

Biology 125 Lab Manual

2023-03-21

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Welcome

To your Biology 125 Labs!

First, a few important and relevant links...

- Canvas course shell
- Syllabus

Second, some key pieces of information for how labs will be run this term...

The following pages detail how labs, assignments, and absences will be handled. In addition to the content here, the lab manual, assignments, quizzes, and additional resources are all supplied on Canvas so take some time to look over the information.

If in doubt about course policies, refer to your syllabus or talk to your TA. To get started read through your course syllabus and the lab manual.

Above all, have fun this term and enjoy the process of science!

Sincerely,

Dr. Tristyn Hay

Labs

Labs will be alternating between on-campus and online, with online labs being conducted in Zoom during your regular scheduled lab section. In order to be successful this term please pay attention to your syllabus where you can find your schedule, mark breakdown, missed lab policy, and all lab requirements for your BIOL125 lab. You will need the information found in this syllabus to be able to answer the Introductory Quiz on canvas. Students will not be excused of any missed or late assignments due to being "unaware" of these policies so be sure you reference this information often.

In your first lab you will have the opportunity to meet your TA and the other students registered in your lab section. There will be some accompanying materials in Canvas. This week will be a very important week as you will have your partner assigned to you and will be setting up for an experiment. For in-person labs, it is vital that you attend the lab for which you are registered - check your registration online to be sure of where you are supposed to be!

During the synchronous labs you may bring a lab coat but this is not required. Closed toed shoes and pants are required for this lab and your TA will turn you away if you are not in proper attire. Any goggles and gloves will be provided in lab.

Assignments

See Canvas for due dates.

All assignments, even those worked on as a group, will need to be submitted individually unless directed to do so by your TA.

Failure to submit an assignment will result in a mark of 0 for that assignment. No exceptions!

Please be sure you have not only submitted assignments on time but that you have double-checked they have been uploaded properly.

Absences

Pay attention to your absence scores - see syllabus for details. Students receiving an absence score over 5 will fail the lab. This applies to both on campus and online assignments. If an assignment is not submitted it counts as an absence. Excused absences get a score of 1 and unexcused a score of 2.5.

Absences can only be excused by myself (Dr. Hay) and not your TA.

Copyright

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Please use the following for citing this document

Hay, T., Vis-Dunbar, M. (2021). *Biology 125 Lab Manual*. <https://ubco-biology.github.io/BIOL-125-Lab-Manual/>

All source files are available <https://github.com/ubco-biology/BIOL-125-Lab-Manual>.

UBCO Biology open materials

This resource is part of a larger project to host UBCO Biology lab materials in an open, accessible format.

All BIOL open materials can be found at <https://ubco-biology.github.io/>

Conventions

Information relevant to lab logistics and grading.

Further insights or notes on presented materials.

Highlights and key take aways.

Optional material that dives deeper into a presented concept.

Lab 1

Welcome

Last updated 2023-03-21

Welcome to your first Biology 125 Lab for Biology for Science Majors II!

For your first week your TA will spend a bit of time going over the lab schedule and mark breakdown, along with some safety information you will need to work in this space safely and professionally. Your TA will then get you going on your first project!

Your TA will provide you with their contact information along with office hours and location. It is your responsibility to ensure you have this information readily available.

Your first project

After this brief introduction you will get into pairs - with one group of 3 in uneven class sizes - and your TA will assign you and your partner(s) an environmental problem in which you both will be spending the better part of the term trying to work through.

But first...



Did you know this little guy is actually real??? Anyone guess what these guys are called?

If you have a guess send me an email at trisyn.hay@ubc.ca or feel free to just say hello.

Research Project: Part 1

Study protocol

This research project will have you looking at specific environmental features - climate, exposure, chemistry - to answer a pretty practical real world problem: will a piece of arable land support the cultivation of a specific crop.

You will be expected to design a study, collect data and report on your findings. You will be recording your data and authoring your report following Open Science best practices, namely, ensuring that your work is transparent, reproducible and well documented.

In this lab, we'll be introduced to the problem, explore how to propose a research question to address the issue and scope out a study design that includes what data we'll need to collect, how we'll organize that data, and how we propose to analyze that data. You'll also get things set up to run your first experiment in Lab 3.

Your assignment will be a protocol, detailing the above.

Meet Elliot

Farmer Elliot is looking to acquire a 20-acre farm to grow mung beans. Farmer Elliot has some basic knowledge of farming as he did some residential gardening in the city and thus understands the basic requirements of plants but has limited knowledge of growing mung beans.

You might be asking why Farmer Elliot is pursuing this when without the needed knowledge ahead of time? Let's just leave it as Farmer Elliot is a "act now think later" kind of person.



Figure 1: Elliot. The character behind the farmer. Find more pics of Elliot in your syllabus!

Finding property

In order to start their search Farmer Elliot has enlisted the help of a real-estate company - "llamaste Realty". Their real-estate company has shown them three properties thus far.

Property 1



Figure 2: Property 1.

This property has 19-acres of flat usable land and is situated next to the base of a large mountain. This land comes with fully automated irrigation and a small one-bedroom home. Though this land is start up ready, Farmer Elliot is concerned that the property may not have enough hours of sunlight due to its proximity to the base of the mountain.

In order to help determine if this is a viable option for their mung bean farm, Farmer Elliot will need to know how many hours of sunlight is required for optimum mung bean germination and growth.

Property 2



Figure 3: Property 2.

This property is 21 acres large with 3 acres designated to residential space and the remaining land is usable agricultural acreage. Running parallel to the longest section of this property is a small alkaline lake. Farmer Elliot has been informed that the adjacent alkali lake has, on average, a salinity concentration ranging from 0-5%.

Not knowing if salinity has an impact on germination and growth of mung beans Farmer Elliot is not sure if this is the best property for their endeavor.

Property 3

This property is located at a much higher elevation than the other properties and located in a very different biogeoclimatic zone than what Farmer Elliot is familiar with and the differences in mineral content and soil texture in this area results in soil pH levels ranging between 6.2-7.2. It comes with a 2-bedroom home and 20 acres of usable ready to grow acreage.

This property appears ideal but Farmer Elliot is unsure if this pH range is tolerable for mung bean germination and growth.



Figure 4: Property 3.

Your mission

In order to better inform Farmer Elliot's decision they've hired you and your partner(s) as consultants.

Your TA will assign a specific property listing to you and your partner(s) and you will be tasked with designing an experiment to test the specified variable on both mung bean germination and growth.

Following this you will need to develop a recommendation report for your client Farmer Elliot.

To help you in this endeavour, you may wish to review the content from BIOL116 on experimental design – Designing the Experiment.

Research Question

First things first, we need a good research question.

In BIOL116 you were introduced to experimental design and hypothesis testing. One of the things we didn't touch on in great detail was how to develop a research question.

How you formulate your research question will impact what you study and how you conduct that study.

When we think about transparency and reproducibility in research design and implementation, every step we take and every decision we make is predicated on earlier decisions; and things begin with a research question. Well, to be fair, developing a research question is an iterative process, but it underpins so many future decisions - it will inform your hypothesis – after all, your hypothesis is the testable statement that addresses your research question – which will then inform your study design and so on. So, we shouldn't gloss over its importance!

A good research question

A good research question will help to limit many biases that Open Science is trying to combat in the conduct of research, including HARKing and making decisions after having looked at one's data.

A good research question is primarily informed by two things:

- Research done to date that has addressed this problem.
- The problem at hand

Background

Consulting the literature

Consulting research done to date will allow you to see how this or similar questions have been addressed by other researchers. Novel ways of addressing the same question are important to move science forward; consulting previous research will help to identify gaps that are opportunities for these novel approaches.

At the same time, consistency in methodology underpins reproducibility, and it's consequently just as important to test the same questions with the same methods in both similar and novel populations as previous research has done, helping to build a body of evidence and identify if earlier findings are generalizable to other populations.

The problem at hand

The problem at hand will come with certain known and unknown elements. In this assignment, depending on the plot of land that you're looking at, you already know certain things about the soil chemistry, geological features or water sources of a given plot.

It is the unknown elements – or a portion of the unknown elements – that your research question will try and address. In this instance, how these factors will impact mung bean production.

A research question that asks

What is the impact of fertilizer x on the growth of mung beans?

would seem a reasonable first attempt at addressing one potential issue at hand. However, it doesn't give a clear definition of what we're measuring as either a dependent or independent variable.

Since the research question informs the hypothesis, which then guides your design, you're leaving yourself with a lot of wriggle room here further down the line.

Phrasing

A testable question

Using the word **what** re-enforces this less than concise formulation of the research question. In fact, predicated your question with **what** or **why** doesn't allow your question to ask exactly what you need it to ask.

In experimental design, we're testing for relationships - asking "is there a relationship?". In fact, we're asking a question that allows for the proposal of a hypothesis; a prediction of what that relationship might be. So, we should think about how we can ask a question that reflects the test or experiment we're planning.

A succinct question

In addition to re-framing our question to one which is phrased as a testable question, we want to clearly articulate our population of interest and our main variables of interest. When phrased as

What is the impact of fertilizer x on the growth of mung beans?

the variables ostensibly include fertilizer and plant growth. But plant growth is more nuanced than this, and our study might be too. In fact, arguably, plant growth is not a variable, but a composite of variables; so, we should ask ourselves, "what do we mean by growth? What about growth are we interested in? Germination rate, germination survival, biomass, height, flower set, fruit set?"

Defining the scope of your population and variables is a key consideration when developing a research question; defining these early means that you won't be asking these questions later, once you've already started to collect, or work with, your data.

So, ultimately, we want a question that:

- Is testable;
- Clearly identifies our population;
- Clearly identifies our primary variables of interest; and
- Is concise

An Example

Let's say our farmer is concerned primarily about fruit set. It seems reasonable then to test for fruit set. Again, fruit set could be defined in many ways - average biomass per fruit, average count per plant etc. And we may or may not be interested in each of these outcomes. In either case, a more concise, testable research question might then look like

Will the application of fertilizer x increase the quantity of fruit set of Vigna radiata?

Compare this with what we had before

What is the impact of fertilizer x on the growth of mung beans?

By specifying a proposed relationship that articulates our variables, not only can we now test this question directly, it identifies exactly what we're interested in testing, and it's concise, which means that we can then readily propose a hypothesis and null hypothesis to address it:

- Ho: fertilizer x will have no impact on the quantity of fruit set of *Vigna radiata*.
- Ha: fertilizer x will increase the quantity of fruit set of *Vigna radiata*.

Reproducibility, meta-analyses, and the evidence base

When we reproduce a study, we always know that there is a chance of error or bias resulting from our sample not being truly representative of its population, for any number of reasons including sampling error, lack of power etc. This is why we should never rely on the findings of just one study.

A meta-analysis is a study of already conducted studies to try and determine if across a series of studies addressing the same research question there is enough agreement in the findings to accept one conclusion, even though this conclusion may be contradicted by individual studies.

Replication enables this aggregation of findings, helping to sift through studies that have suffered from systematic error. To do this well, meta-analyses rely on documentation and homogeneity; studies that use similar methods, instruments, and techniques to address the same question and describe in detail how this was done. This is because comparing two studies of the same phenomenon with two different research questions and two different methodological approaches and data collection tools is extremely confounding and limiting.

Meta-analyses are based on extremely comprehensive literature reviews, reviews that attempt to uncover all literature – published and unpublished – addressing a given research question. Your research question not only informs your hypothesis and study design, it also frames your title and abstract, whether for a lab report, poster, or one day a manuscript. Expressing your research question in a way that clearly and succinctly outlines the variables you plan to test makes the inclusion of your results in a meta-analysis more likely, as your work will be more easily discovered and identified.

In fact, with this in mind, if you were conducting your mung bean research for a particular plot of land in a particular region, this might impact the variables you choose to work with, and you might end up with a still more concise research question that would allow for identification of potential homogeneity and then for comparing your data against other similar studies in a meaningful way. So, for example, in the Okanagan, your research question might be adjusted to

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Will the application of fertilizer x increase the quantity of fruit set
of Vigna radiata in a sandy loam soil of the BC Okanagan Valley?

Research Data Management

Once we know what we want to ask, we need to consider how we're going to organize our project and it's data. How we do this - Research Data Management or RDM for short - is a critical component of reproducibility and transparency in the sciences.

In BIOL116, you were introduced to best practices in file naming. You may wish to review that content. In this lab, you'll be looking at best practices in directory structure management; that is, how we organize our individual files.

Just like with file naming conventions, it is extremely important that our files are organized in a way that logically reflects the structure of our project and can be easily navigated with computational tools, allowing for, at a minimum, computational reproducibility. There is also an increased need to provide documentation that describes the chosen structure; in fact, the more complex a project becomes, the more this documentation is important.

So, please review the content on directory structure management in the BIOL Procedures and Guidelines.

Assignment: Lab 1

Please use the following template for this assignment:

[Lab01_125_Protocol-Assignment \(17 KB\)](#)

Putting it into practice

Drawing on what you learned in BIOL116 and after reviewing the content for this lab, this assignment asks you to articulate the key components of a protocol: a research question, hypothesis, and proposed study time line, as well as to describe the kind of data (variables as well as data types) you'll be collecting, how you'll be collecting it, and what you'll be doing with these data.

Lab 2

Open Science

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This week's lab content is the second half of Open Science: An Introduction.

You are asked to cover Parts 2 and 3, Open Science in Action: Benefits, and Open Science in Action: Challenges, respectfully.

The accompanying quiz can be found in Canvas.

Lab 3

Research Project: Part 2

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Data collection

In Lab 1 we established our protocol. In this lab, we'll put that protocol into practice and start collecting some data.

Your assignment this week will help prepare you for the report that you will ultimately be preparing.

Overview: Lab 3

During this lab, you will...

1. Run your first trial and collect data (this was set up in Lab 1)
2. Prepare your set up for your second trial

Collecting data

You will need to set up your data recording tool - you sketched this out in your protocol and now you'll need to implement it. Keep in mind that at some point you'll need to submit your data as a `.csv` file. How you record your data now might save you time later on.

When collecting data be sure to take notes on any and all observations. These will be very important in helping you interpret your data later on. Take your time when recording and organizing your data.

Preparing for the next trial

Once you have finished collecting your data you will need to set up your experiment again in order to collect a second round of data during your next synchronous week.

If you are wanting to increase your sample size and thus are doing more trials ensure that you follow the same process as the previous synchronous week. Alternatively, you may be setting up to ask an alternative question. In this case, be sure you have your TA take a look and approve the design / modifications before you leave your lab today.

Assignment: Lab 3

Writing a report can be extremely daunting and confusing especially if you have not written many of them. Many students struggle to know what information goes in what part of a report and in particular what should be included in a results section and what should not.

In order to help you better understand how to write a results section you are asked to edit the results section of the following document:

- Lab-03_Results_Assignment.pdf (306 KB)

This results example section contains at least 10 errors. Using the rubric for writing a good results section - found on Canvas, in Lab 5, and pasted below - and the information provided, you must edit this results section by clearly identifying and explaining each error. Take your time as some of them may not jump out at you immediately.

Though there may be more than one type of error each error only counts as one. For example, if you see that multiple graphs are missing a figure caption that still counts as one error, the error being no caption provided.

Regardless of the fact that you are working in partners for your experimental project this assignment is an individual assignment.

If you decide to work together please be cautious as plagiarism is a serious issue that comes up when students work together and as per your academic misconduct unit from last term has serious academic consequences.

Criteria	Description
Results	Includes graphs / figures. No raw data is provided outside of supplemental. Clearly outlines the findings from the study. Flow is sensible with figures present immediately following paragraphs describing the results of figure.
Figures	Are present. Figure selected is best for this type of data. All axes are labelled with units present where applicable and legends found. All figure present have been discussed in write up. Only averages are being shown. Appropriate statistical measures are present. Figures are clear and easy to interpret. No figures present without being discussed.

Lab 4

Research Project: Part 3

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Data analysis

In Lab 3 we started collecting data according what we had mapped out in our protocol. In this lab we'll be working through analysing the data we've collected to date.

Assignment: Lab 4

Download a copy of the assignment Lab_4_RShiny_Assignment.

Use the RShiny App to complete your assignment.

You may wish to refer back to the section on Preparing your data from BIOL 116 and the chapter Tidy Data in the Procedures and Guidelines document.

Upload your completed assignment to Canvas

Using R Scripts as an Alternative to RShiny

If you are feeling ambitious and would like to try making plots, calculating descriptive statistics, and performing analyses using R instead of the RShiny App, some R scripts are provided in the Optional Deeper Dive here in the BIOL 116 Lab manual for your use. These scripts align with the code used to produce figures, stats, and analyses in the RShiny App. However, by using these R Scripts you can edit code to customize the outputs (ie. change the fill colour on your figure etc.).

Keep in mind that there will be no additional support through TA's or instructors should you choose to use these scripts.

Lab 5

Research Project: Part 4

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Bringing things together

At this stage, you've drafted a protocol, set up your experiment, collected some data, and analyzed that data. Now it's time to communicate your findings.

Recommendation Report

In lab 1 you were introduced to Markdown in the context of documenting your project with `readmes` and `data-dictionaries`.

The basic syntax used in Markdown can be found in the BIOL Procedures and Guidelines. In the Procedures and Guidelines you are introduced to generic text editors for writing Markdown.

Markdown is a powerful authoring tool. Part of what makes it powerful is its integration with other tools, such as R. In BIOL202 you will be introduced to statistical analyses using R. You will also be asked to author reports using R and RMarkdown - RMarkdown is one flavour of Markdown. Remember, the content that you're reading right now is all authored using R - when there's analyses being presented - and RMarkdown.

For this assignment, you will be learning RMarkdown and the environment in which we author R and RMarkdown documents - RStudio. You will not be expected to do your analysis in R.

Your Recommendation Report Draft will be submitted as both an RMarkdown document and a pdf. You will also need to include a copy of your data in long format saved as `.csv` and a `_DATA-DICTIONARY.md` file. More details on this in the following sections.

While your Recommendation Report Draft should be approximately 5 double-spaced pages, Times New Roman and font size 12, if you're using RStudio and the templates provided in this class, you should only have to concern yourself with the length of your report; the rest of the formatting will be handled when you export from RMarkdown to pdf.

Science writing

Technical science writing is an art. Unlike English style writing, technical science is clear-cut and lacking in artistic enhancements.

Do not quote your sources but rather read through the information and write it in your own words and cite it. It is a good idea to read an article once all

the way through without making any notes. Then come back and read it again this time making notes in the margins or on some scrap paper. This will help ensure you not only understand the material you are reading but that you are able to describe it in your own words and avoid issues of plagiarism which so often become in issue for students.

You may wish to review the BIOL Procedures and Guidelines content on APA Citations and Academic Integrity.

Preparing to write

Read a lot! It is important that you have a thorough understanding of the topic. At the very least you should have at least 3 primary source papers you are referring too throughout your report to provide further credibility to your recommendation.

Start writing early! Students often make the mistake of starting the night before the lab report is due. This more often than not results in poor submissions and thus lower grades. You should expect that you will have at least 3 rounds of revisions before you submit.

Someone reading your report should be able to tell what question(s) you addressed, why the topic is important, how you tackled the problem, the types of data you will collect, and how your research helps to inform your client.

Need help?

Book an appointment with the Student Learning Hub's writing consultants!

A good report

A good report includes the following headings / sections

- Abstract
- Data availability statement
- Introduction
- Methods
- Results
- Discussion / Conclusion / Recommendations
- References

The goal is to clearly describe to Farmer Elliot what your question was, how you went about answering it, what your results told you and what recommendations you have to help Farmer Elliot make his decision.

Abstract

An abstract is a brief summary of what the report is all about.

Abstracts in the sciences are approached in a couple of different ways, depending on the sub-discipline and journal preferences. For BIOL125, your abstract should be a single paragraph and no more than 250 words. It should clearly outline the question or problem your research is investigating, describe how the question or problem was addressed and identify the key results and recommendations.

In less than 250 words, the reader should be able to attain the most crucial aspects of each segment of the report within this one paragraph.

Data availability statement

As we learned in BIOL116, when appropriate and feasible, the data underlying our analyses should be made available. You will be asked to submit a .csv file of your data in long format. You may wish to review the content from BIOL116 on Preparing Your Data and the content on Tidy Data from the BIOL Procedures and Guidelines. You will also be asked to submit a _DATA-DICTIONARY.md file describing your data. Refer back to the Data Dictionary section of the BIOL Procedures and Guidelines for guidance and an example.

This is a short statement that indicates if data is available and if it is, how it can be acquired.

Introduction

~ 1 page

The introduction should begin with the general topic and then narrow the focus of the details pertinent to the research.

Your introduction should discuss what is currently understood about the topic and how this ties into the study. This is where you want to get across the interesting points of the field that led you to develop your hypothesis and your experimental design. You want to use many sources, particularly primary sources such as journal articles. Ensure your information is cited appropriately (see guidance in the BIOL Procedures and Guidelines). You should have a clear hypothesis stated at the end of this section. This section will be the lengthiest section of your report. Ensure your reader has no doubt where the source of your information comes from.

Your introduction should situate, explain, and identify your research project. It should do this by providing relevant background information that frames the current project and is directly relevant. It should then identify the importance

of this particular project. And finally it should clearly articulate the research question and hypothesis being addressed.

Methods

~ 1/2 - 1 page

This section of your report involves producing a written description of the materials used and the methods involved in performing your experiment. Under no circumstances should you provide bullet points or list one by one the materials used. Rather you need to describe each step clearly enough that someone else could replicate your experiment exactly. You should also include a section outlining what statistical measure(s) you used and how you transformed your data if need be.

It is highly recommended you show this to someone not in your class and see if they can follow along. If they can't you need to ask them where they get stuck and re-write to make sure it's clear. Think of this like following a recipe while cooking. Don't leave anything out that isn't obvious or the recipe will fail for the next person trying to cook.

Remember, for transparency and reproducibility, your methods are key to your audience understanding how you did exactly what you did. And if you wrote a protocol, it is the methods section against which that protocol will be screened to identify bias.

So, it should be clear, concise, and contain sufficient information for someone else to reproduce the experiment. This means it should include things like, how specimens were procured, how data was collected (tools, measurements etc), and how the data was analysed.

The steps should flow logically, and, while being concise, you should not use bullet points.

Results

~ 1/2 - 1 page

The results section is where you will describe what you saw. That is, what the response was to your variable. This should be the driest and easiest section to write as you are just stating what you found and nothing more. There should be no mention of what you did to attain this data or how you went about doing it - that's for your methods section. This is not where you describe why you saw what you saw - that's for your discussion and recommendations section. Nor is it where you try and tie in other research to your research - that's for your introduction and discussion sections.

The results section should include all averaged data from observations during your experiment. This includes charts, tables, graphs, and any other illustrations of data you feel best represents the information you would like to convey. It should not include any raw data. Raw data should be attached as a separate file.

Depending on the information you wish to convey you may feel that a box plot, bar graph or line graph is most descriptive. Whichever way you decide think about what message you are trying to convey and ask yourself if an audience was to quickly look at your graph would they get that messaging easily. If not, you should look at an alternative way to display your graph. Your TA will be able to help you sort this out as well.

Be sure to provide all labels, legends and axes where necessary and a caption which informs the reader of what they are looking at. Remember anyone who is not familiar with your research should be able to quickly look at your figure and understand what message you are trying to show. Please review the BIOL Procedures and Guidelines section on Figures & Tables.

Your results section should clearly outline the relevant findings from your study and should flow directly from your research question and hypothesis.

This section should include graphs or figures to highlight key findings. Graphs and figures should be present immediately following paragraphs describing the results described by these graphs and figures.

While summary data should be provided, raw data should be not; raw data should be included as supplementary content.

Discussion, Conclusions & Recommendations

~ 1 page

This section is where you will discuss what you saw. Were you able to answer the question you set out to answer? Why or why not? In either case try and explain and interpret your results.

This is where you will want to go back to the journals you found and see what they found. Is it similar or not? Why or why not? Did they do something different from you? You can often explain results you may not have anticipated seeing by looking at what others in the area have found. Think about the why?

Is this the right property for Farmer Elliot or should he keep looking?

Your job here is to try and explain what you found and how it relates to what others have found. From here you will make your recommendation to your client.

References

All references used should be included at the end of your report on a separate page. That includes any books, articles, lab manuals, etc. that you used when writing your report. APA citations are required. Ensure you provide a properly formatted list with sufficient references. At least 3 primary source papers should be listed.

For formatting guidance, refer to the APA section of the BIOL Procedures and Guidelines.

RMarkdown and RStudio

When you're writing `readme` files and `data-dictionaries` - or even taking notes in class - a text editor like VS Code is extremely convenient and versatile. When it comes to authoring reports, however, we're going to move you into RStudio.

RStudio is an IDE - an Integrated Development Environment - for R. This is just a fancy way of saying that it's an application that helps you write R code. In BIOL202 and BIOL228, you'll start using RStudio to do analyses in R. Right now, we're just using RStudio to write in RMarkdown and to get used to using the RStudio environment. Along the way, we'll see some R code as we get things set up.

Since RStudio is designed for working with R, we need to install both R and Rstudio. So let's do this.

If you're running a Chromebook, using a tablet, or don't want to install anything new on your computer, all of the Windows computers in the library have R and RStudio installed on them.

While the `tinytex` package is installed on these machines, it's not loaded out of the box. So, you will need to run the following code in the console

```
tinytex::install_tinytex()
```

If prompted to update the `rmarkdown` package, do so. There are more details on `tinytex` and `rmarkdown` in the 'Getting set up' section below.

Installing R

R is available from CRAN - the Comprehensive R Archive Network - and is available for all operating systems. Find and download the installer for your operating system at <https://cran.r-project.org/>. At the time of writing, the latest version is 4.1.2 Any version that is 4.x.x should be fine for what we'll be doing.

Download and Install R

Precompiled binary distributions of the base system and contributed packages, **Windows and Mac** users most likely want one of these versions of R:

- [Download R for Linux \(Debian, Fedora/Redhat, Ubuntu\)](#)
- [Download R for macOS](#)
- [Download R for Windows](#)

R is part of many Linux distributions, you should check with your Linux package management system in addition to the link above.

Installing RStudio

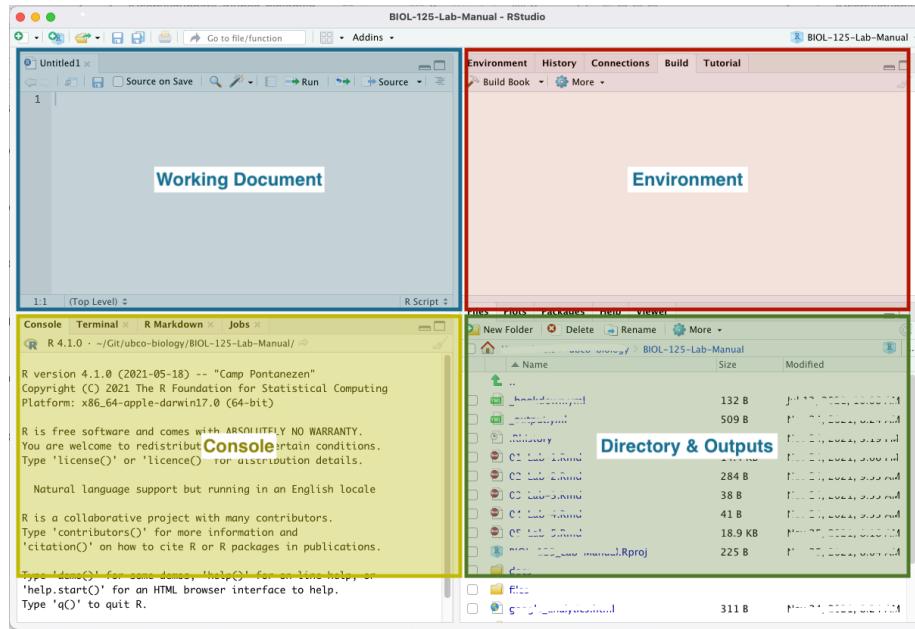
Once you have R installed, you can go ahead and install RStudio, also available for all operating systems. Find and download the installer for your operating system at <https://www.rstudio.com/products/rstudio/download/#download>. At the time of writing, the latest version is 2021.09.0+351 This or any later version that is published should be fine for what we'll be doing.

OS	Download	Size	SHA-256
Windows 10	 RStudio-2021.09.1-372.exe	156.89 MB	1c3d27f5
macOS 10.14+	 RStudio-2021.09.1-372.dmg	203.00 MB	daec6a40
Ubuntu 18/Debian 10	 rstudio-2021.09.1-372-amd64.deb	117.89 MB	921b4f23
Fedora 19/Red Hat 7	 rstudio-2021.09.1-372-x86_64.rpm	133.83 MB	f1be5848
Fedora 28/Red Hat 8	 rstudio-2021.09.1-372-x86_64.rpm	133.85 MB	ba36870d
Debian 9	 rstudio-2021.09.1-372-amd64.deb	118.10 MB	637cd465
OpenSUSE 15	 rstudio-2021.09.1-372-x86_64.rpm	119.78 MB	678d020e

A quick intro to RStudio

Your RStudio window is comprised of 4 panes.

- The upper left is where you'll find your working documents.
- The lower left is your console. It is in the console that we can run R code directly if needed.
- The upper right displays information related to your working environment.
- The lower right is where you'll see any output generated by your R code, like figures, help pages etc. It's also where you'll see a file manager so that you can interact with your files directly from within RStudio.



For report authoring using RMarkdown, we'll mostly be concerned with the upper left pane. We'll occasionally use the console to run a bit of R. And we'll occasionally use the file manager to access files. We won't worry at all about the upper right pane - this will have more relevance when you start computing statistics in R using RStudio.

When you launch RStudio, unless you're opening an existing document, you will only see 3 panes, your console will be on the left, and your environment and output panes will be on the right.

Getting set up

Being able to convert from markdown to pdf is not something we can do with the default install of R. We need to get two add-ons to be able to do this. Add-ons in R are called **packages**. The first package we need to install is **rmarkdown**. The second is **tinytex**. **rmarkdown** handles the general process of reading through your report and getting it ready to be output to a different format. **tinytex** contains the necessary information to produce a **pdf**, so **rmarkdown** will use **tinytex** for that one part of the conversion process.

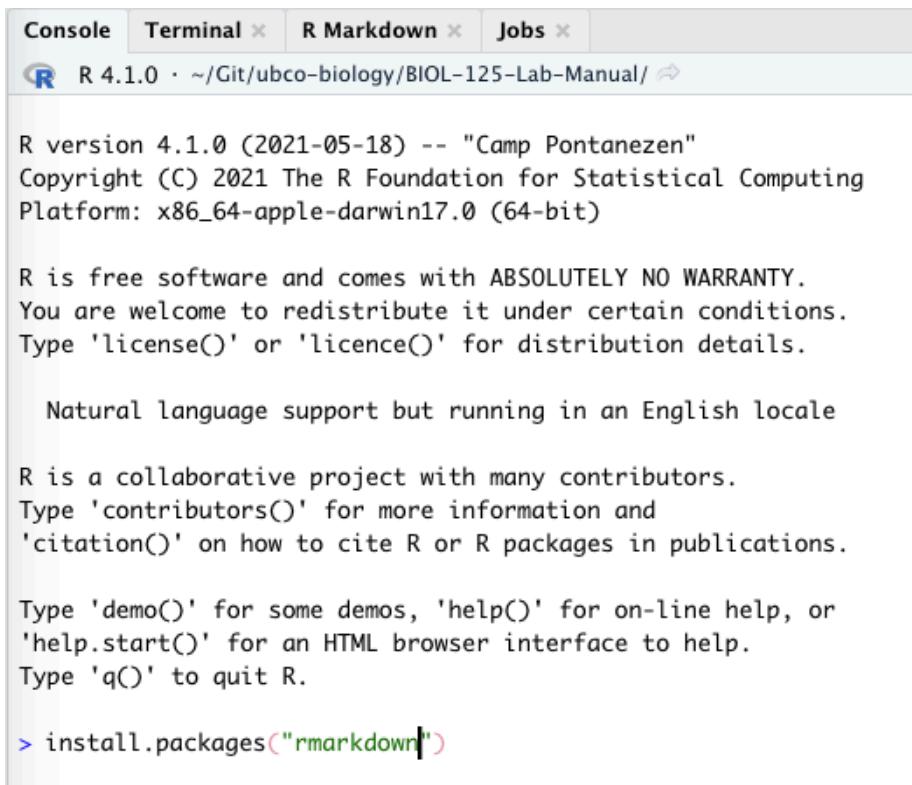
The x in **tinytex** is pronounced like a k, so should read more like **tinytek** or **tinytech**.

Installing Rmarkdown

Open RStudio, in the console type the following and hit 'Enter'.

```
install.packages("rmarkdown")
```

You'll see a bunch of stuff written to the console. When it's all done, you'll see your prompt - > - return.



```
Console Terminal × R Markdown × Jobs ×
R 4.1.0 · ~/Git/ubco-biology/BIOL-125-Lab-Manual/ ↗

R version 4.1.0 (2021-05-18) -- "Camp Pontanezen"
Copyright (C) 2021 The R Foundation for Statistical Computing
Platform: x86_64-apple-darwin17.0 (64-bit)

R is free software and comes with ABSOLUTELY NO WARRANTY.
You are welcome to redistribute it under certain conditions.
Type 'license()' or 'licence()' for distribution details.

Natural language support but running in an English locale

R is a collaborative project with many contributors.
Type 'contributors()' for more information and
'citation()' on how to cite R or R packages in publications.

Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.

> install.packages("rmarkdown")
```

Installing tinytex

Now, in the console type the following and hit 'Enter' again.

```
install.packages("tinytex")
```

When that's all done, type the following and hit 'Enter'

```
tinytex::install_tinytex()
```

That's it. You should be good to go to open the .Rmd template available in the Assignment tab for this lab.

Assignment: Lab 5

Please use the following template for this assignment:

20220704_Lab05_125_Assignment_V2.Rmd (3 KB)

You will need to submit 4 files for this assignment:

- Recommendation report as .Rmd
- Recommendation report as .pdf
- Data in long, tidy, format as .csv
- Data dictionary as .md

You will receive your marked lab report one week from the time it is submitted.

You can decide to resubmit the same lab report draft without making any changes or you will have the opportunity to review the edits and make the needed changes in order to increase your mark.

If you have any questions regarding your mark and / or the comments from your TA please ensure you take the opportunity to chat with your TA to go over these. This will ensure that you are in the best position to attain the highest marks possible for this assignment.

Using the template

All the markdown syntax that you need for RMarkdown can be found in the Markdown section of the BIOL Procedures and Guidelines.

Directory structure & file naming

It is expected that you will have a root project folder for your work associated with this lab. And that at the minimum you will have a folder for your report, your data, and your figures. And that you will download this template into your report/ directory. And that lastly, you will rename the template in accordance with the file naming convention you outlined in your first assignment.

This structure and hierarchy will be important when it comes time to include figures and images in your report.

YAML

The top of the template contains some front matter called YAML. YAML provides instructions to all the pieces of software involved in converting your RMarkdown document to its outputs, in this case, pdf. YAML is very specific to spacing, so don't add any extra spaces!

What you need to do.

1. Provide a title within the quotations after `title`.
2. Provide your name within the quotations after `author`.
3. Provide your abstract within the quotations after `abstract`.

What might be nice to know.

1. `r Sys.Date()` pulls the date from your computer and auto populates this for you.
2. The `output` tag defines the output format. Other options include `html_document` and `word_document`.

What exactly is YAML?

YAML™ (rhymes with “camel”) is a human-friendly, cross language, Unicode based data serialization language designed around the common native data types of dynamic programming languages. It is broadly useful for programming needs ranging from configuration files to internet messaging to object persistence to data auditing and visualization.

Read more at the [Official YAML Web Site](#)

Document body

The template is then pre-populated with first level headers for each section you're expected to include in your report. Each heading re-iterates the key elements the content of these headings should address. This is just place holder text, so replace it with your own.

Images & graphs

There is one sample graph included. Note how it references the figure to be included `../figures/image-name.png`. The `../` means 'go one level up in the directory' which, if you have your project set up in the following way and your `.Rmd` file is in your `report/` directory it means 'look in the `root/` directory for a folder called `figures/`'.

```
root/
  report/20220101_Lab05_125_Assignment_V1.Rmd
  data/
    figures/MVD_BIOL125-Lab5_Fig-1-Boxplot_V1.png
```

If you make a mistake in setting this path, you'll get the following error in RStudio

```
(No image at path ...)
```

You'll also note the following directly after the image path: `{width=50%}`. This reduces the image size by 50%. This works well for the images produced by the ShinyApp used in this course.

As noted in the template, you do not need to write `Figure 1:` before your figures; this small piece of text is handled during the conversion from RMarkdown to pdf. Any other information that you would like to include in the caption should go in the `[]` before the `()` that contain the path to the image.

Figure placement

The engine behind the conversion from RMarkdown to pdf is a typesetting application, one with pretty strict rules about how content should be formatted - much more strict than something like Microsoft Word.

What this means is that if the placement of your images will disrupt your prose - by creating large amounts of empty white space for example - this typesetting application will *push* your figure to somewhere lower in your report where it won't create this white space.

Your figures should be adjacent to the relevant text in your RMarkdown file. How this manifests to your pdf might look a little different; that's ok.

References

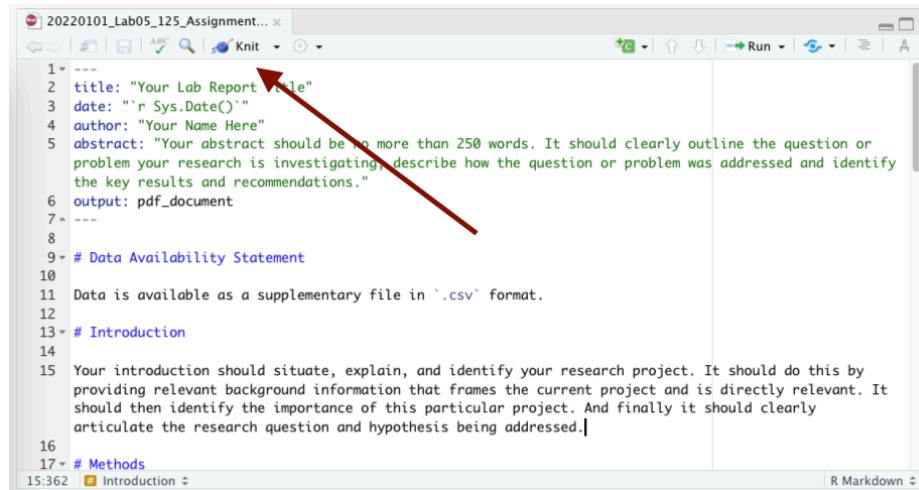
Just before the heading for references you'll see the following

```
\clearpage
```

This creates a page break between your references section and the rest of your report.

Building the pdf

If you've installed R, RStudio, and the `markdown` and `tinytex` packages successfully, when you open the template .Rmd file you should see an option to Knit.



```

1 ---  

2 title: "Your Lab Report Title"  

3 date: ``r Sys.Date()``  

4 author: "Your Name Here"  

5 abstract: "Your abstract should be no more than 250 words. It should clearly outline the question or problem your research is investigating, describe how the question or problem was addressed and identify the key results and recommendations."  

6 output: pdf_document  

7 ---  

8  

9 # Data Availability Statement  

10 Data is available as a supplementary file in '.csv' format.  

11  

12 # Introduction  

13 Your introduction should situate, explain, and identify your research project. It should do this by providing relevant background information that frames the current project and is directly relevant. It should then identify the importance of this particular project. And finally it should clearly articulate the research question and hypothesis being addressed.  

14  

15  

16 # Methods  

17

```

Click this button or select the drop down arrow and select Knit to pdf. This will generate a pdf in the same directory as your .Rmd file.

To test this with the template, ensure the template .Rmd file is in your `report/` directory and download the following image into your `figures/` directory

- MVD_BIOL125-Lab5_Fig-1-Boxplot_V1.png (4 KB)

You should get something that looks like this after Knitting the .Rmd file

- 20220101_Lab05_125_Assignment_V1.pdf (180 KB)

Rubric: Lab 5

Criteria	Description	Pts
Abstract	Brief, no more than 250 words. Clearly outlines the question / problem. Clearly describes how the question/problem was addressed. Clearly highlights/describes the results of the study and recommendations are provided.	4
Data Availability	Data availability statement is present.	1

Criteria	Description	Pts
Introduction	<p>Relevant background information provided. Clearly articulates how the background information is connected to the current project. Importance of this project has been described. Property and Farmer Elliot are discussed. Written well and easy to follow.</p> <p>Flows from more general and broad background information to the focus of the project. Hypothesis and questions posed are outlined at the end of this section. No factual errors are present.</p>	8
Methods	<p>No bullet points. All methods and materials are clearly described. Well written and easy to follow. Enough information has been provided for others to be able to reproduce the experiment. Data analysis procedure is also included.</p>	5

CONTENTS

65

Criteria	Description	Pts
Experimental Design	<p>Procedure is specific and addresses the question / problem.</p> <p>Data collection is clearly defined.</p> <p>Appropriate control (where applicable) has been used – if you don't think a control is appropriate, state why.</p> <p>Indicate sample size and treatment groups.</p> <p>Independent and dependent variables are identified. Student testing only one variable.</p>	6
Results	<p>Includes graphs / figures. No raw data is provided outside of supplemental. Clearly outlines the findings from the study.</p> <p>Well-written and easy to follow. Flow is sensible with figures present immediately following paragraphs describing the results of figure. Figures and tables are referenced directly in text i.e., Figure 1 or (Figure 1).</p>	6

Criteria	Description	Pts
Figures	<p>Are present. Figure selected is best for this type of data. All axes are labelled with units present where applicable and legends found. All figure present have been discussed in write up. Only averages are being shown.</p> <p>Appropriate statistical measures are present.</p> <p>Figures are clear and easy to interpret. No figures present without being discussed. Figure captions are in appropriate place.</p> <p>Figure caption contains all required elements.</p>	10
Discussion & Recommendation	<p>Student displays clear understanding of results. The statistical significance of the results is discussed.</p> <p>Student displays a clear understanding of the meaning of these results. Interpretation of results is founded in the data, observations and/or other studies.</p> <p>Recommendations are sound and based on the current study and / or other studies.</p> <p>Well-written and easy to follow.</p>	12

Criteria	Description	Pts
Spelling & Grammar	No spelling errors. No grammar errors. No awkward sentence structures. Language/tense is consistent throughout the report.	4
References & in-text citations	APA format used properly and consistently. Minimum of 3 primary source papers used in the report. No sources are included that are not peer-reviewed. In-text citations are used when required. Citations and references match up.	5
Plagiarism & Quotations	No plagiarism of any kind has been found. No quotations present. Information attained from outside resources are properly cited.	3
File Uploads & Format	A minimum of 4 files have been submitted (pdf, Rmd, dataset(s), data dictionary). Report has been submitted as pdf and RMarkdown. Report is no more than 5 pages (excluding references). Data has been submitted in Tidy format as csv. Data dictionary has been submitted as .md.	5
Total		69

Lab 6

Animal Systems I: Part One

Last updated 2023-03-21

Overview of the Week

The breakdown for this week's lab;

1. You will be joining your lab mates and TA during your regular scheduled time but online
2. Your TA will go through a PowerPoint presentation online
3. You will be given time to review all material provided on Canvas
4. You must complete all quizzes for this week's lab provided on Canvas
5. Your Recommendation Report Draft is due this week.

See Canvas for assignment due dates.

Before lab you will need to read through the information outlined below in Animal Systems Information for three phyla: Annelida, Mollusca and Arthropoda.

In this lab, you will be working your way through the material posted on Canvas online but during your scheduled lab time. Your TA will spend time going over a quick PowerPoint presentation regarding these animals. You will then need to spend a fair bit of time going through the different videos, images, and written material provided to ensure you have a solid grasp of these animals before coming to campus next week for your synchronous week. You must complete all quizzes associated with the animals found in animal systems I before **11:59 pm on July 20th**. Even though you will be getting together this week there is no reason you can't start reviewing all this information ahead of time so that you are better prepared to get through the material during your lab section.

Animal Systems Information

Phylum Annelida

Biology 125 Biology for Science Majors II Lab Manual. Written by Dr. Tristyn Hay October, 2021. Some content provided by the University of British Columbia and Okanagan Biology Graduate Program students handbook The Fictional Animal Project: A Tool for Helping Students Integrate Body Systems. Adv. Physiol. Edu 41: 239-243 Blatch et al. 2017

The phylum Annelida includes all segmented worms that have a coelom functioning as a hydrostatic skeleton. Other than the first and last portion, they are built on a pattern of repeated segments through which a “one-way” digestive tract (mouth and anus), closed circulatory system (blood is completely enclosed in vessels), and nervous system pass. The annelids do not have specialized gas exchange structures, instead the blood vessels pass very close to the bodies surfaces so that, providing the epithelium is kept moist, diffusion across the body surface can meet the metabolic needs of the animals. However, a number of the marine annelids have heavily vascularized flattened extensions on the sides of each segment thus increasing the surface area across which diffusion can occur. The blood of many types of marine annelids is copper based, not iron, thus giving their blood a greenish colour. Some of the freshwater “earthworms” however have iron-based blood so it is red like ours. These worms are common in water that lacks much oxygen. As a result, they contain large amounts of hemoglobin, appear very red and are called bloodworms (proper name is *Tubifex*) and are sold in pet stores as fish food.

EXTERNAL FEATURES

Earthworms have a tremendous impact on the soil. By burrowing through soil they increase its porosity and thus allow air and water to penetrate it easily. They also enrich soils by carrying surface material such as dead plant material (detritus) into deeper layers.

DIGESTION

Digestion in the phylum Annelida is extracellular. These animals have a complete digestive system, with mouth and anus. Marine worms are filter feeders or scavengers. Earthworms squeeze organic material out of the earth. Just posterior to the mouth opening is the muscular pharynx which contracts to suck food particles into the mouth. The esophagus follows the pharynx, which ends in a thin-walled sac like structure called a crop. The crop opens into a gizzard, which has thick, muscular walls. Food is passed from the gizzard to the intestine, where further digestion and absorption occur. The intestine ends at the anus.

TRANSPORT AND EXCHANGE

Circulation in the earthworm is through a series of closed vessels. The two main vessels that can be seen in your dissection are the dorsal and ventral blood vessels. These vessels are the main pumping structures. In the dorsal vessel, blood moves towards the anterior end. The dorsal vessel is the dark line running along the dorsal surface of the digestive tract. In the ventral vessel, blood moves toward the posterior end. Segmental branches off the ventral vessel supply the intestine and body wall with blood. These branches eventually break into capillary beds to pick up or release nutrients and, oxygen. Gas exchange occurs between the capillary beds of the body surface and the environment. Oxygen is carried by the respiratory pigment hemoglobin, which is dissolved in the fluid portion of the blood. From these capillary beds, blood is collected into larger vessels that eventually unite with the dorsal vessel. Surrounding the esophagus, segmental branches are expanded into five pairs of aortic arches, or what have been called "hearts". They are dark, expanded structures on either side of the esophagus. Although these are contractile, they only function in pumping blood from the dorsal to the ventral vessels.

EXCRETION AND OSMOREGULATION

Annelids possess a pair of tubular excretory structures (called metanephridia) per segment. Metanephridia are open-ended into the coelomic fluid and are surrounded by capillaries. The internal opening of the metanephridium is surrounded by cilia, which beat and draw fluid into the tube; the fluid can then pass to the outside of the body via a pore. The metanephridium in annelids has both excretory and osmoregulatory roles. The epithelium lining the inside of the tubule, reabsorbs most solutes and returns them to the blood in the capillaries, whereas ammonium is excreted along with copious amount of water.

REPRODUCTION

Annelids are hermaphroditic (both sexes in the same organism). Sexual reproduction occurs through the exchange of sperm packets among different individuals (cross fertilization). The received sperm are stored temporarily while a structure called the clitellum secretes a cocoon of mucus. The cocoon slides along the worm and picks up the eggs and the stored sperm. Some annelids also reproduce asexually by budding off into a separate organism (polychaetes). Look on a diagram to locate the oviduct.

Phylum Mollusca

Molluscs, including snails, clams, oysters, squids and octopi, number well over 100,000 species. They appear to be quite diverse but they all have:

- A large ventral muscular foot, which is used in locomotion.
- A visceral mass above the foot which contains a digestive, excretory, circulatory (either openmeaning that blood is not completely contained within blood vessels or closed-meaning that blood is completely contained within blood vessels-depending on lifestyle) and other organ systems.
- A mantle is a heavy fold of tissue that covers the visceral mass and in most species contains glands that secrete a shell. In many species, gills can be found within the mantle cavity; in terrestrial species such as snails and slugs the cavity is highly vascularized and is called the pulmonary cavity.

DIGESTION

As molluscs have a range of body structures (eg. Bivalvia have 2 shells whereas Cephalopoda have none), and generalizations regarding feeding (from suspension to mass feeders) is difficult. In the case of the clam (filter feeders), the food particles that are filtered from the water by the ctenidia are carried by water currents to the mouth by labial palps. The esophagus leads the food to the irregularly-shaped stomach, which lies in the greenish digestive gland (equivalent to liver). From the stomach, the intestine extends through the pericardial cavity to the rectum.

TRANSPORT AND EXCHANGE

Except for cephalopods, all molluscs have open circulatory systems. In clams, two large sheets of tubes called the ctenidia lie beside the muscular foot. The molluscs are good at utilizing the same organ for different purposes. Here, ctenidia function both as gills and as devices for filtering food. Water enters the mantle cavity via an incurrent siphon. Numerous cilia on the gills beat to create a current, which draws water into the mantle cavity and through numerous tiny pores in the ctenidia. Oxygen and carbon dioxide are exchanged in the ctenidia, which are supplied with blood and food is trapped. These tubules carry the water to a dorsal suprabranchial cavity that leads to the excurrent siphon where water leaves the body, creating a continuous flow.

EXCRETION AND OSMOREGULATION

Most molluscs possess a large pair of metanephridia, frequently referred to as a kidney. The kidney plays a large role in osmoregulation in freshwater forms. A very dilute urine containing ammonium is produced (in aquatic forms) and salts are absorbed across the walls of the metanephridia. Land snails may excrete uric acid. These coelomates have an open circulatory system with a reduced coelom. The atria of the heart function as part of the circulatory system and excretory system. Here waste products are filtered out of the blood via the

atria with urine then being excreted into the coelom. Any re-usable products remaining in the urine will be extracted via the nephridia or "kidneys" with the final waste products being discharged into the mantle cavity.

REPRODUCTION

Reproduction differs between the different classes or sub-phyla of the Mollusca. In the class Bivalvia, in which the clam belongs, reproduction is external. Eggs and sperm are shed into the water and fertilized eggs develop into two stages of larvae. The 2nd staged larva settles on a substrate and metamorphosis occurs resulting in an adult form that secretes a shell. Most clams are hermaphroditic, producing sperm and eggs in the gonads. The production of sperm and eggs can occur simultaneously or at different times. Eggs and or sperm are released into the aquatic environment via the excurrent siphon.

Phylum Arthropoda

Arthropods are characterized by a jointed chitinous exoskeleton and jointed legs. The exoskeleton serves both as armor and as a point of attachment for their muscles. Since the skeleton limits their growth they must occasionally molt to increase in size. Their circulatory system is open with an elongated dorsal vessel, which is a heart that pumps blood forward into the arteries, from which it empties into open sinuses where it bathes the tissues and then returns to the posterior portion of the heart. The arthropod phylum is by far the largest with more than a million species. Most of these are in the class Insecta (eg., beetles, butterflies, flies, ants, wasps, grasshoppers, and dragonflies). The other two large groups are the chelicerates (spiders, harvestmen, ticks, mites, scorpions and "horseshoe crabs") and the crustaceans (shrimps, crabs, crayfish, barnacles and lobsters). Many different crustaceans can be found in the lakes and ponds of the Okanagan - Shuswap region.

DIGESTION

Insect mouthparts are formed from several pairs of modified appendages. In grasshoppers, they include mandibles, which are used for chewing. In other insects they may be modified for piercing and sucking. The intestine consists of a liner passage that contains a crop, a gizzard, the intestine and the anus.

TRANSPORT AND EXCHANGE

Gas exchange in insects is accomplished by a tracheal system of branched chitin lined tubes that infiltrate the body and carry oxygen directly to cells. The tracheal system opens to the outside of the body through spiracles, pores that can control air flow and water loss by opening or closing.

EXCRETION AND OSMOREGULATION

Insects and other terrestrial arthropods have unique organs called Malpighian tubules. These tubules function in excretion as well as osmoregulation. The

tubules open into the gut of the insect and blind end into the circulatory fluid surrounding the organs. Nitrogenous wastes are actively transported into the lumen of the tubules and travel to and passes into the rectum. Most of the water and solutes are pumped back across the rectal wall. The ammonia is metabolized (which costs energy) to uric acid, an insoluble nearly dry crystal, which is mixed with feces and excreted. Uric acid is far less toxic than ammonia. The insect can reabsorb nearly all the water. This is one of the key systems that have allowed insects to become so successful on land.

REPRODUCTION

Reproduction in insects is usually sexual, with separate male and female individuals. Fertilization is usually internal. In most species, sperm are deposited directly into the female's ovipositor at the time of copulation. Many insects mate only once in a life.

Life Cycles, Dissection Guides, & Videos

Phylum Annelida

Did you know that an earthworm can range in size from 1 inch to 10 feet!!!

[**Earthworm Life Cycle**](#)

[**Earthworm Dissection Guide & Video**](#)

Click here to download a copy of the Earthworm Dissection Guide.



[**Earthworm Quiz**](#)

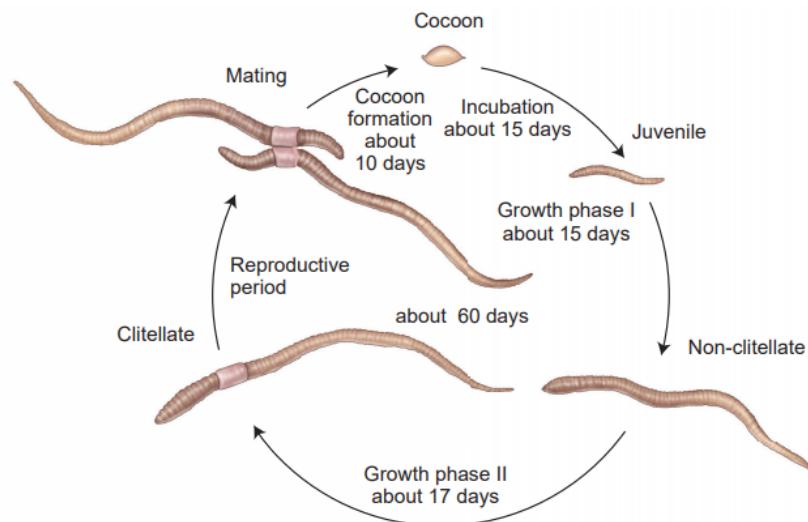
Complete the Earthworm Quiz on Canvas.

Phylum Mollusca

Interesting fact: The giant clam has a lifespan well over that of a human!



Figure 5: Giant Worm. <https://geekologie.com/2014/07/imagine-the-fish-we-could-catch-massive.php>



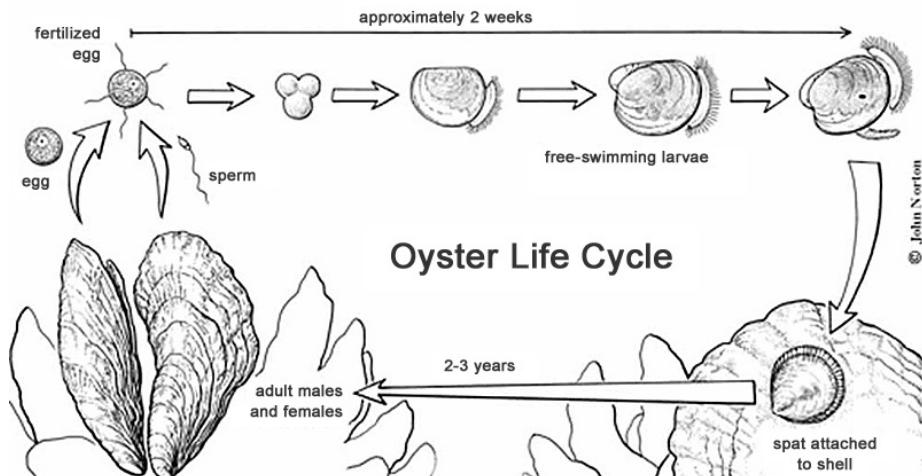
Copyright - <http://www.brainkart.com/media/article/article-Life-cycle-of-Earthw-VM8.png>

Figure 6: Earthworm Life Cycle



Figure 7: Giant Clam

Clam Life Cycle



Copyright - https://uploads-ssl.webflow.com/5e7b9a9b32e915d01c9bfd3c/5ec84994c4d70c1f07c1fa55_image-asset.jpeg

Clam Dissection Guide & Video

[Click here to download a copy of the Clam Dissection Guide.](#)



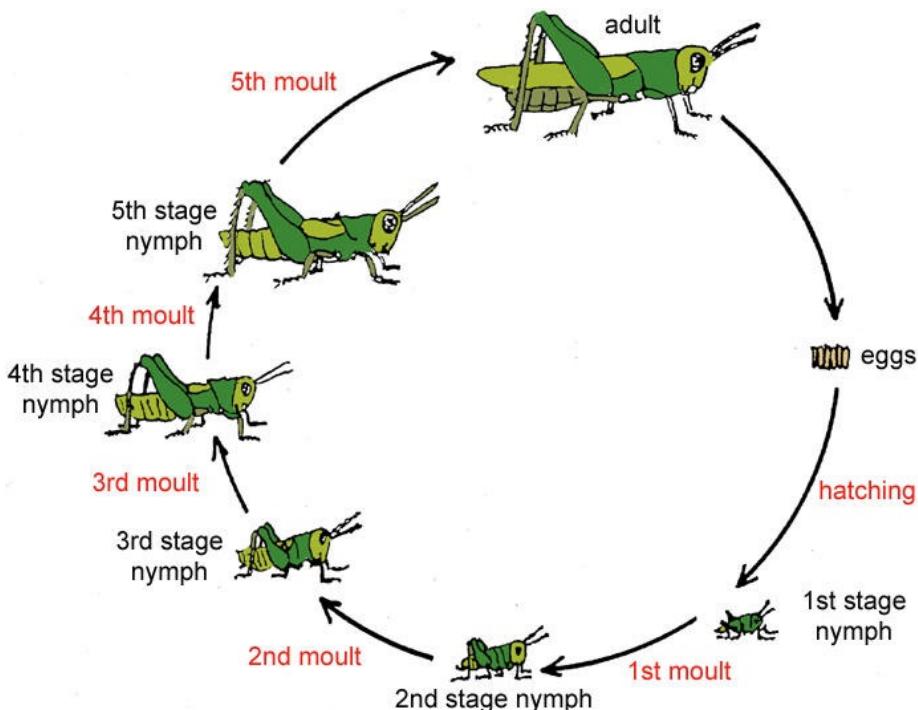
Clam Quiz

Complete the Clam Quiz on Canvas.

Phylum Arthropoda

Grasshoppers can make music without any instruments. Click here to listen to their song.

Grasshopper Life Cycle

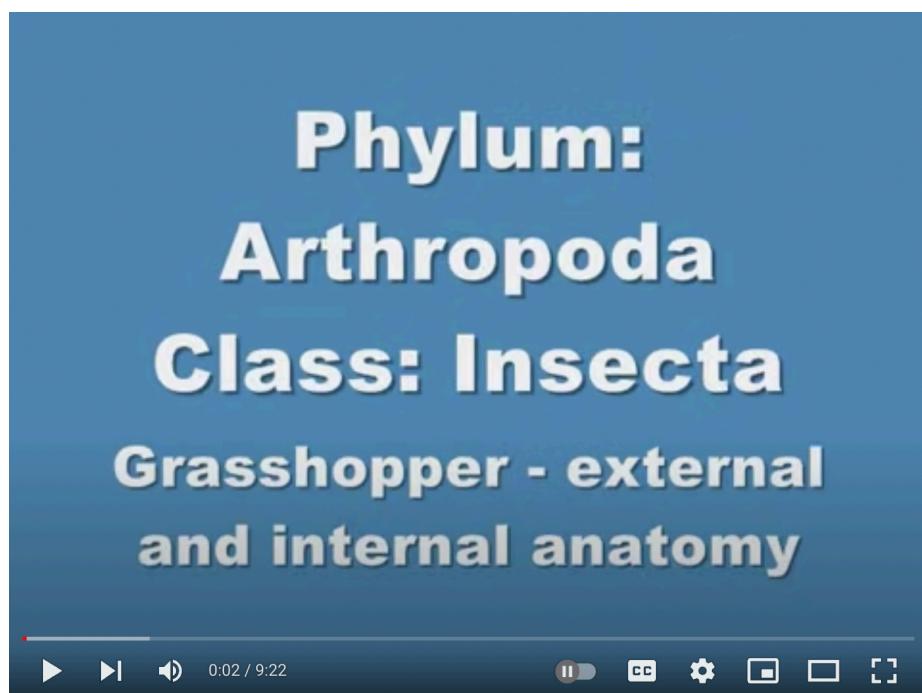
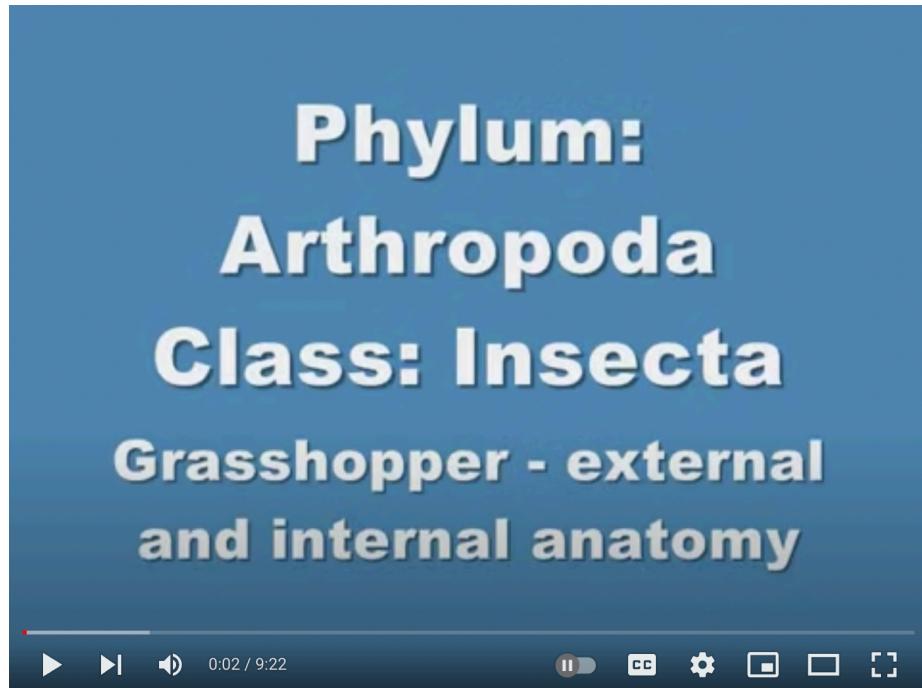


Copyright - <http://www.saburchill.com/ans02/images2/210807001.jpg>

Figure 8: Grasshopper Life Cycle

Grasshopper Dissection Guide & Videos

Click here to download a copy of the Grasshopper Dissection Guide.



Grasshopper Quiz

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Complete the Grasshopper Quiz on Canvas.

Lab 7

Animal Systems I: Part Two

Last updated 2023-03-21

Overview of the Week

Breakdown:

1. Come to lab ready on campus
2. Get assigned an animal and a group by your TA
3. Build a quiz for your fellow students in the lab
4. Complete two quizzes written by your fellow students in the lab
5. Submit Assignment #4 before the end of the lab. Ensure all members have submitted a copy or those students missing a submission will receive a zero for the assignment and an absence score of 2.5.

Last lab you spent a tremendous amount of time learning about annelids, molluscs, and arthropods through videos, images, guides, and quizzes. Now, this week you will get to see these animals up close and personal!

For this week, you will be placed in groups and will be performing some dissections! Though not required, if you have lab coats please feel free to bring them along. All needed gloves and eye protection will be provided in the lab. For those of you who are not comfortable with dissections please know that you can still participate in the activity without having to do the actual dissection.

Make notes and work together as a team to learn, not only about the animal you will be assigned but also those of the other groups, and make a quiz to test other students' knowledge about your animal. Your TA will provide more details about the logistics of how this will work in the lab. In either case, have fun and enjoy the process!

Assignment: Lab 7

[Click here to download a copy of the Assignment.](#)

Lab 8

Animal Systems II: Part One

Last updated 2023-03-21

Overview of the Week

1. You will be joining your lab mates and TA during your regular scheduled time but online
2. Your TA will go through a PowerPoint presentation online
3. You will be given time to review all material provided on Canvas
4. You must complete all quizzes for this week's lab provided on Canvas
5. Submit your final recommendation report Assignment #5

See Canvas for assignment due dates.

This week you will be working your way through the material posted on Canvas online but during your scheduled lab time. Your TA will spend time going over a quick PowerPoint presentation regarding these animals. You will then need to spend a fair bit of time going through the different videos, images, and written material provided to ensure you have a solid grasp of these animals before coming to campus next week for your synchronous week. You must complete all quizzes associated with the animals found in animal systems II **before 11:59 pm on July 27th**. Even though you will be getting together this week there is no reason you can't start reviewing all this information ahead of time so that you are better prepared to get through the material during your lab section.

Animal Systems

Information II

Phylum Echinodermata

Biology 125 Biology for Science Majors II Lab Manual. Written by Dr. Tristyn Hay October, 2021. Some content provided by the University of British Columbia and Okanagan Biology Graduate Program students handbook The Fictional Animal Project: A Tool for Helping Students Integrate Body Systems. Adv. Physiol. Edu 41: 239-243 Blatch et al. 2017

A “spiny skin” characterizes members of the phylum Echinodermata, by only living in marine environments, and by possessing a unique water vascular system. They are also radially symmetrical as adults, but not as larvae. The spiny skin is actually an endoskeleton made up of calcareous plates. Typical echinoderms include seastars (starfish), brittle stars, sea urchins, sand dollars, sea cucumbers and sea lilies. According to DNA evidence, they are closely related to members of the Phylum Chordata, the phylum to which humans belong. Chordates and echinoderms also share a similar pattern of embryonic development, as both are deuterostomes.

EXTERNAL FEATURES OF THE SEASTAR

Pisaster can be seen in the crevices of intertidal rocks and covering the pilings of piers and docks. Pisaster is a rapacious predator on bivalves, but little eats it, except for the occasional desperate seagull.

The underside of the seastar is referred to as the oral side; the opposite side is the aboral side. The external features on the aboral side include the rays (arms) and sieve plate (madreporite). On the surface there are small calcareous bumps called spines and between them are structures called dermal papillae (not visible with the naked eye). On the mouth side tube feet, the mouth and ambulacral groove can be observed.

The sea star uses its water vascular system to capture food and in locomotion and respiration. Water enters the system via the sieve plate. The water is then moved along through a series of canals by the action of cilia out to the rays

and to the ampullae. Contraction of an ampulla forces water into a tube foot lengthening it. Contraction of longitudinal muscles in the foot forces water back into the ampulla shortening the foot. Small suction discs at the end of the feet allow the starfish to move on hard ground and to grasp its prey. The tube feet are also important sites of gas exchange. Pressure generated by the water vascular system also allows the seastar to evert its cardiac stomach and pry open the shells of bivalves like clams, in order to eat them. It is important to realize that the water vascular system is not a true vascular system supplied with a heart as a pump, and that there is no blood that contains special pigments for transporting gases (as is seen in other animals with true vascular systems). Video of tube feet in action

DIGESTION

Seastars feed by everting part of the cardiac stomach through their mouths out into the water (or even directly into the shells of molluscs). Then the food is either brought back into the body of the seastar for digestion or digested in place outside the seastar's body. This allows it to feed on animals much larger than itself. Without being able to evert one of its stomachs, the hard endoskeleton would limit the size of prey that could be eaten by the seastar. The cardiac stomach passes the food to the pyloric stomach, where more digestion takes place. Most of the space in the ray is taken up by two highly branched digestive glands (also called pyloric caeca). They secrete digestive juices from their many lobes. They are connected to the pyloric stomach by a pyloric duct in each ray. Absorption of nutrients occurs in the digestive glands.

TRANSPORT AND EXCHANGE

Gas exchange occurs through two types of structures that extend from the surface of the seastar: the tube feet and the papillae (also called papulae or gills); the latter are thin-walled extensions of the body cavity (coelom) that extend onto the aboral surface of the seastar. They look like small finger-like sacs when the animal is in the water, but may not be visible on these specimens. There is no circulatory system in the seastar. Instead, gases are carried around the body via fluids in the body cavity, powered by the action of cilia.

In one ray the digestive glands have been removed to show the ampullae of the tube feet, which are the bulbs on the aboral side of the tube feet, which contract to extend the tube feet.

EXCRETION AND OSMOREGULATION

In seastars, nitrogenous waste is excreted as ammonia. Solid waste is expelled through the anus. There is no osmoregulation in seastars. They are osmoconformers.

REPRODUCTION

Sometimes individual animals are male or female (dioecious). In other cases, the same gonad can produce both eggs and sperm, either simultaneously or se-

quentially. External fertilization occurs after the gametes have been released through ducts located on the central body between the arms.

Phylum Chordata-Perch

Phylum Chordata includes all those animals (perhaps 50,000 species) with backbones: fish, amphibians, mammals, reptiles, birds, as well as a few other species. A few chordates do not have backbones and are thus classified as invertebrates. These include small marine animals called tunicates and lancelets. To be a chordate an animal must:

1. Have had at least during embryonic development, a structure called a notochord. (this is a flexible supportive rod running longitudinally through the dorsum of the animal just ventral to the nerve cord; it becomes the spinal column in vertebrates);
2. have pharyngeal gill slits at some stage in their development;
3. have a dorsal hollow nerve cord, and
4. Have a post-anal tail.

The perch is a chordate belonging to the Actinopterygii (ray-finned fishes) within the subphylum Vertebrata. Well over 25,000 ray-finned fish species are known today and, as we probe deep ocean regions, we will find many more. Perch are freshwater food and game fish found in Europe and North America. *Perca fluviatilis* or yellow perch is a marginal sport fish, which has been introduced into Vaseux and Osoyoos Lakes in the Okanagan.

THE PERCH – EXTERNAL FEATURES

Be sure that you can identify the dorsal and ventral sides of your specimen and its anterior and posterior ends. Be able to draw and identify the pectoral, dorsal, pelvic, anal, and caudal fins.

Most fish have external fertilization, but a few species, like guppies, have internal fertilization and are livebearers.

DIGESTION

Perch are carnivores. Their digestive tract comprises an alimentary canal (the tube running from the mouth to the anus) as well as accessory structures, such as the liver, salivary glands and pancreas. After the mouth, the alimentary canal includes, in order, the esophagus, stomach, pyloric caeca (secretory and digestive functions), intestine and duodenum.

CIRCULATION AND RESPIRATION

Perch, being aquatic chordates, use gills as a respiratory exchange surface. Cut away the bony operculum to expose the gill chamber and its four gills. Remove

an individual gill to study its structure. The hard-bony support is the gill arch, with posteriorly directed gill filaments. The hard-anterior finger-like projections, the gill rakers, prevent coarse material or food from passing through the gill slits. Gill filaments are supplied with capillary beds across which gas exchange occurs. The flow of blood is opposite to the flow of water across the gills, called counter-current flow; this enhances the concentration gradient and thus the rate of diffusion. This helps metabolically active fish to more efficiently extract oxygen from relatively poorly (relative to air) oxygenated water.

Chordates have closed circulatory systems. The advantage of a closed circulatory system over an open system is that blood can be kept at a higher pressure thus moving through the body more quickly, which is more efficient at servicing body tissues.

The pericardial cavity, just beneath and ventral to the gills, contains the two-chambered heart. Observe the thin-walled posterior atrium extending over the thicker-walled ventricle. Anterior to the ventricle is the bulbus arteriosus, the enlarged base of the ventral aorta that carries blood to the gills and on to the rest of the body. The blood is under pressure when it reaches the gills, but pressure is reduced when the blood passes through the capillary bed. Blood pressure remains low as the blood travels to the rest of the body. This is different from animals with a pulmonary loop, in which the blood travels back from the lungs to the heart, where it is pumped (re-pressurized) to the rest of the body and thus can move more quickly and service body tissues more efficiently than the lower pressure system.

EXCRETION AND OSMOREGULATION

Chordates have kidneys composed of nephrons. In fish and amphibians, the kidneys lie as two straps alongside the spinal column; in reptiles they become attenuated to the posterior portion of the animal, and this phenomenon is even more advance in birds and mammals. Kidneys function as both excretory and osmoregulatory organs. In addition, osmoregulation can be facilitated by other organs, depending upon the type of animal.

In freshwater fish like the perch, the kidney excretes large amounts of dilute urine in order to rid the body of excess water. In marine fish, the kidney excretes salt ions in very concentrated urine. In all fish, ammonium is the form of nitrogenous waste excreted.

Phylum Chordata-Rat

Rats are examples of terrestrial chordates. They are also mammals. Therefore, their anatomy will reflect the fact that they get their oxygen from air, must conserve water, and have internal fertilization with their offspring then developing in a uterus before being born.

DIGESTION

As in all tetrapods, the anterior end of the digestive and respiratory systems is shared. Air, water and food all pass through the oral cavity. In the pharynx, the epiglottis acts as a gate to direct air into the lungs and food or water into the rest of alimentary canal. Like in the perch, the digestive system comprises the alimentary canal (oral cavity, pharynx, esophagus, stomach, small intestine, large intestine, rectum and anus). Each part of the alimentary canal is specialized for a particular function: mechanical or chemical digestion, absorption of water or nutrients, or retention or elimination of undigested solid wastes. Be able to identify the stomach, small intestine, salivary glands, liver, and spleen in preparation for your lab exam.

The accessory structures of the digestive tract include the liver, pancreas and salivary glands. These are exocrine glands, meaning that they secrete chemicals into ducts that lead directly to another structure - in this case, the alimentary canal specifically, the accessory structures supply enzymes, or other chemicals that aid in digestion, to the alimentary canal.

CIRCULATION AND REGULATION

After being directed from the pharynx into the respiratory system, air enters the trachea, the bronchi and then the lungs. The lungs of amphibians are fairly simple invaginated sacs of vascularized epithelial tissue in which there are internal partitions to increase the surface area. Birds and mammals, however, have lungs of a more complex nature. In mammals, the bronchioles divide into finer and finer branches until they end in tiny, blind-ended sacs called alveoli, which greatly increase the surface area across which gas exchange occurs. Birds have other mechanisms to increase gas exchange.

Because air movement into and out of the lungs is based on differences in air pressure, it is important that the lungs be sealed in an air-tight part of the body where movement of muscles can create differences in pressure. This area is called the thoracic cavity. Differences in pressure within the thoracic cavity are created by movement of muscles associated with the ribs, as well as the diaphragm.

The heart of the rat, like all mammals, consists of four chambers: two atria and two ventricles. When the atria contract they fill their respective ventricle with blood; when the ventricles contract, the increased pressure directs blood from the right ventricle to the lungs and from the left ventricle to the rest of the body. Your rat has been double-injected with latex. Blue latex was injected into the veins and red latex was injected into the arteries. Entering the right atrium are three main blood vessels that bring the deoxygenated blood back to the heart from all regions of the body. These blood vessels are the right superior vena cava, the left superior vena cava and the inferior vena cava. The right and left superior venae cavae return deoxygenated blood to the heart from the right and left side of the head, neck and forelimbs. The inferior vena cava returns deoxygenated blood to the heart from the lower part of the body. More in depth detail of a mammal heart will be covered in the next lab.

EXCRETION AND OSMOREGULATION

Rat kidneys, like those of humans, excrete urea. Urea is less toxic than ammonia therefore it requires less water to be excreted; however, energy must be expended in order to make urea from ammonia. Organisms that use urea tend to live in environments where water conservation is important. Rat kidneys lie outside of the abdominal cavity, behind the lining of connective tissue. Thus, they are said to be retroperitoneal. The kidneys are the major osmoregulatory organ in the rat.

REPRODUCTION

In male rats, the scrotum, a large sac of skin, muscle and connective tissue holds the testes on the exterior of the body just ventral to the anus. During non-breeding periods, the testes may be retracted into the abdominal cavity and the scrotum will not be enlarged. Around the outside of each testis is a C-shaped structure known as the epididymis, which is a very long, highly coiled tubule. Part of the epididymis is on the posterior end of the testes and part is on the anterior end. Sperm cells produced in the seminiferous tubules of the testes pass into the epididymis and then into the vas deferens, which is a moderately large tube leading from the epididymis to the urethra, which is a tube located inside the penis. The penis is enclosed in an epithelial sheath and held along the ventral wall of the abdomen.

The prostate glands are found on either side of the urinary bladder. These glands, and some other glands in this region, comprise the accessory sex glands. The secretions of these glands form the seminal fluid, which carries the sperm during ejaculation, activates and provides certain nutrients for them, and contains substances that neutralize the somewhat acid environment in the vagina.

In female rats, as in all mammals, the eggs are produced in the ovaries and then released into the oviducts, through which they travel to the uterus. If fertilization occurs, the fetuses develop in the uterus. The rat uterus has two horns, which join at their base to form the vagina.

Life Cycles, Dissection Guides, & Videos

Phylum Echinodermata

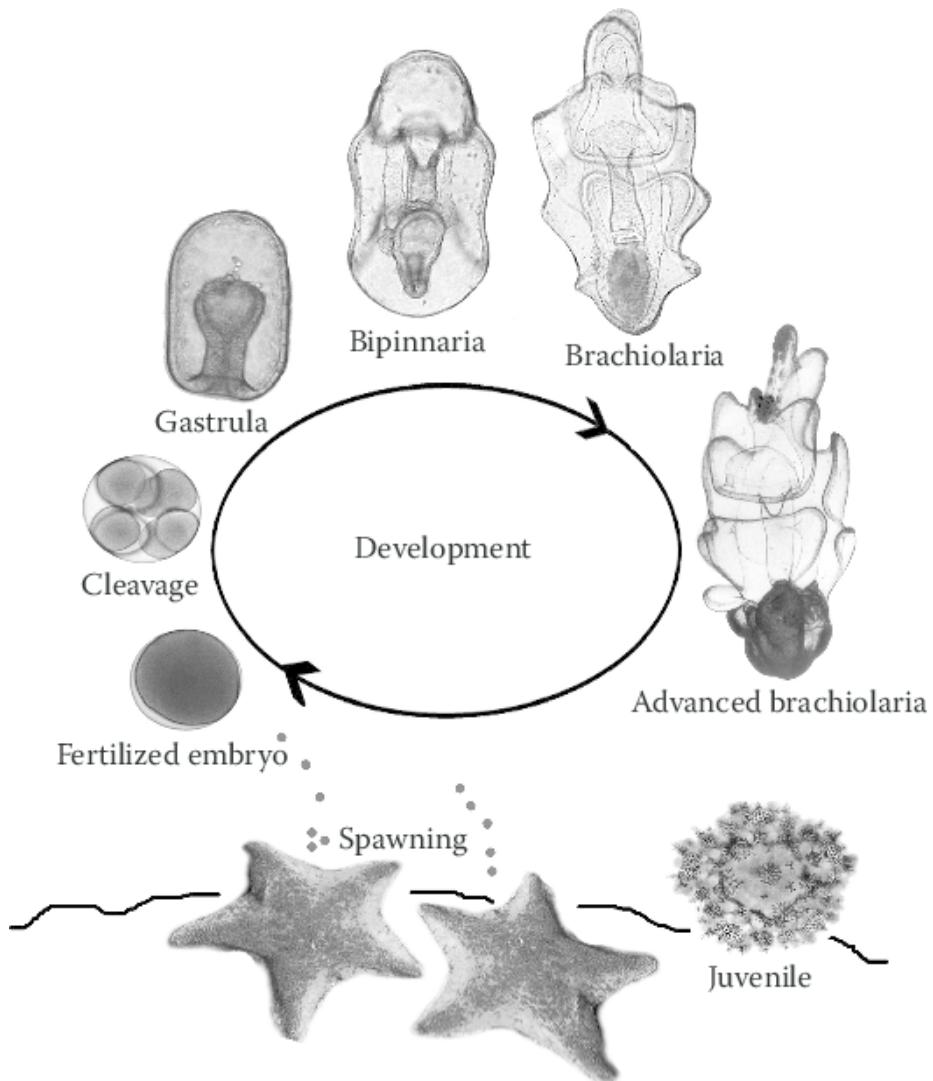
Did you know that a seastar eats with its stomach outside itself? Click the video below to see for yourself! <https://www.shapeoflife.org/video/echinoderms-seastar-time-lapse-eating-mussel>

Seastar Life Cycle

Seastar Dissection Guide & Video

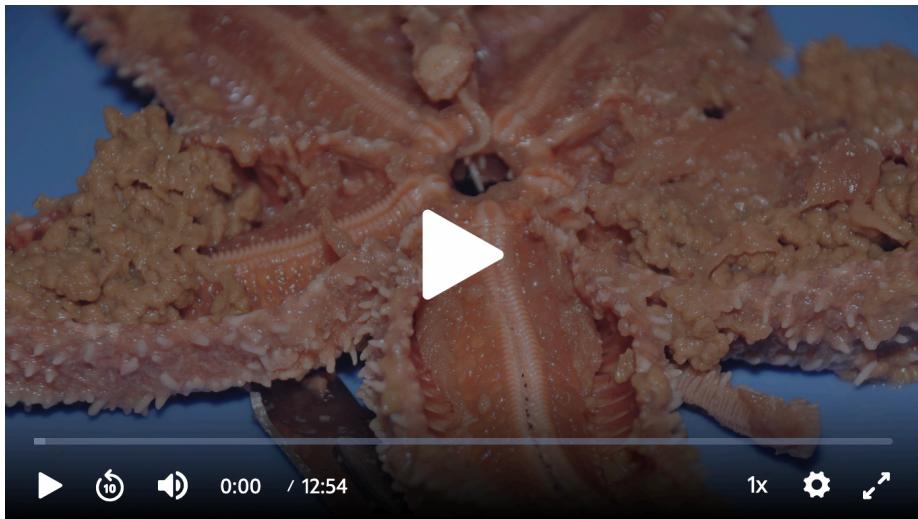
Click here to download a copy of the Seastar Dissection Guide.





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https://www.researchgate.net/profile/Maria_Byrne/publication/228949747/figure/fig1/AS:340715692412928@1458244359117/life-cycle-of-the-seastar-Patiriella-regularis-For-ecological-success-all-life-stages.png

Figure 9: Seastar Life Cycle



Seastar Quiz

Complete the Seastar Quiz on Canvas.

Phylum Chordata-Perch

Ribbons aren't just for presents! Perch lay their eggs in the form of ribbons.

Click here to see more!

Perch Life Cycle

Perch Dissection Guide & Video

Click here to download a copy of the Perch Dissection Guide.



Figure 10: Perch Egg Strand

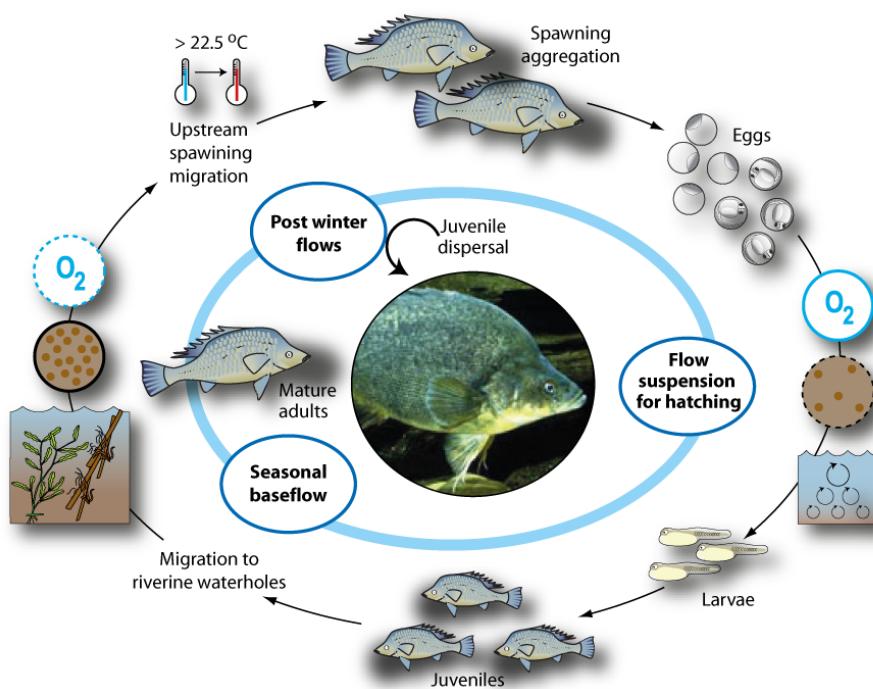


Figure 11: Perch Life Cycle



Perch Quiz

Complete the Perch Quiz on Canvas.

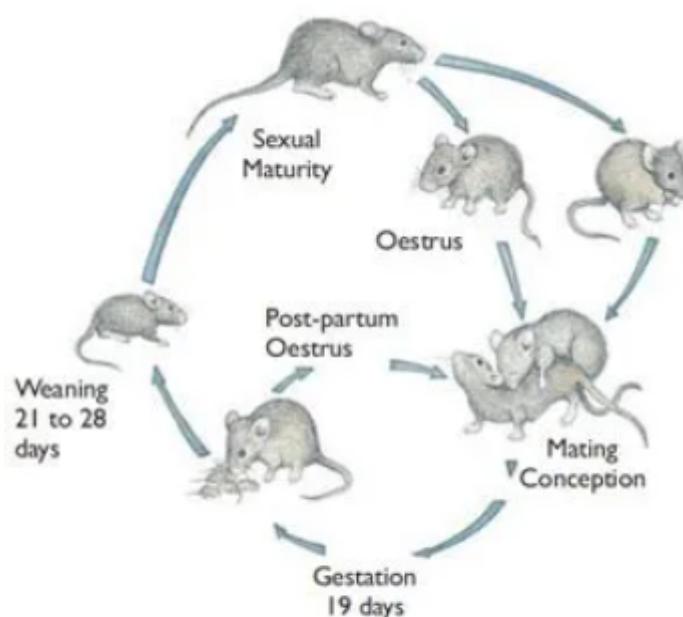
Phylum Chordata-Rat

Rats can swim! And apparently climb up your toilet. Click here to check it out!

Rat Life Cycle

Rat Dissection Guide & Video

Click here to download a copy of the Rat Dissection Guide.



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Figure 12: Rat Life Cycle

**Rat Quiz**

Complete the Rat Quiz on Canvas.

Lab 9

Animal Systems II: Part Two

Last updated 2023-03-21

Overview of the Week

Breakdown:

1. Come to lab ready on campus
2. Get assigned an animal and a group by your TA
3. Build a dissection presentation for your fellow students in the lab. Remember to add two errors to your presentation.
4. Submit Assignment #8 before the end of the lab. Ensure all members have submitted a copy or those students missing a submission will receive a zero for the assignment and an absence score of 2.5. The last lab you spent a tremendous amount of time learning about echinoderms and chordates through videos, images, guides, and quizzes. Now, this week you will get to see these animals up close and personal!

For this lab, you will be placed in groups and will be performing some dissections! Though not required, if you have lab coats please feel free to bring them along. All needed gloves and eye protection will be provided in the lab. For those of you who are not comfortable with dissections please know that you can still participate in the activity without having to do the actual dissection.

Make notes and work together as a team to learn about these groups. You and your group will create a dissection which you will then present to the other groups at your table. You will need to identify each structure and its function to your group. In order to make sure your peers are paying attention you must make up and/or incorrectly label two structures. The job of your peers is to now figure out which structure you presented incorrectly. Your TA will provide more details about the logistics of how this will work in the lab. In either case, have fun and enjoy the process!

Assignment: Lab 9

[Click here to download a copy of the Assignment.](#)

Lab 10

Fictional Animal Systems Project

Last updated 2023-03-21

This assignment was developed from the article "The Fictional Animal Project: a Tool for Helping Students Integrate Body Systems". Adv. Physiol. Educ 41: 239-243 Blatch et al. 2017

In the year 2146, biodiversity is dangerously low and the United Nations has developed a machine that randomly creates animals with varying designs for body systems and other physiological aspects. One example is a homeotherm with unidirectional ventilation, an open circulatory system, an excretory system that secretes only, and an incomplete digestive tract. In order to better understand the animals created and their ability to adapt to their environments, you have been asked to render a detailed anatomical “blueprint” of these animals, provide their scientific name, describe the relationships between the animal's form and function, between function and environment and provide a detailed diagram of its life cycle. This information will need to be presented to the “Zoological Society” in the form of a PowerPoint presentation. Using a random generator your TA will assign your animal design combination during this week’s labs.

Learning goals:

- Understand system integration
- Recognize the effects of adaptations relevant to the environment
- Consider potential trade-offs and physiological constraints.
- Solid understanding of the various animal systems which occur in nature and how they influence one another
- Understand the anatomy involved in each of these systems within their designated animal

The presentation should fit onto one poster paper (approximately 24X36) and include the following information via diagrams/images and/or verbally:

- Blueprint of your animal; a detailed diagram of your organism including all systems and their relevant structures. Flow/current direction within the relevant systems should also be indicated. Remember to include a diagram of the exterior of your organism
- The scientific name of your organism
- A description of your animals' structure and function:
 - The description should align with your diagram
 - Describe each system and how it works and be sure to include all structures relevant to that system
 - Describe how each system interacts with each other
- A description of the habitat your organism would be found in how its structures are adapted for that environment
- Detailed drawing of your organism's life cycle to include;
 - Any forms it takes on at the different stages of its cycle
 - What part of the life cycle is haploid and diploid
 - Where mitosis and meiosis occur
 - Sexual or asexual reproduction

Examples of types of questions to think about when working through your report:

1. Does the circulatory fit with the respiratory system? Why or why not? Your explanation cannot be only because the combination exists in a real animal. Use your diagram to help you figure it out.
2. Does my organism's digestive system fit with the excretory system? Why or why not?
3. What might be an adaptive advantage of the combination of the systems you were assigned?
4. What might be an adaptive disadvantage of the combination of the systems you were assigned?
5. What constraints might be placed on the physiological process of each system by the combination of anatomic structures found in your animal?

Additional instructions for the final project:

Describe an environment it would thrive in. Be specific. Explain why the animal thrives in that environment.

Animal Systems

Presentation Prep

You and your partner will be required to give a 5-minute presentation with each member presenting the same amount of time. Your presentation must be done using standard poster size paper 27 X 40 approximately. Your group will be given a grade for the quality of your oral presentation. It is important that you;

- Outline your talk as early as possible
- Get together to organize and practice the presentation so the timing is accurate and you do not repeat information
- Remember that your goal is to present material in a clear, succinct and interesting manner.

Suggestions for Content and Structure:

- Plan a strong, clear beginning and ending.
- Provide a clear context for your work. Your introduction should include the objective and biological context of your study.
- Include your hypotheses and prediction.
- Present your materials and methods in a simple or streamlined manner. Keep it short and simple.

Presentation pointers for you:

- Practice over and over and over again until you can flow through the material without any hesitation. This will help ensure you have a handle on the material when you are nervous up at the front of the class. Take the opportunity to practice your presentation in the class
- Get ready to perform. This is a performance! Know your lines and your subject.
- Memorizing your lines can be problematic as you may start to sound too scripted. Use bullet points to help tell you what to talk about instead. Remember you are telling a story.

- In order to help deal with nerves before a presentation work out slowing your breathing, visualize yourself giving a relaxed talk and even tell yourself you are confident. You may even want to “power pose” it! For those that don’t watch Grey’s Anatomy this is when you stand like superman or superwomen right before attempting something that makes you nervous. There are studies indicating this is very successful but at the very least it’s not going to hurt right?
- Walk confidently to the front of the room to get you in the right frame of mind
- Stand tall when you are up there and keep your chest lifted. Remember you totally got this!
- Above all...smile! You will instantly appear more relaxed and research shows that smiling can actually reduce your stress level. Plus, there is the added benefit of people enjoying the interaction more as you don’t look like you are totally miserable up there .
- Speak up. People want to hear what you have to say so make sure they can.
- Take your time. For you it’s going to feel like its lasting forever but for your audience you may come across like you just had two coffees and a Red bull. Allow for those “awkward” pauses as for the audience it will actually sound more normal.
- Talk to the audience and not your screen or cue cards. You should know the information so well that all you need is a quick bullet point to get you talking.
- Keep to the time frame. This is where giving yourself lots of practice time will help out. Use the rubric provided to ensure you have covered all requirements of this assignment in order to attain the best possible outcome.

Lab 11

Fictional Animal Systems Presentation

Last updated 2023-03-21

Overview of the Week

Your TA will pre-determine the order of your presentations and will let you know ahead of time. Please ensure you are ready to go. As this is the last lab and it requires a presentation during your scheduled lab section there will not be the option to submit 24 hours late.

Presentation Rubric

Total /**38**

System Integration

This criterion is linked to a Learning Outcome **System Integration**. All systems and regulatory strategies have been thoroughly explained

Possible Points 8

Ratings	Comment
8 pts	Excellent. All four systems are represented and explained.
6 pts	Proficient. 3 of the 4 systems are represented and explained.
4 pts	Satisfactory. 1-2 of the systems are represented and explained.
2 pts	Unsatisfactory. It is unclear what system is being included.

This criterion is linked to a Learning Outcome **System Integration**. All systems and regulatory strategies have been thoroughly explained. This criterion is linked to a Learning Outcome System integration Systems are compatible with each other as described in the final version of the animal.

Possible Points 10

Ratings	Comment
10 pts	Excellent. The compatibility of all 4 systems has been reasoned logically and fully explained for all 4 systems.

Ratings	Comment
8 pts	Proficient. The compatibility of the 3 systems has been reasoned logically and explained.
6 pts	Satisfactory. The compatibility of the 2 systems has been reasoned logically and explained systems.
4 pts	Developing. The compatibility of only 1 system has been reasoned logically and explained systems.
2 pts	Unsatisfactory. Compatibility between the systems is not clearly described.

Life Cycle

This criterion is linked to a Learning Outcome **Life Cycle**. The full life cycle has been provided and all structures and ploidy are indicated.

Possible Points 4

Ratings	Comment
4 pts	Excellent. All criteria are met.
3 pts	Proficient. 3/4 of the criteria are met.
2 pts	Satisfactory. Half of the criteria are met.
1 pts	Developing. The life cycle has been provided but does not fulfill the remaining requirements.
0 pts	Unsatisfactory. No life cycle was provided.

Environment

This criterion is linked to a Learning Outcome **Environment**. Explained how animal and their systems are compatible with the environment.

Possible Points 2

Ratings	Comment
2 pts	Excellent. Logical.
1 pts	Satisfactory. Illogical or incomplete.

Ratings	Comment
0 pts	Unsatisfactory. One member of the group is primarily presenting and expertise is not demonstrated.

This criterion is linked to a Learning Outcome **Environment**. Description of how animal functions/lives/is affected by its environment.

Possible Points 2

Ratings	Comment
2 pts	Excellent. Present and consistent between the animal and its environment.
1 pts	Satisfactory. Present but inconsistent between the animal and its environment.
0 pts	Unsatisfactory. Absent.

Overall

This criterion is linked to a Learning Outcome **Overall description**. Backbone, body design, appendages, covering, size, etc. selections.

Possible Points 3

Ratings	Comment
3 pts	Excellent. All consistent within the animal and it's physiological systems.
2 pts	Proficient. Some inconsistencies within the animal or with its systems.
1 pts	Satisfactory. Most or all inconsistent within the animal and/or its systems.
0 pts	Unsatisfactory. Drawing and description are unclear and non-informative.

This criterion is linked to a Learning Outcome **Overall**. The presentation style is clear, had sensible flow, volume was appropriate, and the presenter was engaging

Possible Points 3

Ratings	Comment
3 pts	Excellent. All criteria are met.
2 pts	Proficient. 3 of the four criteria have been met.
1 pts	Developing. 1-2 of the criteria have been met.
0 pts	Unsatisfactory. 0-1 of the criteria have been met.

Scientific Information

This criterion is linked to a Learning Outcome **Scientific Information**. Details of the process of each system were conveyed with appropriate terminology.

Possible Points 3

Ratings	Comment
3 pts	Excellent. All of the structures and associated functions for each system were described.
2 pts	Proficient. Most of the structures and their associated functions for each system were described.
1 pts	Developing. Some of the structures and their associated functions for each system were described.
0 pts	Unsatisfactory. Many of either the structure or their associated functions were missing.

Presentation

This criterion is linked to a Learning Outcome **Presentation**. Evidence that the student can communicate their ideas accurately and in a meaningful way.

Possible Points 3

Ratings	Comment
3 pts	Excellent. Every major point is well supported and well-articulated. The presenter engages with the audience while conveying a clear understanding of knowledge and understanding of their systems.

Ratings	Comment
2 pts	Proficient. Every major point is adequately supported and well-articulated. The presenter engages with the audience while conveying an adequate understanding of knowledge and understanding of their systems.
1 pts	Developing. Many of the points are adequately supported and articulated. The presenter engages with the audience to some degree but does read from their notes and only partially convey's the necessary information.
0 pts	Unsatisfactory. The presenter is reading word for word notes and does not seem to be able to articulate information about their animal systems.