

Training a biologist's mind through an artist's eye

Brett C. Couch¹, Holly Schmidt² and Christine Goedhart³

¹University of British Columbia, Departments of Botany and Zoology, 3156-6270 University Blvd, Vancouver BC V6T 1Z4, Canada

²University of British Columbia, Morris and Helen Belkin Art Gallery, 1825 Main Mall, Vancouver BC V6T 1Z2, Canada

³University of British Columbia, Department of Botany, 3156-6270 University Blvd, Vancouver BC V6T 1Z4, Canada

(bcouch@mail.ubc.ca; Holly.Schmidt@ubc.ca; christine.goedhart@botany.ubc.ca)

Labs, especially organismal diversity labs, serve a major role within a biology curriculum for developing students' observational skills. Labs should train students to be active, iterative, patient, and critical observers; however, students' reliance on cell phone cameras to record observations, lack of patience, lack of practice with observational heuristics, and lack of skills or confidence in making sketches limits development of observational skills. In this lab, we present multiple fine arts-based observational and mark-making activities that focus on the process of observing. These activities are meant to be flexible and modular. For example, individual activities, or parts of activities, can be implemented in specific labs or woven into the structure of an entire course. The activities presented here have been used in both face-to-face and online formats in organismal biology labs at the University of British Columbia (UBC). Activities were also designed to be applicable to diverse types of labs where students make, interpret, or record visual observations, regardless of the specific organismal or disciplinary focus. Many activities involve making sketches as a tool to promote observation because making an accurate sketch requires structured, repeated, and careful observations, as well as the ability to critically evaluate and revise what has been recorded. The focus of these activities is on the process of making observations rather than the product (e.g. a formal scientific drawing), with the aim of helping students become active observers of material in labs and in the world around them using activities that defy the use of technology for recording observations (e.g. cell phone cameras) and require active participation in the process of making, recording, and revising observations. Methods of evaluation for these activities can include simple participation, reflective activities, and evaluation of recorded observations.

Keywords: observational skills, fine arts, organismal biology, microscopy, observational drawing, visual observations, inquiry-based

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Introduction

As a biologist teaching laboratory classes, think about what visual observational skills students develop in your lab classes. What skills do your students need as professional biologists? What skills do students take from the classroom into their lives and careers outside of biology? Before you read on, take a moment to reflect on this question and make a list for yourself.

The specific observational skills students develop are often related to the content focus of the lab, the types of observations being made, the tools for making observations, and how observations are recorded. The types of observations and observational skills that are taught in labs tend to be lab-content specific. Examples of observational skills include: training students to use specific tools and techniques to make and record observations (e.g. microscopes, spectrophotometers, etc.); training students to make observations for the purpose of recognizing or identifying a species or taxonomic group (e.g. bird calls, reproductive structures in fungi); recognizing and identifying cellular features, such as tissues, organs, etc.; identifying phenotypes important for an experiment (e.g. mutant phenotypes, the sex or developmental state of an organism).

The skills required for success in labs are expected to be transferable to the discipline-specific skills required for a professional scientist, but may not be transferable outside of that specific sub-discipline of biology, particularly relevant to daily life, careers outside the sciences, or to train students in observation as a habit of mind.

We aim to make the development of observational skills an explicit learning outcome in labs and have worked to develop visual observation activities that are generalizable to multiple lab environments, regardless of specific lab content, tools, or methods. We realize that there is limited time for development of diverse skills within a given term and the individual lab instructor is best positioned to decide how to balance the discipline-specific needs with more general skill development. Here we provide a selection of activities that can be used individually or integrated throughout an entire course. The activities range in length from 1.5 hours to 5-20 minutes. It may not be possible to utilize all activities presented here, so we encourage instructors to pick and choose activities that best compliment the goals of their specific classes.

We have taken a cross-disciplinary approach to teaching observational skills in biology labs through a highly productive and intellectually exciting collaboration among biologists, educators, a gallery curator, and an artist-in-residence. Members of the group were appointed in the Faculty of Science at UBC (Botany and Zoology), and the Belkin Gallery at UBC (Faculty of Arts). This process was informed and inspired by the use of Visual Thinking Strategies (Yenawine 2013), the use of gallery experiences in medical education (e.g. Friedlaender et al. 2013), approaches to training observation in artists (Nicolaidis 1975), and Holly Schmidt's work as part of her *Vegetal Encounters* (Vegetal Encounters 2021) and artist-in-residence projects at the Belkin Gallery.

In our organismal biology labs, we have identified three major challenges faced by students in developing skills as critical observers: 1) the need to integrate multiple skills and factual knowledge as part of making observations; 2) lab activities that focus primarily on finding and recognizing structures, organs, organisms, etc.; 3) not being required to justify conclusions regarding a structure or organism by clearly linking specific observations to conclusions.

Seemingly simple lab activities often require students to integrate multiple skills and factual knowledge. As experts, it is easy to underestimate the challenges faced by our novice students. Consider a standard activity where students are asked to find and sketch a particular microscopic structure or organism present on a microscope slide. To do this, students must integrate: 1) discipline specific knowledge and skills (e.g. specific terminology, microscope use, discipline-specific drawing conventions, etc.), 2) observational skills (e.g. sorting through the visual complexity and ambiguity of material present on a slide, recognizing a particular structure based on a general diagram from a lab manual, differentiating relevant structures from artifacts), and 3) the use of mark-making or skills for recording information (e.g. making a drawing or sketch, adding notes about a structure). Each of these sets of skills requires practice and the task of integrating these skills can be daunting if students lack practice or proficiency with one or more components. To address this challenge, our activities begin with practicing observational skills in isolation and using drawing or model-making as tools to develop observational skills. Throughout the term, our students have regular practice developing skills and heuristics that can be increasingly integrated with discipline-specific knowledge, other skills (e.g. microscopy), formal drawing, and use of descriptive language as tools for recording observations.

Labs that are focused on finding and recognizing structures or organisms can result in a scavenger-hunt approach to training observers. In this case, students are asked to find particular structures, such as those important for identifying taxonomic groups, so they learn to recognize them. This is an important component of learning about and categorizing organismal diversity, but also provides a strong incentive for students to simply record a structure or organism by taking a picture with a cell phone so that it can be memorized. If lab activities only focus on recognition, the development of observational skills, inquiry, curiosity, and the practice of supporting conclusions with specific observations are likely short-circuited. Ideally, students should be able to: find and recognize important structures or features of an organism, be curious about the material they are observing, be able to notice relevant details other than those that are assigned, and to deal logically and critically with unexpected or new observations. We want students to be able to link observations to previous knowledge, support conclusions with observational evidence, and recognize when what is observed does not fit with previous knowledge. Rather than students asking

“What is this?” or “Does this look right?” students should be stating “I think this is a nucleus because of these features....” or “I am not sure if this is a nucleus because.....”

In these lab activities we begin with a think-aloud arts-based observation activity and then present a series of additional activities where students will practice specific observational, descriptive, and mark-making skills that can be interspersed through a lab course and easily adapted to support different organismal content.

In this paper, we present a variety of activities that we developed and have used in mycology and eukaryotic microbiology labs at the University of British Columbia (UBC). We realize that lab courses vary in organismal and disciplinary focus, as well as the time available to incorporate skill-building activities. As a result, we have designed the activities to be modular so that instructors can pick and choose activities most suited to their particular situation, and adaptable to different organismal groups or disciplines.

Student Outline

Objectives

Practice a set of basic heuristics for making, recording, and communicating visual observations.

Practice making, refining, and critiquing visual observations.

Use warm-up activities to prepare for sketching exercises.

Use a variety of sketching techniques to practice and develop skills at making visual observations.

Reflect on the observational skills that you will require to be successful in your laboratory class, how you will develop these skills, and identify the value of these skills to you.

Introduction

“The more you look, the more you see.” (Pirsig 1974)

“To pay attention, this is our endless and proper work” (Oliver 1994)

The theme of the lab is building observational skills that will be important for your success in this lab and in other biology labs where you need to make visual observations. In your lab classes, you may be asked to use tools like microscopes to make observations, identify organisms, recognize cellular structures, and describe the behaviour of organisms. All of these skills are important, but can't happen without first making careful observations.

Beyond the discipline-specific skills, knowledge, and tools important for various labs, our objective is for you to emerge from these activities with scientific observational skills as a habit of mind - making visual observations and explicitly linking these observations to conclusions. As a biologist, you should finish your undergraduate degree as an active, iterative, focused, patient, interrogative, careful, and critical observer of the world, not a passive recorder of the world through the lens of a cell phone camera or reliant on others' interpretations of sensory information. These activities will be a start on this journey.

Verbalizing, discussing, comparing, and recording visual observations are important activities for developing your skills as observers. In labs, you will be practicing these skills, including skills needed to make sketches, diagrams, and simple three-dimensional models of organisms and structures that you observe. We do not expect you to be an artist, and being skilled at sketching is not a prerequisite for this course; sketching is one tool you will use to help develop your skills as observers and record information. To verbally describe an organism, sketch an organism, and create a simple model or a written description requires you to slow down and pay attention to observing - the more you look to make and record observations, the more you will see. In labs, we will be emphasizing the process component of observation. The more you embrace the process, the more you will get out of the lab experience.

Methods

Part A: Pre-Lab Questions

Read the following statement. Then in your notebook, respond to the questions that follow.

In the media, scientists, doctors, and detectives are portrayed as having one characteristic in common; they are active, interrogative, meticulous, and critical observers. Although the portrayal of these individuals in the media is not always accurate, it reflects the reality that observational skills are central to a variety of disciplines.

A fundamental skill for a biologist is being a good observer. Careful observation is critical for a variety of activities: collecting data in the lab and in the field, analysis of data, troubleshooting of experiments, development of hypotheses, identification of phenomena of interest, and the list could go on and on. A major goal of this course is to support development of your observational skills. To get you thinking about the importance, development, and challenges of making observations and developing your skills as an observer, please write down your thoughts on the following questions in your lab sketchbook.

The depth of your responses to these questions is up to you; however, this activity is important for you to plan your experience in this lab. This can be done in paragraph form, as a list, or as diagrams. You will need to submit images of your responses to receive participation credit for this part of the activity.

To create a single document that is a chronological record of your experiences in this course, your pre-lab questions must be handwritten in a bound lab notebook.

- 1) What do you think it means to be an active, interrogative, meticulous, and critical observer?
- 2) What are the most important goals that you want to achieve by the end of the lab?
- 3) What do you think will be the main challenges in achieving your goals in the lab?
- 4) Do you think the skills you develop and practice in the lab will be an important part of your undergraduate degree? Briefly explain why or why not.

Part B: Directed Looking

Your instructor will lead you through an activity where you will observe a painting and address three basic questions: 1) What do you see? 2) What makes you say that? and 3) What else do you see? In this activity you are not being asked for the meaning of the painting nor the intent of the artist. This activity is focused on slow looking, description of what you see, and using evidence from observations to support conclusions about what you see. You do not need any specific materials for this activity but are welcome to make notes on the responses from the class or your own observations.

Part C: Warmup and Sketching

Your instructor will lead you through a series of activities. For these activities you will need blank paper or a notebook with blank pages (~8.5X11"), a pen, pencil, and large-tipped marker. The warmup activity is intended to provide some practice in basic skills of mark-making (i.e. the creation of different patterns, lines, textures and shapes using tools like pens and pencils) to help you mentally transition to sketching activities. Just like warming up before exercise or playing an instrument, it helps to warm up before sketching. After the warmup activity, you will be introduced to a variety of approaches for making sketches that will help you contrast different temporal pacing of making and recording observations, as well as focusing on observations of general structure to fine features. Some of these will be fast sketches, some will be slower. Remember, the purpose of this exercise is to train you in different approaches to making observations; making sketches is a tool to train your mind.

Part D: Critique of Directed Looking and Sketching Activities

A critique is defined as a detailed and analytical evaluation. Here you will provide a reasoned evaluation of your experience at the Belkin Gallery. The term critique often implies negative criticism; however, an analytical evaluation will consider positive, negative, and neutral evidence in an evaluation. The critiques will be graded on completeness and argument quality (see rubric below, Appendix B).

The purpose of this activity is for you to provide an honest, reasoned critique of the activities in parts B and C. A critique that is negative, well supported, and shows significant insight can receive full marks for explanation and completeness; a critique that is entirely positive but poorly supported or superficial may receive full marks for completeness but only partial marks for explanation. There is not a specific word limit for the questions; the expectation is that one to two paragraphs per question should be sufficient, but more are acceptable.

A basic argumentation model that you can use in your critiques is the Claim, Evidence, Reasoning (CER) model. A claim is a logical statement that can be defended with evidence and reasoning. Generally, a claim must be stated in a complete sentence. Data, trends, or pieces of information, observations, or even thoughts or emotions can become evidence when they are used to support a particular claim or to corroborate one's reasoning steps. A good argument should also consider contrary evidence that refutes the claim. Reasoning provides the logical connection between the evidence (both supporting evidence and contradictory evidence) and the claim. Reasoning explains how you arrived at your claim by explicitly describing and justifying the logical steps that you took and how certain data or information (evidence) support your claim. A strong argument considers conflicting evidence (i.e., information that by itself contradicts your claim) and includes reasoning to address why

your claim is supported, even considering contrary evidence. If you need more information on the CER model in the context of the types of questions below, please see: <https://itslitteaching.com/cerwriting/>. Another good, detailed writing resource for argumentation is: <https://writingcenter.unc.edu/tips-and-tools/argument/>.

- 1) What were the positive and negative aspects of the experience for you? Briefly explain what made the particular experiences positive or negative for you. (5 marks completeness)
- 2) Using your pre-class reflection as a guide, did this experience contribute to developing an observational skill or skills that will be important for achieving your goals or overcoming anticipated challenges in the labs? Support your answer with evidence (e.g. what you did and thought during or after the activity) and describe your reasoning. (5 marks completeness; 5 marks explanation)
- 3) Why do you think the instructor included this activity in the lab? Support your answer with evidence (e.g. what you did and thought during or after the activity) and describe your reasoning. (5 marks completeness; 5 marks explanation)
- 4) Upload a picture of your favourite drawing or page of drawings that you did during the activity.

Part E: Iterative, Hierarchical Observing and Descriptive Language

Your instructor will lead you through a series of activities beginning with a short video. For this activity, you will need blank paper or a notebook with blank pages (~8.5x11"), three different coloured pencils, a pen, a graphite pencil, and an eraser. A list of descriptive terms is provided below. At this point, don't worry if you don't know the definitions for all terms, you can look them up later.

Cellular Structures and Processes	Shapes (Two Dimensional)	Shape and Form	Forms
Chloroplast Cilium Contractile Vacuole Flagellum Food Vacuole Meiosis Mitosis Nucleus	Circular Elliptical Fusiform Oblong Square Triangular	Geometric Irregular	Conical Cuboid Ovoid Spherical Pyramid / Pyramidal

Textures	Relative Terms	Colour and Interactions with Light	
Bumpy Fibrous Granular Glossy Irregular Perforated Reticulate Ridged Rough Scaly Sharp Striated	Asymmetrical Elongated Symmetrical	Bright Deep [as a description of colour] Gradation Hyaline Opaque Refractile Rich [as a description of colour] Translucent [as a description of colour] Vibrant [as a description of colour]	

Description of Arrangements of Objects in Space	Description of Lines, Edges or Shapes		
Adjacent Agglutinated Aggregate Aperture Benthic Chain(s) Dense Diffuse Occluding Overlapping Parallel Solitary	Coiled Curved Segmented Tapering Thick Thin Uniform Undulating		

Part F: Three-Dimensional Thinking and Model Building

Your instructor will lead you through an activity where you will watch a series of videos of microscopic structures found in a sample of pond water used to cultivate aquatic plants. When you are viewing the videos you should be considering the following questions.

- 1) Are these living organisms, parts of an organism that has died, or nonliving material? Briefly describe why or why not.
- 2) If these structures are from a living organism, do you think they are from the same organism?

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Oliver M. 1994 Yes! No! In: White Pine: Poems and Prose. San Diego (CA): Harcourt Brace.

Materials

Training

If you would like help implementing these activities, would like to see the activities modelled, or would like help training your lab instructors, please contact the first author, B. Couch (bcouch@mail.ubc.ca)

Part A Pre-Lab

Instructors should decide if the pre-lab is submitted for participation credit or not. This activity is meant to set up student reflections on the directed looking activity. Assigning this activity for credit (other than participation) is not recommended.

Part B Directed Looking

For the directed looking activity, instructors can use a high-resolution image of the painting “Carnival at New Hope or the Agony to Be Loved” (Russell FitzGerald 1961, oil on Masonite) and project the image for the class. Distribution of the image and use for this activity has been granted by the copyright holder, Dora FitzGerald. The high-resolution photo is available in the supplemental materials. If possible, it is preferable to have students view a physical artwork in a gallery setting. For institutions that have galleries on or close to campus, we encourage you to contact the curators and work with them to identify appropriate works for your class. Although it is tempting to choose artwork that relates to lab content, the focus of this activity is to practice observational skills, separate from course content.

Part C Warmup and Sketching

Instructors will need to collect subject material for sketching. The subject should be somewhat familiar to the students and complex enough to provide some challenge. Materials like leaves and pine cones work well. It is not necessary to have materials that are directly related to the subject material for the specific course, as the activity is about developing observation habits, not learning about specific organisms or groups of organisms. It is not advised to include discipline-specific material at this stage.

Students will need to bring or be provided with plain paper or a bound notebook for drawing (~8.5 x 11”), graphite pencil (HB, equivalent to #2 pencil in US), three or four distinctly different colours of pencil crayons (aka. coloured pencils), eraser, ruler, a blunt felt marker (any colour, for writing on paper such as a basic Sharpie® marker [not fine tipped], a highlighter, or any felt tip marker will work, the blunter the tip the better!), and a pencil sharpener. Students can bring extra colours of coloured pencil and markers if they choose.

Part D Critique of Directed Looking and Sketching Activities

Students can complete and submit this portion of the activity at the discretion of the instructor. The grading rubric is attached in Appendix B.

Part E Iterative, Hierarchical Observing and Descriptive Language

Students can complete and submit this portion of the activity at the discretion of the instructor. Grading should be participation only. Students will need to bring or be provided with plain paper or a bound notebook for drawing (~8.5 x 11”), graphite pencil (HB, equivalent to #2 pencil in US), three or four distinctly different colours of pencil crayons (aka. coloured pencils), eraser, ruler, a blunt felt marker, any colour, for writing on paper (e.g. a basic Sharpie® marker [not fine tipped], a highlighter, or any felt tip marker will work, the blunter the tip the better!), and a pencil sharpener. Students can bring extra colours of coloured pencil and markers if they choose.

Part F Three-Dimensional Thinking and Model Building

Students can complete and submit this portion of the activity at the discretion of the instructor. Grading should be participation only. Students will need to bring or be provided with: plain paper or a bound notebook for drawing (~8.5 x 11”), graphite pencil (HB), and modelling clay or Play-Doh.

Notes for the Instructor

Part A: Pre-Lab Questions

The pre-lab activities can be collected or submitted and graded for participation.

Part B: Directed Looking

This type of activity works best if it can be done outside of the lab, ideally at a gallery or some type of non-lab space. The idea here is to provide students with an immersive experience outside of their normal comfort zone and without the pre-conceptions they may have associated with lab spaces. In this activity, students will be observing an artwork such as a painting (other types of works can be used), however, large format paintings likely work best for this activity. Large works allow a group of students to view the work without being too crowded. Have students gather around the painting. Encourage them to look close up and at a distance. Initiate a process of close observation by asking - “What do you see?” Students will verbally identify a range of elements in the painting. Some may focus on formal elements such as lines, colours, and shapes, others on figurative aspects such as a bird, cloud, or person, while others may leap to interpretations based on narrative or emotional responses. The instructor's role is to facilitate a process of close looking by first paraphrasing students' observations and following up with the prompt - “Why do you say that?” This is an invitation to seek evidence to support their observations, while also articulating their observations with greater precision. The instructor or facilitator should push students (as appropriate) to justify their statements with specific observations. As observations are shared collectively and observational evidence is discussed, the instructor then extends and deepens the period of observation by asking - “What else do you see?” The duration of time spent looking closely leads to additional observations, often building on the observations of others. This activity should not be rushed. The instructor should budget on 20-30 minutes (or longer) for this activity. Students should be encouraged to take time to observe. Students are often surprised by the complexity of the painting and what they didn't notice at first glance. It's important for the instructor to make them aware that there isn't a “right answer” to the painting. Interacting with the painting is an invitation to look and respond. In our context we used the painting “Carnival at New Hope or the Agony to Be Loved” (Russell FitzGerald 1961, oil on Masonite). This painting was chosen specifically by the curator at the Belkin Gallery for its visual complexity and ambiguity in interpretation.

Part C: Warmup and Sketching

Students without drawing experience can fully engage with these drawing exercises. The emphasis is on drawing as a process for looking, not creating perfect drawings.

The first exercise is what is known as a gesture drawing. This is a common warmup activity in art classes and is also an important exercise for developing specific observational skills. Gesture drawings are done quickly (anywhere between 10 seconds and a couple of minutes) with the intention of capturing movement and/or form of the subject being drawn. It is a rapid recording of a first visual impression. To introduce gesture drawing, instructors can demonstrate a 20 second drawing of a subject, such as a pinecone. Then the instructor can time a series of 20, 30, and 40 second drawings. Following the drawings, the instructor prompts verbal reflection on the experience of gesture drawing. Students may notice that their drawings are messy or lack detail because they were done so quickly, but the basic form is present. These quick sketches will become the foundation for more considered observations captured in further drawings. If you would like a more detailed explanation and demonstration of gesture drawing, there are many good videos on YouTube.

The next exercise is a blind contour drawing. A contour drawing focuses on the contour or outline of the subject. With a blind contour, the drawing is made looking only at the subject and not at the drawing itself. Students are often tempted to look at the drawing, so it is best if they cover the drawing hand with a sheet of paper. This drawing takes a couple of minutes, and students are encouraged to put their felt marker on the page and not pick it up so that their drawing is one continuous line that captures a slow visual journey around the subject. This drawing often produces a lot of humour and helps students to release some perfectionist tendencies that can become obstacles when recording what they observe. With some guided verbal reflection, students can make observations about this process and what they noticed about their own experience. Through reflection, the instructor can introduce the importance of attending to what we see, not what we think we see, when recording our observations.

Following the blind contour, students are invited to use their phone cameras to take a zoomed in photo of a leaf. This image is then used as the subject for a “zoomed” in drawing. This drawing takes that small section of a

leaf or pinecone and expands it to fill the entire page of the sketchbook. The lines of the leaf should spill over the edges of the page. This is a more sustained drawing, taking up to 10 minutes. Students are asked to capture as much detail as possible. After completing the drawing, the instructor has students lay their sketchbooks down. Students are then asked to walk around and look at each other's drawings. They are asked to reflect on the similarities and differences in the drawings, the uniqueness of line quality, and level of detail captured.

Part D: Critique of Directed Looking and Sketching Activities

Even if the activity is not graded, it is worthwhile reviewing students' responses to identify if they found the activity valuable and what they found useful about the activity. This could be paired with an end of the term reflection about the experience of the lab.

Part E: Iterative, Hierarchical Observing and Descriptive Language

The purpose of this skill-building activity is for students to practice a structured approach to quickly make and record observations going from general to specific, and revising or refining observations by repeated looking. Emphasize that this activity is about the process, not the product (drawing); by design, the product will be messy. For this activity, you can use the video provided or any video or image of your choice. This activity can use material that is discipline- or lab-specific, but students should not have previously seen the material or diagrams of the material to avoid having them draw what they remember, rather than what they see. Play the video "BeatyPondDiffugia BF PC20x2" (available through YouTube <https://www.youtube.com/watch?v=EZ49Cm4Cm54>) at 0.5x speed. Students should focus on the large object in the middle of the field of view (a cell of *Diffugia* sp.). Instruct the students that the first time through the video they should just watch and not make drawings or notes. Instruct the students to think about the questions from Part B (What do I see? What makes me say that? and What else do I see?). Play the video. Afterward, instruct students to get a coloured pencil and a new page for drawings and notes. Give students 30 seconds to make a quick sketch of only the general shape of the organism from memory. Remind them that the drawings are fast, like the gesture drawing, so it will be a bit messy – that is ok! Tell students to change the pencil colour. Then play the video again and have students refine the first drawing by drawing over the first drawing and making any necessary corrections. The use of different colours provides a record of their observational process and refinement of recorded observations. The new lines should better reflect the shape of the organism. Tell students to change the pencil colour to a new colour. Instruct students that in this final view they will add any additional details they think are important. Play the video again and stop briefly (max 30 seconds) if they request more time.

Tell students to look at the list of terms in the lab manual and add descriptive terms to their drawing (they can use terms not in the list, but should not take time to look up terms). If you have chosen another video or image, you will need to customize the list of terms. Like adding labels to a formal drawing or sketch, instruct students to use arrows to indicate where a descriptive term applies. Instruct students to partner up and discuss the features that they incorporated into their drawing and explain why they chose particular terms to describe the organism or structures.

At this point in the lab, students likely want feedback on what they have seen. The instructor should show the video again and point out features of the organism. An annotated image of *Diffugia* and description of the major features shown in the video are provided in the appendix.

At the end of the activity, remind students about the process of observation. They looked first then made a general sketch. They looked again and refined the general sketch. They looked again and added details. Finally, they incorporated descriptive terminology to compliment the information in the drawing.

If the instructor chooses, this activity can be extended to include a model building component following the instructions for Part F.

Part F Three-Dimensional Thinking and Model Building

The purpose of this activity is to get students to think about organisms or structures in three dimensions. This is particularly important for activities where students are making observations using a microscope, since they can only view optical slices through a structure using microscopy.

Have students get out pencils and paper for drawing. For this activity, you can use material specific to your lab or the videos provided. Students will watch a series of videos and make sketches of the organisms they view. Each of these videos show a different part or view of Desmids from pond water. The video "Desmid 3D Thinking 1" (available through YouTube <https://www.youtube.com/watch?v=5olgdx-VXQ>) shows a dead cell with only the cell

wall remaining. The cell is composed of two semi-cells that are shaped like beans and are connected by an isthmus that looks like a little port-hole between the semi-cells. The surface of the cell wall is slightly textured.

The video “Desmid 3D Thinking 2” (available through YouTube <https://www.youtube.com/watch?v=23nJM1eEylw>) shows another dead cell from a different view with only the cell wall remaining.

The video “Desmid 3D Thinking 3” (available through YouTube <https://www.youtube.com/watch?v=pWGSa4oMDXQ>) shows a living desmid. The chloroplast and vacuoles are visible in this cell. The nucleus generally sits within the isthmus connecting the semi-cells but is not clear in this video.

The video “Desmid 3D Thinking 4” (available through YouTube <https://www.youtube.com/watch?v=0ok3WbG7gPU>) shows a dead cell with only one intact semi-cell. The two semi-cells have become detached and the circular isthmus connecting the semi-cells is visible.

Once students have drawn each of the views, the instructor should lead a discussion on whether or not these are living and if they are the same organism or parts of the same organism. All of these videos show different aspects of the same organism from broken semi-cells with only cell walls, to dead cells with intact cell walls to a living cell.

Students should then be instructed to make models of the cell using modelling clay.

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About the Authors

Dr. Brett Couch is an Associate Professor of Teaching in the Departments of Botany and Zoology at UBC and has developed labs for Eukaryotic Microbiology and has run a variety of organismal biology labs (eukaryotic microbiology, fungi algae, and bryophytes and mycology) over the past 10 years.

Holly Schmidt is the artist-in-residence with the University of British Columbia Outdoor Art Program, with the Morris and Helen Belkin Art Gallery. Her work focuses on human relationships with the natural world.

Dr. Christine Goedhart is Science Education Specialist in the department of Botany at UBC and has worked on diverse projects in course development and assessment.

Appendix A

“Carnival at New Hope or the Agony to Be Loved” Russell FitzGerald 1961, oil on Masonite. Low resolution image. A high resolution image is available in the supplemental materials.



Appendix B

Grading rubric for Critique of Directed Looking and Sketching Activities

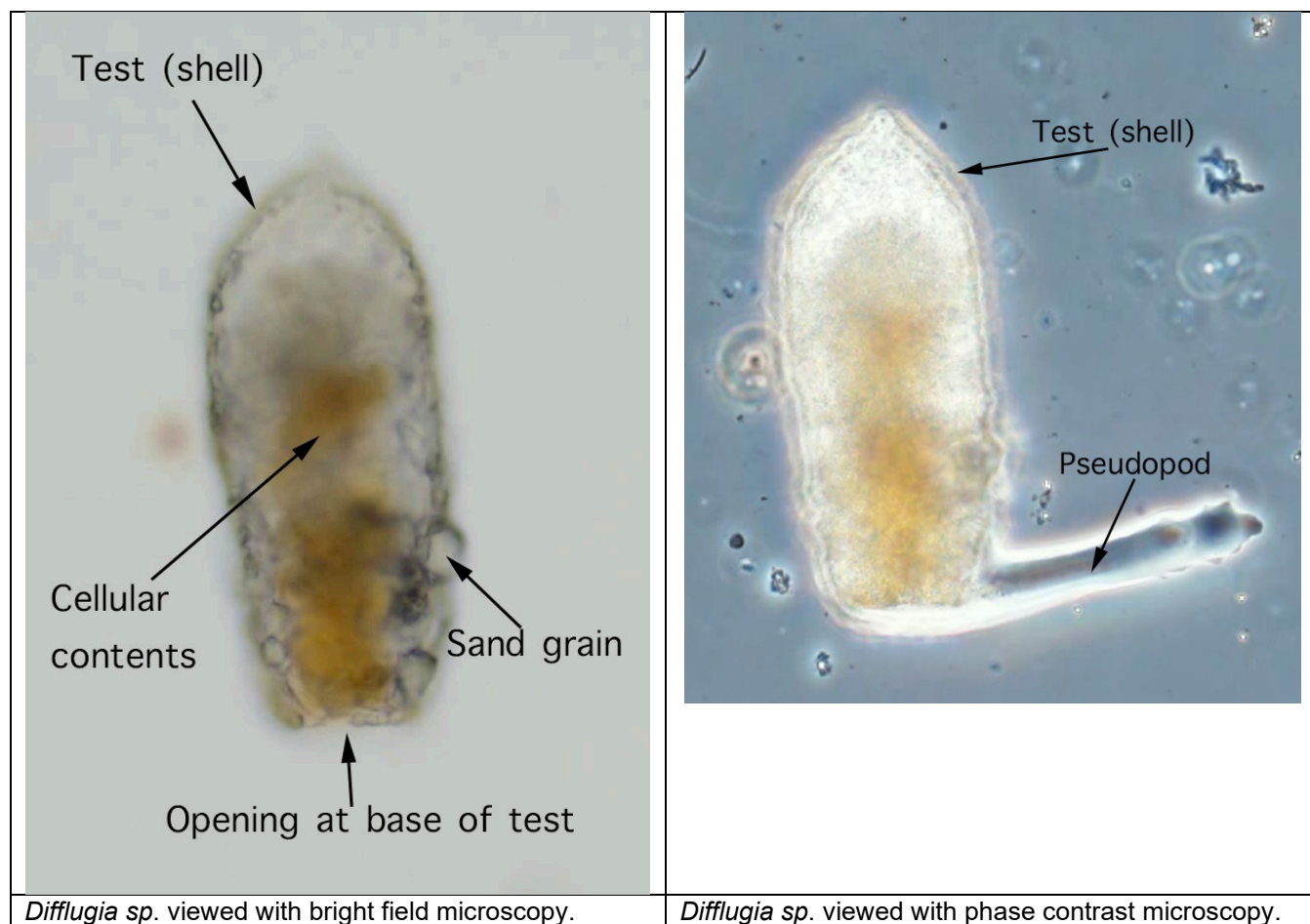
	0	3.0	5.0
Completeness	Not completed	Writing prompt only partially addressed; some components missing (e.g. explanation was lacking).	All parts of the question were addressed.

	0	2.5-3.25	3.75-4.5	4.75-5
Argumentation	No evidence or reasoning provided.	Claim clear. Evidence and reasoning present; evidence does not support claim and/or evidence not logically connected to claim; reasoning not logical / confusing or does not support claim; grammatical errors or writing style interferes with the ability to understand the evidence or reasoning.	Claim clear. Evidence and reasoning present; evidence generally supports claim. Reasoning generally logical and connects evidence to claim. May have some unexplained logical connections. Evidence of some insight, introspection or reflection.	Claim clear. Evidence and reasoning present; claim is well supported by evidence and evidence is clearly connected to claim. Significant insight, introspection or reflection on the part of the writer.

	2	1	0
Sketch From Sketchbook	Submitted and image clear.	Submitted but image is not clear and would be difficult to evaluate due to shadows, lighting etc.	Not submitted.

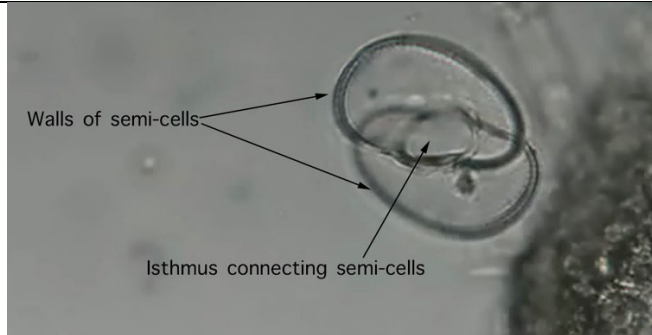
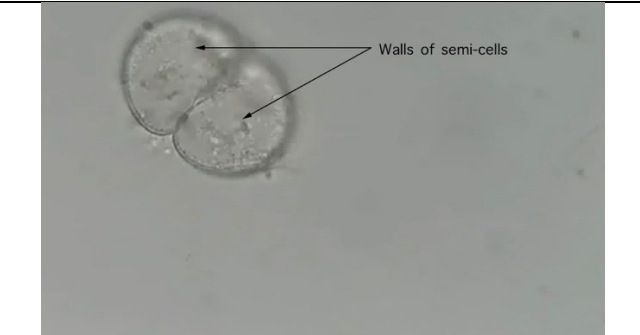
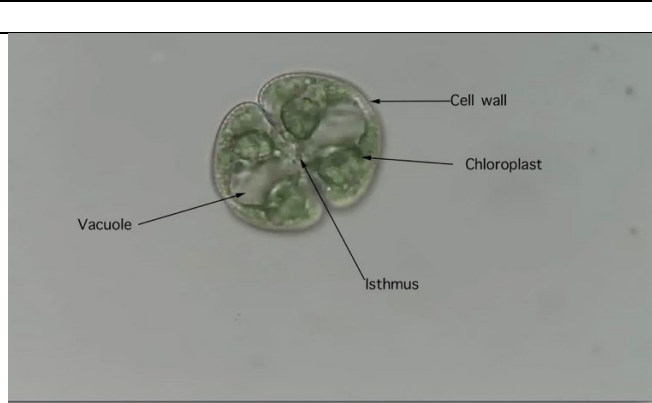
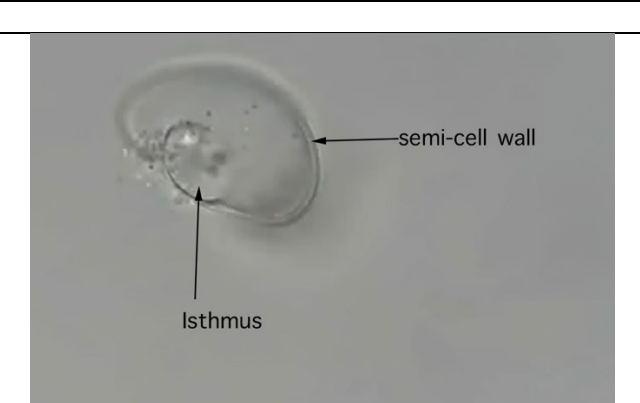
Appendix C

The video "BeatyPondDiffugia BF PC20x2", shows a microscopic image of a testate amoeba, *Diffugia* sp. A test is an external shell. In this species the test is composed of sand grains that have been stuck together. Throughout the video the focus is adjusted up and down through the cell so the viewer can see the entire organism. In the first part of the video, the organism is viewed with bright field and then the optics are changed to phase contrast to view pseudopods extending from the test. The major structural features of the organism are shown in the figures below.



Appendix D

The videos “Desmid 3D Thinking” show microscopic images of a freshwater desmid, *Cosmarium* sp. found in a tank for maintaining aquatic plants in the UBC Department of Botany greenhouse. Videos #1, #2 and #4 show cell walls from dead cells and video #3 shows a living cell. Throughout the videos the focus is adjusted up and down through the so the viewer can see the entire structure. The major structural features of the organism are shown in the figures below.

	
<p>Image from “Desmid 3D Thinking 1” showing cell walls of a dead desmid cell. The two bean-shaped semi-cells and the circular isthmus connecting the semi-cells are visible in this view. Small pores are visible in the cell wall and appear as tiny lines through the wall.</p>	<p>Image from “Desmid 3D Thinking 2” showing cell walls of a dead desmid cell. The two bean-shaped semi-cells are visible in this view.</p>
	
<p>Image from “Desmid 3D Thinking 3” showing a living cell. The nucleus is located at the isthmus connecting the semi cells but is not visible in this view.</p>	<p>Image from “Desmid 3D Thinking 4” showing a cell wall of a dead desmid cell. Only a single semi-cell is present in this view.</p>

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