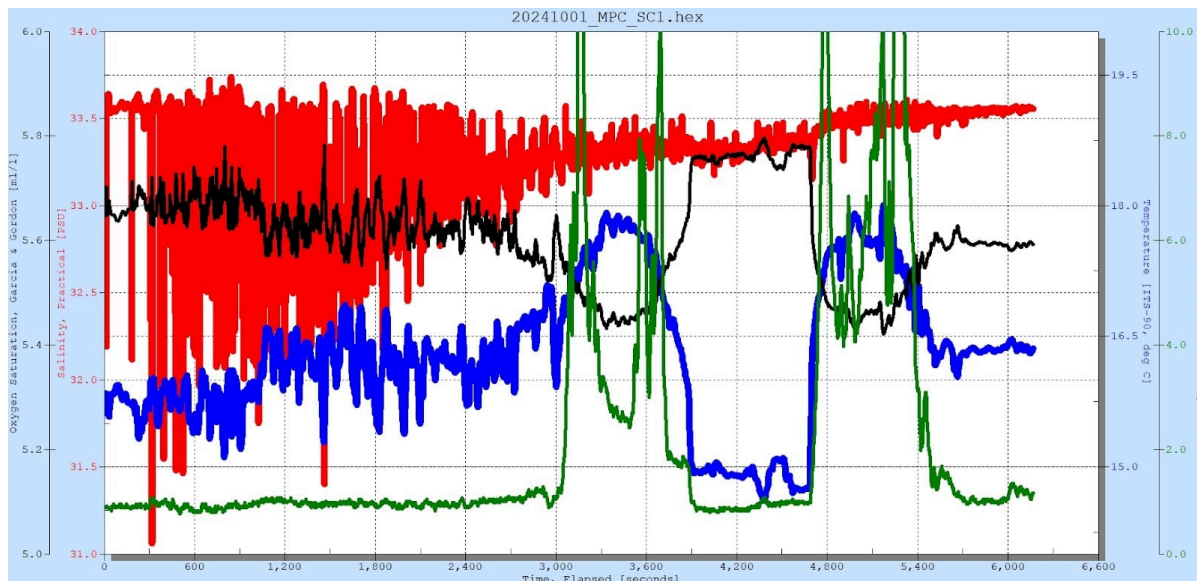
CTD Data



Flow-Through Data

The flow-through data is below. It is running in time from left to right. On the far left is when we were still on the dock, and then it shows us going out to sea and returning as we move to the right. The colors of the data are different than the CTD graph: salinity (red), oxygen (black), temperature (blue), and fluorescence (green). Note how the data changes as we leave the dock (on the left side), start moving out to sea (middle), and then turn around and head back (far right). Look at the green lines and see how we hit a bunch of phytoplankton on the way out and then hit it again on the way back in. Pretty cool!

Flow-Through Seawater Data



Assignment:

1. You will analyze both the CTD and Flow-Through graphs and try to find a few interesting features of the slice of the ocean they each sampled.
2. On each, look for data that are connected to each other in some way, either they both go up or down at the same time, or they are opposite (inverse) of each other.
3. Why do you think they are showing that pattern? What is the connection between these data?
4. Looking at the fluorescence data on both the CTD and Flow-Through graphs, what interesting things do you notice about where the phytoplankton are found? Is it found randomly from the surface down to the bottom (CTD), or consistently along the path the boat sailed (Flow-through)? Why do you think the phytoplankton was found where it was?
5. What is one question that the data makes you wonder about and how could we answer it if we had another day on the boat?

Put your answers in a document and turn it in on Canvas.

19: Online Environmental Research Presentation

Potential Research Project Topics

Some potential topics...you are encouraged to choose things not on this list, but clear them with Dr. R.

Biological Effects of Desalination	Overfishing and Seafood Watch
Ocean acidification	Harmful algal blooms
Marine toxins	Effects of pesticides and fertilizers
Carbon Dioxide Sequestration effects on biology	Overexploitation of marine resources
Biological effects of Oil exploration	Exotic Species
Marine Aquaculture	<u>Your own Marine Environmental topic is always BEST!!!</u>
The effects of ocean garbage patches	

Presentation Format about 8 minutes (~8-12 slides)

- Statement of the issue
- Introduction (background research)
- Point/Counterpoint (if appropriate for topic)
- Solutions to the issue
- Conclusions (your opinion)
- References (at least 5)

The simplest way to organize your in-class presentation is to use Google Slides

Presentation will be loaded onto the Canvas class website by 1 hour BEFORE the presentation day. No exceptions.

We are going to use Google Docs at: <https://drive.google.com/>

1. Log in to your Google Drive (create one if you don't have a Gmail or Google account).
2. Click "Create Presentation" (or "New Slides" in another version).
3. Make your presentation (and share it with your partner so they can also edit the file. Put in their email and make sure you select "Can edit."
4. When you are ready to post it (and you can still make changes), then go up and click on the button. You will then need to change the settings so anyone with a link can view the document. Under "Share" set "Who has access", select "Change." Or in the other version, go to "Share, Get shareable link."

5. The next box will pop up and let you change who can see your file. **Select “Anyone with the link.”** Under “Access:” make sure it is set to “Can view.”

6. Finally, hit Save, and then you can copy the link and then post it on the Presentation Forum on the class website, and anyone will be able to look at it.

For more information, check out the video I made on the class website.

Thumbnail image: “[Marine litter. The everpresent crunched waterbottle.](#)” by [Bo Eide](#), [CC BY-NC 2.0](#)

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20: Organism Presentations

Organism Presentations

Organism Presentations

Coming up in the lab, you will be giving a short 5-minute presentation on a marine creature of your choice. This week, you can start to choose your topic and sign up on the Google Doc **[Presentation Sign-up sheet found on Canvas](#)**. Once a topic is taken, it is off-limits for others, so sign up early so you can reserve the topic. You are able to change your topic up until the presentation is due. The species should be at least occasionally found in Monterey Bay.

Your presentation will be made up of slides with images and text that help us all understand your topic. Please use Google Slides

What should be in your presentation?

Grading Rubric:

Your score will be based on the following criteria, so make sure you address each of these in your presentation.

1. Taxonomy (from Kingdom down to *species*)
2. Habitat (Where is it found, both in terms of geography and habitat)
3. Ecology (relationships with other things)
4. Prey and predators (who is eating whom?)
5. Reproduction and life cycle (how do they reproduce and mature into an adult)
6. Behavior (what does it do, how does it respond to the environment)
7. Human interactions or threats (what does it do to us, and what do we do to it)
8. Other interesting facts...
9. Bibliography of all of your sources on the last slide using proper citation formatting, including a full web address (minimum 5 sources).
10. Good use of images and video. Make sure your text is not too small and that the presentation uses many images.

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21: Marine Habitats Table

Marine Habitats Table

Describe **two** typical groups of living things (specific types of organisms) and **two** of the main physical (non-living) characteristics that **define** the major habitats below.

Focus on what is unique and different between the habits. Items can only be used once in a single box.

	Biological Groups	Physical Factors
Intertidal		
Meiofaunal		
Estuary		
Shallow Subtidal		
Tropics		
Epipelagic		
Mesopelagic		
Deep-sea		

Lab thumbnail image: Amy Apprill, CC BY-SA 4.0 <<https://creativecommons.org/licenses/by-sa/4.0>>, via Wikimedia Commons

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