Underwater Exploration Lab Manual Spring 2021

Chaunacops coloratus

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Lab 1: Introduction, Library Research Day

Structure of lab: syllabus overview; oceanic exploration lecture; introduction of NOAA, MBARI, and CVision partners via zoom; explanation of online library resources with demonstration; explanation of scuba requirements, if necessary.
Estimated length of lab: approx. 2 hrs
Materials: CAPSTONE paper; Dive 10 summary

Why is the ocean important?
When people hear the word "ocean", they typically imagine going on cruises in the Caribbean, surfing along the California coast, or watching the sun set over Hawaiian waters. However, these recreational activities are not all that the ocean has to offer; in fact, it plays an essential role in maintaining life on earth. The ocean produces more than 50% of the world's oxygen through the phytoplankton, microalgae that contain chlorophyll and undergo photosynthesis, that live in its upper regions. Phytoplankton are also a source of food for fish, shrimp, jellyfish, and other marine animals, which form a significant portion of the world's food supply. Additionally, the ocean serves to regulate the climate in two ways: first, it works as a carbon sink, dissolving more carbon dioxide into its waters than it releases to the atmosphere; and second, the movement of ocean currents forms a "global conveyor belt" by which heat is distributed across the planet. Resources from the ocean are used for food, medicine, and technological products, and more than half of U.S. trade relies on marine transportation.

Sources used:
- NOAA. Why should we care about the ocean? National Ocean Service website, https://oceanservice.noaa.gov/facts/why-care-about-ocean.html#:~:text=The%20air%20we%20breathe%3A%20The,our%20climate%20and%20weather%20patterns, 2/26/21.
- NOAA. What are phytoplankton? National Ocean Service website, https://oceanservice.noaa.gov/facts/phyto.html, 2/26/21.
- NOAA. The Global Conveyor Belt. National Ocean Service website, https://oceanservice.noaa.gov/education/tutorial_currents/05conveyor2.html,

How do we explore the ocean?

Though the ocean covers ~70% of the world's surface, both the Moon and Mars have been mapped and studied in greater detail than the ocean floor. This is largely due to the difficulties involved in reaching and observing the ocean. After all, humans can typically only hold their breath underwater for about 30 seconds—a limitation that doesn't leave much time for exploring! An additional challenge is posed by the rapid increase in pressure that one faces as they descend into the ocean's depths. The first technologies that attempted to overcome these barriers started to be developed in the 1800s. In 1867, dredging operations were conducted off of the coast of Florida. This technique consisted of a ship dragging a net behind it along the ocean floor to collect specimens, and it gave researchers some significant information about ocean ecosystems. However, there were some limitations: animals that were motile could easily swim or crawl out of the nets, and were thus not accounted for in these sampling operations, and small animals were not retained by them.

The creation of submersibles was the next step in oceanic exploration. In 1960, the Bathyscaphe *Trieste* was used to carry scientists to the depths of the Mariana Trench. The human operated vehicle (HOV) *Alvin* was then launched in 1964. Both of these submersible vehicles required human operators within them to control movements and make observations; *Alvin*, which remains in use to this day, can hold two scientists and has manipulator arms for collecting samples from the ocean floor.

Remotely operated vehicles (ROVs) were first used in the mid-1900s and became significantly more common in the early 2000s. This mode of exploration allows scientists to pilot the submersible vehicle from the safety of a surface vessel, while viewing the video footage transmitted by the ROV from the ocean floor. ROVs can also have a variety of sensors, manipulator arms, and sample collection boxes to allow for the collection of additional data.

Methods of ocean exploration that allow scientists to observe the ocean without the aid of a vehicle include snorkeling, free-diving, and SCUBA diving. Though those who snorkel and free-dive are unable to dive further than they can travel on a single breath, SCUBA divers avoid this constraint by the use of the Self-Contained Underwater Breathing Apparatus (SCUBA) that they carry. The first modern version of this was the fully automatic Aqua-Lung, which was first developed by Jacques Costeau and Emile Gagnan in 1943. SCUBA technology significantly improved the depths which scientists could reach and the duration of their dives. However, they are still limited to approximately 130 ft of travel on regular air and 250 ft with technical diving and rebreathers.

Sources used:

- NOAA. History of NOAA Ocean Exploration Timeline: The Breakthrough Years (1866-1922). National Ocean Service website, https://oceanexplorer.noaa.gov/history/timeline/welcome.html?page=2, accessed 6/1/21.
- NOAA. History of NOAA Ocean Exploration Timeline: The Age of Electronics II (1946-1970). National Ocean Service website, https://oceanexplorer.noaa.gov/history/timeline/welcome.html?page=4, accessed 6/1/21.
- NOAA. Human Occupied Vehicle Alvin. National Ocean Service website, https://oceanexplorer.noaa.gov/history/timeline/welcome.html?page=4, accessed 6/1/21.
- NOAA. What is an ROV? National Ocean Service website, https://oceanexplorer.noaa.gov/facts/rov.html#:~:text=Remotely%20operated%20vehicles%2C%20or%20ROVs,would%20play%20a%20video%20game, accessed 6/1/21.
- Britannica, T. Editors of Encyclopaedia. "Underwater diving." Encyclopedia Britannica, https://www.britannica.com/topic/underwater-diving, September 20, 2017.

NOAA, CAPSTONE, and MBARI

The National Oceanic and Atmospheric Administration (NOAA) is an agency of the United States Department of Commerce with the mission to "understand and predict changes in climate, weather, oceans, and coasts, to share that knowledge and information with others, and to conserve and manage coastal and marine ecosystems and resources." The NOAA Office of Ocean Exploration and Research (OER) is specifically dedicated to "innovating, incubating, and integrating research" by engaging in and funding a variety of research expeditions, and the deep-sea video footage we will be working with in this course was collected during one of these. NOAA's CAPSTONE (Campaign to Address Pacific Science Technology and Ocean NEeds) mission was intended to increase our understanding of deepwater areas in the Pacific Ocean. It resulted in the recording of 891.5 hours of ROV video during 187 dives. The footage was collected using the NOAA Ship *Okeanos Explorer*, the only federal vessel with the sole purpose of advancing scientific knowledge of the ocean, in conjunction with the ROVs Deep Discoverer and Seirios.
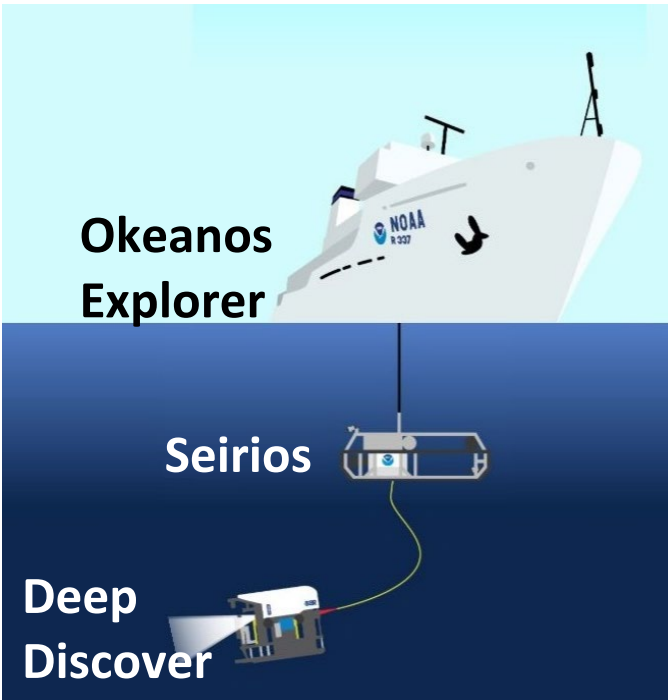
The ROVs were suspended in the water column beneath the *Okeanos Explorer*. Seirios was connected to the vessel by a five mile long steel cable while Deep Discoverer was connected to Seirios by a 30 meter long tether. Deep Discoverer directly filmed the ocean floor, and was equipped with lights, video cameras, two manipulator arms, and six collection boxes. Seirios shed light on the ocean floor, absorbed heave from the Okeanos Explorer, and possessed sensors for collecting environmental data and cameras which the pilots utilized for navigation.

Figure 1. Setup of *Okeanos Explorer* and ROVs; image courtesy of NOAA's office of Ocean Exploration and Research

We will be focusing on a series of dives conducted in the Musician's Seamounts. This series of 25 underwater mountains, each of which are named after a famous composer, sits northwest of the main Hawaiian Islands. Their location means that they "may serve as refuge for transient fish populations that Hawaii relies upon, provide additional habitat, and serve as a pool of genetic diversity for deep sea coral populations known from the deep waters around the Hawaiian Islands"; as a result, they were an important target for mapping and the collection of ROV video.

Other institutions, like the nonprofit Monterey Bay Aquarium Research Institute (MBARI), also work with ROV technology to explore the ocean and collect underwater footage. MBARI was created to "achieve and maintain a position as a world center for advanced research and education in ocean science and technology, and to do so through the development of better instruments, systems, and methods for scientific research in the deep waters of the ocean" and to emphasize "the peer relationship between engineers and scientists." The organization has three research ships and two ROVs, and it is located in Moss Landing, California, with close access to Monterey Bay.

Sources used

- Kennedy, B.R.C., Cantwell, K., Malik, M., Kelley, C., Potter, J., Elliot, K., et al. 2019. The Unknown and the Unexplored: Insights Into the Pacific Deep-Sea Following NOAA CAPSTONE Expeditions. J. Frontiers in Marine Science, doi: 10.3389/fmars.2019.00480.
- NOAA. About NOAA Ship Okeanos Explorer. National Ocean Service website, https://oceanexplorer.noaa.gov/okeanos/about.html, accessed 6/1/21.
- NOAA. What's in a Name? A Brief History of the Musicians Seamounts. National Ocean Service website, https://oceanexplorer.noaa.gov/okeanos/explorations/ex1708/background/history/welcome.html, accessed 6/7/21.
- MBARI. About MBARI. Monterey Bay Aquarium Research Institute website, https://www.mbari.org/about-mbari, accessed 6/1/21.

CVision and Tator

CVision AI is a software development company that "develops innovative video analytics products" to "turn imagery into insights." Their tools harness the power of computer vision and artificial intelligence to store and analyze images and video footage, and one of these tools is Tator—short for "annotator." Tator is a collaborative video annotation tool created to perform three functions: media streaming, media annotation and analysis, and algorithm inference.

The footage of the ocean floor that NOAA, MBARI, and other agencies have collected is not quantitative data. That is, if a scientist wanted to know how many starfish were found in the Pacific Ocean during the CAPSTONE expeditions, he would need to watch the thousands of hours of collected video and count them himself. In some instances, the storage of footage on hard drives in agency offices adds additional challenges to using the vast quantity of video that is yielded by even one expedition. Fortunately, Tator will be able to streamline this process. By using the data provided by man-made annotations and localizations (tags placed in video footage to show the software where and what organisms are, often taking the form of bounding boxes drawn around organisms), the algorithms that are integrated into Tator are trained to recognize and count organisms for researchers. Tator could make underwater footage more accessible and usable for researchers in the future.

Library Resource Guide (edit with relevant information for your institution)
1. Navigate to the Cowan-Blakley Memorial Library website.
2. Click the "Subject Guides" button. Click on the dropdown menu and select "Biology Library Research Guide." Hit "Go."
3. Once on the page for the Biology Library Research Guide, select "Find Articles and Books" and scroll down to the "Best Bets for Biology Databases" section.
4. Click the link for any database to navigate to it.

a. Suggested starting places:
   i. [Biological Science Collection](#)
   ii. [Science and Technology Collection](#)
   iii. [Science Direct](#)

b. Signing in:
   i. Username: the first section of your UD email address.
      1. Example email: name@udallas.edu
      2. Example username: name
   ii. Password: your UD ID number.

5. Use the search field at the top of the page to enter your desired terms. Start with a broad search and, after seeing the number of results, narrow it by changing the keywords you are searching or restricting the dates and types of documents you are accepting in your results.

   a. If you wish to search for multiple terms or you want to exclude results that include a term, you can use Boolean operators.
      i. Using AND between the terms yields the set containing both.
      ii. Using OR yields the set with one or both.
      iii. Using NOT yields the set that excludes the second term.

6. Once you have found one or more sources that you want to use, return to the [Biology Library Research Guide](#) page. Select "Cite Sources," scroll down, and click "RefWorks." Create an account or sign in.

7. Return to the database webpage for your source and click the "Cite" button. Select "Save to Refworks" and confirm the export of the citation.

8. After adding citations to Refworks, you can organize them into folders, tag them with your choice of keywords, and export them individually or as a set in the citation style of your choice.

9. If you need assistance during the research process, you can contact library staff via [text, call, email, or the live chat function on the website](#). You can also create an in-person appointment so they can walk you through any step of it.

Assignment

1. Read the Frontiers paper for background on NOAA's CAPSTONE campaign. https://www.frontiersin.org/articles/10.3389/fmars.2019.00480/full

2. Read the Dive 10 Summary for information on the organisms and geography that we will observe. https://www.ncei.noaa.gov/waf/okeanos-rov-cruises/ex1708/ (may need to be changed for your class)

3. Use the library resources that you learned about in lab to look up at least one article that discusses the biodiversity of the deep sea.

4. Write one page (~500 words) that summarizes the article you found and addresses the question: "What do you think the ocean floor looks like, two miles beneath the surface?"

Lab 2: Introduction to Taxonomy

Sources used:
- Khaled bin Sultan Living Oceans Foundation's Coral Reef Ecology Curriculum.

Structure of lab: taxonomy lecture (use powerpoint), introduction of activity 1 (taxonomy spreadsheet) (because a number of students made mistakes when giving the taxonomy of organisms down to levels above genus or species, it would probably be best for the instructor to walk through the process for a single image), introduction of activity 2 (localizing organisms in video clips, worksheet)
Estimated length of lab: lecture + activity 1, approx. 1 hr; activity 2, approx. 1 hr
Materials: powerpoint, list of assigned images for activity 1 (edit with relevant information for your class), activity 1 spreadsheet, activity 1 spreadsheet key, activity 2 worksheet, activity 2 worksheet key

What is taxonomy?
The countless living organisms on Earth are divided into categories based on their evolutionary ancestry, common characteristics, and shared genetics. The science of classifying organisms in this manner is called taxonomy, and the first modern system used to do so was developed by Carl Linnaeus. His system, which was published in the work _Systema Naturae_ in 1758, contained eight levels of division that could be used to categorize any organism. These levels of division begin with the broadest category (Domain) and end with the narrowest (species).

Domain	Broadest division, contains the greatest number of organisms
Kingdom	
Phylum	
Class	
Order	
Family	
Genus	
Species	Narrowest division, contains the smallest number of organisms

At the domain level, there are three categories into which organisms can be divided: Eukarya, Archaebacteria, and Eubacteria. The six kingdoms are Archaebacteria (in the domain Archaebacteria), Eubacteria (in the domain Eubacteria), Plantae, Animalia, Protista, and Fungi. Most of the organisms observed in NOAA video footage are in the Domain Eukarya and the kingdom Animalia, and they have fallen into approximately ten phyla thus far: Porifera, Cnidaria, Echinodermata, Arthropoda, Chordata, Annelida, Mollusca, Ctenophora, and Bryozoa. Starting with the class division, there are over

twenty different categories, with each becoming more and more specific until a single species designation is left. Below are two organisms with their scientific classifications.

Groundhog

Figure 1. University of Dallas Groundhog; image courtesy of UD Marketing & Communications

Domain: Eukarya
Kingdom: Animalia
Phylum: Chordata
Class: Mammalia
Order: Rodentia
Family: Sciuridae
Genus: *Marmota*
Species: *Marmota monax*

Anglerfish

Figure 2. *Chaunacops coloratus*

Domain: Eukarya
Kingdom: Animalia
Phylum: Chordata
Class: Actinopterygii
Order: Lophiiformes
Family: Chaunacidae
Genus: *Chaunacops*
Species: *Chaunacops coloratus*

These two organisms are of the same domain, kingdom, and phylum. They start to differ taxonomically at the class level. Animals that share a greater number of categories are more closely related evolutionarily.

Naming System
Organisms are named using binomial nomenclature, a two-part naming system with a genus name and species epithet. There are several rules that must be followed when giving the scientific name of an organism.
1. The genus name is written first. Example: chaunacops.
2. The species epithet is written second. Example: chaunacops coloratus.
3. The genus name is capitalized, while the species name is not. Example: Chaunacops coloratus.
4. The genus and species names are both italicized. Example: *Chaunacops coloratus.*

5. If the scientific name is used multiple times in a document, the entire name must be used first. Subsequently, the genus name may be shortened to the first letter and a period. Example: *Chaunacops coloratus* (first mention); *C. coloratus* (subsequent mentions).

In some cases, when identifying organisms from video footage, the organism cannot be identified all the way to the species level. The organisms might be classified by the class, order, family, or genus instead. However, because the use of a genus name by itself refers to all species included within that genus, the genus name is followed by "sp."—an abbreviation for species—to designate an animal that was able to be identified to the genus level, but not to the species. Similarly, "cf." and "nr." can be used between the genus and species names to demonstrate a degree of uncertainty with regards to the species name.

Activity 1
Use the WORMS (http://www.marinespecies.org/index.php) and MBARI (http://dsg.mbari.org/dsg/home) databases to make a google sheets document with the major taxonomic classifications (kingdom, phylum, class, order, family, genus, species) for each assigned animal.

1. Obtain the list of assigned groups of two from NOAA Expedition 1708 Dive 10.
2. Open the "Taxonomy Lab Images" Google Drive Folder. Observe the select images of the assigned individuals.
3. Open the WORMS (http://www.marinespecies.org/index.php) or MBARI (http://dsg.mbari.org/dsg/home) search platforms. Type the scientific name into the search bar. Select the entry for the individual and observe the taxonomic classification.
   a. Delete the "sp.", "cf.", or "nr." from the Scientific Name before searching the individual if present.
   b. When entering the scientific name in WORMS, the given name may be followed by a last name and year, indicating the scientist who initially described the animal.
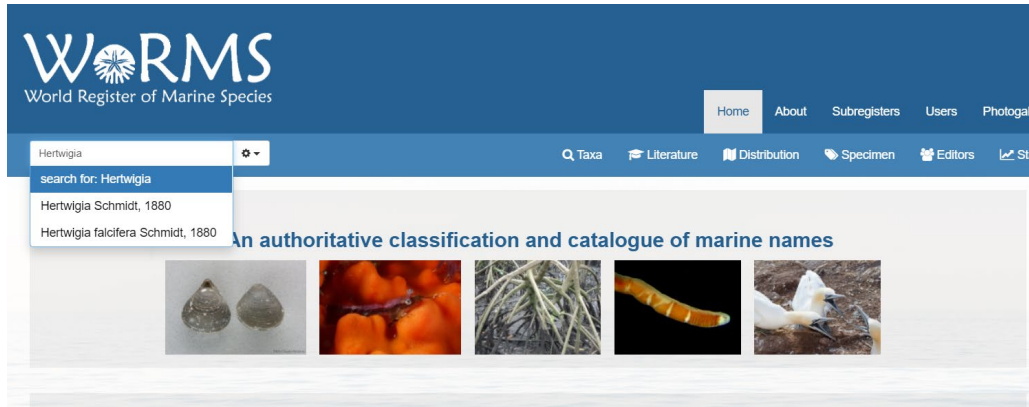
Figure 3. WORMS taxonomy website

4. Make a copy of the Google Sheets "Taxonomic Key Template." Within each row, fill in the taxonomy for the individual, using only the taxonomic classifications in the template. For instance, in the entry for *Coryphaenoides longicirrhus*, only enter the kingdom, phylum, class, order, family, subfamily, genus, and species.
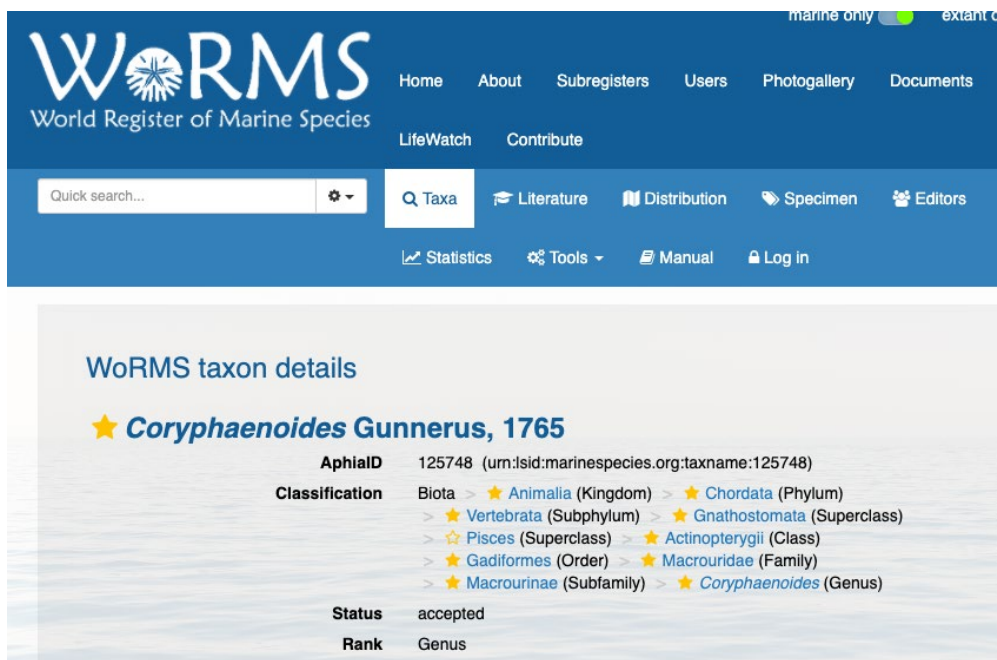

Figure 4. Detail of taxonomy from WORMS website.

Figure 5. Detail of taxonomy from MBARI Deep-Sea Guide.

5. Only list the taxonomy to the rank denoted in the image title. If an individual is not classified out to the species level, put two hyphens (--) in the data entry box for each box within the row beyond the given classification.
6. Continue to fill out the template for each assigned individual.

Activity 2
Watch the four provided video clips from tator, using the Animal ID guides to identify the animals listed on the provided worksheet (also linked here) (worksheet key) and recording the time at which they are seen. Then, write a description of each animal as you observed it in the video; because this activity is intended to teach you to identify animals, you should focus on those characteristics that allowed you to recognize each of them. Turn in your worksheet through Brightspace before the start of next week's lab.

1. Tator Clips
   a. Animal Diversity Lab Video 1
   b. Animal Diversity Lab Video 2
   c. Animal Diversity Lab Video 3
   d. Animal Diversity Lab Video 4
2. Research links
   a. NOAA's Benthic Deepwater Animal Identification Guide V3: can search by phylum and class/family; shows images of organisms
   b. MBARI's Deep-Sea Guide: can search by name.

      c. HURL's <u>Animal Guide</u>: can search by name or by phylum.
      d. Project MINUET's <u>Animal ID Guide</u>: can search by any classification level; shows images of organisms.
      e. <u>WoRMS</u> (World Register of Marine Species): can search by any classification level.

3. For more guidance in identifying and distinguishing between organisms, reference <u>this guide</u>.

Assignment

Submit the completed spreadsheet and worksheet on Brightspace along with a 350-500 word summary of what you learned in this lab.

Lab 3: Animal Diversity

Sources used:
- The [Online Biology Book](#) by Estrella Mountain Community College.

Lab structure: animal diversity lecture (play videos linked in manual), introduction to activity (dissections and observations worksheet)
Animals used: boring sponge (Cliona celata), loggerhead sponge (Spheciospongia vesparium); rock anemone (Aiptasia pallida), various corals in classroom aquariums; turbo snails (Astria); preserved earthworms; dwarf hermit crab (Pagurus longicarpus); short spined sea urchin (Lytechinus variegatus); various fish in classroom aquariums
Estimated length of lab: approx 3 hrs
Materials used: [dissection and observation worksheet](#)

Introduction

Animals are multicellular organisms in the kingdom Animalia. They are composed of cells that lack cell walls and, being heterotrophs, they obtain energy and nutrients by consuming other organisms. They are motile during at least one stage of their life cycle. They may also have skeletons for support, skin to prevent water loss, muscles for movement, brains and nervous systems for responding to stimuli in complex ways, and digestive systems; these characteristics are all present in the most complex animals, but are absent or limited in more simple ones.

The predominant animal body plan is that of a tube, with one opening for food to enter the body and another for waste products to exit. Many animals are formed from three embryonic tissue layers: the endoderm, the mesoderm, and the ectoderm. The endoderm layer produces the digestive and respiratory systems; the mesoderm layer produces the muscular, skeletal, integumentary, and reproductive systems; and the ectoderm produces the integumentary and nervous systems. However, more simple animals may lack some or all of these layers. Sponges lack all three, while cnidarians only possess the endoderm and ectoderm layers. Animals are also classified by whether or not they possess a coelom, which is a fluid-filled body cavity completely lined by mesoderm-derived tissue; those animals that lack this tissue layer are acoelomate or, if they have a body cavity that has formed from a different tissue layer, they are pseudocoelomate. Coelomate animals are either protostomes or deuterostomes depending on what the first opening in the blastula becomes. If this opening develops into the mouth, the organism is a protostome. If the opening develops into the anus, the organism is a deuterostome. Vertebrates fall into this category.

In addition, animals are categorized by what planes of symmetry their bodies can be divided along to form mirror images. Asymmetrical animals (such as sponges) do not

have an axis of symmetry. Radially symmetrical animals (such as corals and sea stars) have bodies that are organized about a central point and can be divided along multiple planes of symmetry. Bilaterally symmetrical animals have a single axis of symmetry and can only be divided into mirror images along one central plane.

Activity

Explore the phyla that will be seen in Dive 10 by observing and dissecting specimens according to the instructions below. Draw your observations and answer the questions on the provided worksheet (also linked here). Turn your worksheet into your TA before the end of lab.

The below phylogenetic tree displays the evolutionary relationships of animal phyla. We will start our exploration of them with the phylum Porifera.
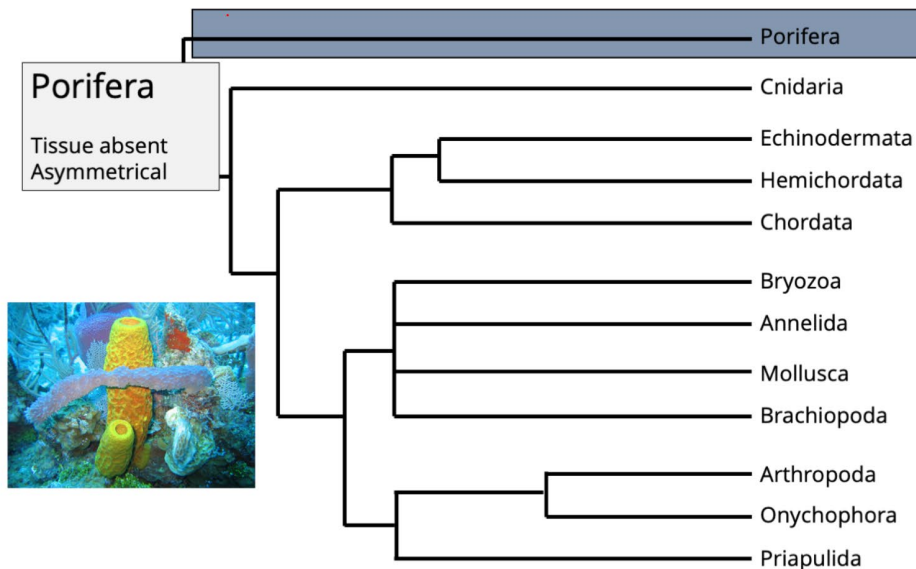
The position of phylum Porifera in the animal tree of life. Phylogenetic tree by Jonathan R. Hendricks; inset image of modern sponges by NOAA (Creative Commons; public domain).

Figure 1. Animal tree of life with Porifera highlighted.

PORIFERA

These videos provide useful information about sponges: https://vimeo.com/37433377, https://youtu.be/pTZ211cIjX8.

Phylum Porifera consists of sponges. Sponges are asymmetrical animals that lack specialized tissues, consisting of cells arranged to form a sack-like body around a central cavity. They feed by filtering water through pores along the body into the central cavity and out through an opening called the osculum at the top of it. Sponges can reproduce sexually by releasing eggs and sperm into the central cavity to form a motile larvae, which is released into the water column, or asexually by budding; in either

instance, the adult form of the sponge is a stationary organism. Sponges are differentiated based on the composition of their spicules, which are small pointed structures embedded in their tissue to provide support to the body and deter predation. In the video footage we will be working with, we will observe sponges in the class Hexactinellida. These sponges are also called glass sponges because their spicules are made of silica.

A   B   C

Figure 2. Several examples of Hexactinellida (glass sponges): A, *Dictyaulus* sp.; B, Farreidae; C, *Regadrella* sp.

Obtain a sponge sample, scalpel, and dissecting tray. Record the name of your sponge on your worksheet. After observing your sponge with the naked eye, use your scalpel to take a thin slice from it. Place your sample under the dissecting scope at your lab bench and draw what you see.

Next, obtain a glass dish. Use an eyedropper to place enough bleach on top of the sample to entirely submerge it and use your scalpel to break it up. Allow the bleach to dissolve the tissue in the sample for 5 minutes before using the light microscope to observe it. You should see the spicules; if you are unable to find them, allow the sample to sit for several more minutes before returning to it. Use the diagram below to determine what kind of spicules your sponge sample has before drawing what you see under the microscope.
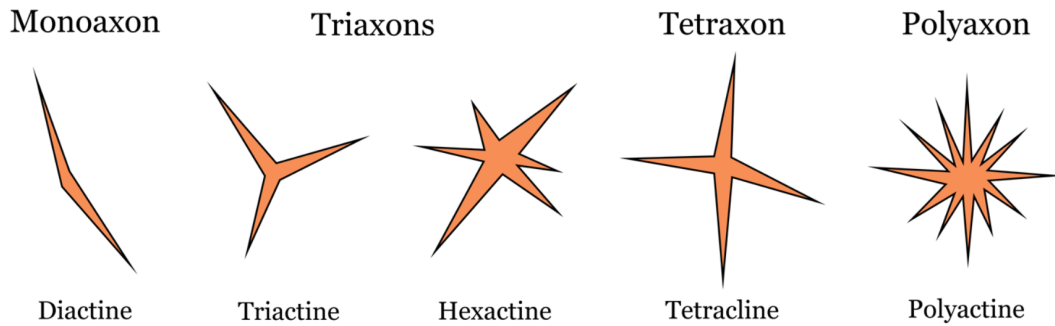
Sponge spicule diversity. Top labels correspond to number of axes, bottom labels correspond to number of growth directions. Image by: Jaleigh Q. Pier is licensed under a Creative Commons Attribution-ShareAlike 4.0 International License.

Figure 3. Examples of sponge spiracles.

CNIDARIA

Phylum Cnidaria consists of animals that have radial or bilateral symmetry and develop from two tissue layers, the ectoderm and endoderm. They lack advanced organs or organ systems but possess a gastrovascular cavity, muscle fibers, and a nerve net. Though all have planktonic larvae, adult cnidarians are formed along one of two body plans: they are sessile polyps, whose gastrovascular cavities have upward facing openings that are surrounded by tentacles, or they are motile medusas, whose mouth and tentacles are downward facing. In some species, sessile polyp-type adults may produce motile medusa-types through budding.

The class Anthozoa is composed of sea anemones and corals. Anemones consist of a single polyp which is anchored to its substrate by a disc while corals have numerous polyps which function as a single organism. Both corals and anemones are heterotrophic, with the larger anemones consuming small fish and arthropods while corals feed on smaller planktonic organisms. Some shallow-water corals have symbiotic relationships with dinoflagellate algae called zooxanthellae, which reside within their tissues; algae receive protection and CO_2 to use in the process of photosynthesis, and they provide the coral with the excess nutrients that they produce.

The deep-water corals that we will observe are primarily from the order Alcyonacea and are also known as gorgonian or soft corals. Coral polyps cover skeletons consisting of calcium carbonate sclerites which are alternated with soft proteins; the degree of hardness and rigidity of skeletons varies between species, but they are all flexible enough to bend in ocean currents without breaking. Larger colonies serve as habitats for a range of marine organisms, from other cnidarians like anemones or hydrozoans to arthropods and gastropods.
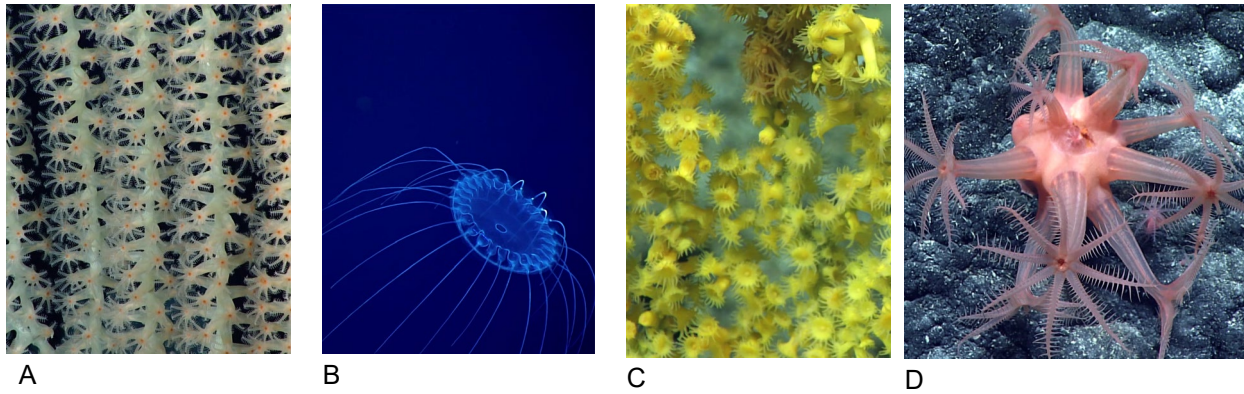
18

Figure 4. Several examples of Cnidaria: A, Keratoisidinae; B, jellyfish in water column; C, *Kulamanamana haumeaae*; D, *Anthomastus* sp.

Cnidarians are characterized by their possession of stinging cells called cnidocytes on their tentacles. The barb-like nematocysts inside cnidocytes are deployed when a hairlike projection experiences tactile stimulation, and they can be used for obtaining food or defense against predators.
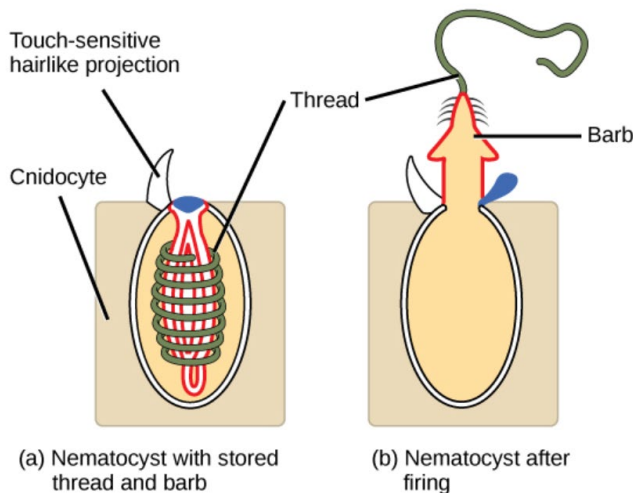

Figure 5. (a) shows the cnidocyte prior to deployment and (b) shows the cnidocyte with the nematocyst released.

Obtain your cnidarian sample from your TA. Record the name on your worksheet and observe its color and behavior. Remember that animal tissue is clear; based on what you have learned, what do you think could be creating its color?

Use scissors and forceps to cut off one tentacle from the polyp; polyps will retract their tentacles when touched, so this may be difficult. Ask your TA for assistance if you need it. Place the tentacle on a glass slide and squash it with a glass cover slip, then use the light microscope to locate and observe the nematocysts. Draw what you see on your worksheet.

MOLLUSCA

Watch this video about mollusca: https://www.shapeoflife.org/video/mollusc-animation-abalone.

Phylum Mollusca consists of organisms that possess a true coelom containing internal organs, which is contained in a region called the visceral mass and is partially covered by a mantle. The mantle may secrete a hardened calcium carbonate shell. The respiratory structures, typically gills, are located between the mantle and the visceral mass while the mouth is found on the muscular foot that is used for movement. Inside the mouth is a tonguelike organ covered with rows of teeth called a radula. The nervous system consists of neural ganglia and nerve cords, and the open circulatory system is characterized by a heart that pumps blood throughout the body before it returns by diffusion. Class Aplacophora consists of worm-like animals with no outer shell. Class Gastropoda consists of organisms with asymmetrical bodies that are typically protected by a coiled shell.
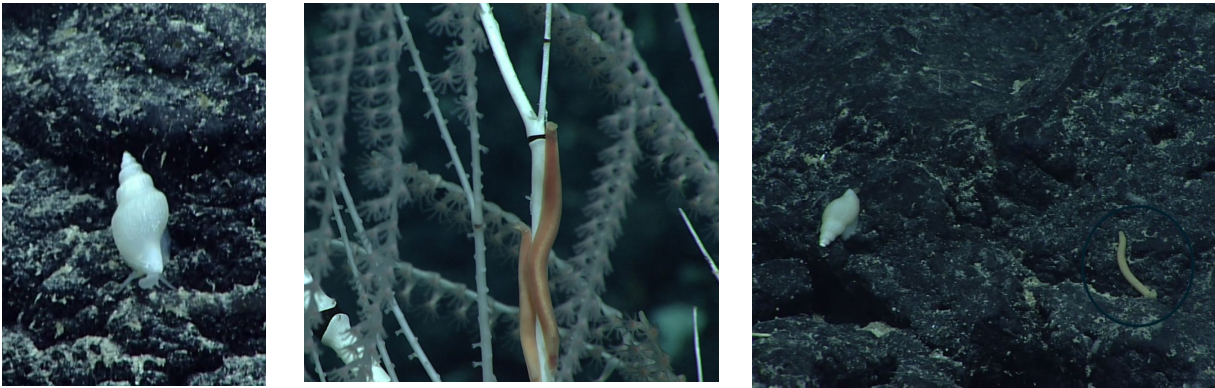

Figure 6. Several examples of mollusks: A, gastropoda; B, *Epimenia* sp. on a coral; C, gastropoda and Aplacophora.

Obtain a living gastropod from your TA. Record the name on your worksheet. Observe the animal's movement, appearance, and response to stimuli, and draw it in the space provided. Use the image below to label the anatomical structures that you can see.
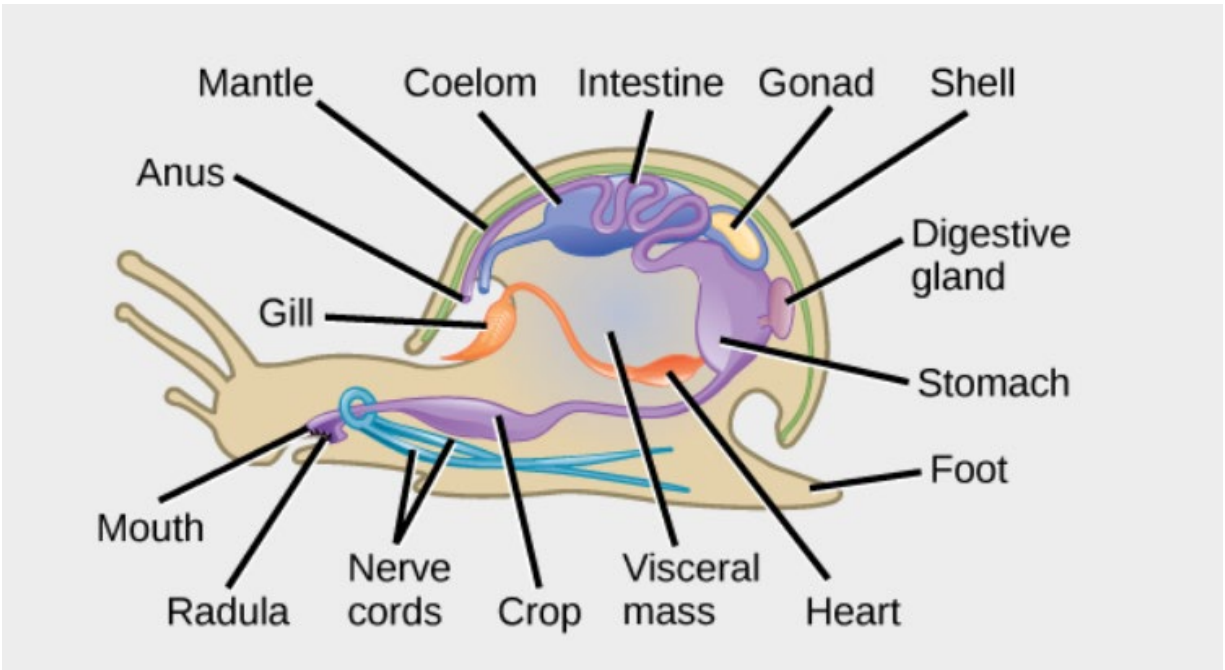
Figure 7. Anatomy of a snail.

ANNELIDA

Phylum Annelida consists of segmented worms. They have a large coelom with internal organs. They have a closed circulatory system, with blood vessels carrying blood to the different body segments. Their nervous system has a brain, nerve cord, and neural ganglia, while the digestive system has a pharynx, stomach, intestine, and other organs. Class Polychaeta is composed of annelids with parapodia (paddle-like appendages) and setae (bristles to anchor the worm to a substrate). Class Clitellata consists of leeches with anterior and posterior suckers that suck blood and contain the anticoagulant hirudin in their saliva.
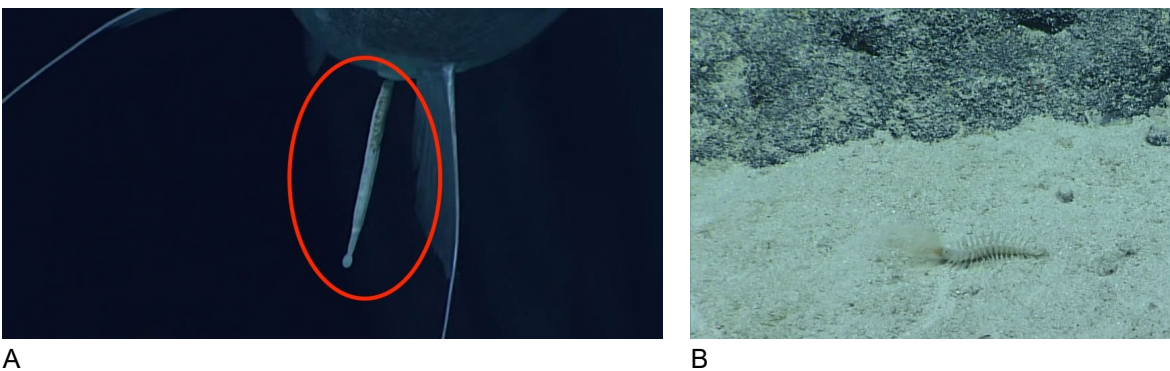

A   B

Figure 8. Several examples of annelids: A, Hirudinea feeding on a *Coryphaenoides longicirrhus*; B, Teuthidodrilus sp.

Obtain an earthworm, dissecting tray, scalpel, and gloves from your TA. Record the name on your worksheet and draw its exterior appearance. Follow this link for instructions on how to dissect your worm. Draw and label your dissected specimen.

ARTHROPODA

Phylum Arthropoda consists of animals with segmented bodies and appendages. They have rigid exoskeletons, a pair of jointed appendages for each body segment, and a nervous system with a brain, nerve cord, and sensory organs. The three principal body segments are the head, thorax, and abdomen. Class Malacostraca contains shrimps and crabs, while class Pycnogonida contains sea spiders characterized by long legs and small bodies.
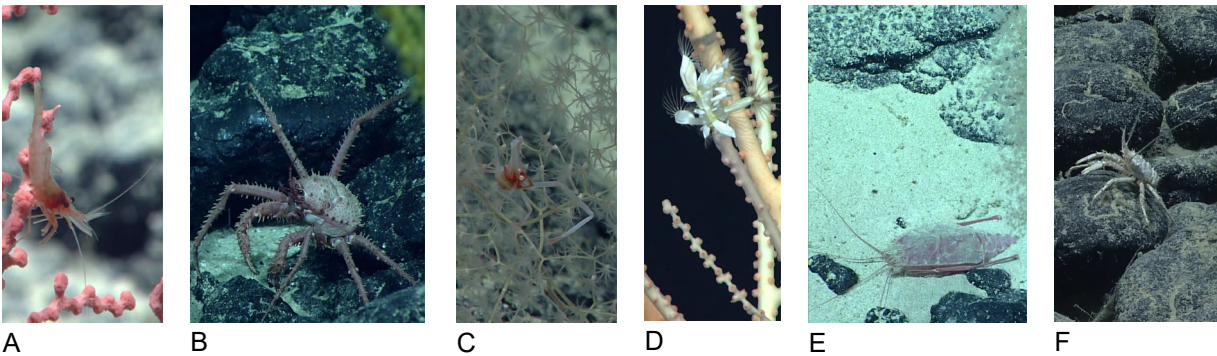

A   B   C   D   E   F

Figure 9. Several examples of arthropods: A, *Lebbeus* sp.; B, *Paralomis* sp.; C, *Uryoptochus* sp.; D, Poecilasmatidae; E, *Homeryon asper*; F, *Munidopsis* sp.

Obtain your living arthropod from your TA. Record its name on your worksheet and draw it in the provided space. Observe its appearance and movements. How does it move? How does it obtain energy?

ECHINODERMATA

Phylum Echinodermata consists solely of marine animals whose larvae have bilateral and adults have radial, typically pentaradial, symmetry. They have an endoskeleton, a water vascular system that allows them to move, and lack brains. Class Crinoidea consists of stalked sea lilies and motile feather stars, which have branched arms used for filter feeding. Class Holothuroidea consists of sea cucumbers with long bodies and feeding tentacles near their mouths. Class Echinoidea consists of sea urchins with long spikes used for movement and defence. Class Ophiuroidea consists of brittle stars with long, flexible arms for movement that extend from a central disk. Class Asteroidea consists of sea stars, which have a flattened body with five (or a multiple of five) thick arms extending from a central disk. One side of their body contains the mouth and tube feet, and they feed by extending their stomach around their prey. They have nerves and eyespots, and may have spines for defense.
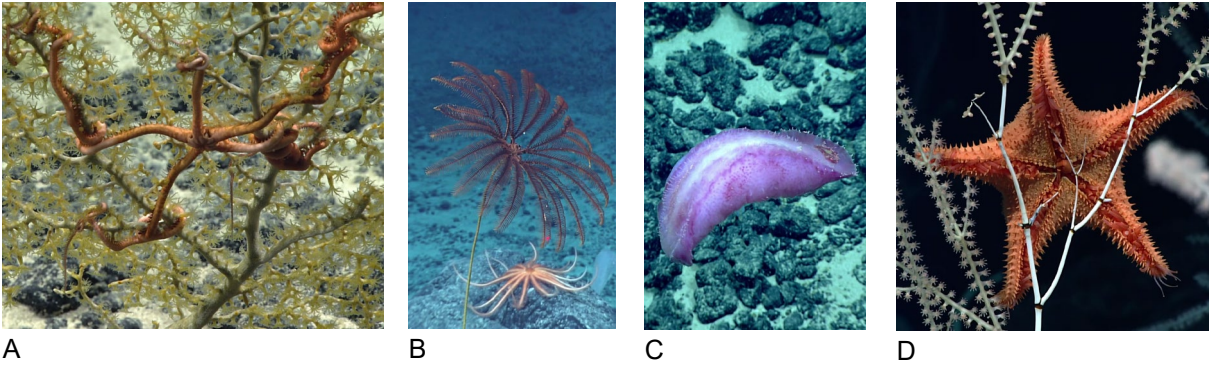
A   B   C   D

Figure 10. Several examples of echinoderms: A, Euryalidae; B, stalked Crinoidea (foreground) and Brisingidae (further back); C, *Benthothuria* sp.; D, *Hippasteria muscipula* feeding on Keratoisidinae.

Obtain an echinoderm from your TA. Record its name on your worksheet and, while observing its appearance and reaction to stimuli, draw it in the space provided. How does it move? How do you think it obtains energy?

CHORDATA

Phylum Chordata is characterized by the possession of a notochord; a dorsal hollow nerve chord; pharyngeal slits; and a post-anal tail, all of which are present in at the embryonic form of an organism. Subphylum Vertebrata consists of chordates with backbones. Class Actinopterygii consists of ray-finned fish, which have bones in their fins to hold them out and away from the body. They also have scales to cover their bodies, gills, and a gas-filled swim bladder to help change and maintain their depth in the water column.
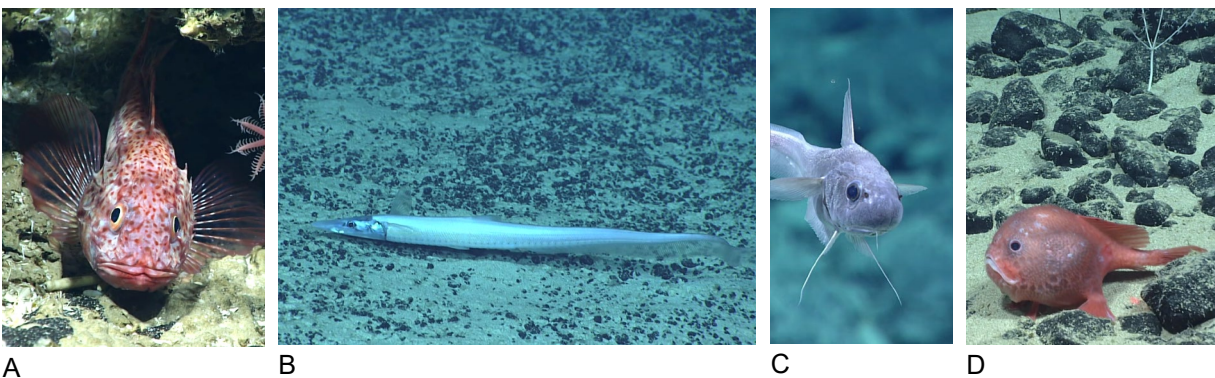

A   B   C   D

Figure 11. Several examples of chordates: A, *Setarches* sp.; B, *Aldrovandia affinis*; C, *Kumba* sp.; D, *Chaunacops coloratus.*

Go to one of the aquariums in lab. Observe one of the chordates in the tank. Describe its appearance and behavior; how does it move? How frequently does it move, and does it seem to prefer being out in the open or hiding? What do you think it eats? Do you think it eats organisms from the benthic or pelagic environment, and why do you

think this? Draw the chordate, provide its name if you can, and answer the questions on the worksheet.

Before leaving lab, turn in your worksheet to your TA.

Assignment
1. Watch at least the coral anatomy portion (10:30 to 14:30) of the documentary *Chasing Coral*, which can be found on Netflix. In addition, write a 500 word reflection on the assigned segment; if you watch the whole film, include information from the entirety of it. Inform your instructor if you do not have access to Netflix.
2. Test your Tator account:
   a. Open Google Chrome on a computer. Go to the Tator platform (https://www.tatorapp.com/accounts/login/). Type in the given username and password.
      i. Username: first initial and last name
      ii. Password: first name _ init_pass
      iii. Example: John Doe. Username: jdoe. Password: john_init_pass
   b. Under the "Projects" heading, you should see a project named "NOAA CAPSTONE Clone." If this project is visible, your Tator account is fully set up for next week's lab.

Lab 4: Tator Basics

Sources used:
- MINUET's "Localization Protocol and SOP."

Structure of lab: introduction to assignment (walk through process, demonstrate all tools being used)
Estimated length of lab: approx. 2 hrs
Materials: grading rubric for activity

Background and Definitions
While the video footage collected by ROVs is fascinating to watch, it does not give researchers a searchable, quantitative data set with information about the number, type, and habitat of organisms that are observed. Expert annotations, which are notes made in a video to show that there is an animal within a given range of frames, are used to create this data set; they give the identification of the animal and the substrate on which they are located. However, they do not show where the animal is in the frame. This is the role of the localizations that we will be making. Localizations are boxes drawn around annotated organisms, and they serve two roles: first, they allow researchers to easily locate and view an organism in which they are interested; and second, they train the AI that is integrated into Tator to recognize these animals and identify them without human input.

Assignment
Use the following instructions to make localizations for the provided list of annotations. Use the instructional video as needed for clarification and a visual representation of instruction.

Instructions
1. Open Google Chrome on a computer. Go to the Tator platform (https://www.tatorapp.com/accounts/login/). Type in the given username and password.
   a. Username: first initial and last name
   b. Password: first name _ init_pass
   c. Example: John Doe. Username: jdoe. Password: john_init_pass
2. Under the "Projects" heading, click on the "NOAA CAPSTONE Clone" link. To the left of the screen, find the list of NOAA expeditions. Select the assigned dive or expedition to bring up the images of the video clips in the center of the screen.
3. If localizing an entire dive, click on the video clip prior to the first one showing the ocean floor. If localizing assigned video clips, use the "Next" button at the bottom of the page as needed to find the assigned clip number. The clips are named

with the expedition number, the date the footage was taken, and a T######
sequence number (example: EX1708_VID_20170916**T223000**Z_ROVHD.mp4).
Videos will be assigned using the T###### sequence number. For this lab, select
the provided links from the "Assigned Frames for Lab 4" Google Sheet.
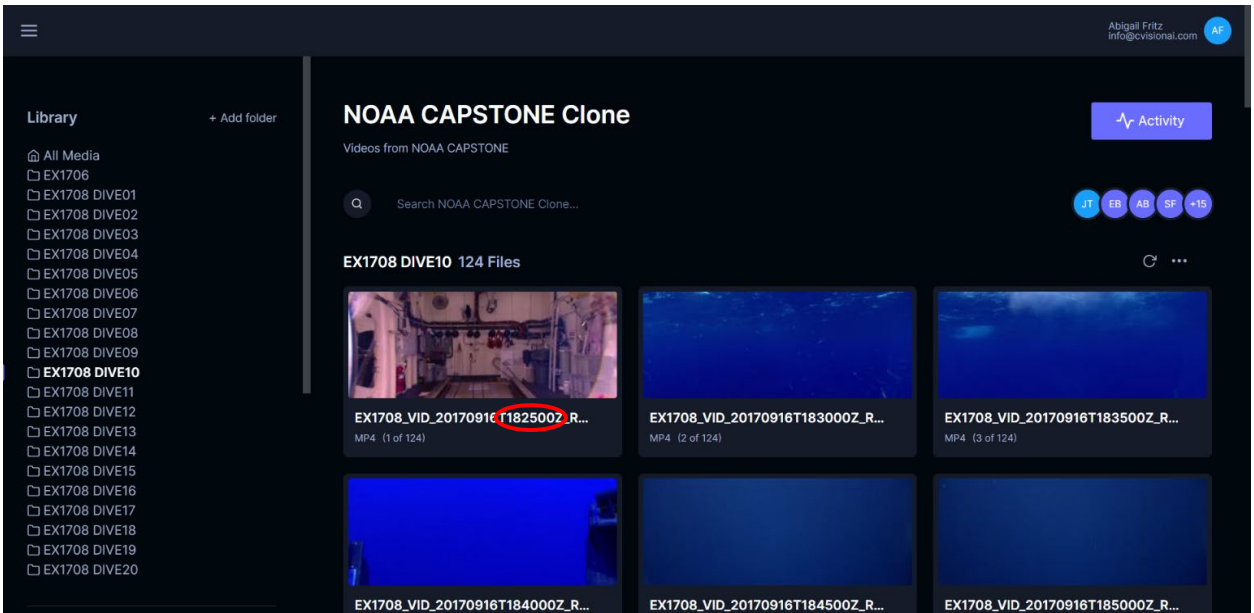

Figure 1. Location of T###### sequence number on each segment in Tator.

4. After accessing a video clip, ensure that you are working on the correct layer.
   Click on the box above the video frame that contains an eye.
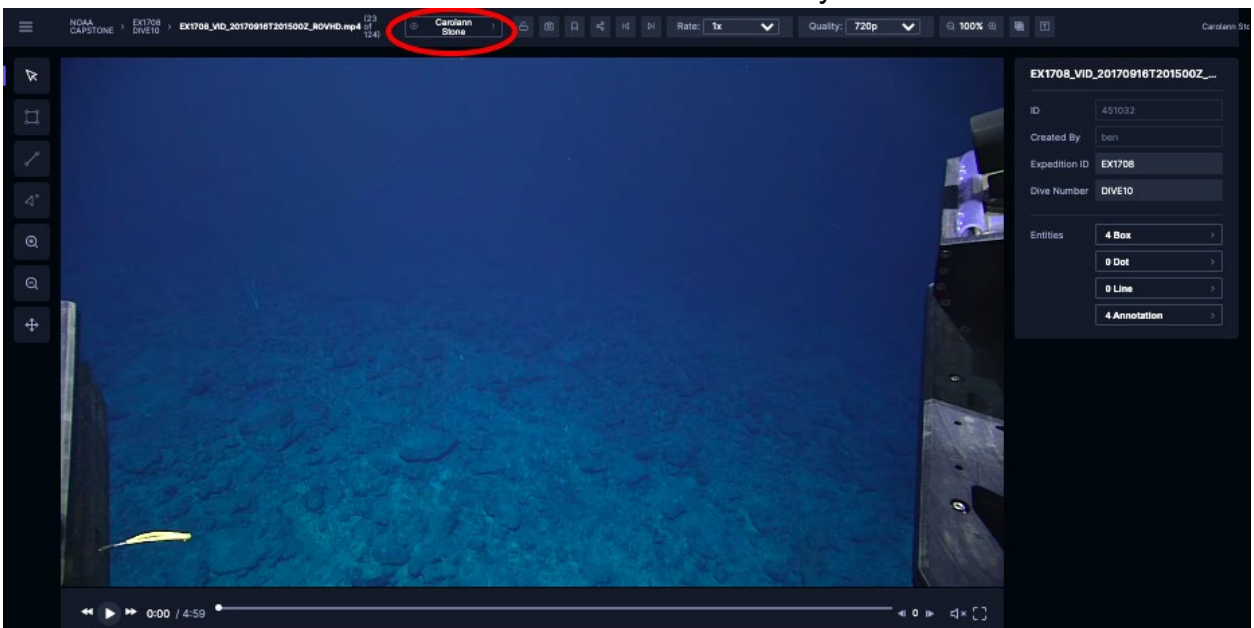

Figure 2. View of Tator after selecting a video clip.

This will either display a name or "Baseline." If it does not display your name,
click on the button. Within the menu click "View version" next to your name.

5. Click on the sound button below the video frame and increase the volume to unmute the audio. Play the video clip while observing the animals and geological features described by scientists during the expedition.
6. Under the "Entities" heading to the right of the video, click on the "# Box" button to bring up the expert annotations. If you are familiar with all organisms listed, proceed to step 7. If you are not, research it in one of the provided Animal ID guides to find a reference image or use a google search to find an expert source.
    a. NOAA's [Benthic Deepwater Animal Identification Guide V3](#)
    b. MBARI's [Deep-Sea Guide](#)
    c. Project MINUET's [Animal ID Guide](#)
    d. HURL's [Animal Guide](#)
    e. [WoRMS](#) (World Register of Marine Species)
7. Starting with the first annotation (underneath the "Grouping, On/Off" option), click on the scientific name. Next, select the "Go to entity's frame" button. This will advance the video clip to the frame that the annotation was made on.
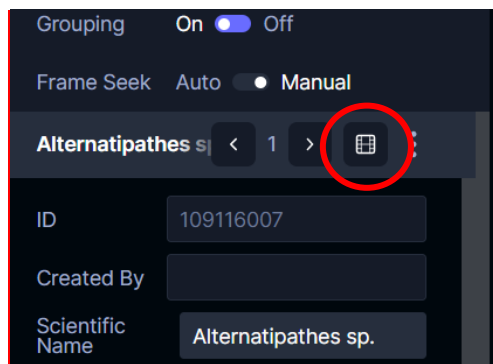

Figure 3. View of the "Go to entity's frame" button (circled in red) within Tator.

8. Look for the organism in the frame. The "Zoom in (+)" button can be used to magnify parts of the screen. To use, select the magnification button to the left of the video, use the magnification mouse to click on part of the frame, and pull diagonally to create a box. This will magnify the details within the enclosed box by expanding them to fit the video frame; to avoid distortion of the image when it expands, make a box in the same proportions as the frame. After you have magnified the frame, you can use the "Pan" button to move around within it. Additionally, the scrub bar at the button of the video can be used to advance the video. This can be useful if the animal is motile and blends into the background, or to look for shadows of an organism. For this first lab, all organisms are in the original frame.
    a. Tip: scroll down to the "Substrate" field in the annotation to find out if the organism you are looking for is located on a coral, sponge, or rock formation.

9. Once the animal is found, click on the redraw button next to the organism's scientific name.
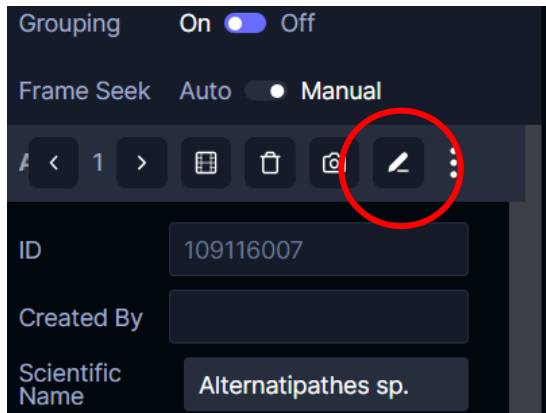

Figure 4. View of the "Redraw" button (circled in red) within Tator.

This will make the mouse a + sign. To make a localization, use the mouse to click on part of the screen to the upper left of the organism. Drag the mouse diagonally to enclose the organism within the box. After releasing the mouse, hold the mouse over the edges of the created box to adjust the box parameters to enclose the entire organism, with a slight gap between the edge of the organism's body and the border of the localization.

10. If mistakes are made when localizing an annotation, do not use the delete button to redo it; this button deletes the annotation, not the box that was drawn for it. Instead, click the redraw button and use it to "redraw" the "bad" box.

11. Fill out the "Box Confidence" drop down menu. If you *think* you know what the organism is and were able to draw a box, but are unsure, click the drop down menu for "Box Confidence" and click "unsure". If you are confident that you found the correct organism for the annotation, click "confident". If you cannot find the organism at all, click "Couldn't find".

12. Continue creating bounding boxes until all expert annotations have been localized.

Other Tools

In addition to making localizations, you can take screenshots, share links to individual frames in a video, and bookmark segments that you are working on. These tools are located above the video screen.
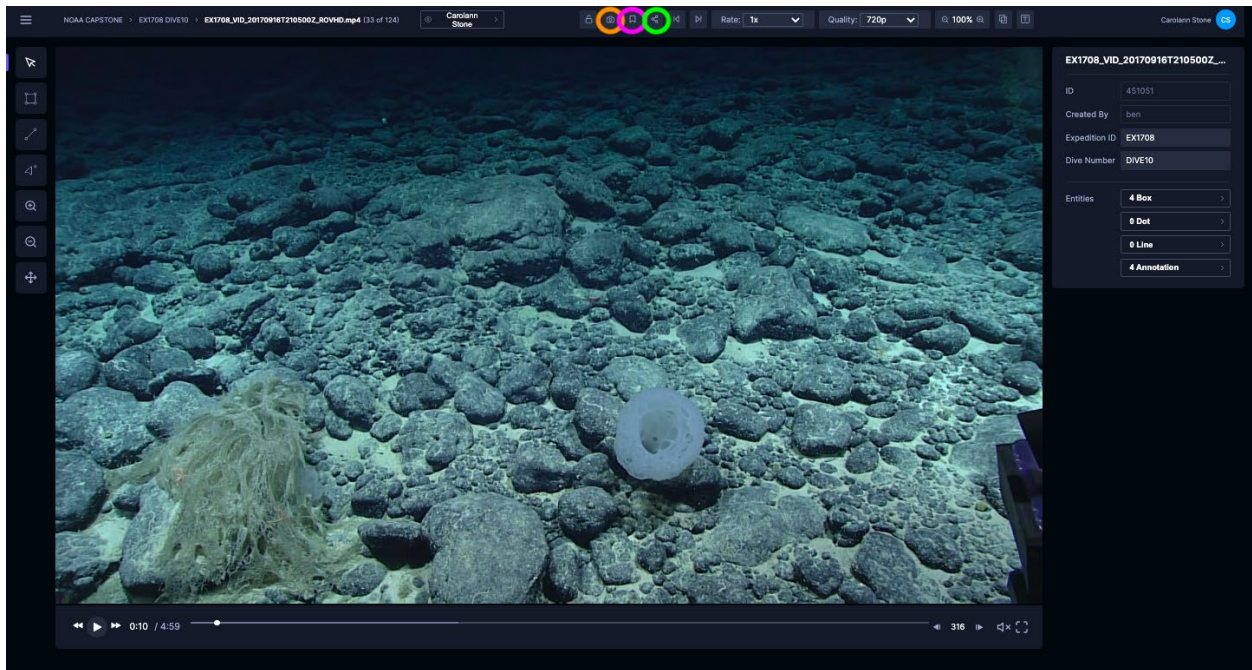
Figure 5. View of Tator. Supplementary tools are circled at the top in orange, pink, and green.

To take a screenshot, click on the camera icon on the top bar of the screen. This will give you the option to obtain the screenshot of the video with or without the localization boxes by using the on/off selection. Click on the second camera icon in order to take the screenshot. This image will be added to the downloads file on your computer.
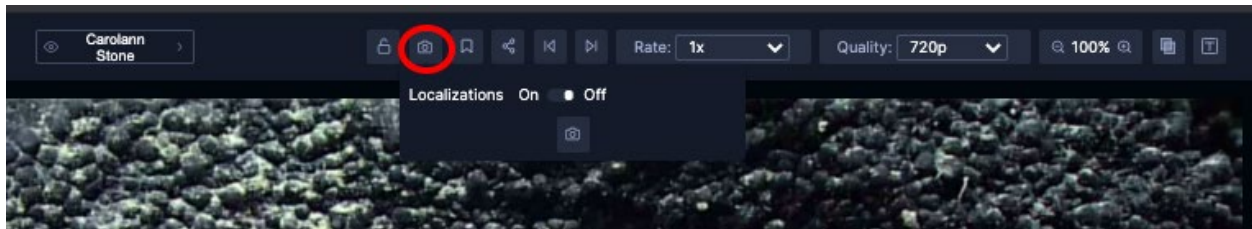
Figure 6. View of screenshot button in Tator (circled in red).

To obtain a link to a particular part of the video, select the link button on the top bar. This will copy the link to the clipboard.
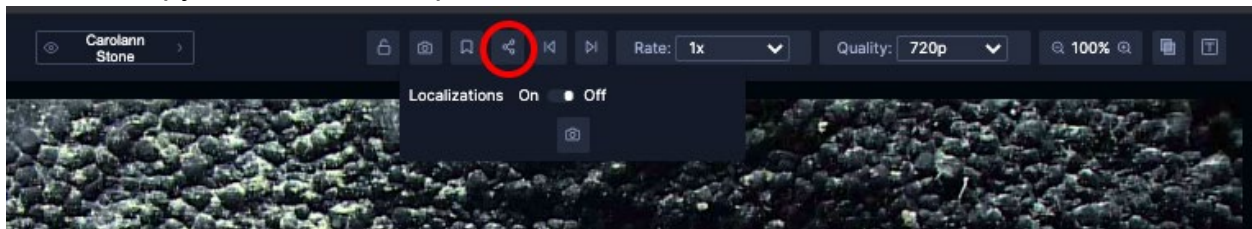
Figure 7. View of link button in Tator (circled in red).

To bookmark part of the dive segment (either for review or for later reference), select the bookmark button on the top bar. This will open up a window for you to name the bookmark. You can later find the bookmark under the "Bookmarks" heading on the main page of Tator.
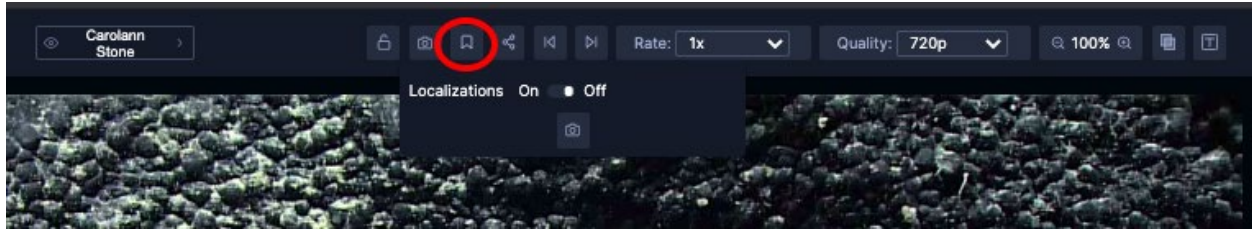
Figure 8. View of bookmark button in Tator (circled in red).
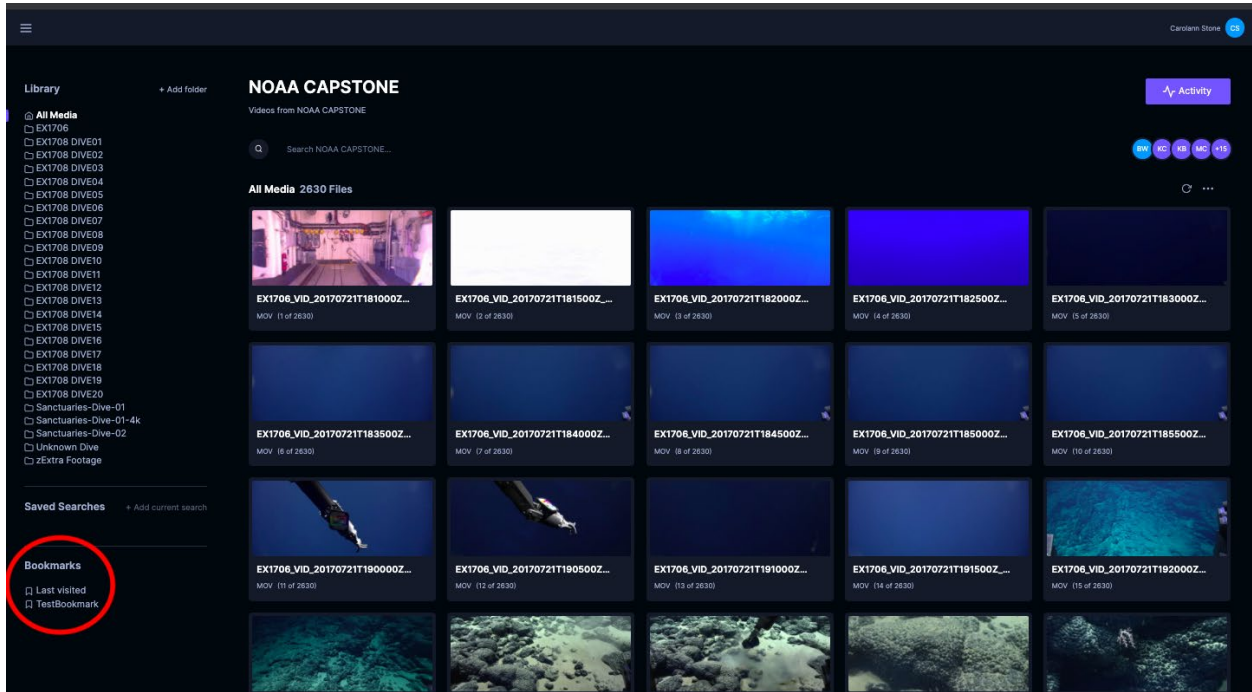
Figure 9. View of bookmarks in the main page of Tator (circled in red in the bottom left corner).

To navigate to a specific frame, click the frame number on the bottom bar of the screen, enter the desired frame number, and hit enter.

Figure 10. View of frame number in Tator (boxed in red in the bottom right corner).

*The TA will review your work within the Tator Program.

Lab 5: Advanced Tator I

Introduction
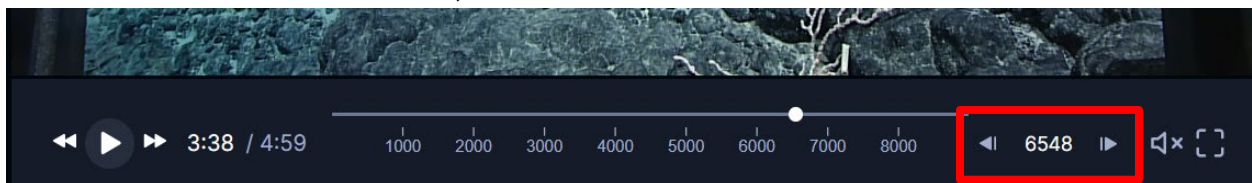Unfortunately, expert annotations were not always made on frames that are ideal for machine learning. The annotations in the footage were originally made using a platform based on the time that the organism was seen, rather than the given frame. Thus, some annotations are on frames with blurry images or do not contain the entire organism. In these cases, it may be necessary to move the original annotation to a different frame. Additionally, annotations are sometimes made for more than one organism. However, the redraw function can only make a single localization. A different function is needed to make these additional localizations. This lab will teach you how to make these changes, and allow you to practice on the provided footage.

When to Move Annotations
The localization protocol indicates that an annotation should only be moved *if the initial annotated frame is blurry, if the whole organism is not in the annotated frame, or if there is a better, more detailed view in another frame.*

Sometimes, the whole organism is not within the frame of the original annotation. In the case of this annotation for *Ilyophis sp.*, some of the fish is cut off in the original frame.

Figure 1. View of *Ilyophis sp.* as annotated in the video.

This is an inadequate view of the animal for the purposes of machine learning. The image below is a better frame for the primary annotation of the animal, because it contains the entirety of it.
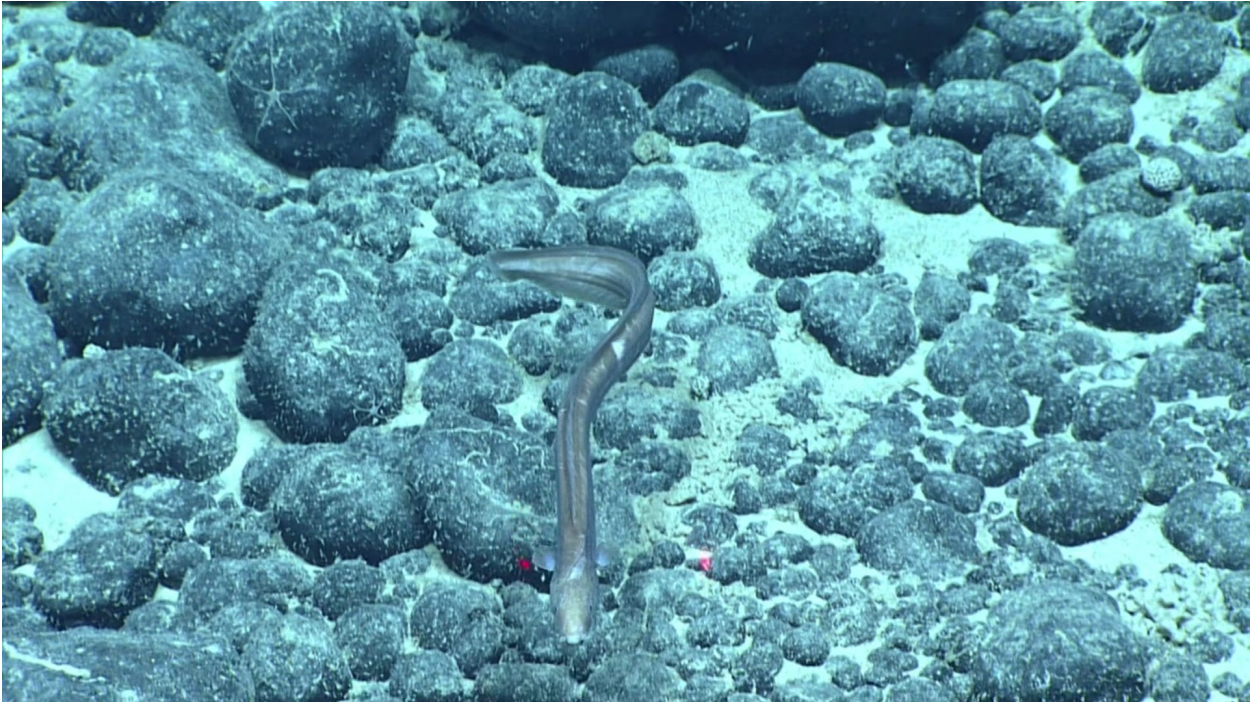

Figure 2. Better view of *Ilyophis sp.* in terms of machine learning.

Though this frame does not contain as much detail as the original one, it contains the entire organism without being blurry. The original annotation should be moved to this or a similar frame.

Instructions for Moving Annotations

1. In the given video segment, click on the "# Box" button to the right of the video screen. Use the "Go to entity's frame" button to go to the frame with the annotation.
2. If the annotated organism does not meet the criteria for localization (blurry, cuts off part of the animal), you will need to move the annotation. You should start by making the localization as detailed in Lab 4.
3. Use the scrub bar or the forward and backward buttons at the bottom of the video screen to find a frame with a clearer frame or a more complete view. Make note of the frame number.
4. Return to the frame with the created localization. Click on the localization to make the box appear white (rather than orange). Use the "Control X" command on the keyboard to cut the localization and annotation. Note: on Apple computers, use "Control" rather than "Command" for cutting and pasting in Tator.
5. Use the scrub bar or forward and backward buttons at the bottom of the video screen to go to the noted frame. Note: you cannot play the video to advance the frames when you have cut the annotation.
6. On the noted frame, use the "Control V" command to paste the localization and annotation on the new frame.
7. Move and resize the localization as needed to fit the organism on the new frame.

Annotations with Individual Counts Greater than 1

In instances where the "Individual Count" in the annotation indicates that more than one organism was observed, it is necessary to make additional annotations for these organisms. This often requires that you move the original annotation to a frame in which all individuals are visible before creating the additional annotations. In the case of this annotation for *Ophioplinthaca sp.*, the original annotator indicated that 10 individuals were observed. The original frame has several organisms that one could properly localize; however, some of the organisms are cut off or are not within this frame.
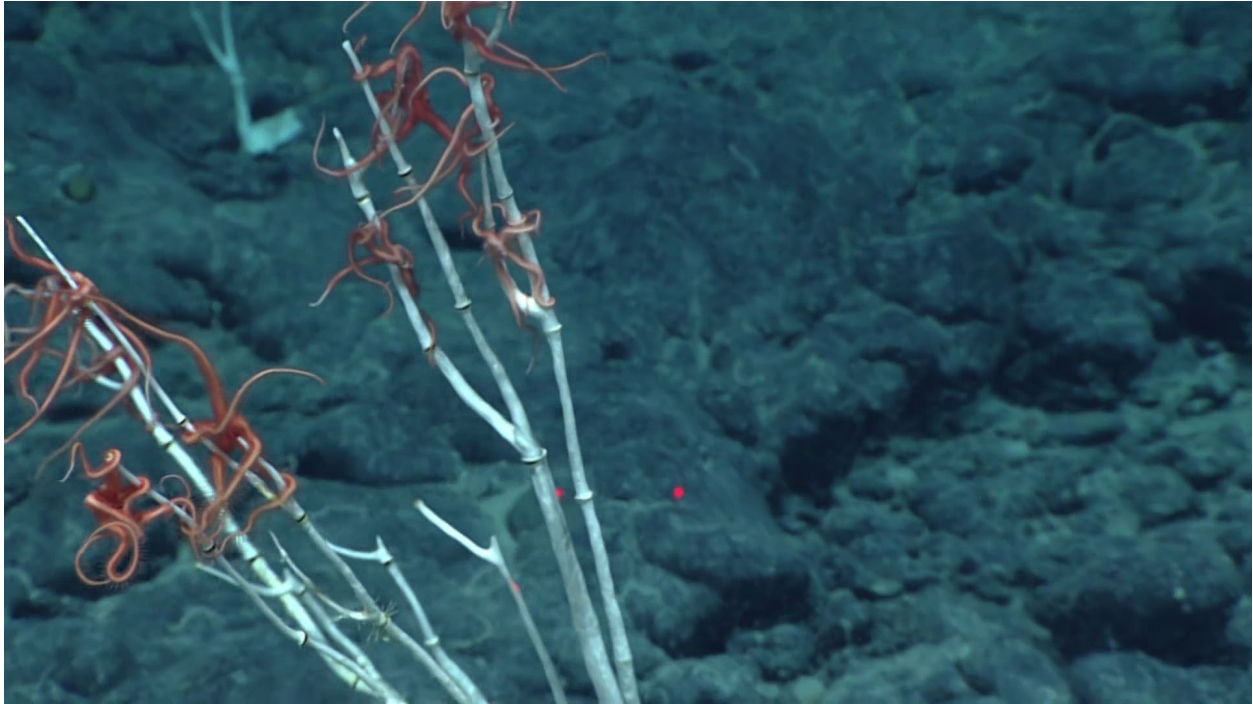
Figure 3. View of *Ophioplinthaca sp.* as annotated in the video.

In order to meet the localization requirements, the annotation should be moved to a frame in which all organisms are visible. An example of this is seen below.

Figure 4. Better view of *Ophioplinthaca sp.* in terms of machine learning.

While this view is not as zoomed in as the original, all of the annotated organisms are within the same frame. A frame such as this, in which all of the individuals are visible,

should be used when making multiple localizations; this lends itself better to training the AI to identify and count organisms.

Instructions for Annotations with Individual Counts Greater than 1
1. In the given video segment, click on the "# Box" button to the right of the video screen. Use the "Go to entity's frame" button to go to the frame with the annotation.
2. Look at the Individual Count in the annotation details to determine how many individuals the original annotator observed. Determine if you are able to find that number of individuals in the frame. If not, watch the sections of the video that are just prior to and after the annotated frame; if you see a higher number of individuals in any of these frames, use the protocol for moving annotations to change the frame of the original.
3. If you are able to identify the same number of individuals as noted in the annotation details, use the redraw button to make a localization around one of the individuals.
4. For the additional individuals, use the "Box" button below the cursor to the left of the video screen to make new annotations. Click on this button and use the + cursor to make a box around the individual. In the window that appears, enter the Scientific Name, Taxon Rank, and your box confidence then select "save" at the bottom.
   a. Tip: it is helpful to copy and paste the scientific name from the original annotation due to the complex spelling of many names.
5. Adjust the size and placement of the localization as needed.
6. Continue to make additional boxes for all of the noted individuals. The arrows near the scientific name and redraw button can be used to determine how many localizations you made in a given frame. If you are unable to localize as many individuals as noted, write "Located fewer individuals than were recorded in the Individual Count" in the "Boxer Remarks" for the original annotation. If you localize more individuals than are noted, write "Located more individuals than were recorded in the Individual Count."
   a. How close to the individual count do you need to get?
      i. The count is frequently an estimate, and the accuracy of it varies. If there are more individuals—and you are confident that they are not a different animal or attached to a different annotation—box all of them, going as far into the background of the frame as you can while maintaining 100% confidence. If there are fewer individuals, box those that you see. Do not box dead animals or those that are partially cut off by the frame.

Making Multiple Localizations for a Single Individual

It is helpful to provide multiple distinctive views of the same individual when training programs like Tator. Therefore, when we see different angles of an organism because it moves, the camera focuses on and pans around it, or the camera zooms in, we want to use the tracking tool to create additional localizations for a single individual.

Figure 5. View of Keratoisidinae as annotated in the video.

With some minor adjustments to obtain the whole organism in the frame, this is a good view of this organism and should be localized. However, the ROV zooms in on this individual, providing us with additional—albeit incomplete—views that we want to capture .
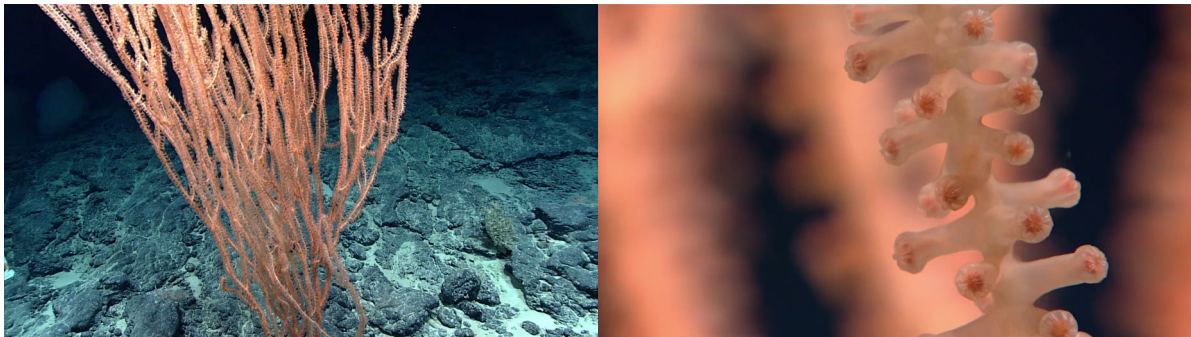
A   B

Figure 6. Supplementary views of Keratoisidinae annotation: A, details of the branching; B, details of the polyps.

Instructions for Making Multiple Localizations for a Single Individual

1. In the given video segment, click on the "# Box" button to the right of the video screen. Use the "Go to entity's frame" button to go to the frame with the annotation.

2. After completing the original annotation for the organism, watch the rest of the video clip to determine if there is a magnified view of the organism or a different angle of the organism. Note the frames on which you would like to create additional localizations.
3. If an additional view is found, use the "Edit" button to the left of the video screen to right click on the localization box. Select "Create new Object Track," enter the scientific name of the organism in the relevant field, and click "Save."
4. The "Object Track" menu will now be displayed in place of the "Box" menu, and you will see the "All Object Track" entity that you created. You will also see your object track box on the frame.
5. Right click on the box and select "Set as main track."
6. Move forward in the video and use the redraw button to create additional localizations on the desired frames. You will need to enter the scientific name for each new localization.

Annotating Unannotated Organisms

After you have localized all the expert annotations for a video segment, you may realize that one or more organisms were not annotated. You will need to create an annotation and identify the organism to the best of your ability.

This decapoda was not originally annotated; as you can see in the "Box" column in the right of the screen, there were no annotations created for this entire segment. It was identified to the lowest level of classification at which the boxer felt confident—in this case, order—based on similarities to other decapods seen in the MINUET Animal ID guide, boxed, and the lack of an original annotation was noted in the boxer remarks.
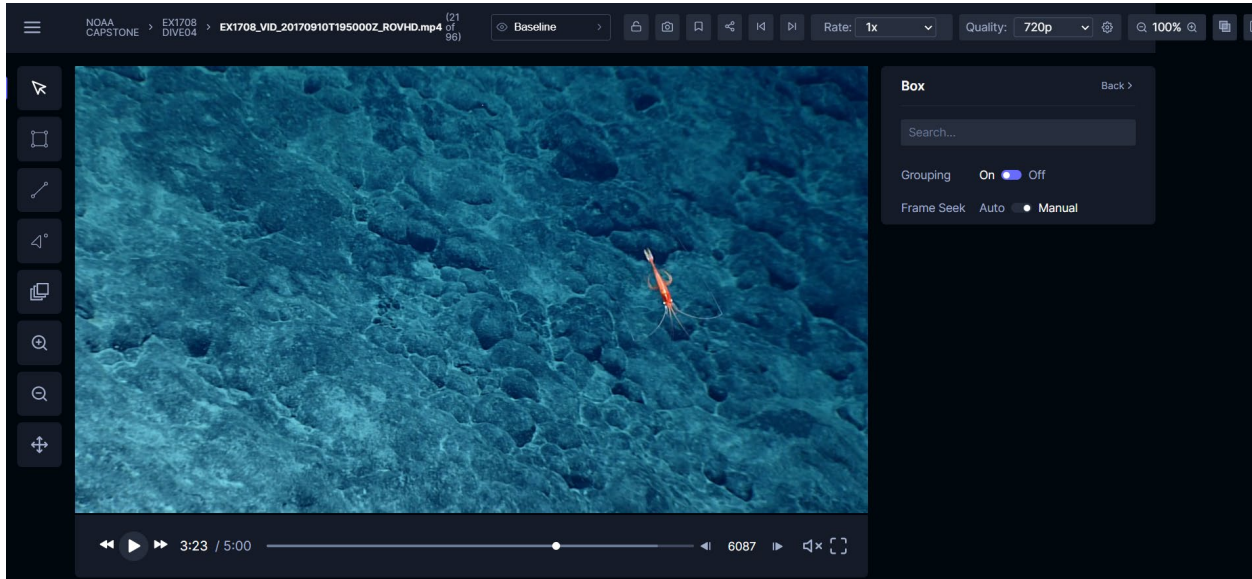

Figure 8. Organism lacking an expert annotation.
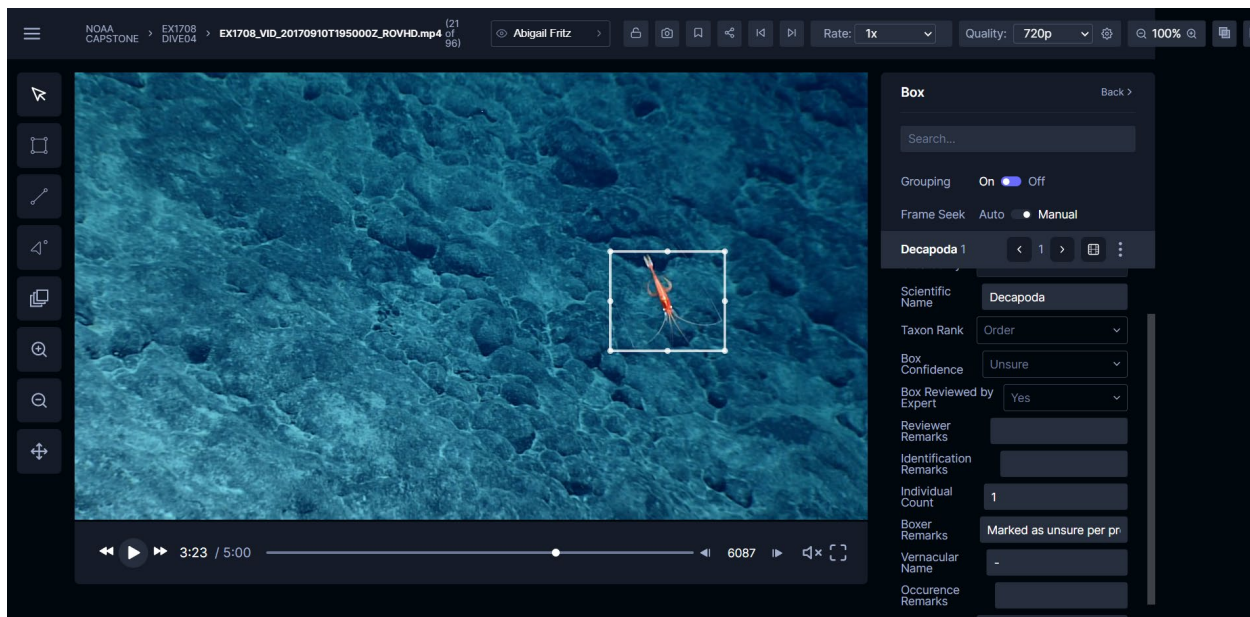
Figure 9. New annotation for a previously unannotated organism.

Instructions for Creating Annotations for Unannotated Organisms

1. Localize all existing annotations in the segment. After you have done so, watch through the entirety of the segment again with the audio playing. Make a note of any organisms that you don't remember localizing.

2. If you recognize an organism as being the same as one localized elsewhere in the dive, confirm that it does not belong to the same annotation. If there were any annotations for which you felt unsure of your localization, use the animal ID guides listed in previous labs to confirm that you boxed the correct organism.

3. After you have confirmed that the organism is not annotated elsewhere, ID it to the lowest level of classification at which you feel confident. Consider similarities between it and other organisms that you have seen in your dive or in an animal ID guide. It's okay if you can only identify it to the phylum or class level!

   a. Tip: to identify the organism, you may want to start by pulling up the MINUET Animal ID Guide in a new window so you can view the guide alongside it. Scroll through the guide and note any organisms that look similar to yours. Return to those names, ranking them in order of most to least similar; after doing so, identify the organism to the lowest level of classification that is shared by the 3 to 5 most similar organisms. If you need assistance, email your TA with a screenshot of and link to the unannotated organism.

4. Mark your box confidence as "Unsure." In the boxer remarks, write "Marked as unsure per protocol for new annotations."

   a. Tip: it is helpful to copy and paste this phrase to ensure that you always use the same terminology.

Reminder: you should always use the redraw button when making a localization for an existing annotation; only use the "Box" button when you are creating new annotations for additional individuals, extra views of an organism, or previously unannotated organisms. In addition, you should try to box as many organisms on the same frame as possible.

Assignment

Use the Basic Tator instructions from Lab 4 and the Advanced Tator instructions in this lab to make localizations for all of the annotations in the assigned dive segments. See the "Assigned Dive Segments for Advanced Tator Labs" (spreadsheet for dive assignments, and use this google form to report your work before the start of next week's lab.

*The TA will assess your work within Tator.

Lab 6: Advanced Tator II

Structure of lab: introduction to assignment, explanation of errors from previous lab with each individual student
Notes: the "Assigned Dive Segments for Advanced Tator Labs" for Lab 5's assignment is also used for Lab 6; students were assigned ~58 annotations (5-7 segments) in total, and were told to complete half before the start of Lab 6. During Lab 6, students received one-on-one feedback on the segments they had completed. They were then told to complete the remaining segments before Lab 7.

Assignment

Use the comprehensive instructions below to make localizations for all of the annotations in the assigned dive segments. See the "Assigned Dive Segments for Advanced Tator Labs" spreadsheet for dive assignments. Make sure to move annotations as necessary to comply with the protocol requirements, add additional localizations to meet the individual counts, and add additional localizations for the same organism as deemed necessary. Use this google form to report your work.

Instructions

1. Open Google Chrome on a computer. Go to the Tator platform (https://www.tatorapp.com/accounts/login/). Type in the given username and password.
2. Under the "Projects" heading, click on the "NOAA CAPSTONE Clone" link. To the left of the screen, find the list of NOAA expeditions. Select the assigned dive or expedition to bring up the images of the video clips in the center of the screen.
3. If localizing an entire dive, click on the video clip prior to the first one showing the ocean floor. If localizing assigned video clips, use the "Next" button at the bottom of the page as needed to find the assigned clip number. The clips are named with the expedition number, the date the footage was taken, and a T###### sequence number (example: EX1708_VID_20170916**T223000**Z_ROVHD.mp4). Videos will be assigned using the T###### sequence number.
4. Within the video clip, ensure that the proper version is selected. Above the video frame, click on the box with an eye symbol. This will either display a name or "Baseline." If it does not have the right name, click on the button. Within the menu, click "View version" next to your name.
5. Click on the sound button and move the volume up to unmute the audio. Play the video clip, observing the animals and listening to the dialogue of the scientists during the expedition.

6. Under the "Entities" heading to the right of the video, click on the "# Box" button to bring up the expert annotations. If you are familiar with the organisms, proceed to step 7. If you are unfamiliar with the organisms, research them in a provided Animal ID guide. If the organism is not found in these, a Google search from expert sources can be done.
   a. NOAA's Benthic Deepwater Animal Identification Guide V3
   b. MBARI's Deep-Sea Guide
   c. HURL's Animal Guide
   d. Project MINUET's Animal ID Guide
   e. WoRMS (World Register of Marine Species)
7. Starting with the first annotation (underneath the "Grouping, On/Off" option), click on the scientific name. Next, select the "Go to entity's frame" button. This will advance the video clip to the frame that the annotation was made on. Make note of the given individual count
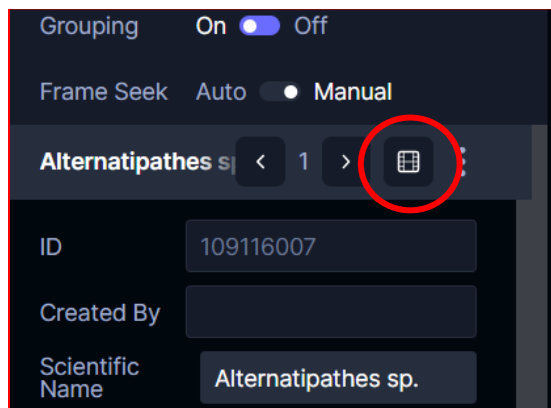
Figure 2. View of the "Go to entity's frame" button (circled in red) within Tator.

8. Look for the organism in the frame. The "Zoom in (+)" button can be used to magnify parts of the screen. To use, select the magnification button to the left of the video. Use the Magnification mouse to click on part of the frame, and pull diagonally to create a box. This will magnify the details within the enclosed box. Additionally, the scrub bar at the button of the video can be used to advance the video.
9. Once the animal is found, click on the redraw button next to the organism's scientific name.
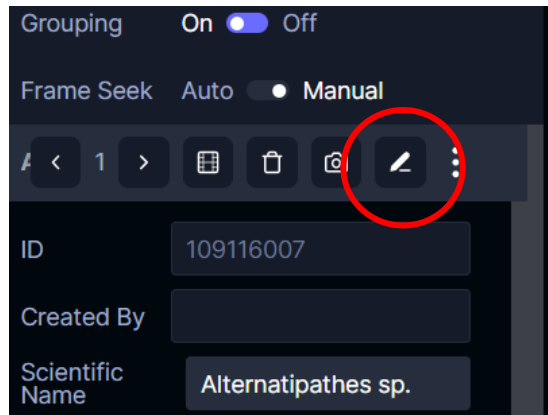
Figure 3. View of the "Redraw" button (circled in red) within Tator.

This will make the mouse a + sign. To make a localization, use the mouse to click on part of the screen to the upper left of the organism. Drag the mouse diagonally to enclose the organism within the box. After releasing the mouse, hold the mouse over the edges of the created box to adjust the box parameters to enclose the entire organism, with a slight gap between the edge of the organism's body and the border of the localization. If the organism is not clear or there is not a complete view of it in the original frame, proceed to step 10. If a clear and entire organism is able to be localized, proceed to step 11.

10. Moving an annotation
    a. Use the scrub bar or the forward and backward buttons at the bottom of the video screen to find a frame with a clearer frame or a more complete view. Make note of the frame number.
    b. Return to the frame with the created localization. Click on the localization to make the box appear white (rather than orange). Use the "Control X" command on the keyboard to cut the localization and annotation.
   c. Use the scrub bar of forward and backward buttons at the bottom of the video screen to go to the noted frame. Note: you cannot play the video to advance the frames when you have cut the annotation.
    d. On the noted frame, use the "Control V" command to paste the localization and annotation on the new frame.
    e. Move and resize the localization as needed to fit the organism on the new frame.
11. Fill out the 'Box Confidence' drop down menu. If you *think* you know what the organism is and were able to draw a box, but are unsure, click the drop down menu for 'Box Confidence' and click 'unsure'. If you are confident that you found the correct organism for the annotation, click 'confident'. If you cannot find the organism at all click 'Couldn't find' in the 'Box Confidence' drop down menu. If there is only one organism noted in the original annotation, continue on through

the video until all expert annotations have been identified. If there is more than one organism noted, proceed to step 12.

12. Annotations with more than one organism in the individual count
    a. For the additional individuals, use the "Box" button below the cursor to the left of the video screen to make new annotations. Click on this button and use the + cursor to make a box around the individual. In the window that appears, enter the Scientific Name, Taxon Rank, and your box confidence then select "save" at the bottom.
        i. Tip: it is helpful to copy and paste the scientific name from the original annotation due to the complex spelling of many names.
    b. Adjust the size and placement of the localization as needed.
    c. Continue to make additional boxes for all of the noted individuals. The arrows near the scientific name and redraw button can be used to determine how many localizations you made in a given frame. If you are unable to localize as many individuals as noted, write "Located fewer individuals than were recorded in Individual Count" in the "Boxer Remarks" for the original annotation. If you localize more individuals than are noted, write "Located more individuals than were recorded in the Individual Count."
    d. If multiple individuals are visible on the same frame, try to make all localizations on that frame.

Instructions for Making Multiple Localizations for a Single Individual

1. In the given video segment, click on the "# Box" button to the right of the video screen. Use the "Go to entity's frame" button to go to the frame with the annotation.
2. After completing the original annotation for the organism, watch the rest of the video clip to determine if there is a magnified view of the organism or a different angle of the organism. Note the frames on which you would like to create additional localizations.
3. If an additional view is found, use the "Edit" button to the left of the video screen to right click on the localization box. Select "Create new Object Track," enter the scientific name of the organism in the relevant field, and click "Save."
4. The "Object Track" menu will now be displayed in place of the "Box" menu, and you will see the "All Object Track" entity that you created. You will also see your object track box on the frame.
5. Right click on the box and select "Set as main track."
6. Move forward in the video and use the redraw button to create additional localizations on the desired frames. You will need to enter the scientific name for each new localization.

Instructions for Creating Annotations for Unannotated Organisms
1. Localize all existing annotations in the segment. After you have done so, watch through the entirety of the segment again with the audio playing. Make a note of any organisms that you don't remember localizing.
2. If you recognize an organism as being the same as one localized elsewhere in the segment, confirm that it does not belong to the same annotation. If there were any annotations for which you felt unsure of your localization, use the animal ID guides listed in previous labs to confirm that you boxed the correct organism.
3. After you have confirmed that the organism is not annotated elsewhere, ID it to the lowest level of classification at which you feel confident. Consider similarities between it and other organisms that you have seen in your dive or in an animal ID guide. It's okay if you can only identify it to the phylum or class level!
    a. Tip: to identify the organism, you may want to start by pulling up the MINUET Animal ID Guide in a new window so you can view the guide alongside it. Scroll through the guide and note any organisms that look similar to yours. Return to those names, ranking them in order of most to least similar; after doing so, identify the organism to the lowest level of classification that is shared by the 3 to 5 most similar organisms. If you need assistance, email your TA with a screenshot of and link to the unannotated organism.
4. Mark your box confidence as "Unsure." In the boxer remarks, write "Marked as unsure per protocol for new annotations."
    a. Tip: it is helpful to copy and paste this phrase to ensure that you always use the same terminology.

Use this google form to report your work before the start of next week's lab.

***The TA will assess your work within Tator.**

Lab 7: Extending to Novel Dive

Assignment
Read the Dive Summary Report for the assigned dive in NOAA expedition 1706. Use instructions from Lab 6 to make localizations for the assigned segments in expedition 1706 (this may need to be updated for future classes). Report your work with this google form.

Adding Names to MINUET's Animal ID Guide
As you work on segments from a new dive, you may come across identifications that are not in MINUET's Animal ID Guide. You should add these names, in addition to a NOAA reference image, to it so that you and your fellow researchers can use it as a reference in the future.

Instructions for Adding Names to MINUET's Animal ID Guide
1. Search the name in one of the other Animal ID guides.
   a. NOAA's Benthic Deepwater Animal Identification Guide V3
   b. MBARI's Deep-Sea Guide
   c. HURL's Animal Guide
   d. WoRMS (World Register of Marine Species)
2. Ensure that you are viewing the "Public Access Copy of MINUET's Animal ID Guide," not the "MINUET's Animal ID Guide" file.
3. Find the phylum in which the name belongs. Scroll to that phylum's section of the guide, and click the "+" button in the upper left corner of the screen to add a new slide.
4. In the "Click to add title" section of the slide, write the name with the classification level noted in parentheses next to it.
5. In the "Click to add text" section of the slide, list the levels of classification between phylum and the name. Do not list levels like suborder, subfamily, superorder, etc.
6. Search the name in google images. Look for a reference image that has been produced by NOAA (see Figure 1 below for an example); if none are available, find an alternative reference image and make a note of it when you report your addition of the slide.

7. Insert the image into the slide for the name.
8. Note the number of the slide. Copy the name and scroll to the spreadsheet on Slide 2 of the presentation. Find the column for the phylum to which the name belongs, and paste the name into the first empty row of the column.
9. If the name belongs to any other classification level than *Genus species*, consult the guide in the first column to find the proper classification code. Write it in parentheses next to the name.
10. Highlight the name and press Ctrl+K. When the dialog box appears, click "Slides in this Presentation," scroll down to the slide you have created, select it, and click "Apply."
11. Click the name and, when the dialogue box appears, click the "Copy link" button.
12. Use the aforementioned google form to report your creation of the new slide. Paste the link to the slide in the designated field.

*The TA will assess your work in Tator

Lab 8: Biodiversity Analysis (non-SCUBA students only)

Sources used:
- University of Dallas' General Biology II Lab Manual

Introduction
In this lab, we are going to explore the ecology of the community observed in Dive 10 by examining the individuals that were localized in terms of their taxonomic class. Community ecology is the study of a group of interacting populations and their relationships with the environment. Biodiversity is the study of variation in the distribution of life on earth; generally, areas near the equator are considered to be more diverse than areas closer to the poles (compare a tropical rainforest to the tundra). This diversity is measured in terms of species richness and species evenness. Species richness refers to the number of different "species" (or other taxon rank, such as family or class) in a sample. For example, a rainforest might have 700 species of trees, while a tundra may only have 40. The rainforest, therefore, has greater species richness. Species evenness is a measure of how many organisms belong to each "species" and how they are distributed in space. Organisms can be uniformly distributed, randomly distributed, or aggregated. However, distribution is not going to be determined by the calculations we will be doing today. Instead, we will work with the species richness and evenness in terms of the number of organisms belonging to each "species." These numbers will be used to calculate the Shannon-Wiener diversity index.

Shannon-Wiener Diversity Index
The Shannon-Wiener Diversity Index is a biodiversity calculation that combines the number of "species" present (richness) with the relative proportion of individuals represented by each "species" (evenness). For the Dive 10 data, the furthest taxonomic classification that all the organisms can be classified to is class. As a result, we will be using class rather than individual species for these calculations. A higher calculated number indicates that there is more diversity (richness and evenness) than a community with a lower diversity index number. This is not always solely dependent on the *number* of individuals in a dive, but largely depends on how the individuals are distributed between classes. Note the biodiversity table for three different dives in NOAA Expedition 1708.

Table 8.1: Example of Shannon-Wiener Diversity Index Calculation

Class Name	# of individuals in Dive 1	# in Dive 14	# in Dive 19
Hexactinellida	91	21	93
Anthozoa	1072	140	2142
Hydrozoa	6	6	22
Ophiuroidea	106	8	102
Asteroidea	9	19	22
Crinoidea	47	45	206
Hexanauplia	43	15	710
Malacostraca	31	28	82
Actinopterygii	5	19	7
Polychaeta	1	13	8
Demospongiae	1	3	1
Holothuroidea	1	4	0
Ascidiacea	0	1	1
Ctenophore (phylum)	0	0	1
Aplacophora	0	1	6
Solenogastres	0	0	5
Gastropoda	0	2	1
Pycnogonida	0	1	2
Echinoidea	0	2	0
Tentaculata	0	1	0
Total Population	1413	329	3411
Shannon-Wiener (H')	0.974508408	2.011194782	1.207755148

As seen here, Dive 14 had the greatest Shannon-Wiener Diversity Index, despite having the smallest total population. This is due to the population being distributed more evenly amongst the classes, rather than being aggregated in a few main classes (as in Dive 1).

The formula for the Shannon-Wiener Diversity Index is $H' = -\Sigma p_i ln(p_i)$. H' is the diversity index. p_i is the proportion of the individuals in a class in relation to the whole

population. This calculation can be performed by using a calculator or by using the provided Google Sheet.

Instructions
1. Download the Dive 10 csv file (will be provided by your CVision contact) with the complete class localizations.
    a. This file has a LOT of information! For ease and the purposes of this exercise, delete the following columns to avoid confusion: media_id; media; thumbnail; user_id; x; y; width; height; and AphiaID.
    b. Insert a column to the left of the Scientific Name column and label it "Class Name."
    c. Under the "view" tab, freeze the top row in the sheet.
2. Scroll across the sheet to the Boxer Remarks column. Delete any row that says "same as XXXXXX." These are your duplicate localizations.
3. Scroll across the sheet to the Confidence column. Delete any row that says "couldn't find." No localizations were made for these annotations.
4. Select the whole "Scientific Name" column. Select "sort sheet by column D, A → Z" under the "data" tab.
5. Go through the entries, consulting the taxonomy guides as needed, and type the class that each individual belongs to in the "Class Name" column.
6. Select the whole "Class Name" column. Select the Sort and Filter button and sort the entries A to Z. Make sure to select the "expand the selection" option.
7. Record the number of entries for each class on the provided spreadsheet. Use the Autosum function to find the total number of individuals in Dive 10.
8. To find p_i, divide the total number of individuals in a class by the total number of individuals in the dive. Record this number in the row entry for that class. Repeat for the rest of the classes.
9. Use a calculator or the spreadsheet to find the natural logarithmic function of the p_i value ($\ln(p_i)$). Record this number in the row entry for that class. Repeat for the rest of the classes.
10. Multiply the p_i value by the $\ln(p_i)$ value for each class.
11. Take the negative sum of the products from step 9 to find the H' value for the dive.

If you are unsure of how to perform the calculations described above, you can reference this Excel Formulas and Functions Tutorial or Google Sheets Formulas Tutorial; timestamps for specific functions can be found in the video descriptions. You can also contact your TA for additional assistance.

Assignment

1. Complete the Shannon-Wiener diversity index calculations for your data from Dive 10.
2. Write a laboratory report in the structure of a scientific paper, which means that it will include the following sections: Introduction, Methods, Results, and Discussion. For more information on what should be included in these sections, see the Laboratory Report Instructions here and at the end of this lab manual.

Labs 9-13: Independent Project Development

SCUBA STUDENTS

Work on online course work and complete dives, both pool and open-water. Dive certification proof in the form of a copy of dive license must be submitted by Lab 13.

NON-SCUBA STUDENTS

Begin independent projects. Work on hypothesis and experimental design and development, collect data, and analyze it.

Final presentation & Lab Reports due for Lab 13.

Structure of Labs 9-13: Non-scuba students used MBARI's VARS database to explore a question of their own devising and create a lab report (example). They then created a powerpoint (example) to use while presenting their research to the class.
Materials: VARS query, MBARI demonstration videos, How-to video for creating pivot tables

Week 1/Lab 9: download VARS query, choose an animal, find animal on VARS on Tator data sheets, expanding and narrowing taxonomic search to get a manageable number of data points, compose a question to research
Week 2/Lab 10: week off to work on data and hypothesis
Week 3/Lab 11: make graphs, finish hypothesis and draw conclusions from results
Week 4/Lab 12: week off to work on Lab Report; draft due for feedback at start of lab
Week 5/Lab 13: lab reports due, SCUBA certification cards due, present research for class

Tator FAQs

When should I move the frame used for an expert annotation?
You should move the frame for an expert annotation when the organism is blurry, partially cut off by the frame, or a better view of it is found elsewhere.

When should I use the tracking tool?
The tracking tool should be used when the camera zooms in on an organism, focuses on and pans around an organism, or when the organism itself moves in space so an alternative angle of it is shown.

How close to the individual count given in an expert annotation do I need to get?
The count is frequently an estimate, and the accuracy of it varies. If there are more individuals—and you are confident that they are not a different animal or attached to a different annotation—box all of them, going as far into the background of the frame as you can while maintaining 100% confidence. If there are fewer individuals, box those that you see. Do not box dead animals or those that are partially cut off by the frame.

What organisms should be boxed?
You should box all organisms that are not dead or partially cut off by the frame; if an organism is annotated, but is always cut off by the frame, you should box it on the frame with the most complete view of it.

For more guidance in identifying and distinguishing between organisms, reference this guide.

Lab Report Guidelines

Introduction

In the introduction you should give background on the **theoretical context** for your project. For example, if you are testing whether biodiversity decreases with increasing depth, you should define biodiversity and explain what other studies have discovered about the relationship between greater depths and biodiversity. The examples you provide should set the reader up to understand what questions and hypotheses you address, and this is where the majority of your citations will exist. Questions and hypotheses should be addressed in the final paragraph of the introduction. The introduction should typically be 500-600 words. You should include 3 or more primary literature citations in this section. You will use the previously discussed citations guidelines to format the in-text citations as well as your literature cited section.

Methods

You will begin this section with a 'system background' section. In the system background section you will provide the biological characteristics and natural history so that the reader has a relevant understanding of the study location(s)/organism(s). For example, if you are asking a question about the density of Keratoisidinae, you would describe that species here.

You will then provide enough detail so that someone unfamiliar with your experiment could easily repeat it. This means that you should be rigorous with being specific here. Provide enough description of experimental setup, equipment used, volumes of substances, description of study animals, etc. You will also provide a paragraph that discusses the process of statistical analysis, if used.

Results

In this section you will do TWO things:

1. Provide a written description that REPORTS the results of the experiment, which should include statistical values. DO NOT describe what you found, only report what you found.

2. Display graphs/tables that show the data collected. These figures should include figure descriptions below that are relevant and help the reader to understand the figure. You should have one table or graph for each section. DO NOT repeat data. This means if you have a graph displaying the data, do not also create a table with the same data.

Discussion

The discussion should begin by summarizing the results that you found. Then, you should go on to discuss the implications of these results. In this discussion you will

again address the theoretical context that you started with in the introduction, providing more studies with which your results either align or conflict. You will also discuss any shortcomings to your experiment. You will finish the discussion with a paragraph that will talk about potential directions that future research could go in. In this section you should have at least three citations and, overall, you should have a *total of 10 citations* in the full lab report. Although the vast majority of your citations will occur in the Introduction and the Discussion sections, citations can be distributed throughout the report as necessary.

Literature Cited
This section will alphabetically list all primary literature cited throughout the text. You will use the citations guidelines provided (see here) for the formatting of both in-text citations and the literature cited list.

Follow this link for the Report Grading Rubric.

Rubric for Independent Project Report

Each category on this rubric has a yes/no option. If the element is included, it will get a check and receive the associated points. If it doesn't, the points will not be assigned for that element.

Element	Included?	Points poss.	Earned
Introduction			
Includes a sufficient amount of background on topic chosen	_____	5	_____
Introduces appropriate background information	_____	5	_____
Narrows down to what the student focused on in this paper	_____	5	_____
Includes proper citations		5	
Methods			
Provides location background/species background	_____	5	_____
Provides detail on where, what, how	_____	10	_____
Provides well-laid out experimental design	_____	5	_____
Results			
Provides a paragraph(s) reporting the quantitative data	_____	5	_____
Provides statistical or other appropriate quantitative analysis	_____	5	_____
Provides at least one graph/table (or more)	_____	10	_____
Discussion			
Provides a summary of results		5	
Provides and explanation of results	_____	5	_____
Provides theoretical background for the results (links to other studies)	_____	5	_____
Provides comparison of data collected to other known work	_____	5	_____
Provides appropriate citations	_____	5	_____
Provides thoughts on future work		5	
Literature Cited			
Provides references in format described in the citations guidelines	_____	5	_____
Provides at least 10 citations of primary lit articles	_____	5	_____
Total Points		100	_____

Dr. Soper's Citation Guidelines

These citation guidelines come from the journal *Evolution*. You can use refworks and add the journal *Evolution's* output style to your reference manager if you so wish, but you should be aware that there are often errors that will need to be corrected. As a result, use of a citation manager should be the start to compiling your references list, not the end. You will need to edit and manage the citations after the bibliography is created. If you need help with refworks, I would suggest going to the library. They are the experts when it comes to citations! The below instructions should be considered the rules for citation and any deviance from this structure will result in a loss of points.

Instructions to Authors on References

Citation to papers by up to two authors in the text should be in full, e.g. (Able & Charles, 1986). If the number of authors exceeds two, the first author plus *et al.* should be used (e.g. Frank *et al.*, 1986). When different groups of authors with the same first author and date occur, they should be cited by using a,b,c, etc. after the date (e.g., James *et al.*, 1986a,b). References should be listed in chronological order in the text, e.g. (Lowe *et al.*, 1986; Able *et al.*, 1997). At the end of the paper, references should be listed in alphabetical order. Names and initials of authors (**up to six**), year of publication, the full titles of papers, chapters and books, **the abbreviated titles of journals**, volumes and inclusive pagination should be provided. Do not include the DOI (digital object identifier) if the journal article is already published within an issue, instead simply state the volume and page range. Do not include the total number of pages of single volume works (e.g. entire books or reports). Multi-authored works should list the first six authors followed by *et al.*

Examples of reference style are given below:

Journal Article

Smith, D.R., Crespi, B.J. & Bookstein, F.L. 1997. Fluctuating asymmetry in the honey bee, *Apis mellifera*: effects of ploidy and hybridization. *J. Evol. Biol.* **10**: 551-574.

Journal Article with more than six authors

Werren, J.H., Richards, S., Desjardins, C.A., Niehuis, O., Gadau, J., Colbourne, J.K. *et al.* 2010. Functional and evolutionary insights from the genomes of three parasitoid *Nasonia* species.*Science* **327**: 343-348.

In Press Journal Article:

Briggs, C.W. 2012. Plumage polymorphism and fitness in Swainson's hawks. *J. Evol. Biol.*, in press.

Journal Article – Online Only (no print copy requires a doi)

Wiens, J.J., Sparreboom, M. & Arntzen, J.W. 2011. Crest evolution in newts: implications for reconstruction methods, sexual selection, phenotypic plasticity and the origin of novelties. *J. Evol. Biol.*, doi: 10.1111/j.1420-9101.2011.02340.x.

Book Chapter:

Lynch, M. 1989. The gauge of speciation: on the frequencies of modes of speciation. In:*Speciation and its Consequences* (D. Otte & J.E. Endler, eds), pp. 527–553. Sinauer Associates, Sunderland, Massachusetts.

Book:

Ridley, M. 1996. *Evolution*, 2nd edn. Blackwell Science, Oxford.

Presentation Proceeding:

Simon, C. 1992. Molecular systematics. In: *Proceedings of First International Symposium on Molecular Techniques in Taxonomy* (J.C. Avise, ed.), pp. 23–34. Denton, Texas, 4–6 November 1992. Springer, Berlin.

References to a paper 'in press' are permissible provided that it has been accepted for publication. The use of 'in preparation' or 'submitted for publication' is not permitted. References to material available on the World Wide Web can be given, but only if the information is available on an official site. Although, websites are typically not utilized in scientific writing unless the information is completely necessary and not published elsewhere. This happened to me when I was writing a paper that utilized techniques for the species *C. elegans* that were only published online and all other journal articles that used this technique cited this website. So, I had to use the following citation, which looked like this:

> Stiernagle T. 2006. *Maintenance of C. elegans* (*February 11, 2006*). In *WormBook*, ed. The *C. elegans* Research Community, WormBook. See http://wormbook.org.

If there is an author on the webpage, cite the author and date of publication as above. If there is no author, then use the following structure: Website name. Date of publication (if available, if not omit). Date of access. Website. *When citing the website be sure to use the most succinct website address possible.

Specifications for Tables and Figures
Tables
Tables should be cited consecutively in the text and numbered with Arabic numerals (Table 1, Table 2, etc.). Each table should be titled and typed double-spaced on a separate sheet. Units must be clearly indicated for each of the entries in the table. Footnotes to tables should be identified by the symbols *, †, ‡, §, ¶ (in that order) and placed at the bottom of the table. No vertical rules should be used.

Figures
Figures should be cited consecutively in the text (e.g. Fig. 1, Fig. 2, etc.) and should be embedded in the text in the approximate area where they are first discussed.

Scientific names
Provide the Latin names of each species in full, together with the authority for its name, at first mention in the main text. Give priority to scientific names in the text (with colloquial names in parentheses if desired).

Units and symbols
Authors are requested to use the International System of Units (SI, System International d'UnitŽs) where possible for all measurements (see Quantities, Units and Symbols, 2nd edn., 1975, The Royal Society, London). Note that mathematical expressions should contain symbols, not abbreviations. If the paper contains many symbols, it is recommended that they should be defined as early in the text as possible, or within a subsection of the Materials and Methods section. In-line equations should be typed as text.

Project Presentation Instructions and Rubric
Underwater Exploration
Spring 2021

Paper Presentation (50 points)

You will prepare a **15-minute presentation** that will cover and explain your project. The presentation will be in PowerPoint format and will be uploaded to the Dropbox on Brightspace by 11:59 the night before your presentation. An absence *for any reason* other than a hospital stay or death in the family on the day you are scheduled to present will result in a zero. If you must quarantine due to COVID, you must attend and present virtually.

You will be graded based on organization, content, and presentation style. See the rubric below for the point breakdown. You should include appropriate visuals (i.e. pictures of the study system, diagram(s) of experimental set up, and previous data collected by others for the introduction & discussion). You will present your project in the same order and with the same content as your written laboratory report.

Rubric for Oral Presentation

	10 points	8 points	6 points	4 points	2 points	Total Points
Content & Clarity	Contains all necessary slides, content is clear on slides as is the explanation	Contains all necessary slides, content could be clearer on slides and in explanation	Contains all necessary slides, but content is fairly unclear & needs more organization	Contains most of the necessary slides, unclear content	Missing many require slides, unclear content	
Scientific Understanding (process & content)	Clearly defines scientific question/hypotheses addressed, critically evaluates data collected, well-thought out experimental design, has an advanced understanding of required	Defines question/hypotheses, evaluated data collected, sufficient experimental design, has a good working understanding of scientific content	Lacks clarity in question/hypothesis proposed, basic evaluation of data, sufficient experimental design, unclear on some scientific content	Poor clarity of question/hypothesis, evaluation of data was nonexistent or weak, weak experimental design, several misunderstandings of scientific content	question/hypothesis missing, data was not evaluated, experimental design was unclear, several misunderstandings of scientific content	

	scientific concepts					
Figures & Visual Aids	Contains, excellent, appropriate figures & visual aids that support the understanding of the content	Contains good visual aids & figures	Contains fair visual aids & figures	Contains poor visual aids & figures	Many places should have had visual aids or figures, but didn't	
Presentation Style; Length	No distracting behaviors, clear explanation, use of appropriate and correct terminology; Is 15 minutes long +/- 2 mins.	No distracting behaviors, good explanation, use of appropriate and correct terminology; Is +/- 3 min from 15 mins	No distracting behaviors, fair explanation, use of appropriate and correct terminology; Is +/- 4 min from 15 min	A few distracting behaviors, poor explanation of material; Is +/- 5 min from 15 min	Several distracting behaviors, poor explanation of material; Is +/- 6 min from 15 min	
Ability to Answer Questions	Anticipates audience questions Understands audience questions Can integrate knowledge to answer questions Thoroughly responds to questions	Has trouble understanding Questions and integrating knowledge to answer questions; leaves some parts of questions unanswered	Answered questions, but with minimal explanation	Did not anticipate questions, didn't understand the questions, attempted to answer, provided incorrect information	Did not answer questions	

Total points accumulated _____