

Fall 2026



Idaho State
University

Biology II Laboratory

BIOL 1102L

Academic Year 2025-2026

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Prepared by:



Idaho State
University

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<https://www.isu.edu/biology/biolab>

Please note that this manual is a work in progress and was compiled specifically for the ISU Department of Biological Sciences. It changes each semester/session. It is a free and unpublished manual that has not seen reviewers or editors; there are errors.

ROAR

Laboratory Policies (<https://www.isu.edu/biology/biolab/student-behavior/laboratory-rules/>)

1. **No** food or drink allowed.
2. Coats, bags, purses, backpacks, etc. must be stored on the shelves provided on the side of the room. Do NOT keep them next to you at your workstation. Only your binder with syllabus, task sheets, pencil, colored pencils, and mini-stapler should be with you at the workstation.
3. Standard lab attire is required:
 - work shirt that covers the upper torso and arms,
 - lower body clothing that covers the leg to the knee (e.g., pants, skirt, coveralls, lab coat) and fully protects exposed skin
 - shoes that have a closed toe AND heel (i.e. NO flip flops or sandals).
4. Long hair must be restrained for safety reasons (i.e., braided, tied in a pony tail, etc.).
5. Notify your instructor of unsafe conditions such as broken glassware or water on the floor.
6. Never pour chemical reagents down the sink drain unless instructed to do so.
7. Participation in lab is required. If the lab instructor observes that a student is not actively participating in the completion of the task sheet, the student will receive a zero on the task sheet.
8. **No** mobile electronic devices are allowed in the lab (smartphones, tablets, smartwatches, smart glasses, ear pieces, and laptops). If a student has one on his/her person OR anywhere near their seat they will receive a zero on their quiz and/or task sheet. They must be placed in your bag or coat and stored on the shelves provided.
9. **No** use of generative artificial intelligence (AI) allowed in the lab or on lab assignments. If a student uses AI, they will receive a zero on their quiz and/or task sheet.
10. Random assigned seating is required during each lab.
11. Before and after each lab, wipe down all student benches, computer keyboard and mouse, microscope knobs and eyepieces, and all other equipment that is touched during lab with the correct cleaning supplies.
12. Instructors must also wipe down the instructor benches, computer keyboard and mouse, microscope knobs and eyepieces, projector remote, as well as any other equipment they use during lab the correct cleaning supplies.

Welcome to the laboratory portion of Major Concepts in Biology II (BIOL 1102L), introductory biology for students majoring in the biological sciences. The laboratory is intended to reinforce the concepts and information presented in the lecture portion of the course and to provide you with opportunities to:

- ✓ Gain transferable skills.
- ✓ Become proficient in the language of biology and science.
- ✓ Use and improve your critical reasoning, analytical, and communications skills.

Learn your laboratory instructor's name and keep a record of his or her contact information:

Instructor | _____ Section | _____
E-mail Address | _____ Office hours | When: By Appointment Where: _____

Take the syllabus Google quiz (linked in Canvas), read about and acknowledge the following:

- Occupational Health & Safety
- Academic Integrity
- Attendance Policy

Attendance & Communication Policy (<https://www.isu.edu/biology/biolab/student-behavior/attendance--communication/>):

Attendance

For the first lab of the semester, it will be considered an UNEXCUSED ABSENCE if a student:

- Does not attend the laboratory for which they are registered,
- Registers after labs have begun, OR
- Attends a lab section for which they are not registered although they are registered for another section.

For the duration of the semester, students are expected to:

- Arrive on time,
- Stay for the entire lab,
- Attend the laboratory section for which they are enrolled, and
- Contact the lab instructor four business days BEFORE a lab is missed to request an excused absence. **Excused absences** are granted for university-sponsored extra-curricular activities only and the student must provide a note from their coach, trainer, etc. **Unexcused absences** cannot be made up.

Communication

When students communicate with their instructor using e-mail they are required to use the **ISU Academic Communication guidelines** (<https://www.isu.edu/advising/atoz-index/academic-communication/>) as well as specific rules 1-4 or the instructor is NOT required to respond. Instructors are also not required to respond to an e-mail if it is about an assignment that is due in 2 business days or less OR an absence that has already occurred or will occur in less than two business days.

1. Subject must include the course number (i.e. Biol 1101L) AND the section number for which you are registered (i.e. 01, 02 etc.),
2. A greeting that includes your instructor's name,
3. A concise paragraph that explains your situation and/or asks a question, and
4. A salutation that includes your full name AND Bengal ID number.

IMPORTANT NOTE: The **lab syllabus** and **entire manual** must be printed by the student before the first lab.

Disruptive Behavior (<https://www.isu.edu/biology/biolab/student-behavior/disruptive-behavior/>):

You are expected to behave in a congenial and respectful manner as you participate in all laboratory activities. Disruptive behavior will not be tolerated. This syllabus is your first warning. Examples of disruptive behavior include but are not limited to:

- ✓ Not following laboratory rules and safety.
- ✓ Behavior that impedes another student's ability to learn such as talking out of turn, texting, talking on your cell phone, etc.
- ✓ Disrespectful, rude, or threatening behavior directed toward a classmate or instructor.
- ✓ Cell phones or other electronic devices may not be used; they need to be turned off and placed with your personal belongings on the shelves provided. If others need to contact you at any time, give them the telephone number of the Biology Office (282-3765) or Public Safety (282-2515).
- ✓ Eating and drinking in the lab.
- ✓ Inappropriate use of any electronic devices.

Grades

The points accumulated in laboratory will be scaled to **25% of your final grade** for the course. Your laboratory grade can help your overall grade for the course, so apply yourself responsibly:

- ☐ **Lab Notebook (pencil, mini-stapler, hole-punch are also needed):** You will bring a 3-ring binder to lab to create a laboratory notebook consisting of the lab syllabus, appendices A and B, assigned journal article, handwritten terms and definitions, and all completed and to-be completed task sheets. Your lab instructor will review your notebook each week and points will be awarded; be sure to keep it up-to-date. You will turn in the completed notebook during Lab 15.
- ☐ **Quizzes:** you will have a quiz during the first ten minutes of each lab using the quiz sheet provide by your instructor. The quiz will cover the important terms and any information from the task sheet before completion. If you are late, you cannot take the quiz
- ☐ **Task sheets:** Complete the lab task sheets using information found within the task sheets themselves, supplies offered in lab, and the course textbook. If you do not stay for the entire lab period and do not hand in your completed task sheet you will lose all points.
- ☐ **Journal article assignments (JAA):** read the directions found in the task sheet for lab 1. JAA can be up to one week late BUT it will be worth only 50% of the points earned; after that no late work will be accepted.
- ☐ **Extra Points:** complete by the submission date and time using the assigned materials. Late submissions will not be accepted.
- ☐ **Appendices:** read the directions found in **Appendices A & B** of the lab manual on Canvas.
- ☐ Do not participate in academic dishonesty. Academic Integrity expected of all students. **Academic dishonesty** (<https://www.isu.edu/biology/biolab/student-behavior/attendance--communication/>) in any form is unacceptable. Academic dishonesty includes cheating (e.g. providing or using unauthorized materials) and plagiarism (e.g. representing another's work as your own). Penalties for cheating and plagiarism include reduction in grade for the assignment, grade of F in the course, and dismissal from the University.
- ☐ **ANY violation of laboratory rules and safety** (<https://www.isu.edu/biology/biolab/instructor-training/lab-safety/>) **will result in a zero for all lab grades on the day the violation occurred.**

Graded	#	Points	
		Each	Total
JAA		25, 150	175
Lab Notebook	15	5	75
Quizzes	10	10	100
Task sheets	14	50	500
Appendices	2	100, 25	125
Extra points	Used to offset points missed due to unexcused absences		70

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- ✓ **No** use of generative artificial intelligence (AI) is allowed in the lab or on lab assignments (except during Lab 1). If a student uses AI, they will receive a zero on their quiz and/or task sheet.
- ✓ Random assigned seating is required during each lab.
- ✓ Before and after each lab, wipe down all student benches, computer keyboard and mouse, microscope knobs and eyepieces, and all other equipment that is touched during lab with the correct cleaning supplies.
- ✓ Instructors must also wipe down the instructor benches, computer keyboard and mouse, microscope knobs and eyepieces, projector remote, as well as any other equipment they use during lab the correct cleaning supplies.

Academic Success / Reasonable Accommodations

Idaho State University is committed to providing equal opportunity in education for all students. If you have a diagnosed disability or if you believe you have a disability (physical, learning, hearing, vision, psychiatric) that might require reasonable accommodation in this course, please contact the Disability Services Center, Rendezvous Building, Room 125 (208-282-3599). It is the responsibility of students to contact instructors during the first week of each semester to discuss appropriate accommodations.

How to Succeed in this Course

- ✓ Take responsibility for your own education:
 - Always attend lecture and laboratory.
 - Take notes and review your notes after class each day so you are sure you understand them before lab. Check your notes for accuracy by comparing them to a colleague's or the textbook. If you have questions, ask your instructor.
 - Read the assigned materials before lab.
 - Review and think about what you have heard and read.
- ✓ Visit your laboratory instructor during his or her office hours and "talk biology." Learn about what they are doing in their research programs.

Schedule for BIOL 1102L (subject to change):

DATES	LAB	TOPIC		DUE DATES
August 26 – 27	1 ^A	Software Install (bring your laptop), Journal Article Assignment (<i>terms due</i>)		• Task sheets and quizzes – DURING the lab in which they are assigned. • Extra point terms – Bring to Lab 1 and to the first lab of each unit. • Lab Notebook – DURING each lab • JAA – Bring to Lab 4 • Appendix B – Lab 12 • Appendix A – Lab 15
September 2 – 3	2	Unit I: Introduction to Life (<i>terms due</i>)		
September 9 – 10	3	Unit II: Plants	Parts 1-3. Structure (<i>terms due</i>)	
September 16 – 17	4 ^B		Part 4. Plant Diversity	
September 23 – 24	5			
September 30 – October 1	6	Unit III: Reproduction & Development	Part 1. Land Plants (<i>terms due</i>)	
October 7 – 8	7		Parts 2-3. Fungi & Animals	
October 14 – 15	8	Unit IV: Animals	Parts 1-2. Structure (<i>terms due</i>)	
October 21 – 22	9		Part 3. Dissection & Presentations of Invertebrates	
October 28 – 29	10		Parts 4-5. Comparative Morphology – Dissection, Measurements, & Presentations	
November 4 – 5	11			
November 11– 12	12			
November 18 – 19	13 ^C		Part 6. Comparative Morphology - Analysis & Questions	
December 2 – 3	14 ^D	Unit V: Conclusion	Part 1. IMNH - This is Idaho (<i>terms due</i>)	
December 9 – 10	15		Part 2. Tree of Life	

^{A,B,&C} Bring your laptop to the lab this week. ^D You will meet your instructor at the IMNH.

Journal Article Assignment (JAA)

Objectives of the assignment are to learn about the;

- Scientific method
- Experimental design
- Technical and quantitative methods
- Relevance, utility, intellectual merit, and broader impact

Terms & Definitions

Animals - multicellular heterotrophs with cells that lack cell wall. Most animals have nerves, muscles, the capacity to move at some point in their life cycle, and the ability to reproduce sexually, with sperm fusing directly to eggs.

Axes of a graph:

- A. x-axis is the horizontal axis of a graph; typically describes the predictor (independent) variable.
- B. y-axis the vertical axis of a graph; typically describes the response (dependent) variable.

Cephalopod - an active predatory mollusk of the large class Cephalopoda, such as an octopus or squid.

Chordates - an organism that has or at some point in its life has had a notochord and a hollow dorsal nerve cord; includes all vertebrates and some invertebrates.

Controlled experiment groupings:

- A. Control - in a clinical trial, the group that does not receive the new treatment being studied. This group is compared to the group that receives the new treatment, to see if the new treatment works
- B. Experimental - the sample in an experiment that is subjected to some type of variation that does not occur.

Controls - constant and unchanging standards of comparison in scientific experimentation:

- A. Negative - is not exposed to any treatment (experimental or otherwise) that is known to produce the expected effect.
- B. Positive - is exposed to some other treatment that is known to produce the expected effect but not the experimental treatment.

Domain - one of the three major categories of life; Bacteria, Archaea, and Eukarya.

Experimental design - the laying out of a detailed experimental plan in advance of doing the experiment. Well chosen experimental designs maximize the amount of "information" that can be obtained for a given amount of experimental effort.

Fungi - a eukaryotic kingdom of the domain eukarya that is composed of heterotrophic unicellular, multicellular, or syncytial spore-producing organisms, including molds, yeast, mushrooms, and toadstool

Generative artificial intelligence (AI) - programming models that emulate the structure and characteristics of input data in order to generate derived synthetic content such as text, images, music, videos, code, and more, based on the input data and prompts; computational frameworks used to train machines to perform specific tasks by learning from data.

Genus - a taxonomic category ranking used in biological classification that is below family and above species.

Gnathostome - vertebrates that possess jaws.

Hexapod - the subphylum Hexapoda (from the Greek for six legs) constitutes the largest number of species of arthropods and includes the insects as well as three much smaller groups of wingless arthropods: Collembola, Protura, and Diplura (all of these were once considered insects)

Investigator error - is a type of systematic error caused by technical skills of the investigator and can result from measuring solutions inaccurately, not rinsing equipment well enough between tests (contamination), etc.

Large language model (LLM) - the foundation of AI. LLMs are trained on vast amounts of text to understand existing content and generate original content. They function as chatbots, responding to user prompts by processing natural language in a conversational, human-like way. They can perform a variety of language-based tasks, like generating, summarizing, and translating text.

Life history - the pattern of survival and reproduction events during the life of an organism; life history traits include maximum body size, longevity, age at maturity, and fecundity.

Observational / measurement error - the difference between a measured value of a quantity and its true value and can be the result of systematic error and random error. Systematic error always occurs, with the same value, when we use the instrument in the same way and in the same case and can be reduced with standardized procedures. Random error varies from one observation to another:

- A. Accuracy - how close or far off a given set of measurements (observations or readings) are to their true value, accurate if their average (mean) is close to the true value.
- B. Precision - how close or dispersed the measurements are to each other; standard deviation is relatively small.

Kingdom - a taxonomic group; the second largest after domain.

Mammal - a animal that nourishes its offspring with milk from female mammary glands and has hair.

Organism - a living thing that maintains an internal order that is separated from the environment; descended from a single-celled ancestor that appeared almost 4 billion years ago: Consist of one or more cells, Contain genetic information, Use genetic information to reproduce themselves, Are genetically related, Covert molecules obtained from their environment into new biological molecules, Extract energy from the environment and use it to do biological work, Can regulate and internal environment.

Plagiarism - representation another person's language, thoughts, ideas, or expressions as one's own.

Plant - a taxonomic group that includes land plants and green algae. The group is defined as being eukaryotic with cell walls made of cellulose and the ability to make food via photosynthesis using double-membrane-bound chloroplasts and both chlorophyll a and b. The glucose product of photosynthesis is stored as starch.

Phylum/division - in taxonomy, a subdivision of a kingdom.

Quote - direct quotation (often referred to as "quotes") is the exact language taken from source material. Direct quotations match the source material word-for-word and must be contained within quotation marks, usually introduced with a "says" verb or integrated into your own sentence structure.

Reasoning - the process of thinking about something in order to make a decision; logical thinking:

- A. Inductive - a logical process that argues from specific instances to a general conclusion; deriving a generalization from specific details.
- B. Deductive - making a prediction about the outcome of a test; generating a specific expectation from a generalization.

Science - the observation, identification, experimental investigation, and theoretical explanation of natural phenomenon.

Scientific method - a hypothesis-prediction approach to acquiring scientific knowledge about the natural world.

- A. Observation - a note, record, of an occurrence, or phenomenon. Observations may be made directly or indirectly using tools.
- B. Question - address something that can ultimately be measured. This means that the question has to be answerable – one that can be used to propose a set of hypotheses that can be tested and a set of predictions against which one can compare the results from the study.
- C. Hypothesis - a tentative statement, derived from inductive reasoning, that proposes a possible explanation to the question and states a generalized relationship between two variables.
- D. Prediction - a specific statement, derived from deductive reasoning, about what will occur (i.e. the outcome or pattern that will be observed) in a particular research investigation (e.g., an experiment).

Specimen - something shown or examined as an example

Species - a group of related organisms that share a distinctive form in nature and (for sexually reproducing species) are capable of interbreeding.

Species name – a formal system of naming species of living things by giving each a name composed of two parts (binomial nomenclature) and are italicized.

The two words are as follows:

- A. generic name – identifies the genus to which the species belongs and is capitalized.
- B. specific name or specific epithet – distinguishes the species within the genus and is not capitalized.

Taxon(a) - a group of species that are evolutionarily related to each other. In taxonomy, each species is placed into several taxons that form a hierarchy from large (domain) to small (genus)

Taxonomy - the field of biology that is concerned with the theory, practice, and rules of classifying extinct and extant organisms and viruses

Ray-finned fishes – Actinopterygii; bony fish with fins composed of webs of skin supported by bony or horny spines.

Statistics - a branch of mathematics that estimates the reliability of data by dealing with the collection, analysis, interpretation, presentation, and organization of data:

- A. Data - a collection of discrete values that convey information, describing quantity, quality, fact, statistics, other basic units of meaning, or simply sequences of symbols that may be further interpreted.
- B. Descriptive statistics - quantitatively describe or summarize features of a collection of information.
- C. Mean - is a descriptive statistical measure that reports the central location in a sample of data. A central value of a discrete set of numbers: specifically, the sum of the values divided by the number of values.
- D. Replication - the repetition of an experimental condition so that the variability associated with the phenomenon can be estimated
- E. Standard deviation - a measure that is used to quantify the amount of variation.

Testable - possible to evaluate through observations of the measurable universe.

Tetrapod – a vertebrate having four legs or leg-like appendages.

Theory - a broad explanation of some aspect of the natural world that is substantiated by a large body of evidence.

Variables - any characteristics, number, or quantity that can be measured or counted.

- A. Predictor - causes or affects the response variable; are also known as explanatory or independent variables; are denoted by an X and are shown on the horizontal x-axis.
- B. Response - influenced by the predictor variable; are also known as dependent variables; are denoted by a Y and are shown on the vertical y-axis.

Part 1. Software/Applications

- ☐ Bring your laptop and charging cord (please contact your instructor if you do not have a laptop).
- ☐ Load software onto your personal laptop: R, Microsoft Office 365 Education, and Adobe Reader.
- ☐ Test the functionality of the software and create a table and a figure (Figure JAA-1).

1. **Using your ISU Google account gmail, send the Word document that contains the tables and figures to your lab instructor.**

Tables/Figures			Points	
			Possible	Acquired
Tables	A	One table composed of all analyzed data.	4	
	B	Proper labeling of columns and rows.	4	
	C	Table caption included above table and are numbered (Table 1).	2	
	D	Caption include an introductory statement of what the table is showing.	4	
	E	Tables are formatted correctly.	2	
Figures	F	One figure with three graphs (each graph has a label A-C) .	6	
	G	Figure caption included below figure and are numbered (Figure 1) .	2	
H. All captions include sample size.			1	

Figure JAA-1. This grading rubric will be used to grade your table and figures. Leave blank for your instructor.

Part 2. Assigned Journal Article

You will be required to read **one journal article** and answer questions about the article. The article must describe an **experimental study done by the authors, NOT a review / note / comment**. Articles will be chosen from a specific group of journals from a specific publication year. Each student regardless of lab section will have a different article.

- ☐ The article must be about a PLANT and published between:
 - Fall semesters January - June PRESENT year
 - Spring semesters: July - December PAST year
- 2. Is the article your instructor chose for you an experimental/observational study with a methods section and actual variables? If you chose an article that is not an experimental/observational study with a methods section and actual variables you will NOT receive points for the entire assignment. _____
- 3. List the journal article: Year _____, Volume _____, Issue _____, Pages _____
- 4. What is your articles DOI (Digital Object Identifier)? _____

- 5. Cite your article in the format you would use for the Reference List of the assignment (see Part 3C of the manual).
- 6. What is the species name of one of the plants studied in the assigned journal article.

- 7. To which phylum/division, class, order, family, and genus does the species belong?

- 8. What is the plant's habitat?

9. What is the plant's native geographical location?
10. What is the plant's most unique trait.

Part 3. JAA Directions

A. Format

☐ Word Document

- In the upper RIGHT corner:
 - Your name
 - Date
 - Course #
 - Section #
 - Lab instructor name
 - Journal Article Assignment

- **Question & Answer Format** - question written out (with Q#) followed by the answer in paragraph form.
- Times New Roman 12 pt. font
- 1 inch margins
- Double-spaced
- Reference List on last page

☐ Reference List

- All citations in the list need to follow the specific format found in Part 1C.
- All lines after the first line of each entry in your reference list should be indented ½ inch from the left margin. **This is called hanging indentation.**
- Authors' names are inverted (last name first); give the last name and initials for all authors of a particular work for up to and including seven authors. If the work has more than seven authors, list the first six authors and then use ellipses after the sixth author's name. After the ellipses, list the last author's name of the work.
- Reference list entries should be alphabetized by the last name of the first author of each work.
- Cite your resources in the body of your answers excluding the article under study. You must cite ALL your resources in the correct format. If you do not, you will not receive any of the points possible See below!
- The last page must be a Reference List that lists the article under study as well as ALL other resources. If you do not list all your resources and you do not use the correct format you will lose ALL points possible.

☐ Species name:

- ✓ Is always *italicized*.

- ✓ Is always binomial (e.g. consisting of two words):
genus name (also known as generic name)
specific name (also known as specific epithet or trivial name)
- ✓ Always has the first word but not the second word capitalized.

Ex 1: The North American Elk species scientific name is *Cervus canadensis* (Table UI-1).

- ✓ You only need to write out the species scientific name in full when you first introduce it after that you can abbreviate it.

Ex. 2: The North American Elk, *Cervus canadensis*, is one of the largest species in the Cervidae family. Although *C. canadensis* is one of the largest mammals found in North American it has a relatively short life span of 13 years.

B. Policies

- ☐ Instructors and students are required to use the journal article assignment (JAA) rubric made available on the Canvas course site.
- ☐ Students are required to use the JAA template made available on the Canvas course site.
- ☐ Students must print and turn in the following on the due date and time found in the lab syllabus:
 1. The completed JAA.
 2. The article assigned to complete the assignment.
- ☐ The assignment will not be graded if the assignment:
 - was completed using an incorrect article (not the one assigned),
 - is not in question/answer format, and/or
 - is not turned in by the due date and time.
- ☐ Points will be not be awarded for a question if an instructor finds any amount of the following has been used on said question:
 - Plagiarism
 - AI copy & paste
 - Quoting

C. Questions & Rubric

- ☐ Review the Canvas JAA rubric & JAA template:
 1. Go to the Lab 1 module on Canvas.
 2. Click the "Journal Article Assignment" folder.
 3. Read the rubric.
 4. Determine the sentence requirements for each question and/or sub-question.
 5. Determine the point values for each question and/or sub-question.
- ☐ Answer questions 1-7:
 - Concise, thoughtful.
 - Complete sentences and paragraph form.
 - You will not understand many, if not most, of the terms and acronyms in the articles; look them up, and then use the definition to help you construct your answer. When looking up the definitions make sure you cite your resources in the body of the text and list it in the Reference List.
- ☐ Complete questions 8-9

C. Referencing / Citing

Referencing or citing your sources is an important part of academic writing. It lets you acknowledge the ideas or words of others if you use them in your work and helps avoid plagiarism. It also demonstrates that you have read relevant background literature and you can provide authority for statements you make in your assignments. In your Reference List include the journal article under study, all the resources you used to understand your paper, and where you found the scientific species name and taxonomic information of the study organism from the article. All in-text citations must be included in your reference list.

Article from a Scientific Journal:

- ✓ Present the journal title in full and maintain the punctuation and capitalization that is used by the journal in its title.
- ✓ Most of the journals you will be using are organized by volume AND issue; include BOTH in your citation.
- ✓ Include the Digital Object Identifier (DOI). If the article does not have a DOI include the URL instead.
 - Author, A. A., Author, B. B., & Author, C. C. (Year). Title of article. *Title of Journal*, volume number(issue number), pages. <http://dx.doi.org/xx.xxx/yyyy>
 - The in-text citation format would be (Author, Author, & Author, Year). In subsequent citations, only use the first author's last name followed by "et al." (Author et al., Year).

Books with and without editions:

- Author, A. A. (Year of publication). *Title of work: Capital letter also for subtitle*. Location: Publisher.
- The in-text citation format would be (Author, Year). In subsequent citations, only use the first author's last name followed by "et al." (Author et al., Year).
- Brooker, R., Widmaier, E.P., Graham, L. E., & Stiling, P.D. (2019). *Biology* (3rd ed.). New York, NY: The McGraw Hill Companies.
- The in-text citation format would be (Brooker, Widmaier, Graham, & Stiling, 2014). In subsequent citations, only use the first author's last name followed by "et al." (Brooker et al., 2014).

Generative AI:

- OpenAI. (2025). ChatGPT 5 (August 14 version) [Large language model]. <https://chatgpt.com/>

Lab manual:

- Fultz, J.E. (2021). *Major Concepts in Biology I Laboratory Manual*. Lab 2: Acids & Bases (pages 2-1 to 2-8) (Unpublished). Idaho State University, Pocatello, ID.

OR

- Fultz, J.E. (2021). *Major Concepts in Biology I Laboratory Manual*. (Unpublished). Idaho State University, Pocatello, ID.
- The in-text citation format would be (Fultz, 2021).

Lecture or Lab Notes:

- ✓ Course lecture notes taken by a student are considered 'personal communication' as they are unpublished and 'non-retrievable'. For this reason, they are only cited within the text and not included in the Reference List. For example, lecture notes taken for a lecture given by Professor C. Hale:
 - It is reported that (Professor R. Hale, personal communication, November 15, 2021)
- ✓ Power point notes are in a format that can be retrieved and need to be treated more formally.
 - Hale, R. (2021). Fermentation [PowerPoint slides]. Retrieved from <http://elearn.isu.edu/moodle/>
 - The in-text citation format would be (Hale, 2021)

Online Dictionary or Encyclopedia:

- Feminism. (n.d.). In Encyclopædia Britannica online. Retrieved from <http://www.britannica.com/EBchecked/topic/724633/feminism>
- The in-text citation format would be (Encyclopædia Britannica online, n.d.).

Wikis:

- ✓ You can use wikis only when looking up the scientific name of an organism or the definition of a term. All other references should be from journal articles or .edu/.org sites
 - Elk. (n.d.). In Wikipedia. Retrieved March 7, 2014, from <https://en.wikipedia.org/wiki/Elk>
 - The in-text citation format would be ("Elk" 2014).

Unit I. Introduction

Objectives:

- Review classification and microscopy.
- Observe two species of bacteria.
- Observe nine species of mostly microscopic eukaryotes.
- Construct a tree diagram from the species observed in lab.
- Begin growing a C-Fern from a spore.

Terms & Definitions:

Adaptation - the process and structures by which organisms adjust to changes in their environment.

Adaptive radiation - the process by which a single species evolves into a wide array of descendant species that differ greatly in their habitat, form, or behavior.

Ancestor - a plant, animal, or object that is related to one existing at a later point in time. Autotroph - an organism that has a metabolic pathways that use energy either from inorganic molecules or light to make organic molecules.

Anterior - refers to the end of the animal where the head is found.

Archaea - one of the three domains of life that encompasses those one-celled organisms called archaeans.

Axes of anatomy - a hypothetical axis used to transect an anatomical entity in a straight line through space:

- A. Anterior-posterior (AP) - extends longitudinally from head to tail.
- B. Dorsal-ventral (DV) - ventral typically faces toward, and dorsal away, from a substrate (meaning towards the ground for land-dwelling organisms or towards the ocean or river/lake bottom for marine or aquatic organisms).
- C. Left-right (LR) - to a plane running along the anterior-posterior midline.

Bacteria - one of the three domains of life that encompasses those one-celled organisms called bacteria.

Biological classification - is a system for comparing and grouping organisms, and the naming of those groups.

Biogeography - the study of geographic distribution of extinct and modern species.

Biological diversity (Biodiversity) - variety within and among living organisms.

- A. Diversity - a measure of biological diversity that incorporates both the number of species in an area and the relative distribution of individuals among species.
- B. Richness - the numbers of species in a community.

Biology - the study of life

Cell - the simplest unit of a living organism:

- A. Cell wall - a relatively rigid, porous, structure located outside the plasma membrane of prokaryotic plant, fungal, and certain protists cells; provides support and protection.
- B. Cilium(a) - membrane-bound organelle attached to the cell membrane that can be motile or non-motile.
- C. Chloroplast - plastids found in plant and algal cells that carry out photosynthesis.
- D. Cytoplasm - the region of the cell that is contained within the plasma membrane.
- E. Cytoskeleton - in eukaryotes, a network of three different types of protein filaments in the cytosol called microtubules, intermediate filaments, and actin filaments.
- F. Cytosol - the semifluid portion of the cytoplasm.
- G. Endoplasmic reticulum: the transportation system of the eukaryotic cell, and has many other important functions such as protein folding. Smooth - lacks ribosomes and helps synthesize and concentrate various lipids, phospholipids as in plasma membranes, and steroids needed by the cell. Rough - studded with protein-manufacturing ribosome.
- H. Flagellum(a) - relatively long cell appendages that facilitate cellular movement or the movement of extracellular fluid.
- I. Golgi apparatus - a complex of vesicles and folded membranes within the cytoplasm of most eukaryotic cells, involved in secretion and intracellular transport.
- J. Lysosome - a membrane-bound organelle found in many animal cells. They are spherical vesicles that contain hydrolytic enzymes that can break down many kinds of biomolecules. A lysosome has a specific composition, of both its membrane proteins, and its luminal proteins.
- K. Microtubule - protein structure that moves chromosomes around during mitosis and meiosis.
- L. Mitochondrion(a) - organelle found in eukaryotic cells that supply most of a cell's ATP.
- M. Nuclear envelope - a double-membrane structure that encloses the cell's nucleus.
- N. Nucleolus - a prominent region in the nucleus of nondividing cells where ribosome assembly occurs.
- O. Nucleus - cell structure that houses DNA; found in eukaryotes.
- P. Organelle - a subcellular structure or membrane-bound compartment with its own unique structure and function.
- Q. Peroxisomes - small, membrane-enclosed organelles found in the cytoplasm of virtually all eukaryotic cells that contain enzymes involved in a variety of metabolic reactions, including several aspects of energy metabolism.
- R. Plasma (cell) membrane - the biomembrane that separates the internal contents of a cell from its external environment.
- S. Pseudopod - a part that temporarily sticks out of the protoplasm (= the liquid inside a cell) of some organisms that have only one cell, used for movement and to get food
- T. Ribosome - a structure composed of proteins and rRNA that provides the site where polypeptide synthesis occurs.
- U. Vacuole - a space that contains air or liquid inside a living cell, often storing an important chemical or food substance.

Chitin - a tough, nitrogen-containing polysaccharide that forms the external skeleton of many insects and the cell walls of fungi.

Classification system - method for organizing biological diversity.

Evolution - the phenomenon that populations of organisms change from one generation to the next. As a result, some organisms become more successful at survival and reproduction.

- A. Convergent - the process whereby two different species from different lineages show similar characteristics because they occupy similar environments.
- B. Divergent evolution - the process whereby two different species from the same lineages show different characteristics because they occupy different environments.

Evolutionary trees - a model of evolutionary relationships among groups of organisms that is based on similarities and differences in their DNA, physical features, biochemical characteristics, or some combination of these. It maps the relationships between ancestral groups and their descendants, and it clusters the most closely related groups on neighboring branches.

- A. LUCA - last universal common ancestor is the most recent population of organisms from which all organisms now living on earth are descended.
- B. Most recent common ancestor - the most immediate ancestor that two lineages shares.
- C. Node - the point in an evolutionary tree indicating the moment in time when an ancestral group split, or diverged, into two separate lineages. The node represents the most recent common ancestor of the two lineages in question.
- D. Root - in an evolutionary tree a root represents the ancestral lineage, and the tips of the branches represent the descendants of that ancestor.

Dorsal - the upper side of an animal.

Endosymbiotic theory - the leading evolutionary theory of the origin of eukaryotic cells from prokaryotic organisms. The theory holds that mitochondria, plastids such as chloroplasts, and possibly other organelles of eukaryotic cells are descended from formerly free-living prokaryotes that were taken inside in by endosymbiosis. Both types of organelles contain their own genomes, as well as their own biosynthetic machinery for making RNA and organelle proteins. endoderm - the innermost layer of cells formed during gastrulation;

lines the gut and gives rise to many internal organs.

Eukaryote - one of the three categories into which all forms of life can be placed. The distinguishing feature of eukaryotes is cell compartmentalization, including a cell nucleus; includes protists, fungi, plants, and animals.

Germ layers - three primary germ layers in the very early embryo; cells or tissue of an embryo in early development:

- A. Ectoderm - the outermost layer or the parts derived from this, which include the epidermis and nerve tissue.
- B. Endoderm - the innermost layer or the parts derived from this, which include the lining of the gut and associated structures.
- C. Mesoderm - the middle layer or the parts derived from this, which include the muscle, bone, and nervous tissue.

Gram stain - method of staining used to classify bacterial species into two large groups:

- A. Gram-positive - thick layer of peptidoglycan within the cell wall that retains the crystal violet stain used in the test resulting in a purple color.
- B. Gram-negative - thin layer of peptidoglycan sandwiched between an inner cell membrane and a bacterial outer membrane that cannot retain the violet stain causing them to take up the counterstain (safranin or fuchsin) and appear red or pink.

Habitat - place where an organism lives.

Heterotroph - organism that cannot produce their own organic molecules and thus must obtain organic food from other organisms.

Hyphae - thin, stringy fungal material that grows over and within a food source.

Life - a monophyletic group (refers to a group that consists of an ancestor and all of its descendants) that includes all known organisms. Characterized by a nucleic acid based genetic system (DNA or RNA), metabolism, and cellular structure. Some parasitic forms have secondarily lost some of these features and rely on the cellular environment of their host.

Microscope - a magnification tool that enables researchers to study very small structures and cells:

- A. Depth of field - is determined by the distance from the nearest specimen plane in focus to that of the farthest plane also simultaneously in focus.
- B. Magnification - the ratio between the size of an image produced by a microscope and its actual size.
- C. Field of View - the visible area seen through the microscope when the specimen is in focus. The greater the magnification the smaller the view.
- D. Focus - a specimen is in focus at the desired magnification when the image seen through the ocular lens is sharp and clear.
- E. Objective lens - the primary optical system which produces a magnified image of the specimen. There are typically four objective lenses attached to the nosepiece with the magnification of each objective engraved on its side.
- F. Ocular lens - the secondary optical system that you look through. The ocular lens further magnifies (10x) the image and brings the light rays to a focal point.
- G. Resolution - point-to-point resolving power in the plane perpendicular and parallel to the optical axis. The ability to observe two adjacent objects as distinct from one another; a measure of clarity of an image

Mycellium - fungal body composed of microscopic branched filaments known as hyphae.

Multicellular - the condition of being composed of many coordinated cells.

Organ - a group of tissues with similar functions.

Organ system - a biological system consisting of a group of organs that work together to perform one or more functions. Humans have eleven organ systems: respiratory system, digestive system, circulatory system, urinary system, integumentary system, skeletal system, muscular system, endocrine system, lymphatic system, nervous system, and reproductive systems.

Phylogeny - evolutionary history of a group of organisms.

- A. Monophyletic - a group of species, a taxon, consisting of the most recent common ancestor and all of its descendants.
- B. Paraphyletic - a group of organisms that contains a common ancestor and some, but not all, of its descendants.

Plane (section) - a flat 2D plane intersecting an anatomical continuum (a thing that retains its identity even though its states and relations may change), dividing it into two adjacent portions:

- A. Transverse (Synonyms: axial plane; axial section; cross section) - anatomical plane that divides body into anterior and posterior parts.
- B. Frontal (Synonyms: horizontal anatomical plane; longitudinal section; horizontal section; coronal plane) - anatomical plane that divides bilateral body into dorsal and ventral parts.
- C. Sagittal (Synonyms: left/right plane; sagittal section; longitudinal section; median plane) - anatomical plane that divides a bilateral body into left and right parts, not necessarily of even size.

Population - a group of individuals of the same species that occupy the same environment and can interbreed with one another.

- A. Biological - individuals of the same species that live and breed in the same geographic area.
- B. Ecological - the study of how populations grow and what factors promote or limit growth.
- C. Genetics - study of the factors in a population that determine allele frequencies and their change over time.

Speciation - formation of new species

- A. Allopatric - evolution of a new species from biological populations that have become geographically isolated from each other to an extent that prevents or interferes with gene flow.
- B. Sympatric - evolution of a new species from a surviving ancestral species while both continue to inhabit the same geographic region.

Symmetry - the balanced distribution of duplicate body parts or shapes within the body of an organism; generally with respect to external appearance only:

- A. Spherical - any plane that passes through the center of the object divides the form into two identical halves that are mirror images of each other.
- B. Radial - all planes passing through a central axis divides the form into two identical halves that are mirror images of each other.
- D. Biradial - a combination of both radial and bilateral symmetry. The organs are arranged radially and the body can be divided into two by a mid-longitudinal plane.
- C. Bilateral - only one plane will divide an organism into roughly mirror image halves.

Systematics - the study of biological diversity and evolutionary relationships among organisms, both extinct and extant.

Thylakoids - membrane structures of various types of pigments contained inside chloroplasts and cyanobacteria that are the site of the light-dependent reactions of photosynthesis.

Tissues - the association of many cells of the same type:

- A. Connective - the tissue that supports, protects, and gives structure to other tissues and organs in the body; develops from the mesoderm.
- B. Epithelial - line the outer surfaces of organs and blood vessels throughout the body, as well as the inner surfaces of cavities in many internal organs; develops from the ectoderm or endoderm.
- C. Muscle - a soft tissue that makes up the different types of muscle in animals, and gives the ability of muscle to contract; develops from the mesoderm.
- D. Nervous - the main tissue component of the nervous system; develops from the ectoderm.

Trait/character - a characteristic of an organism, such as the appearance of seeds, flowers, or stems; an identifiable characteristic; refers to a variant:

- A. Adaptive - a genetic trait that helps an organism to maximize its reproductive success
- B. Homologous - a feature that is similar across species because of common descent. Homologous traits may begin to look different from one another over time.
- C. Quantitative - a trait that shows continuous variation over a range of phenotypes.
- D. Shared derived - a trait that is shared by a group of organisms but not by a distant common ancestor.
- E. Shared ancestral - a trait shared with a distant ancestor.

Unicellular - an organism that is composed of only one cell.

Name: _____

Group #: _____

Section #: _____

Part 1. Prokaryotes

The differences between members of Archaea and Bacteria are greater than their similarities. In fact, ribosomal proteins from Archaea are more similar to those of Eukarya than Bacteria, indicating that Archaea are actually more closely related to Eukarya than to Bacteria (Table UI-1). The oldest known fossils, 3.5 billion years old, are of prokaryotes. Prokaryotes influenced the composition of the Earth's atmosphere, which subsequently influenced many of the features of eukaryotic organisms that appeared on Earth later in time. Archaea was determined to be distinct from Bacteria in 1977 by Carl Woese and George Fox based on their unique ribosomal RNA (abbreviated as "rRNA"). As you recall from Biology I, rRNA is the central component of the ribosome, the protein-manufacturing machinery of all living cells. The most conserved (least variable) gene in all cells is rRNA. For this reason, rRNA gene sequences can be used to assess evolutionary relationships through extremely long periods of time. This work led to a major reorganization of the five-kingdom system of classification proposed in 1969 by Robert Whittaker, producing the three-domain system that is widely accepted today.

Table UI-1. Some distinguishing characteristics of the three domains of life.

Characteristic	Bacteria	Archaea	Eukarya
Membrane-enclosed nucleus	N	N	Y
Membrane-enclosed organelles	N	N	Y
Cytoskeleton	N	N	Y
Methionine Initiator in tRNA	N	Y	Y
Peptidoglycan in cell wall	Y	N	N
Ribosomes sensitive to chloramphenicol and streptomycin	Y	N	N
Ribosomes sensitive to diphtheria toxin	N	Y	Y

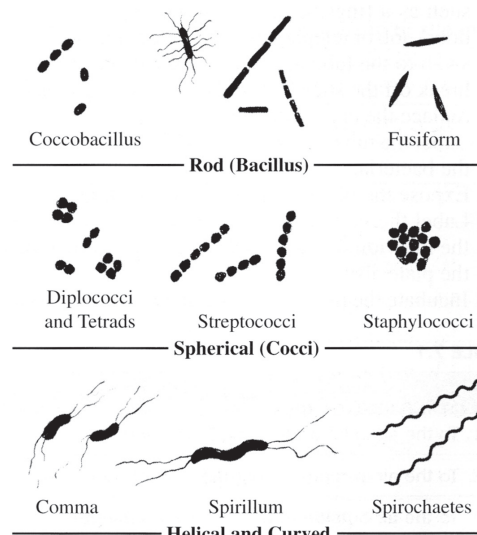


Figure UI-1. Bacterial morphology.

A. Archaea

Most Archaea are extremophiles, organisms that thrive under extreme environmental conditions and therefore occupy ecological niches that

are not tolerated by most other organisms. The variety of colors typical of thermal pools in Yellowstone National Park is due primarily to varieties of these organisms. Although some archaeans occupy relatively moderate environments (e.g., *Methanobrevibacter smithii* is the methane-producing archaean that lives in our colons), the extreme environments in which they occur are difficult to recreate. That limits our ability to observe them extensively in a laboratory setting. All known Archaea are harmless to eukaryotic organisms, including humans.

B. Bacteria

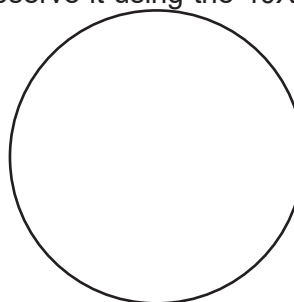
Bacteria are the most abundant of all organisms and they occur everywhere; in air, soil, water and other organisms. They include some organisms that are pathogenic (disease-causing) and others that are essential to the lives of different species with which they interact. Bacteria can be classified using morphology such as size, shape (rod, cocci, helical) and the presence of filaments, pili, endospores, flagella, or capsules. They can also be classified using staining (Gram-negative or positive), biochemical tests, and genetics. Gram staining is a method of differentiating bacteria into two large groups based on the composition of their cell walls. If the bacteria are positive (stained purple) they have a thick cell wall of peptidoglycan whereas if they are negative (stained pink) the wall is much thinner.

1. Make a wet mount of the cyanobacteria *Oscillatoria* and observe it using the 40X objective lens of a compound microscope:

A. Sketch.

B. Label each with genus and phylum name.

C. Label each with the total magnification you viewed it at.



Genus: _____

Phylum: _____

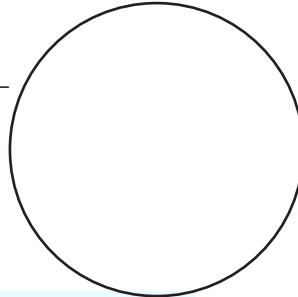
Total magnification: _____

2. Prepare three separate wet mounts of the living cultures (yogurt, mother of vinegar, wheat berry).
 A. Sketch the four genera (yogurt has two).
 B. Label each with genus and phylum name.
 C. Label each with the total magnification you viewed it.

Genera: _____ & _____

Phylum: _____

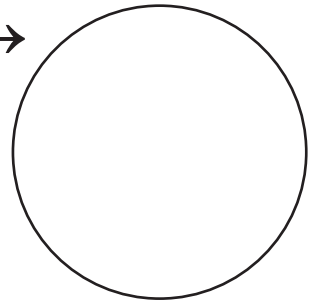
Total magnification: _____



Genus: _____

Phylum: _____

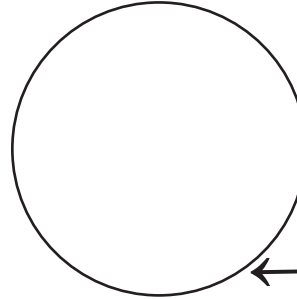
Total magnification: _____



Genus: _____

Phylum: _____

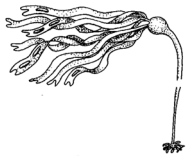
Total magnification: _____



Part 2. Introduction to the Eukaryotes

A. Little Known

- ☐ Examine the living and preserved unicellular and multicellular eukaryotes available in lab. Match the images to the specimens you observed and label accordingly. Include the morphological characters specific to each genus where indicated.



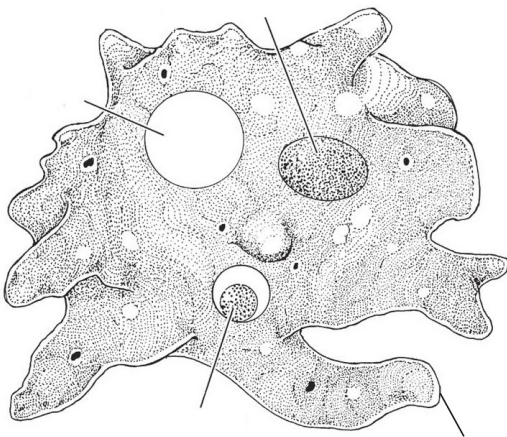
3. Phylum: _____

Genus: _____

Habitat: _____

Autotroph and/or Heterotroph

Total Magnification: _____



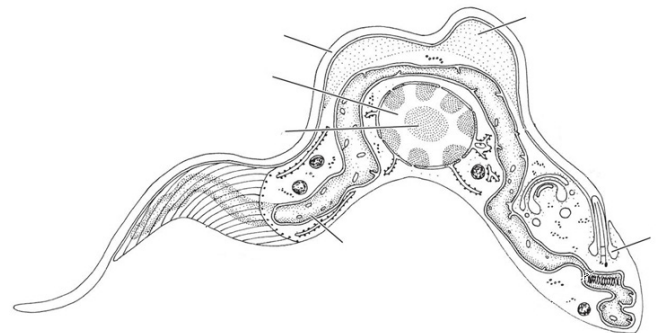
4. Phylum: _____

Genus: _____

Habitat: _____

Autotroph and/or Heterotroph

Total Magnification: _____



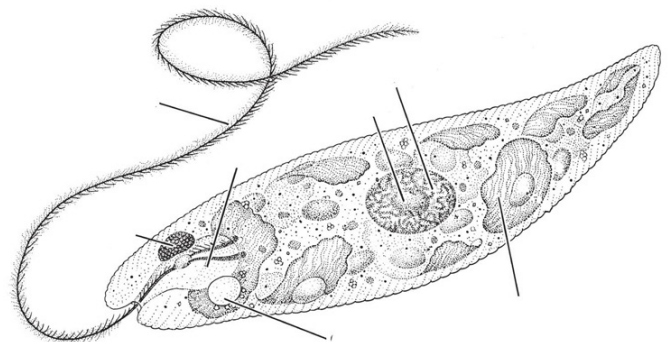
5. Phylum: _____

Genus: _____

Habitat: _____

Autotroph and/or Heterotroph

Total Magnification: _____



6. Phylum: _____

Genus: _____

Habitat: _____

Autotroph and/or Heterotroph

Total Magnification: _____

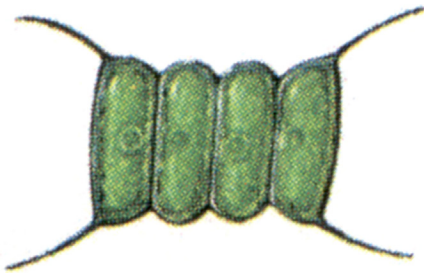
B. Plant Beginnings

Green plants and algae are defined as those photosynthetic organisms with:

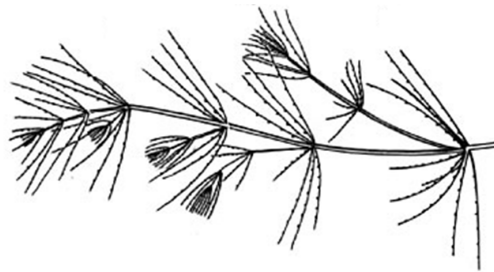
- chlorophyll a and b
- photosynthetic products stored as starch inside double-membrane-bound chloroplasts
- cell walls made of cellulose

Red algae are defined as those photosynthetic organisms with accessory photosynthetic pigments phycoerythrin, phycocyanin and allophycocyanins arranged in phycobilisomes, and the absence of flagella and centrioles. Both groups have chloroplasts derived from captured cyanobacteria and have cell walls, commonly but not always, made of cellulose. Most red and green algae are unicellular but some are multicellular such as seaweed. We can view only a few organisms that are representative of this extremely diverse group. Our goal is to introduce the organisms that specifically help to provide the framework for understanding the evolution of another important group of eukaryotes, the land plants that we will cover later.

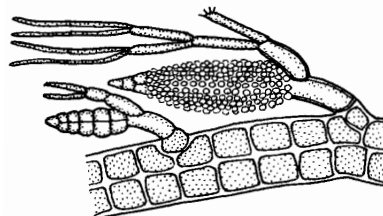
☐ Examine the living and preserved green and red algae. Match the images to the specimens you observed and label accordingly.



7. Phylum: _____
 Genus: _____
 Habitat: _____
 Autotroph and/or Heterotroph _____
 Total Magnification: _____



8. Phylum: _____
 Genus: _____
 Habitat: _____
 Autotroph and/or Heterotroph _____



9. Phylum: _____
 Genus: _____
 Habitat: _____
 Autotroph and/or Heterotroph _____
 Total Magnification: _____

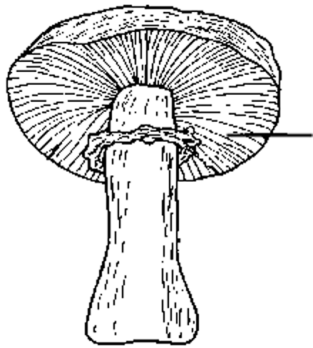
C. Fungi

Both fungi and plants have cells with cell walls, while animal cells have only a plasma membrane. Increasing knowledge about the relationships among organisms shows that the fungi are really a distinct group that can be better classified as a distinct taxon. How are fungi different from plants? The cell wall of fungi is made of chitin and in plant cells it is made of cellulose and pectin. The most structurally complex fungi are made of filamentous cells called hyphae (singular: hypha) that are threaded together (like a tangled ball of yarn) into structures like mushrooms. Collectively, a large group of hyphae growing together are called a mycelium (plural: mycelia).

A unifying theme among the fungi is that they are heterotrophic – they rely on other organisms for food. Different fungi have different strategies to get their food. Some attack living organisms and live parasitically, drawing the nutrients they

need to grow for an extended period of time ("Athlete's Foot"?). Fungi can also be more aggressive, attacking their host with a level of enthusiasm that kills the host in short order. Finally, some fungi arrive after an organism dies and find the nutrients they require in organic tissues that are dead on arrival. Fungi have external digestion. They cannot engulf food, so they break it down enzymatically in their immediate environment and then absorb the chemical components through their cell walls and cell membranes.

☐ Examine the living and preserved fungi. Match the images to the specimens you observed and label accordingly. Include the morphological characters specific to each genus where indicated.



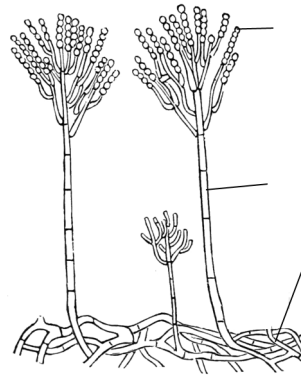
10. Phylum: _____

Genus: _____

Habitat: _____

Asexual and/or sexual stage

Autotroph and/or Heterotroph



11. Phylum: _____

Genus: _____

Habitat: _____

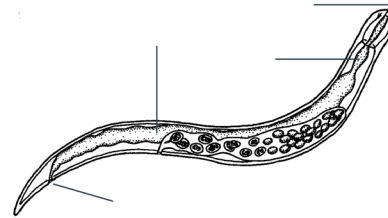
Asexual and/or sexual stage

Autotroph and/or Heterotroph

Total Magnification: _____

D. Animals

Animals are multicellular, eukaryotic, aerobic heterotrophs with cells that lack walls. Most animals have nerves, muscles, the capacity to move at some point in their life cycle, and the ability to reproduce sexually, with sperm fusing directly to eggs. They can range in size from 0.00033 in (8.5 μm) to 110 ft (33.6 m).



12. Phylum: _____

Genus: _____

Habitat: _____

Autotroph and/or Heterotroph

Total Magnification: _____

Part 3. Symmetry, Axes, Planes, & Sections

Symmetry in biology is the balanced distribution of duplicate body parts or shapes within the body of an organism. In nature and biology, symmetry is always approximate. For example, plant leaves – while considered symmetrical – rarely match up exactly when folded in half. Symmetry creates a class of patterns in nature, where the near-repetition of the pattern element is by reflection or rotation. The body plans of most multicellular organisms exhibit some form of symmetry, whether radial, bilateral, biradial, or spherical. A small minority, notably among the sponges, exhibit asymmetry. Positional terms have long been used in anatomy to describe the spatial symmetry of the impressive diversity of organismal forms of both plants, animals, and other organisms. Axes and planes are applicable to many bilateral organisms as well as other symmetries.

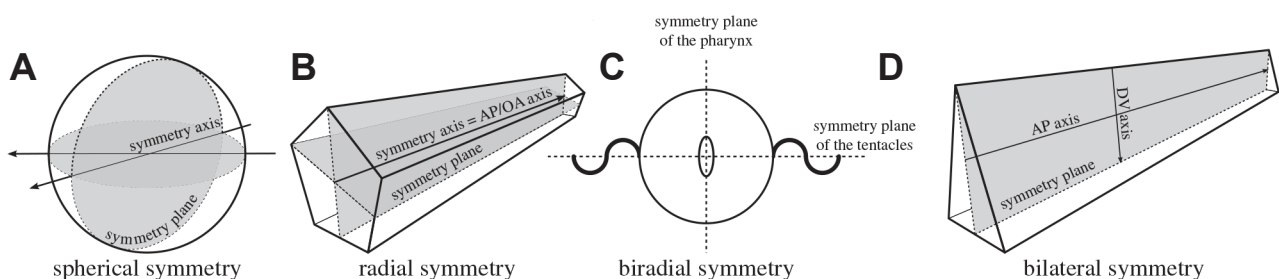
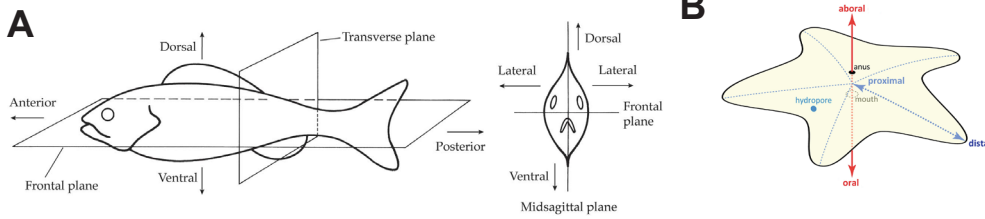


Figure UI-2. Schematic of A) spherical B), radial, C) biradial and D) bilateral symmetries.

13. Label the correct symmetry on the animal diagrams below:



A. _____

B. _____

A. Axes

An **anatomical axis** is a hypothetical axis used to transect an anatomical entity in a straight line through space. The primary or main axis is considered the **anterior-posterior (AP) axis**, which extends longitudinally from head to tail. The **dorsal-ventral (DV) axis** is recognized in that ventral typically faces toward, and dorsal away, from a substrate (meaning towards the ground for land-dwelling organisms or towards the ocean or river/lake bottom for marine or aquatic organisms), whereas the **left-right (LR) axis** is defined in relation to a plane running along the anterior-posterior midline.

- AP axis (Synonyms: anterior-posterior axis, longitudinal axis, cephalocaudal axis; craniocaudal axis; rostrocaudal axis; rostral/caudal) - an axis that extends through an organism from head end to opposite end of body or tail.
- LR axis (Synonyms: left to right axis; dextro-sinister axis; R-L axis; L-R axis; LR axis; right to left axis; right-left axis; RL axis) - an axis that bisects an organism from left to right sides of body, through a sagittal plane.
- DV axis (Synonyms: dorso-ventral axis; dorsoventral axis; D-V axis.) - an axis that is approximately perpendicular to the anterior-posterior axis and that extends through the horizontal plane of the body.
- AA axis (Synonyms: Adaxial-abaxial axis) - an anatomical axis that extends from the side of the anatomical entity that is closer to an axis (adaxial) to the side that is further from the same axis (abaxial).
- Proximal-distal axis (Synonyms: proximal/distal; proximodistal) - an axis that extends from the point of attachment of a structure (proximal) to the point furthest away from the plane of attachment (distal).
- Apical-Basal axis (Synonyms: apical/basal) - an axis that extends through an organism or organism part from the part of the organism or organism part attached to a substrate (basal) to the furthest from the attachment (apical). Note that the apical-basal axis is often used for organismal parts where there is attachment via a basal lamina or other structure. OR an axis of a plant structure that is determined by the direction of apical growth, either by an apical meristem or an apical cell. Apical is toward the direction of apical growth: toward the tip of a growing shoot axis, root, thallus, or non-vascular leaf. Basal is away from the direction of apical growth: toward the root-shoot junction in the case of the primary root or stem, toward the primary root or stem for higher order roots or branches, toward the point of attachment for non-vascular leaves, and toward the original point of growth (as determined in the embryo) for thalli.
- Oral-aboral axis - An axis that extends from the oral opening to the furthest point in an organism that is directly opposite.

B. Planes & Sections

An **anatomical plane** is a flat 2D plane intersecting an anatomical continuant (a thing that retains its identity even though its states and relations may change), dividing it into two adjacent portions. An anatomical plane is also called a section, anatomical cross-section, plane, or anatomical section.

- Transverse (Synonyms: axial plane; axial section; cross section) - anatomical plane that divides body into anterior and posterior parts.
- Frontal (Synonyms: horizontal anatomical plane; longitudinal section; horizontal section; coronal plane) - anatomical plane that divides bilateral body into dorsal and ventral parts.
- Sagittal (Synonyms: left/right plane; sagittal section; longitudinal section; median plane) - anatomical plane that divides a bilateral body into left and right parts, not necessarily of even size.

14. On Figures UI-3 and UI-4 draw, color, and label the three planes: sagittal (yellow); frontal (blue); transverse (red)

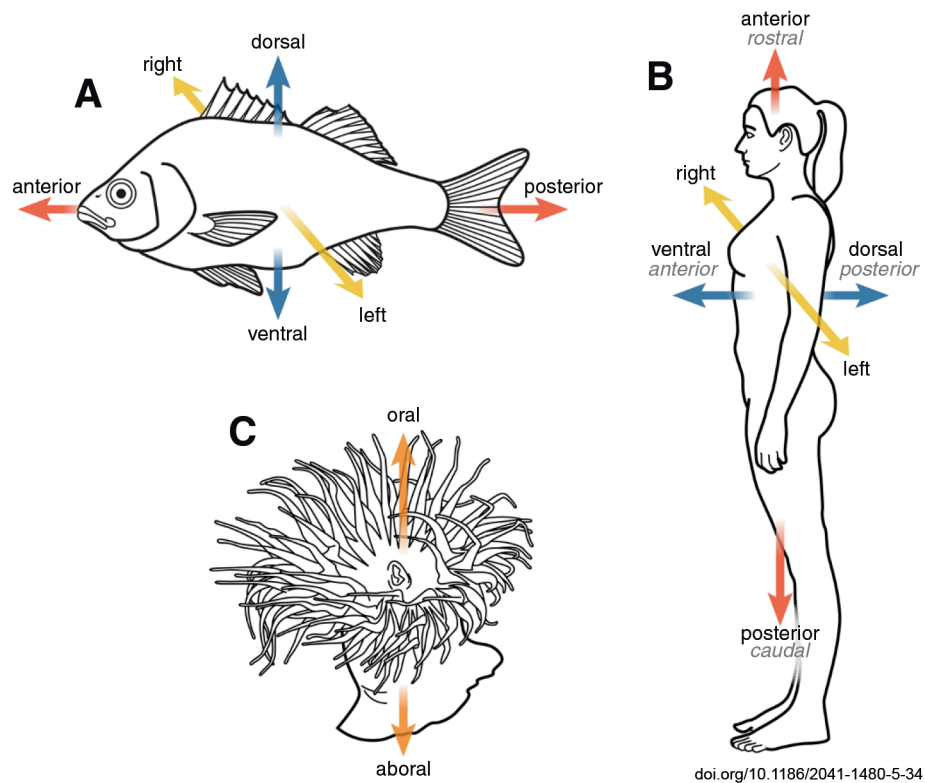


Figure UI-3. Comparison of primary organismal axes designated in a diversity of species and their representation in Biological Spatial Ontology (BSPO). **A)** In fishes and **B)** in humans, 'anterior-posterior axis' (narrow synonym 'rostral-caudal axis' in humans) is shown in red, 'dorsal-ventral axis' (narrow synonym 'anterior-posterior axis' in humans) shown in blue, and 'left-right axis' shown in yellow. A cnidarian (sea anemone) (**C**) has an 'oral-aboral axis', shown in orange.

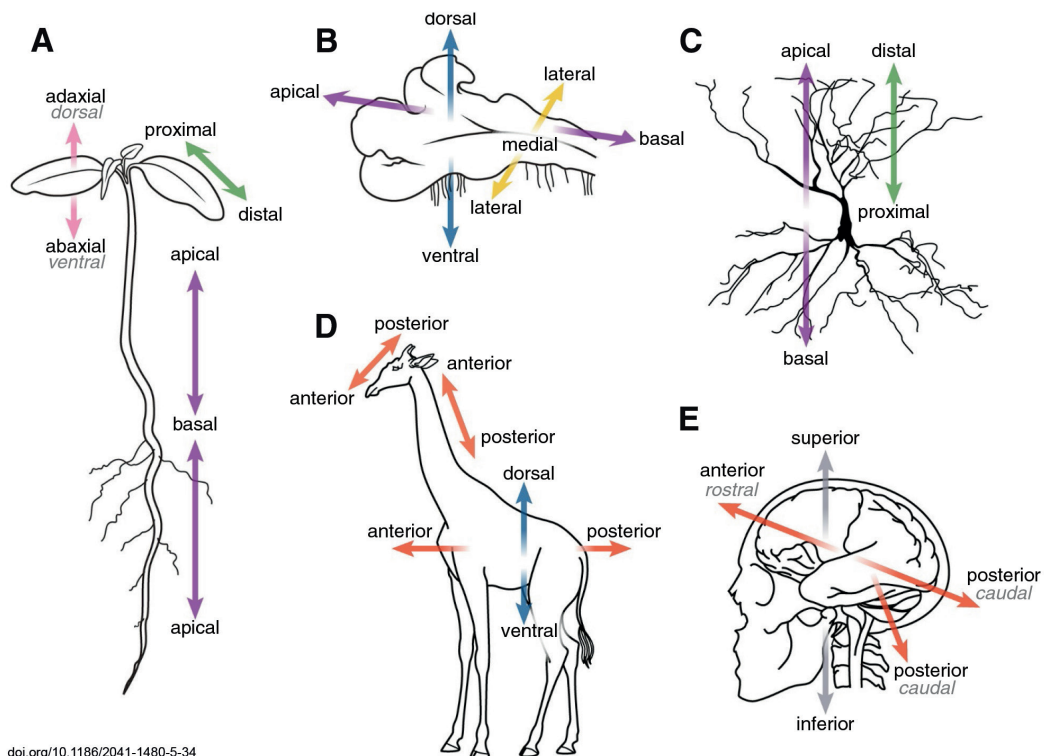


Figure UI-4. Axes applied to organism parts. **A)** In vascular and **B)** non-vascular plants, the 'apical-basal axis relative to direction of growth' (purple) runs in the direction of apical growth, in both shoots and roots. **A)** For lateral organs such as branches or leaves, the primary axis is the 'proximal-distal axis' (green) and the 'adaxial-abaxial axis' (pink). **B)** In plants or organisms with a thalloid growth form, the 'apical-basal axis relative to direction of growth' often runs parallel to the substrate, resulting in a 'dorsal-ventral axis' that runs perpendicular to the substrate and a 'medial-lateral axis' that is perpendicular to the 'apical-basal axis'. **C)** Hippocampal pyramidal neuron, showing the application of the BSPO classes 'apical-basal axis relative to substrate' and 'proximal-distal axis' to the whole cell or portions thereof. **D)** AP axes for the head, neck and trunk of the giraffe. Note that these axis definitions delineate a "bent" version of the primary AP axis. **E)** AP axis of the human brain (double-headed red arrow) relative to the AP axis of the body (single red arrow). Note the use of "superior" and "inferior" to refer to structures relative to the substrate. <https://doi.org/10.1186/2041-1480-5-34>.

Unit II. Plants

Objectives

- Name, identify, and define the various cells, tissues, and systems of the major taxonomic plant groups.
- Observe the diversity of plants found in the departmental greenhouse.
- Construct and give a formal presentation on one plant species that can be found in the greenhouse.

Terms & Definitions

Abaxial – facing away from the stem of a plant and denoting the lower surface of a leaf.

Active transport - the transport of a solute across a membrane against its gradient (from a region of low concentration to a region of higher concentration). Requires an input of energy. Primary active transport that uses adenosine triphosphate (ATP), and secondary active transport that uses an electrochemical gradient.

Adaxial – facing toward the stem of a plant and denoting the upper surface of a leaf.

Chloroplast - a plastid organelle found in plant and algal cells that carries out photosynthesis.

- A. Intermembrane space - a thin region about 10–20 nanometers between the outer and inner chloroplast membranes.
- B. Inner membrane - a membrane borders the stroma and regulates passage of materials in and out of the chloroplast.
- C. Outer chloroplast membrane - a semi-porous membrane that small molecules and ions can easily diffuse across.
- D. Stroma - the fluid-filled region of the chloroplast between the thylakoid membrane and the inner membrane.
- E. Thylakoid - a flattened, platelike membranous region found in cyanobacteria and the chloroplasts of plants and algae.

Cellulose - a structural polysaccharide found in cell walls and composed of glucose molecules.

Central cylinder – structure composed of phloem, xylem, and endodermis

Cohesion-tension theory - the explanation for long-distance water transport as the combine affect of the cohesive forces of water and evaporative tension.

Cortex - the area of a plant stem or root beneath the epidermis that is largely composed of parenchyma tissue.

Dermal cells & tissue - out covering of a plant on roots, stems and leaves; transpiration, gas exchange, and defense. Made up of the a single layer of epidermis cells and, possibly, stomata and guard cells for gas exchange. It may contain root hairs that increase surface area or trichomes used in transpiration or defense. It may contain a waxy cuticle if found on the upper surface of leaves, to aid with lowering transpiration.

- A. Epidermis – outermost, protoderm-derived layer of cells covering the stem, root, leaf, flower, fruit, and seed parts of a plant.
- B. Guard cells – a specialized plant cell that allows epidermal pores (stomata) to close when condition are too dry and to open under moist conditions, allowing the entry of carbon dioxide.
- C. Stomata – small pores on leaves, that are opened or closed under the control of a pair of banana-shaped cells called guard cells (see figure above). When open, stomata allow CO₂ to enter the leaf for synthesis of glucose, and also allow for water, H₂O, and free oxygen, O₂, to escape.

Endodermis – specialized tissue of vascular plants, composed of a single layer of modified parenchyma cells forming the inner boundary of the mesophyll.

Ground cells & tissue – parenchyma, sclerenchyma, and collenchyma cells and tissue functioning in photosynthesis, storage of carbohydrates, and support:

- A. Collenchyma – living supportive tissue that has elongated cells and an unevenly thickened primary cell wall. Its main function is the mechanical support of young stems and leaves via turgor.
- B. Parenchyma – spherical, elongated cells with a thin primary cell wall. It is a main component of young plant organs. The basic functions of parenchyma are photosynthesis and storage.
- C. Sclerenchyma – a dead supportive tissue that consists of long sclerenchyma fibers or short, crystal-like cells (sclereids). Sclerenchyma fibers occur in groups (bundles).
- D. Mesophyll – tissues of a leaf that are located in between the layers of epidermis and carry on photosynthesis, consisting of the palisade layer and the spongy parenchyma.

Guttation – droplets of water at the edges of leaves that are the result of root pressure.

Leaf - the principal appendages of a vascular plant stem, usually borne laterally above ground and specialized for photosynthesis.

Lignin - complex organic polymers that form key structural materials in the support tissues of most plants. Lignins are particularly important in the formation of cell walls, especially in wood and bark, because they lend rigidity and do not rot easily.

Non-vascular plant – a plant that does not produce lignified vascular tissue (phloem and xylem). Includes the Bryophytes - liverworts, mosses, and hornworts, the modern nonvascular land plants.

Macromolecule - molecules bonded together to form a polymer.

- A. Carbohydrate - organic molecules often with the general formula C(H₂O)_n; a carbon-containing compound that includes starches, sugars, and cellulose.
- B. Lipid - a molecule composed predominately of hydrogen and carbon atoms; nonpolar and insoluble in water.
- C. Nucleic acids - an organic molecule composed of nucleotides. The two types of nucleic acids are deoxyribonucleic acid (DNA) and ribonucleic acid (RNA)
- D. Protein - a functional unit composed of one or more polypeptides. Each polypeptide is composed of a linear sequence of amino acids.

Meristem - a plant tissue that consists of undifferentiated cells capable of cell division.

- A. Apical - undifferentiated meristems that differentiate into three kinds of primary meristems.
- B. Shoot apical - develops into leaves and flowers.+
- C. Root apical - develops in to roots.

Pericycle – a cylinder of plant tissue having cell division (meristematic) capacity that enclosed the root vascular tissue.

Passive transport - a type of membrane transport that does not require energy to move substances across cell membranes:

- A. Diffusion - in a solution, the process that occurs when a solute moves from a region of high concentration to a region of lower concentration.
- B. Facilitated diffusion - the process of spontaneous passive transport (as opposed to active transport) of molecules or ions across a biological membrane via specific transmembrane integral proteins.
- C. Filtration - movement of water and solute molecules across the cell membrane due to hydrostatic pressure generated by the cardiovascular system.
- D. Osmosis - the movement of water across membranes to balance solute concentrations. Water diffuses from a solution that is hypotonic (lower solute concentration) into a solution that is hypertonic (higher solute concentration).

Photorespiration - a series of reactions triggered by the closing of stomatal openings to prevent water loss.

Photosynthesis - the process whereby light energy is captured by plant, algal, or bacterial cells and is used to synthesize organic molecules from CO₂ and H₂O.

Phloem loading - the process of conveying sugars to sieve-tube elements for long-distance transport.

Photosystem I & II - distinct complexes of proteins and pigment molecules in chloroplasts that absorb light (PSI) or generate oxygen from water (PSII) during the light reaction of photosynthesis.

Pith - a tissue in the stems of vascular plants. Pith is composed of soft, spongy parenchyma cells, which store and transport nutrients throughout the plant. In eudicotyledons, pith is located in the center of the stem. In monocotyledons, it extends also into flowering stems and roots. The pith is encircled by a ring of xylem; the xylem, in turn, is encircled by a ring of phloem.

Plant photosynthetic pigments - a molecule present in chloroplasts or other photosynthetic organisms that can capture and absorb light energy which can then be converted to chemical energy by the organism

- A. Carotenoid - accessory pigment in photosynthetic organism that extends the range of absorbed wavelengths (470 nm and 500 nm) and protects the chlorophyll from oxidation.
- B. Chlorophyll - the primary pigment in photosynthetic organisms and the primary electron donor in the electron transport chain of PSII (P680) and PSI (P700). Absorbs light most strongly in the blue portion of the electromagnetic spectrum as well as the red portion while reflecting a majority of green. It is found in the mesosomes of cyanobacteria, as well as in the chloroplasts of algae and plants. Chlorophyll a (430 nm and 662 nm) and chlorophyll b (453 nm and 642 nm) absorb in slightly different ranges of the general chlorophyll spectrum.

Plastid - a membrane-bound organelle found in some eukaryotic organisms. They are considered to be intracellular endosymbiotic cyanobacteria.

Pressure - force per unit area:

- A. Hydrostatic pressure - the physical force exerted by a fluid on a structure (HB). Blood pressure is the force exerted per unit area by the blood as it presses against the internal surface of the vessel wall. Interstitial fluid hydrostatic pressure is the force of interstitial fluid on the external surface of the blood vessel.
- B. Pressure gradient - a physical quantity that describes in which direction and at what rate the pressure increases the most rapidly around a particular location.
- C. Osmotic pressure (**turgor**) - the minimum pressure which needs to be applied to a solution to prevent the inward flow of its pure solvent across a semi-permeable membrane. A plant cell is described to be **turgid** when the cytosol is so full of water that the plasma membrane presses right up against the cell wall: as a result, turgid cells are firm or swollen.

Pressure-flow hypothesis - explains sugar translocation in plants as a process driven by differences in turgor pressure between cells of a sugar source, where sugar is produced, and cells of a sugar sink, where sugar is consumed.

Primary meristem:

- A. Ground meristem - develops into the cortex and the pith. Composed of parenchyma, collenchyma and sclerenchyma cells.
- B. Procambium - inside of the protoderm and develops into primary xylem and primary phloem. It also produces the vascular cambium, and cork cambium, secondary meristems.
- C. Protoderm - lies around the outside of the stem and develops into the epidermis.

Resin canals/ducts - elongated, tube-shaped intercellular spaces surrounded by epithelial cells which secrete resin into the canal. These canals are orientated longitudinally and radially in between fusiform rays. They are usually found in late wood: denser wood grown later in the season.

Rhizome - continuously growing horizontal underground stem which puts out lateral shoots and adventitious roots at intervals.

Root - one of two main structural axes of a vascular plant, modified to provide anchorage for the plant and take in water and nutrients.

Seed plant - the informal name for gymnosperms and angiosperms.

Secondary vascular tissue:

- A. Cork cambium, which gives rise to the periderm, which replaces the epidermis.
- B. Phloem - a type of phloem that forms from the vascular cambium during the secondary growth.
- C. Vascular cambium - a secondary meristematic tissue of plants that produces both wood and inner bark.
- D. Xylem - formed during secondary growth from vascular cambium.

Selectively Permeable - the property of membranes that allows the passage of certain ions or molecules but not others.

Spectrum - used to classify something, or suggest that it can be classified, in terms of its position on a scale between two extreme or opposite points:

- A. Absorption spectrum - a diagram that depicts the wavelengths of electromagnetic radiation that are absorbed by a pigment.
- B. Action spectrum - the rate of photosynthesis plotted as a function of different wavelengths of light.
- C. Electromagnetic spectrum - all possible wavelengths of electromagnetic radiation, from relatively short wavelengths to much longer wavelengths.

Starch - a polysaccharide composed of repeating glucose units that is produced by the cells of plants and some algal protists.

Stem - one of two main structural axes of a vascular plant, modified to support leaves, flowers and fruits, transport water and dissolved substances between the roots and the shoots in the xylem and phloem:

Stele - the central core of the stem and root of a vascular plant, consisting of the vascular tissue (xylem and phloem) and associated supporting tissue

Tonicity - a measure of the effective osmotic pressure gradient; the water potential of two solutions separated by a partially-permeable cell membrane:

- A. Hyper- a greater concentration of non-permeating solutes than another solution.
- B. Hypo- a lower concentration of solutes than another solution.
- C. Iso- the concentration is the same as that of another solution.

Translocation – a process in plants in which phloem transports substances from a source to a sink.

Transpiration – the evaporative loss of water from plant surfaces into sun-heated air.

Vascular bundle – primary plant vascular tissues that occur in a cluster.

Vascular cells & tissue:

- A. Phloem - specialized conducting tissue in plant stems and leaves; usually transports organic compounds like sugars made during photosynthesis around the plant body
 - i. Companion cells - a type of cell found within the phloem of flowering plants. Each companion cell is usually closely associated with a sieve element. Its function is uncertain, though it appears to regulate the activity of the adjacent sieve element and to take part in loading and unloading sugar into the sieve element.
 - ii. Sieve-tube element – a component of the phloem tissues of flowering plants; thin-walled cells arranged end to end to form transport pipes.
- B. Xylem – specialized conducting tissue in plant stems and leaves that transports water and minerals from the roots to the rest of the plant body.
 - i. Tracheid – a type of dead lignified plant cell in xylem that conducts water and dissolved minerals and provides structural support.
 - ii. Vessel element – a type of plant cell in xylem that conduct water, along with dissolved minerals and certain organic compounds.

Vascular plant – a plant that contains lignified vascular tissue.

Water potential – the potential energy of water per unit volume relative to pure water in reference conditions. Water potential quantifies the tendency of water to move from one area to another due to osmosis, gravity, mechanical pressure and matrix effects such as capillary action (which is caused by surface tension).

Wavelength - the distance from the peak of one wave to the next.

Name: _____

Group #: _____

Section #: _____

Part 1: Plant Systems

Plant tissues consist of similar cells that work together to perform a specific function. There are three general types of cells; parenchyma, collenchyma, and sclerenchyma found in both vascular and non-vascular land plants. Those plants that do not contain lignified vascular tissue are the nonvascular plants and include the mosses, hornworts and liverworts. Vascular plants are those plants that contain lignified vascular tissue and includes all living land plants except for the mosses, hornworts and liverworts. Plant tissues can be organized into three types: vascular, dermal, and ground.

A. Dermal Tissue System

Dermal tissue is the outer covering of plant. It consists of closely packed cells that function to protect. The epidermis covers the plant but is replaced by cork (periderm) in the branches and roots of woody plants. The shoot epidermis secretes the cuticle (a waxy layer made from cutin) that protects the plant from desiccation. Epidermal cells, guard cells, subsidiary cells, and epidermal hairs (trichomes) make up the system. The epidermal cells are the most numerous, largest, and least specialized. These are typically more elongated in the leaves of monocots than in those of dicots.

B. Ground Tissue System

The function of **ground tissues** is that of support, storage, and photosynthesis. This includes the cortex and pith of many plants. Ground tissue can also be responsible for the formation of chemicals used by the plant to attract or defend against other organisms. **Parenchyma** cells are thin-walled and not as specialized as the other two cells types. They usually function in **photosynthesis or storage** and contain chloroplasts or have colorless plastids called amyloplasts used in starch storage. **Collenchyma** cells have thicker primary cell walls, especially at the corners. They form bundles just beneath the epidermis for flexible support of immature parts of the plant body. **Sclerenchyma** cells have thick secondary cell walls, usually toughened with a **rigid polymer called lignin**. Many lignin-supporting cells are actually dead at functional maturity. These lignified cells develop alongside the other cells of the plant; die in place and function to support the surrounding tissues – sometimes even after the whole plant is dead. They are called sclerenchyma fibers. A secondary cell wall is one that is produced after the cell is mature. It is produced inside the primary cell wall. Most sclerenchyma cells are nonliving. They function to support mature regions and produce hard parts (example: nut shells).

C. Vascular Tissue System

Non-seed land plants such as the moss, liverworts, and hornworts do not have vascular tissue but ferns, conifers, and angiosperms do. **Vascular tissue** is composed of **xylem** and **phloem**. Xylem transports water and minerals from roots to leaves and is composed of hollow, nonliving cells such as **tracheids** and **vessel elements**. Tracheids are elongated cells with tapered ends and pits or depressions along their length. Vessel elements are larger with open ends forming a continuous pipeline. Phloem is composed of living cells that transport organic nutrients, usually from leaves to roots such as sieve-tube cells. **Sieve-tube cells** have no nucleus and connect to each other by **plasmodesmata**. Sieve plates are found at the ends of the cells. **Companion cells** contain a nucleus and are located in close proximity to sieve-tube cells. They are connected to sieve tube cells by plasmodesmata.

The water-conducting cells of the xylem are tracheids (most plants) and vessel elements (usually only angiosperms). These cell types are dead at functional maturity and therefore devoid of any intracellular contents (in other words, there is only cell wall, without a protoplast inside). Although water moves throughout the cells of the plant body, long-distance translocation occurs most rapidly in the xylem, where the cells are specialized into microscopic conduits. At the cellular level, the difference between tracheids and vessel elements is based on the way they connect with cells of the same type. Vessel elements are designed like straws: they have cell wall material along the sides and open ends. Stacking cells end-to-end makes very long microscopic tubes that water can move through. Tracheids can also be stacked together, but they have thin amounts of wall material where any two adjacent cells interconnect. Of course, water can penetrate plant cell walls, so water can still move from one cell to the next.

1. Compare pine (*Pinus*; vascular seed plant that **does not flower**) and maple (*Acer*, a vascular seed plant that **does flower**) macerated wood. Sketch and label the tracheids and vessel elements (if present):

Genus: _____

Phylum: _____

Total magnification _____

Genus: _____

Phylum: _____

Total magnification _____

Part 2: Meristems & Growth

A. Meristems

The production of new cells from apical meristems results in the formation of the cells that make up the plant body. Unlike algae where most cells are relatively similar in structure, land plant bodies have cells that have become specialized for various functions. After embryogenesis, apical meristems remain active increasing in length through mitosis and cell stretching and expansion.

Three primary meristems arise from the apical meristem and continue cell division activities in regions behind the apical meristems. Ground meristem yields ground tissues. Protoderm yields epidermis. Procambium yields vascular tissues. Thus, the apical meristems essentially supply new cells to the primary meristems and the primary meristems are locations where these cells differentiate into tissues that make up the plant body.

2. Examine the prepared slides of the **root** and **shoot tips** of vascular plants.

- Match the slides with Figure UII-1 A or B. Fill in the figure caption with genus name and whether it is **root** or **shoot** tip.
- Match the term with the correct structure on the diagram.
- Color the ground meristem yellow.
- Draw an arrow next to each image showing the direction of growth.

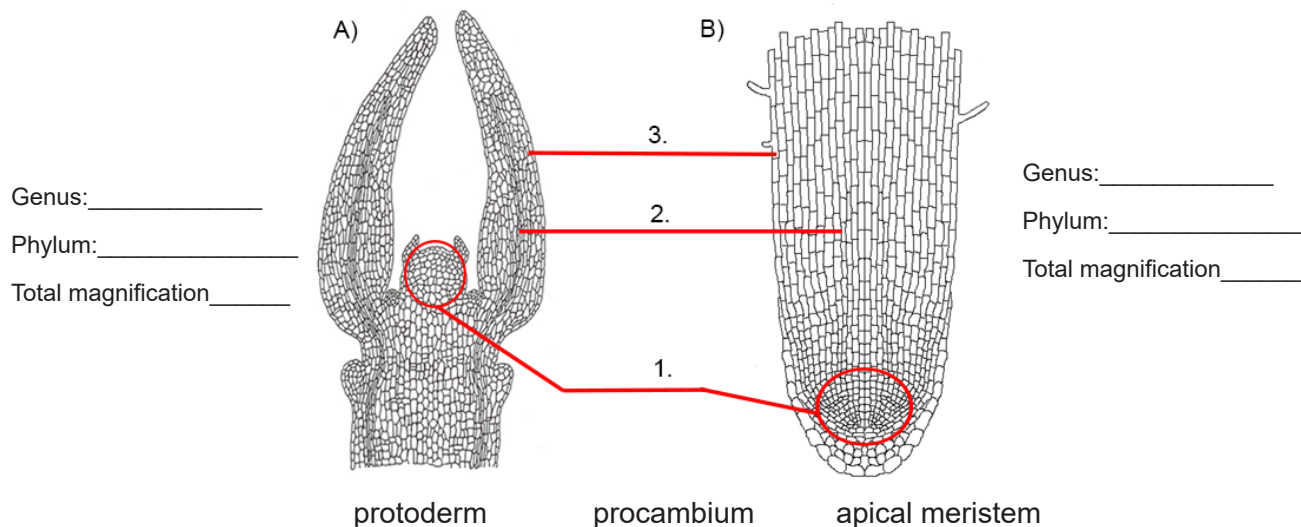


Figure UII-1. Longitudinal cross-section diagrams of the; A) _____ tip of a _____ and B) the _____ tip of a _____ both of which are vascular plants.

B. Growth

Primary growth occurs only at the shoot and root tips for a short distance behind the apical meristems. **Primary growth is responsible for elongating the plant.** In areas that contain only primary growth, stem thickness increases by cell enlargement, not by the production of new cells.

Secondary growth is produced by lateral meristems (vascular and cork cambium) that make the stems and roots thicker. Secondary growth occurs only during the second and subsequent years and only in woody species. Initially, vascular cambium is found between the xylem and phloem in the vascular bundles of eudicots. After one year of growth, it joins to form a continuous ring and cell division forms secondary xylem and phloem. The cork cambium produces cork cells with cell walls impregnated with suberin making them waterproof. Pockets of cells lack suberin. These are called lenticels and function to allow gas exchange through the periderm. **Bark** consists of **primary and secondary phloem, cortex, and the periderm (composed of cork cambium and cork).**

3. Examine Figure UII-2 and the prepared slide of linden tree (*Tilia*) stem cross-sections at 1, 2, and 3 years:

- Color the phloem green and the xylem red (primary and secondary for both).
- List the structures that make up bark and then highlight them on Fig. UII-2.

- How does the 1st year stem differ from the 3rd year.
- How does the 2nd year stem differ from the 3rd year.

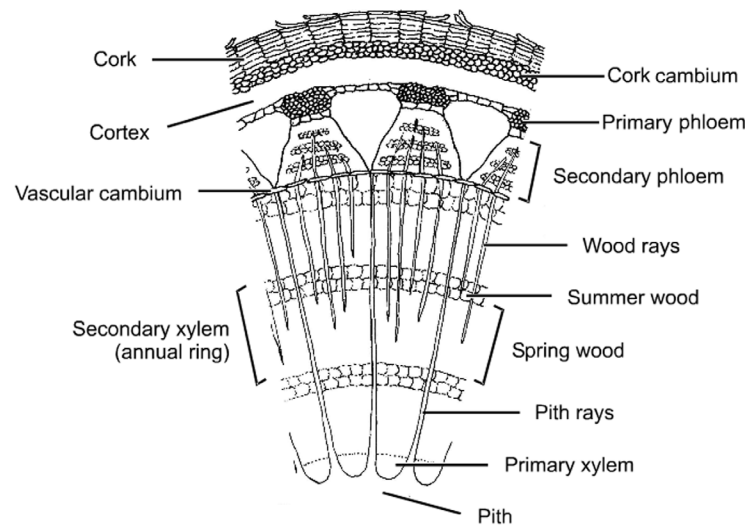


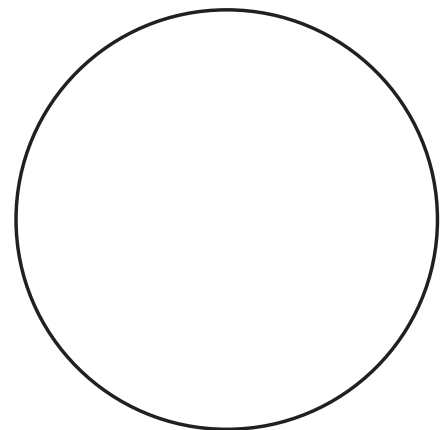
Figure UII-2. Cross-section of a 3rd year *Tilia* stem. *Tilia* is a vascular seed plant also called a linden tree.

Part 3: Systems

A. Roots

A radical or primary root emerges from a seed, grows down, and produces a more extensive root network. The new root system is used to stabilize the plant and access water and mineral nutrients in the soil. The root of both eudicots and monocots are composed of all three tissue types: **epidermis, cortex, and the stele.** The **cortex** is composed of parenchyma cells that contain amyloplasts that store starch. The **stele** is made up of **endodermis, pericycle, phloem, and xylem.** In monocots the stele has a center made up of parenchyma cells called a **pith** that is surrounded by a ring of large xylem cells. In Eudicots the xylem in cross-section looks like a cross.

- Observe the *Pteridium* (vascular non-seed) macerated rhizome slide.
 - Sketch.
 - Label the vessel element - like xylem conducting cells.
 - Label the total magnification and the genus and phylum names.



Genus: _____

Phylum: _____

Total magnification _____

5. Examine the prepared slide of monocot and eudicot **root** cross-sections.
- Match the slides with Figure UII-3 A or B.
 - Fill in the figure caption with genus name and whether it is a eudicot or monocot.
 - Match the term with the correct structure on the diagram.
 - Color the phloem green and the xylem red.
 - What tissues make up a stele and what is its function?
 - How does the arrangement of tissues in the stele differ between monocots and eudicots?

_____ pericycle _____ phloem _____ xylem _____ epidermis _____ cortex _____ endodermis _____ pith

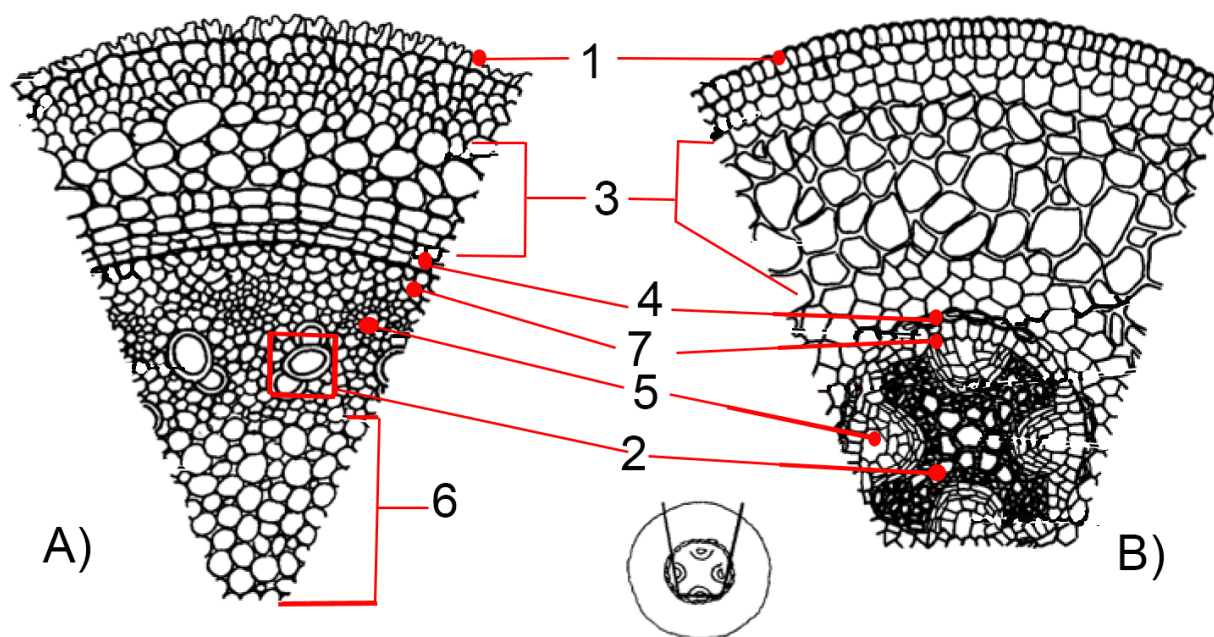
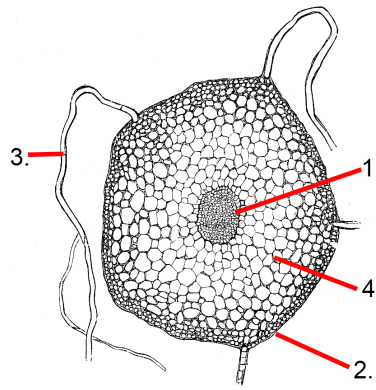


Figure UII-3. Root cross-section diagrams of A) _____ a _____ and B) _____ a _____.

B. Shoots

Shoot systems include the stems, leaves and flowers of a plant. The vascular tissue of shoots is found in bundles with **sclerenchyma fiber**. In eudicots, the **bundles are arranged in a ring** with the sclerenchyma fiber toward the outside, the xylem on the inner side of the bundle, and the phloem sandwiched between the two. **Vascular cambium** occurs between the **phloem** and **xylem**. The **cortex** is located in the area between the **vascular bundles** and the **epidermis** and the **pith** is in the center of the stem and often functions in storage. In monocot stems the **vascular bundles are scattered in the stem**. The bundles have **sclerenchyma fibers**, companion and sieve tube cells (**phloem**), **xylem**, and an air space.

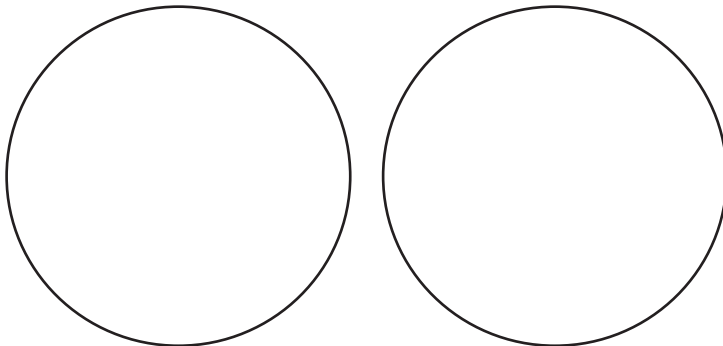
6. Observe the *Mnium* stem cross section slide.
 - A. Fill in Figure UII-4 caption with genus name and whether it is vascular or non-vascular plant.
 - B. Match the term with the correct structure on the diagram.
 - C. Does it have:
phloem? _____,
xylem? _____.



_____ central cylinder
_____ cortex
_____ rhizoids
_____ epidermis

Figure VII-4. Stem cross-section diagram of _____ which is a _____ plant.

7. Observe the *Psilotum* (vascular non-seed) **stem** cross and longitudinal section slide.
 - A. Sketch both.
 - B. Label the epidermis, cortex (composed of parenchyma cells), phloem, and xylem.
 - C. Color the phloem green and the xylem red.
 - D. Label the total magnification and the genus and phylum names.



Genus: _____

Phylum: _____

Total magnification_____

8. What is a plant vascular system and which plant, *Mnium* (mosses) or *Psilotum* (ferns), has one.

This image shows a blank sheet of white paper designed for writing. It features ten horizontal light blue lines spaced evenly down the page. A single vertical red line runs parallel to the left edge, creating a narrow margin. The paper is otherwise completely empty of any text or markings.

9. Examine the prepared slide of monocot and eudicot (both are vascular plants) **stem** cross-sections and match the slides with Figure VII-5 A or B.
 - A. Fill in the figure caption with genus name and whether it is a eudicot or monocot.
 - B. Match the term with the correct structure on the diagram.
 - C. Color the phloem green and the xylem red.
 - D. What tissues make up a vascular bundle and what is its function?
 - E. How does the arrangement of tissues in the vascular bundles differ between monocots and eudicots?

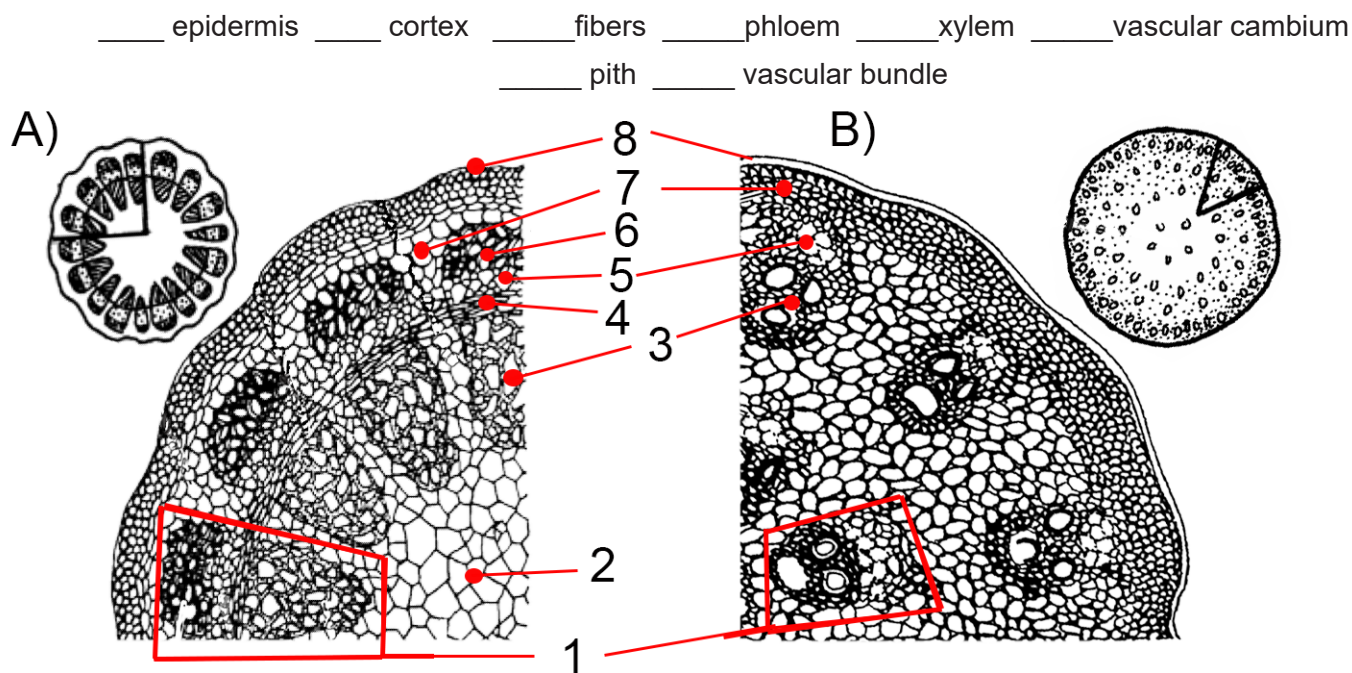


Figure UII-5. Stem cross-section diagrams of A) _____ a _____
 and B) _____ a _____.



C. Leaves

Most leaves develop clearly defined upper and lower surfaces. Light capturing is the specialization of the **adaxial** or upper surface and the **abaxial** or lower surface is specialized for gas exchange. **Mesophyll**, ground tissue composed of parenchyma cells, can be found beneath the epidermal layers interwoven with air spaces through which CO_2 and O_2 circulate around the cells. The mesophyll cells have numerous chloroplasts. The epidermis has pores called **stomata** that allow the exchange of CO_2 and O_2 between the surrounding air and the photosynthetic cells in the leaf. The stoma can open and close with the aid of specialized epidermal **guard cells**. The phloem and xylem vascular tissue of the leaf is continuous with the vascular tissue of the stem and allows the transport of water, minerals, organic products include sugar throughout the plant body. **Phloem** can be found on the abaxial side of the of the vascular bundle with **xylem** on the adaxial side.

The leaves of flowering plant (Phylum Angiospermae) eudicots have two types of mesophyll, palisade and spongy. The **palisade mesophyll** is composed of elongated cells that lay perpendicular to the adaxial epidermis. Palisade cells contain the largest number of chloroplasts per cell, which makes them the primary site of photosynthesis. The **spongy mesophyll** is below the palisade layer and has fewer chloroplasts. The veins of the angiosperms create a transport network and a framework that reinforces the leaf. Each vein is reinforced with a **bundle sheath** that regulates the movement of substance between the vascular bundle and mesophyll.

Conifers (Phylum Pinophyta) are naked-seed plants that produce sperm and eggs in cones. Plants in this group can have needle-like leaves or flat scale-like leaves. The needle-like leaves usually occur in bundles. Cross-sections of needles show the **adaxial** and **abaxial epidermis**, **hypodermis**, **mesophyll**, and **central cylinder** (endodermis with two vascular bundles composed of xylem and phloem). The leaves also have **stomata** that allow gas exchange and **resin canals** or ducts that are elongated, tube-shaped intercellular spaces surrounded by epithelial cells that secrete resin into the canal.

10. Examine the prepared slides of monocot and eudicot (both are vascular plants) **leaf** cross-sections and match the slides with Figure UII-6 A or B. A.

A. Fill in the figure caption with genus name and whether it is a eudicot or monocot.

B. Match the term with the correct structure on the diagram.

C. Color the phloem green and the xylem red.

_____ adaxial epidermis _____ spongy mesophyll _____ palisade mesophyll _____ phloem _____ xylem
 _____ fibers _____ air space _____ abaxial epidermis _____ stomata with guard cells _____ bundle sheath cells

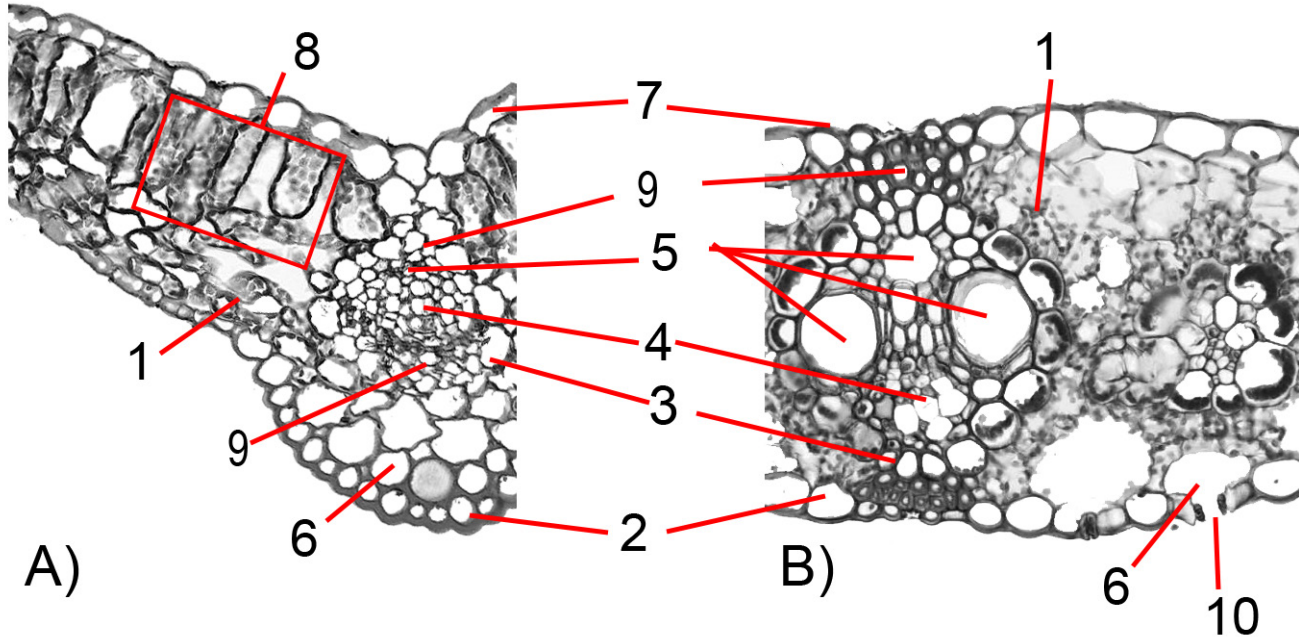


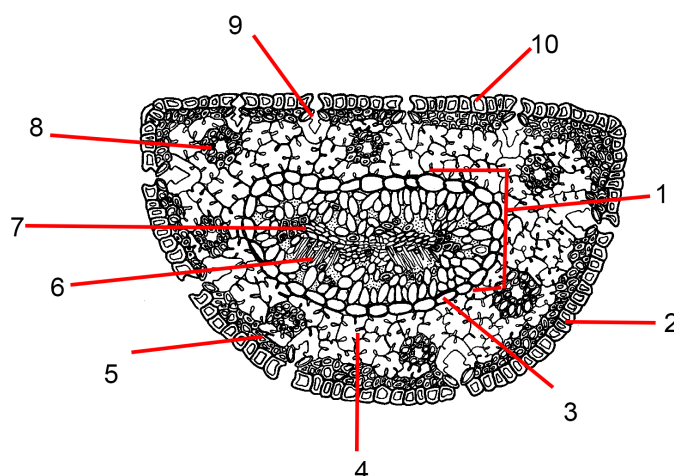
Figure UII-6. Leaf cross-section diagrams of A) _____ a _____
 and B) _____ a _____.

11. Examine the prepared slide and Figure UII-7 of a pine needle cross-section.

A. Fill in the figure caption with the correct information.

B. Match the term with the correct structure on the diagram.

C. Color phloem green and xylem red.



_____ adaxial epidermis
 _____ abaxial epidermis
 _____ central cylinder
 _____ phloem
 _____ xylem
 _____ hypodermis
 _____ mesophyll
 _____ stomata
 _____ endodermis
 _____ resin canal

Figure UII-7. _____ at total magnification _____X.

Name: _____

Section #: _____

Part 4: Plant Diversity

A. Greenhouse

- ☐ Meet at LS 261 (Pocatello Sections) and then tour the ISU Greenhouse OR plants will be made available in CHE 107 (Idaho Falls Sections).
- ☐ Choose one plant from one of the four pods (humid, dry, temperate, warm). Everyone needs to choose a different plant.
- ☐ Find the plant on the instructor list for that zone and fill in your lab section and name next to the plant name.
- ☐ Write in the species name and common name here: _____

B. Research

- ☐ Go to the computer lab.
1. Create an informative presentation on the plant that you choose.
 - Review the scoring rubric (Figure UII-9) before you begin.
 - Include the topics listed in the rubric (Figure UII-9).
 - Begin your research by consulting multiple reliable sources (journal articles, encyclopedias, .edu websites, reference books).
 - Take notes on the most relevant and interesting information from your sources.
 - Complete your research by ensuring that you have enough information to answer all questions in the rubric (Figure UII-9) .
 - Focus on providing accurate and relevant information about your plant in a way that will keep your audience interested.
 - Organize all information logically, smoothly, and purposefully.
 - Use at least 8 images showing different aspects of your plant that relate to the presentation.
 - Include a references slide with all the references that you used.
 2. **Your presentation must be uploaded to Canvas before the beginning of lab 5.**

C. Presenting

- ☐ The presentation must be 4-5 minutes long.
- ☐ The presentations should have, at most, 10 slides.
- ☐ Slides must be legible. Use large fonts, few words, and few special effects.
- ☐ You should spend, at most, 1 minute on each slide. Each slide should illustrate or highlight one or two points. That's as much as the audience can grasp and remember.
- ☐ Do not read the slides to the audience!
- ☐ Speak slowly, clearly, and loudly. People sitting farthest from you need to hear you.
- ☐ Speak directly to your audience, making eye contact as frequently as possible.
- ☐ Don't be afraid to show some enthusiasm for your topic but don't become a clown—you want to be taken seriously.
- ☐ End your presentation by thanking the audience for their attention.
- ☐ Take time to consider each question asked but it is OK to say "I don't know".

3. Turn Unit II Part 4 at the beginning of lab 5.

Informative presentation			Points	
			Possible	Acquired
Content	1.	Species name composed of the genus and specific name (image)	4	
	2.	Common name	2	
	3.	Taxonomic Classification (domain, kingdom, phylum/division, class, order, family)	6	
	4.	Habitat (image)	4	
	5.	Native and introduced geographic location (use range map images)	6	
	6.	Ethnobotanical uses	4	
	7.	Unique anatomical features (image)	4	
	8.	What are the sporophyte and gametophyte stages (images)	6	
	9.	Where do eggs and sperm develop (image)?	6	
	10.	What type of pollen vector do they use (image)?	7	
	11.	After the pollen is vectored, how do the egg and sperm reach each other to produce a zygote.	7	
	12.	The zygote develops into an embryo. Where is the embryo located on the parent plant (image).	7	
	13.	How does the embryo leave the parent plant and where does it develop into a mature plant?	7	
Presentation	14.	Oration	4	
	15.	Grammar / spelling	4	
	16.	Format	4	
	17.	Questions	4	
	18.	All required images were part of the presentation.	10	
	19.	Reference slide (name of source and url)	4	
Total			100	

Figure UII-9. Informative presentation rubric. Leave blank for your instructor to fill in.

Unit III. Reproduction & Development

Objectives

- Name, identify, and define the various life stages that form the life cycles of the major taxonomic groups.
- Mate the types of one fungus species to observe the life stage produced through sexual reproduction.

Terms & Definitions

Amniotes – a group of tetrapods with amniotic eggs that includes reptiles, birds, and mammals.

- A. Allantois – one of four extraembryonic membranes. The precursor of the umbilical cord in mammals and is one of several embryonic regions, including the yolk sac and dorsal aorta, that undergoes vasculogenesis, the de novo formation of blood vessels.
- B. Amniotic egg – a type of egg produced by amniotic animals that contains the developing embryo and four separate extraembryonic membranes that it produces: the amnion, yolk sac, allantois, and chorion.
- C. Amnion – one of four extraembryonic membranes. It protects the developing embryo in a fluid-filled sac called the amniotic cavity; a blood vessel that carries blood away from the heart.
- D. Chorion – one of the four extraembryonic membranes. Exchanges gases between the embryo and the surrounding air.
- E. Yolk sac – one of four extraembryonic membranes. Exchanges nutrition.

Cell cycle - the series of phases a eukaryotic cell progresses through from its origin until it divides by mitosis:

- A. Interphase – it is the portion of the cell cycle during which the chromosomes are decondensed and found in the nucleus. G1 (first gap cycle), S (DNA synthesis phase), and G2 (second gap cycle) are stages of interphase.
- B. Prophase – phase of mitosis during which the chromosomes condense and the nuclear membrane begins to vesiculate.
- C. Prometaphase – phase of mitosis during which the mitotic spindle is completely formed.
- D. Metaphase – the phase of mitosis during which the chromosomes are aligned along the metaphase plate -
- E. Anaphase – the phase of mitosis during which the sister chromatids separate from each other and move to opposite poles; poles themselves also move farther apart.
- F. Telophase – the phase of mitosis during which the chromosomes decondense and the nuclear membrane re-forms.
- G. Cytokinesis – the division of the cytoplasm to produce two distinct daughter cells.

Cell cycle structures:

- A. Centriole - a cylindrical organelle composed mainly of tubulin protein that helps anchor microtubules during cell division.
- B. Centromere - a region (not a true structure) of a chromosome where sister chromatids are attached and to which microtubules bind.
- C. Centrosome - a structure near the cell nucleus that forms the main microtubule organizing center during division. Each centrosome is composed of two centrioles at right angles to each other. Duplication occurs during the G1 phase and S Phase.
- D. Kinetochore - a protein structure that can be found in the centromere region of a chromosome where the microtubules attach during cell division to pull sister chromatids apart.

Cellular division – in eucaryotic cells, the process by which one cell divides into two cells:

- A. Mitosis – the process in which nuclear division results in two nuclei, each of which receives the same complement of chromosomes.
- B. Meiosis – the process by which haploid cells are produced from a cell that was originally diploid.

Cnidaria – a phylum under kingdom Animalia of aquatic radially symmetrical animals known as jelly fish and anemones that consist of mesoglea sandwiched between two layers of epithelium that are mostly one cell thick with mouths surrounded by tentacles that bear cnidocytes:

- A. Cnidocyte (cnidoblast) – specialized stinging cells that they use mainly for capturing prey.
- B. Cnida (nematocyst, spirocysts, ptychoyst) – large intracellular capsule with a hinged operculum that are used for prey capture, defense, locomotion, and attachment.
- C. Tentacles – a flexible, mobile, and elongated organ present in some invertebrate animals and usually occur in one or more pairs.

Ctenophore – a phylum under kingdom Animalia of marine biradially symmetrical animals known as comb jellies that consist of mesoglea sandwiched between two layers of epithelium that are mostly two cells thick with comb rows and colloblasts:

- A. Colloblast – a cell covered with sticky granules on the tentacles of a ctenophore, which aid in capturing prey.
- B. Comb rows (comb plates, costae, ctenes) – fused cilia used for locomotion.
- C. Tentacles – a flexible, mobile, and elongated organ present in some invertebrate animals and usually occur in one or more pairs.

Porifera – a phylum under kingdom Animalia aquatic asymmetrical animals known as sponges that have a cellular level of organization, lacking true tissues and organs, and create inner water current using choanocytes:

- A. Amoebocyte – a mobile cell within a sponge's mesophyll that absorbs food from choanocytes, digests it, and carries the nutrients to other cells.
- B. Atrium (spongocoel) – the large, central cavity of sponges.
- C. Choanocyte – a specialized cell of sponges that functions to trap and eat small particles.
- D. Osculum (plural oscula) – is an excretory structure through which the current of water exits after passing through the atrium.
- E. Spicule – needle-like structures that are usually made of silica and form lattice-like skeletons in sponges possibly helping to reduce predation.

Diploblastic – having two distinct germ layers-ectoderm and endoderm-but no mesoderm.

Embryogenesis (plant angiosperm)- a sequential series of dynamic processes that include cell division and growth, and the elaboration of differentiation programs leading to cell fate specification:

- A. Cotyledon – a embryonic seed leaf.
- B. Epicotyl – the portion of the an embryonic plant stem with two tiny leaves in a first bud; located above the point of attachment of the cotyledons.
- C. Hypocotyl – the portion of the embryonic plant stem located below the point of attachment of the cotyledons.
- D. Radicle – an embryonic root, which extends from the plant hypocotyl.

Embryogenesis (animals) - a sequential series of dynamic processes that include mitotic cell division and growth, and the elaboration of differentiation programs leading to cell fate specification:

- A. Archenteron – the digestive cavity formed during the early stages of gastrulation.
- B. Blastopore – a small opening created when a band of tissue invaginates during gastrulation. It forms the primary opening of the archenteron to the outside.
- D. Blastula – a hollow fluid-filled sphere of cells that surrounds the blastocoel, a central hollow cavity.
- E. Cleavage – the initial mitotic cell divisions of the zygote that produces blastomeres (cells). There are two types of cleavage patterns that occur between the 4-cell stage and the 8-cell stage. Spiral cleavage occurs in protostomes whereas deuterostomes have radial cleavage.
- F. Gastrula – multi-layered sphere of cells. An indentation at the vegetal pole (blastopore) will form and the resulting internal cavity is the archenteron.
- G. Gastrulation – in which the blastula invaginates and folds inwards forming three germ layers, endo-, ecto-, and mesoderm.
- H. Morula – a solid ball of blastomeres (cells).

Ecdysis - the process of shedding the old skin (in reptiles) or casting off the outer cuticle (in insects and other arthropods).

-gamy - ancient Greek suffix used to form nouns describing forms of fertilization, pollination, or reproduction:

- A. Karyogamy – the fusion of two nuclei within a cell, especially as the second stage of syngamy.
- B. Plasmogamy – stage of fungal sexual reproduction joining the cytoplasm of two parent mycelia without the fusion of nuclei.
- C. Syngamy – the fusion of two gametes to form a zygote; fertilization.

Life cycle – sequence of events that characterize the steps of development of the individuals of a given species:

- A. Gametic (diplontic) life cycle – a life cycle where all cells except the gametes are diploid, and the gametes are produced by meiosis.
- B. Sporic (haplodiplontic) life cycle or alternations of generations – the phenomenon that occurs in plants and some protists in which the life cycle alternates between multicellular diploid organisms, called sporophytes, and multicellular haploid organisms, called gametophytes.
- C. Zygotic (haplontic) life cycle – life cycle of most unicellular eukaryotes in which haploid cells develop into gametes. Two gametes fuse to form a diploid zygote.

Life history - the pattern of survival and reproduction events during the life of an organism; life history traits include maximum body size, longevity, age at maturity, and fecundity.

Mesoglea – a layer of extracellular matrix that contains scattered cells and collagen fiber and functions as a hydrostatic skeleton.

Metamorphosis – a biological process by which an animal physically develops after birth or hatching, involving a conspicuous and relatively abrupt change in the animal's body structure through cell growth and differentiation.

- A. Incomplete (hemimetabolous) – development proceeds in repeated stages of growth and ecdysis (moulting); these stages are called instars. The juvenile nymphal forms closely resemble adults, but are smaller and lack adult features such as wings and genitalia. The size and morphological differences between nymphs in different instars are small, often just differences in body proportions and the number of segments; in later instars, external wing buds form.
- B. Complete (holometabolous) – immature stages are called larvae and differ markedly from adults. Insects which undergo holometabolism pass through a larval stage, then enter an inactive state called pupa (called a "chrysalis" in butterfly species), and finally emerge as adults.

Meiosis – the process by which haploid (1n) cells are produced from a cell that was originally diploid (2n).

- A. I – the separation of homologous chromosomes but the sister chromatids remain together resulting in two haploid cells (1n); occurs only in germ cells.
- B. II – similar to a mitotic division but the connected sister chromatids remaining from meiosis I will separate to form four haploid cells.

Triploblastic – having three distinct germ layers: endoderm, ectoderm, and mesoderm.

- A. Deuterostome – a multicellular organism whose mouth develops from a secondary embryonic opening, includes all vertebrates.
- B. Protostome – an animal whose development exhibits spiral determinate cleavage and in which the blastopore becomes the mouth.

Ploidy – the number of sets of chromosomes in a cell, or in the cells of an organism.

- A. Diploid – carrying two complete sets of chromosome; denoted by 2n.
- B. Haploid – carrying one set of chromosomes; designated as 1n.

Reproductive terms (Fungi) - the tissues and cells used in reproduction.

- A. Conidia – a spore produced asexually by various fungi at the tip of a specialized hypha.
- B. Zygomycete – a phylum of fungi that produces distinctive large zygospores as the result of sexual reproduction.
- C. Zygosporangium – sporangium in which zygospores are produced
- D. Zygospore – a diploid reproductive stage in the life cycle of many fungi and protists. Zygospores are created by the nuclear fusion of haploid cells. A zygospore remains dormant while it waits for environmental cues, such as light, moisture, heat, or chemicals secreted by plants. When the environment is favorable, the zygospore germinates, meiosis occurs, and haploid vegetative cells are released.

Reproductive terms (General) – the tissues and cells used in reproduction.

- A. Egg (a fertilized egg) - an egg cell/ovum and sperm that have gone through syngamy to produce a zygote. The zygote has gone through mitosis and the tissues have begun to differentiate to produce an embryo. A vessel grown by an animal to carry a possibly zygote or embryo.
- B. Egg cell/Ovum – gamete produced by a female organism.
- C. Embryo – the developmental stage commencing after the first mitotic divisions of the zygote and ending when body structures begin to appear.
- D. Fertilization – the union of two gametes, such as an egg cell with a sperm cell, to form a zygote.
- E. Gamete – a haploid cell that is involved with sexual reproduction, such as a sperm or egg cell.
- F. Germ cells – any biological cell that gives rise to the gametes of an organism that reproduces sexually.
- G. Sexual reproduction – a process that requires a fertilization event in which two gametes unite to produce a cell called a zygote.
- H. Gonad – a reproductive, sex, mixed gland that produces the gametes and sex hormones of an organism.
- I. Ovary – female structure; animal gonad where eggs are formed; lowermost portion of the flower pistil that encloses and protects the ovules.
- J. Sperm cell - gamete produced by a male organism.
- K. Testes – male gonads that produce sperm.
- L. Zygote – a diploid cell formed by the fusion of two haploid gametes.

Reproductive terms (Plant) - the tissues and cells used in reproduction.

- A. Antheridia – round or elongate gametangia that produce sperm in plants.
- B. Archegonia – flask-shaped plant gametangia that enclose an egg cell.
- C. Endosperm – a nutritive tissue that increases the efficiency with which food is stored and used in the seeds of flowering plants. The cell with the 2 polar nuclei (2N) + sperm (1N) becomes endosperm (3N) through mitosis.
- D. Gametangia – specialized structures produced by many land plants in which developing gametes are protected by a jacket of tissue.
- E. Megasporangia (female sporangia, nucellus) – specialized structure that produces megasporocytes that will undergo meiosis.
- F. Megaspore (megaspore mother cell) – the cell that undergoes meiosis.
- G. Megagametophyte (female gametophyte) – haploid “plant” produced via mitotic division that develops into haploid tissue. The tissue produces the antipodal, polar nuclei, synergids, and the egg.
- H. Megaspore – a large haploid cell spore that undergoes mitosis to produce the female gametophyte.
- I. Microsporangia (nucellus) – male sporangia producing microsporocytes that yield microspores through meiosis.
- J. Microspore – haploid cell that undergoes mitosis to produce the male gametophyte.
- K. Microsporocyte (microspore father cell) – cell that undergoes meiosis.
- L. Microgametophyte (male gametophyte/pollen grain) – haploid “plant” that is produced via mitotic division forming haploid tissue which produces and surrounds the haploid sperm.
- M. Plant embryo – egg (1N) + sperm (1N) = zygote (2N) which divides through diploid mitosis into the embryo (2N).
- N. Flower – a bloom or blossom, the reproductive structure found in flowering plants:
 - Anther – the uppermost of a flower stamen, consisting of a cluster of microsporangia that produce and release pollen.’
 - Filament – thin tubular part of the stamen that extends and supports the anther.
 - Ovary – lowermost portion of the flower pistil that encloses and protects the ovules.
 - Ovule – a megaspore producing megasporangium and enclosing tissues known as integument. An ovule is made up of female gametophyte (1N) + megasporangium (2N) + 2 layers of integument (2N)
 - Pistil – a flower structure that may consist of a single carpel or multiple, fused carpels and is differentiated into stigma, style, and ovary.
 - Petals (corolla leaf) – modified leaves that surround the reproductive parts of flowers
 - Sepal (calyx leaf) – modified leaves that encase or cover a flower bud as it develops.
 - Stamen – the pollen-producing reproductive organ of a flower
 - Stigma – the top of the pistil with a surface receptive to pollen
 - Style – the stalk of the pistil
- O. Pollination – the process in which pollen grains are transported to an angiosperm flower or a gymnosperm cone by way of animals and wind (sometimes water).
- P. Sporangia – structures that produce and disperse the spores of plants, fungi, protists.
- Q. Spore – a reproductive cell capable of developing into a new individual without fusion with another reproductive cell.
- R. Sorus (plural sori) – a cluster of sporangia (structures producing and containing spores) in ferns and fungi.

Sporic (haplodiplontic) life cycle or alternations of generations – the phenomenon that occurs in plants and some protists in which the life cycle alternates between multicellular diploid organisms, called sporophytes, and multicellular haploid organisms, called gametophytes:

- A. Gametophyte – the sexual stage in the life cycle of plants. It is a haploid multicellular organism that develops from a haploid spore that has one set of chromosomes. Through mitosis it produces gametes, haploid sex cells that participate in fertilization to form a diploid zygote in which each cell has two sets of chromosomes. Cell division of the zygote results in a new diploid multicellular organism, the second stage in the life cycle known as the sporophyte, the function of which is to produce haploid spores by meiosis.
- B. Sporophyte – the diploid generation of plants or multicellular protists that have a sporic life cycle; this generation produces haploid spores by the process of meiosis.

Name: _____

Group #: _____

Section #: _____

A life cycle (Figure UIII-1) is a series of changes in form that an organism undergoes, returning to the starting state. Transitions of form may involve growth (through mitosis), asexual reproduction (through mitosis and/or meiosis), and sexual reproduction (through mitosis and/or meiosis). In regard to changes of ploidy, there are three types of cycles (haplontic, haplodiplontic, and diplontic).

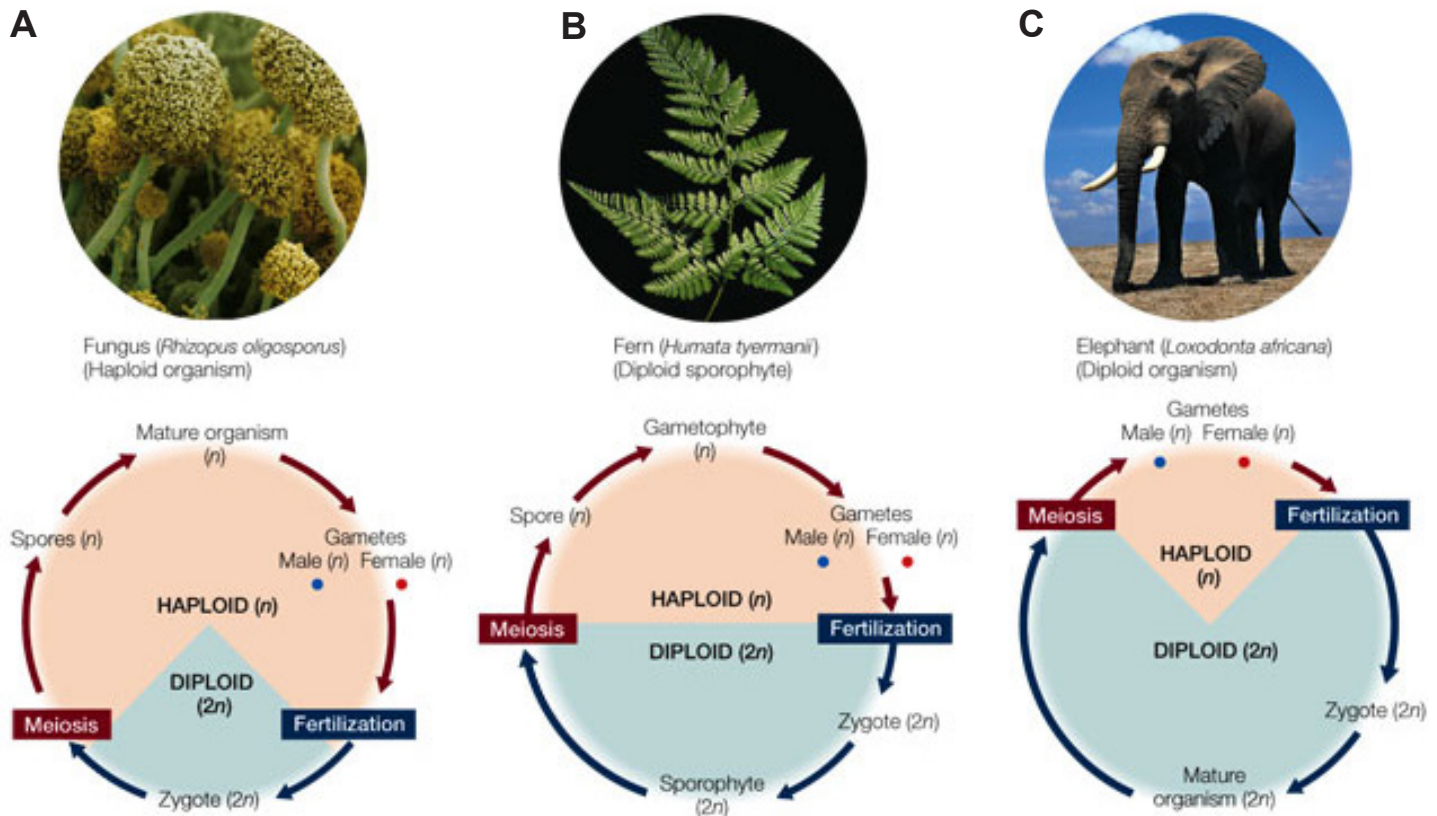


Figure UIII-1. **A)** haplontic life cycle - the organism is haploid and the zygote is the only diploid stage, **B)** Haplodiplontic life cycle - the organism passes through both haploid and diploid stages, and **C)** Diplontic life cycle - the organism is diploid and the gametes are the only haploid stage.

A. Haplontic (Zygotic) Life Cycle

The **haploid stage is multicellular and the diploid stage is a single cell.** (Figure UIII-1A). A zygotic meiosis is a meiosis of a zygote immediately after **karyogamy, which is the fusion of two cell nuclei.** This way, the organism ends its diploid phase and produces several haploid cells. These cells divide mitotically to form either larger, multicellular individuals, or more haploid cells. Two opposite types of gametes (e.g., male and female) from these individuals or cells fuse to become a zygote. In the whole cycle, zygotes are the only diploid cell; **mitosis occurs only in the haploid phase.** The individuals or cells as a result of mitosis are haplonts, hence this life cycle is also called haplontic life cycle. Haplonts can be: fungi, green algae, golden algae, dinoflagellates, apicomplexans, e.g. Plasmodium, excavates, amoebozoans.

B. Haplodiplontic (Sporic) Life Cycle

Multicellular diploid and haploid stages occur, meiosis produces spores (Figure UIII-1B). In sporic meiosis, the zygote divides mitotically to produce a multicellular diploid sporophyte. The sporophyte creates spores via meiosis which also then divide mitotically producing haploid individuals called gametophytes. The gametophytes produce gametes via mitosis. In some plants the gametophyte is not only small-sized but also short-lived; in other plants and many algae, the gametophyte is the “dominant” stage of the life cycle. Haplodiplonts are: land plants, green algae (*Ulva*), red algae (which have two sporophyte generations), brown algae (except the *Fucales*), rhizaria, fungi. Some animals (bees, wasps) have a sex-determination system called haplodiploid, but this is **NOT related** to the haplodiplontic life cycle. In this system a female insect will decide whether or not she wants to fertilize her egg with sperm (which are stored in the female after mating). If she chooses not to, the egg will develop into a male who will be haploid. The fertilized eggs develop into females that are diploid.

2. Examine the prepared slides of a fern (Phylum/Division Pteridiophyta, Genus *Polypodium*) life cycle and then match them to the structure images in Figure UIII-3.

A. Label the name of the structure on the diagram.

B. Match the parts of the life cycle with the listed terms.

C. What type of nuclear division (including ploidy level) is occurring at

A _____, B _____, and

C _____

D. Color the tissue/cells: haploid yellow and diploid orange.

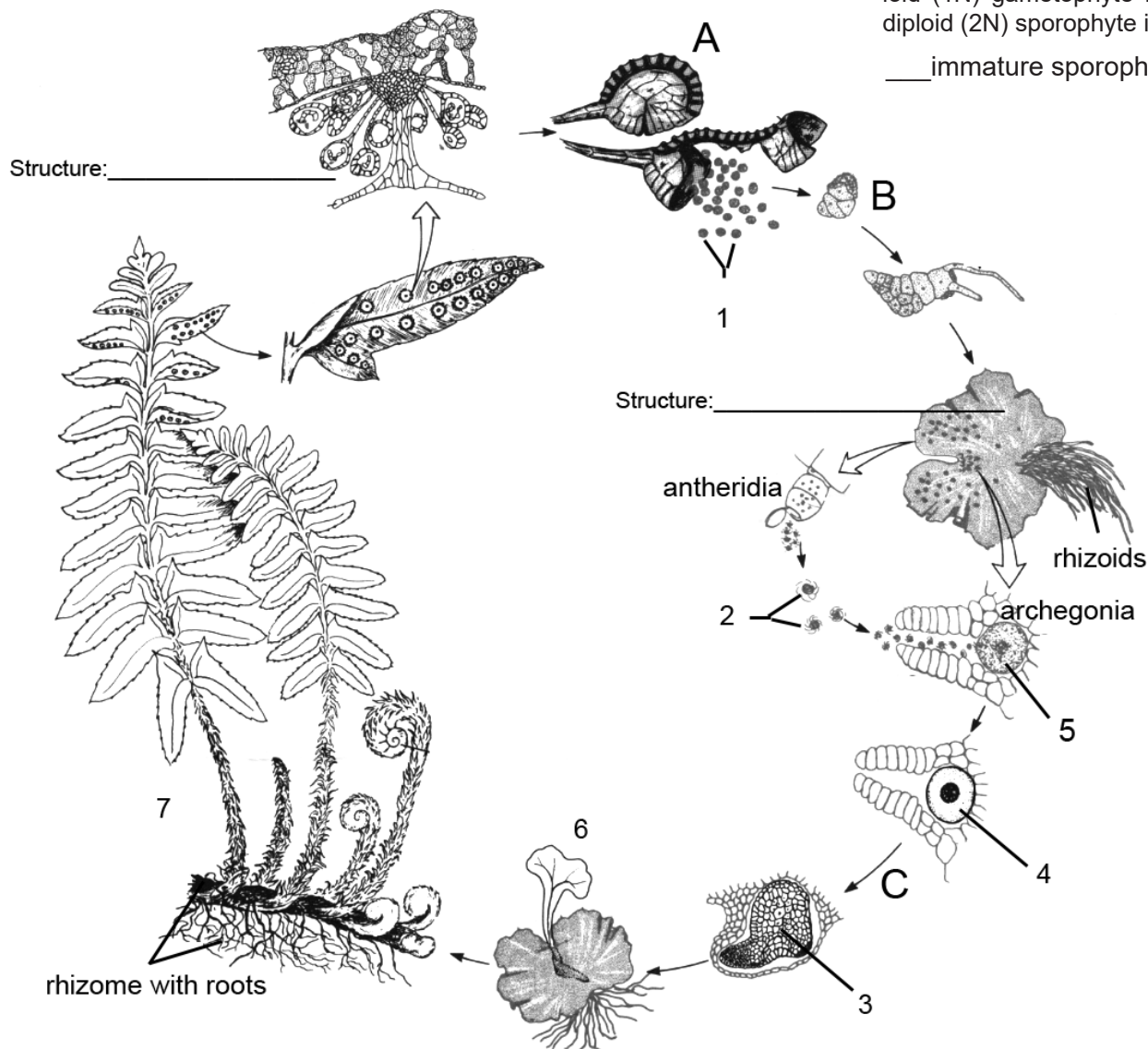


Figure UIII-3. *Polypodium* life cycle. The haploid (1N) gametophyte is colored yellow and diploid (2N) sporophyte is colored orange.

____ immature sporophyte on gametophyte

____ zygote

____ sporophyte

____ sperm

____ spores

____ embryo

____ egg

3. Examine the prepared slides of a lily (Phylum/Division Angiosperm, Genus *Lilium*) life cycle and then match them to the structure images in figure UIII-4.

A. Label the name of each structure.

B. Match the parts of the life cycle with the listed terms.

C. What type of nuclear division (including ploidy level) is occurring at

A _____, B _____

D. Color the tissue/cells: haploid yellow and diploid orange. Don't color the cells going through Meiosis I & II.

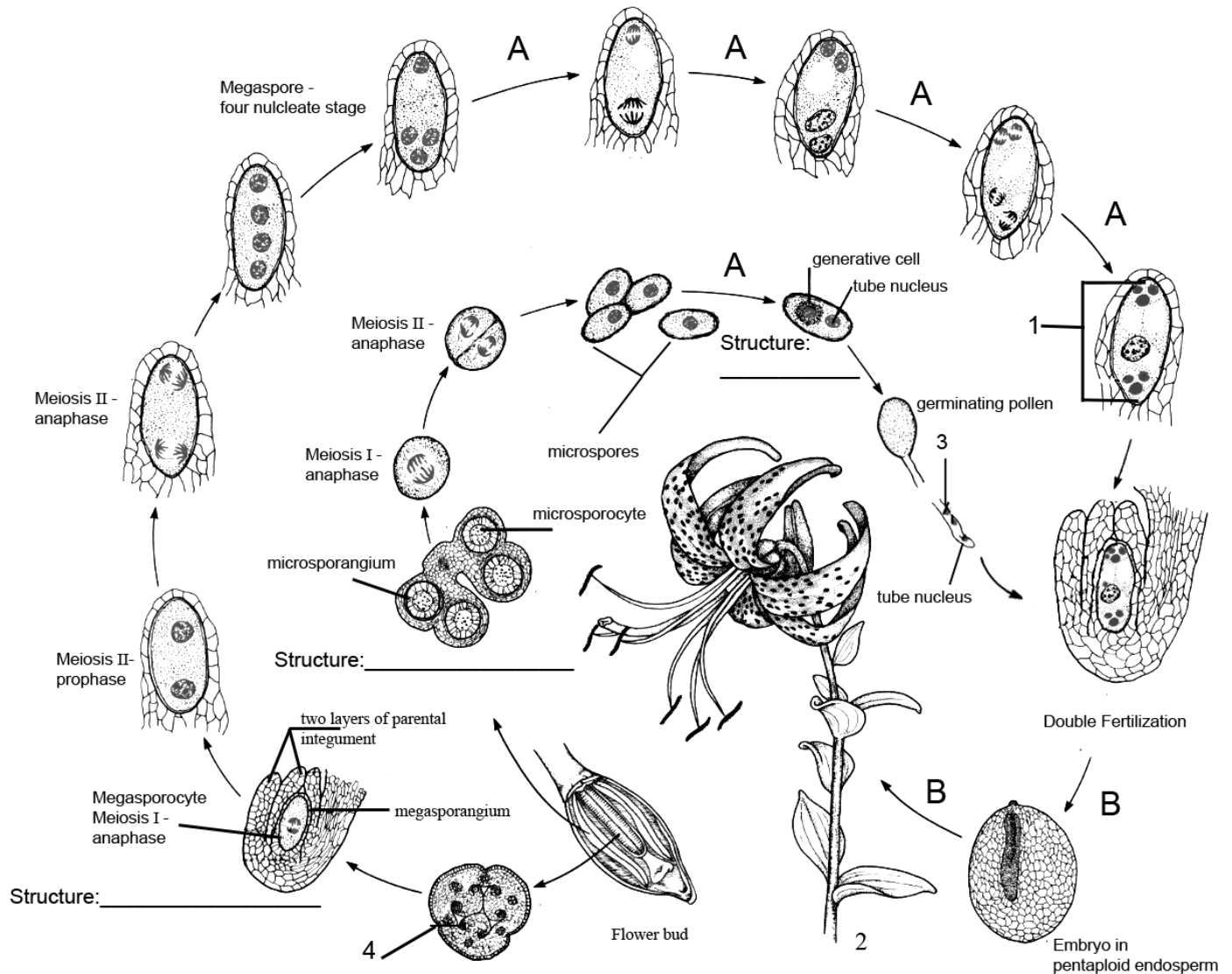


Figure UIII-4. Lilium life cycle. The haploid (1N) gametophyte is colored yellow and diploid (2N) sporophyte is colored orange.

___ sporophyte ___ ovary (with many ovules inside)
 ___ sperm cells ___ megagametophyte (aka embryo sac)

B. Development

4. Examine the prepared slides of Shepard's purse (Phylum/Division Angiosperm, Genus *Capsella*) that show a series of developmental stages inside of a seed and then match them to the stages in Figure UIII-5.
 - A. Label the name of each stage on the diagram.
 - B. Match the parts in the images with the listed terms.
 - C. Color the gametophyte (haploid) tissue yellow.
 - D. Color the offspring tissue/cells (diploid): zygote, proembryo, embryo purple.
 - E. Color the endosperm (polyploid) tissue pink.
 - F. Color the parental tissue (diploid) orange.
 - G. What type of life cycle is this: _____

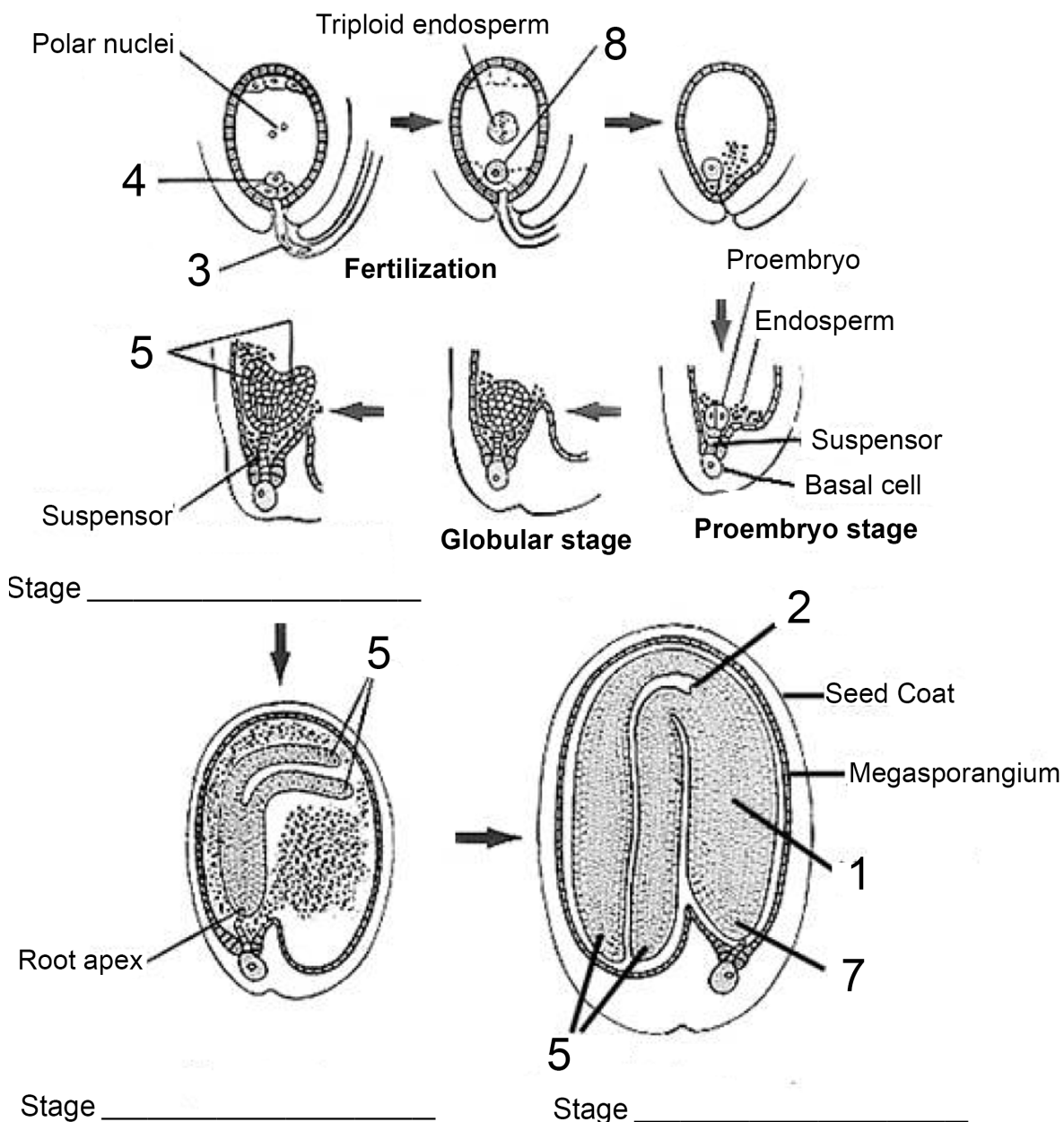


Figure UIII-5. *Capsella* embryo development. *Capsella bursa* (Shepherd's purse) is a species in the mustard family. It is native to Europe but is an introduced species across North America.

___ hypocotyl ___ egg ___ cotyledons ___ zygote ___ epicotyl (shoot meristem)
 ___ radicle (root meristem) ___ sperm

The affinities of all the beings of the same class have some-times been represented by a great tree. I believe this simile largely speaks the truth.

~ Darwin, Charles (1859), *On the Origin of Species by Means of Natural Selection*

Name: _____ Group #: _____ Section #: _____

Part 2. Fungi Life Cycle & Development

Asexual reproduction allows fungus to reproduce without exchanging genetic information with another individual within the same species. The individual produced through asexual reproduction is identical to the parent. They do this by producing haploid vegetative cells (spores), budding, or fragmentation. Spore production and budding requires mitosis but fragmentation does not. Each spore contains a single nucleus with all the genetic information needed for the organism to become re-established after dispersal. The spores are small and are produced in large numbers. Sexual reproduction allows fungus to exchange genetic information with another individual within the same species producing a new individual that is genetically different from the original individuals. Sexual reproduction occurs when the hyphae of two genetically different individuals of the same species encounter each other. Things to remember:

- The fungi we see are usually haploid (1N).
- The zygote produced when hyphae meet during sexual reproduction is diploid (2N).
- Spores are haploid (1N); produced during sexual reproduction by meiosis or asexual reproduction by mitosis.

A. Demonstration

Cultures of mold (Phylum Zygomycota, Genus *Phycomyces*) can be grown in a manner very similar to bacteria. Agar plates inoculated with *P. blakesleeenanus* consist of potato agar, and dextrose. Remember to maintain sterile (aseptic) technique for this experiment because there are many other bacteria and fungus that feed on potato agar.

- ☐ Work as a group of TWO.
- ☐ Place a several hyphae of each *P. blakesleeenanus* mating strain (- and +) on opposite sides of an agar plate (Figure UIII-6).
- ☐ Label your plates with your names, lab section, date, and where you placed each mating strain.

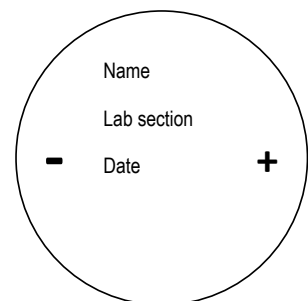


Figure UIII-6. Inoculation of agar plates with *P. blakesleeenanus* haploid sporangia.

B. Results

- ☐ Examine the mating (+ and – strains) cultures of *Phycomyces blakesleeenanus* to observe the life cycle of *Phycomyces* (Fig. UIII-7).
- ☐ Place the plate under a dissecting microscope. Focus at 4X on the mating line.
- ☐ Using forceps pull away any hyphae that are covering the mating line.

5. On your plate, observe the different structures of *Phycomyces* life cycle:
- Match the parts that make up each stage with the listed terms.
 - What type of nuclear division (include ploidy level) is occurring at A _____ and what type of reproduction is this? _____
 - What type of nuclear division is occurring in the zygosporangium (include ploidy level)? _____ and what type of reproduction is this? _____
 - What type of life cycle is this: _____ Why?

___ karyogamy ___ plasmogamy ___ spores ___ mature zygosporangium (zygospore held inside)

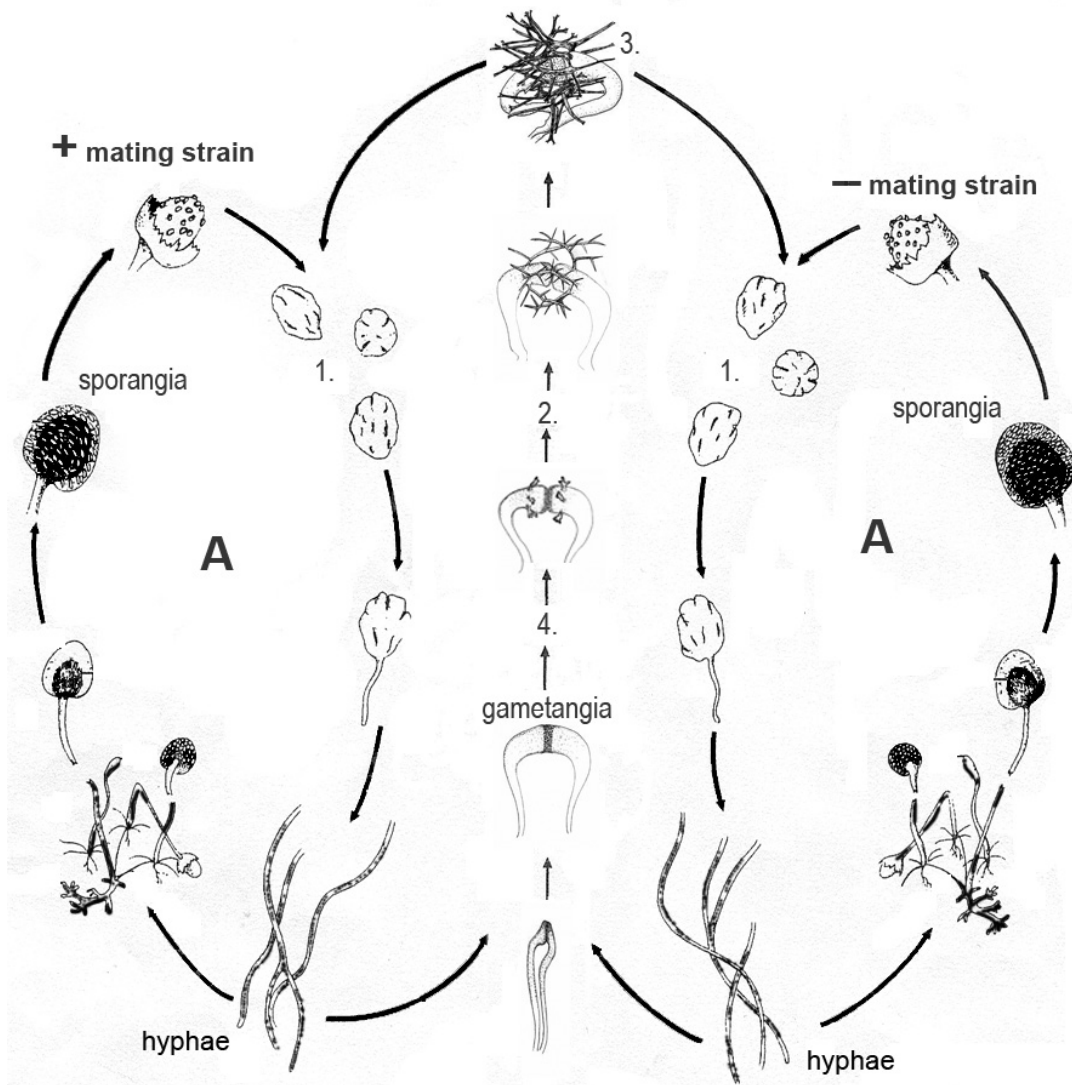


Figure UIII-7. Life cycle of *Phycomyces*.

Part 3. Animal Life Cycle & Development

The life cycle of an animal, includes all of the stages from the end of the last generation to the beginning of the next. Most animal species begin life as a single egg cell that is then fertilized (syngamy) by a sperm cell to produce a zygote. All animals excluding the sponges have germ layers. A **germ layer** is a layer of cells that act together in the early stages of embryonic development to differentiate into tissue and organ systems. A tissue is a group of similar cells specialized for the performance of certain functions. Tissues are coordinated into organs and organs coordinated into systems that work together. Animals are organized into two groups, **diploblastic or triploblastic**, based on germ layer number.

6. Match the term with the correct germ layer on Figure UIII-8

_____ Mesoglea _____ Mesoderm

_____ Ectoderm _____ Endoderm

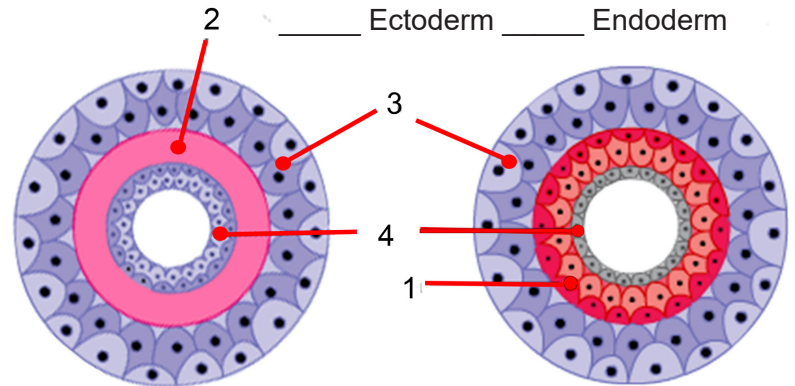


Figure UIII-8 A) Diploblastic and B) triploblastic germ layers.

A. Porifera

Poriferans have a **cellular level of organization** comprised of specialized cells that perform specific functions. Cells are held loosely together and supported by a skeleton of spicules and/or collagen. **Spicules** can be composed of calcium carbonate or silica. Spicules serve as stiffening material, and are especially important for maintaining the shape of the sponge. Sponges are primarily marine organisms and as adults are sessile, filter-feeders. They filter water by using the current created by the **choanocyte** flagella which moves water through the **pores**, into the **atrium**, and out the **osculum**. They can reproduce asexually by budding but they also release egg cells and sperm. Most sponges are poisonous or protected by their spicules, and are rarely eaten by other animals. Sponges have three asexual methods of reproduction: after fragmentation; by budding; and by producing gemmules. Most sponges are hermaphrodites and have no gonads. Sperm are produced by choanocytes that form spermatocysts while egg cells are formed by transformation of **amoebocytes**. Each egg generally acquires a yolk by consuming “nurse cells”. During spawning, sperm burst out of their cysts and are expelled via the osculum. If they contact another sponge of the same species, the water flow carries them to choanocytes that engulf them but, instead of digesting them, metamorphose to an ameboid form and carry the sperm to the eggs, which in most cases engulf the carrier and its cargo.

_____ choanocyte _____ pore _____ osculum

_____ amoebocyte _____ spicule

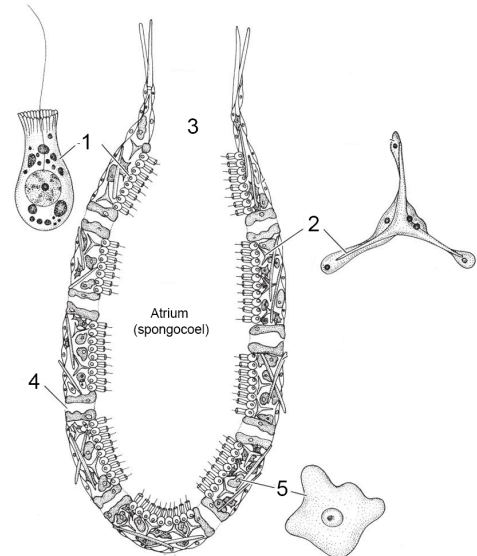


Figure UIII-9. Sponge (*Grantia*) longitudinal section.

7. Observe the sponge specimens on display .
 - A. Match the term with the correct structure on Figure UIII-9.
 - B. Does this animal have organs? _____
 - C. Draw the direction of the water movement in blue.
 - D. What cell is used to create a current that will move water through the sponge?

E. What type of symmetry do sponges have?

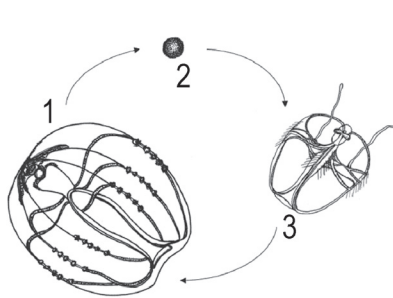
- F. On the diagram label the cell that would produce eggs.
- G. On the diagram label the cell that would produce sperm.
- H. Draw the direction of sperm movement into and out of the sponge in pink.

B. Diploblastic Animals

Animals that are diploblastic include the cnidarians and ctenophores. Both have two distinct tissue layers (**ectoderm and endoderm**) separated by a **mesoglea**, muscles (usually derived from ectoderm), and a simple net-like nervous system. Cnidarians have radial symmetry and tentacles lined with cnidoblasts that each contain one nematocyst (cnida) that deliver toxin for defense or prey capture. Ctenophores have biradial symmetry with plates of fused cilia arranged in rows (comb rows) and have tentacles lined with adhesive **colloblasts**.

8. Observe the comb jelly specimen (Phylum Ctenophora, Class Tentaculata) on display:

- What type of symmetry do ctenophores have? _____
- Match the terms with the correct life stage on Figure UIII-10 _____
- What type of nuclear division produces the comb jelly gametes? _____
- The comb jelly gametes fuse (syngamy, fertilization) to form a _____.
- What type ploidy level does this organism have at each stage (1, 2, 3)? _____



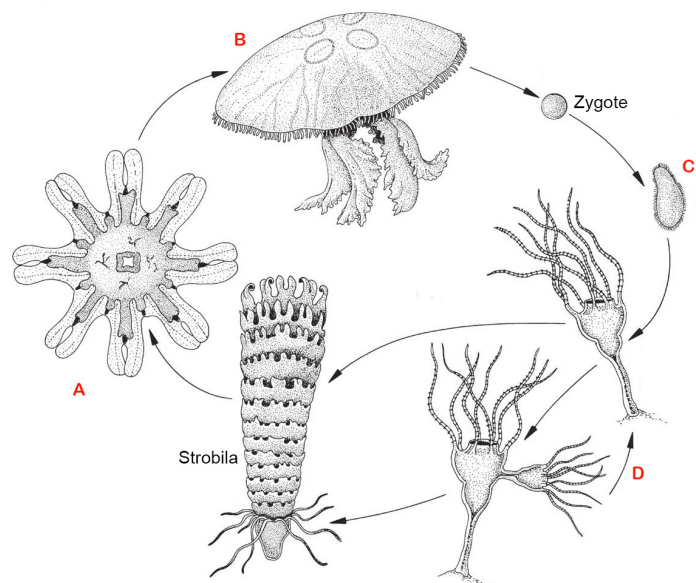
_____ Zygote _____ Cydippid Larva _____ Adult

Figure UIII-10. Generalized life cycle of the comb jelly. Most studied species are hermaphroditic with both male and female gonads, releasing eggs and sperm into the water, where fertilization produces larvae. All but one ctenophore order (Beroida) have two -tentacled larvae which quickly grow and develop into adults. In Beroids, fertilized eggs hatch into miniature versions of the adult animal, rather than distinct larval forms.

9. Examine the prepared slides of a moon jelly (Phylum Cnidaria, Class Scyphozoa, Genus *Aurelia*) life cycle and then match them to the structure images in Figure UIII-11.

- What type of symmetry do cnidarians have? _____
- Match them to the images in Figure UIII-11 and fill in the figure caption. _____
- What type of nuclear division produces the moon jelly gametes? _____
- The moon jelly gametes fuse (syngamy, fertilization) to form a _____.
- What type ploidy level does this organism have at each stage (A, B, C, D)? _____

Figure UIII-11. Generalized life cycle of the moon jelly. Moon jellies are a common and rather large jellyfish. They have oral arms surrounding the mouth, a ring canal, sense organs, and gonads among other tissues and organs. They will form large swarms at specific temperatures or salinity layers in the sea and the male will release sperm into the water. The female will collect the sperm and fertilize her eggs. A **zygote** is released by the gastric pouches of a female and will develop into life stage C _____. This stage will swim through the water to find a suitable place to settle and will then develop into a sessile life stage D _____. This stage can go through two forms of asexual reproduction. Budding produces morphological and genetically identical individuals but strobilation produces a **strobila** of morphologically different but genetically identical individuals. As the layered individuals composing the strobila mature they will detach from the top of the strobila and swim away. This new life stage A _____ will gradually mature into adult life stage B _____ that will begin the cycle again through sexual reproduction.



C. Triploblastic Animals

In all triploblastic animals (**deuterostomes** and **protostomes**) three distinct embryonic cell layers (**ectoderm**, **endoderm**, **mesoderm**) are formed during development. These animals are usually bilaterally symmetrical, oriented on an axis that passes from the anterior to the posterior with dorsal, ventral, and lateral sides of the body (in some triploblastic animals the bilateral symmetry occurs only during the larval stage). Most triploblastic animal species begin life as a single-celled zygote and proceed through 4 stages of embryogenesis. 1) Cleavage is the initial cell divisions of the zygote that produces blastomeres (cells). There are two types of cleavage patterns that occur between the 4-cell stage and the 8-cell stage. **Spiral cleavage** occurs in protostomes whereas deuterostomes have **radial cleavage**. 2) The morula is a solid ball of cells. 3) The blastula is a hollow fluid-filled sphere of cells that surrounds the **blastocoel**, a central hollow cavity. 4) The gastrula is a multi-layered sphere of cells. An indentation at the vegetal pole (**blastopore**) will form and the resulting internal cavity is the **archenteron**. The gastrula becomes an embryo and consists of three germ layers. In protostomes the blastopore develops into the adult animal's mouth. The mesoderm is derived from a blastomere located near the vegetal pole of the embryo, which subsequently splits to form the coelom (schizocoely). In deuterostomes the blastopore develops into the adult animal's anus and a second embryonic opening develops into its mouth. The mesoderm is derived from an out-pocketing of the archenteron which, when expanded, forms the coelom (enterocoely). Organogenesis follows gastrulation and is the process of cell specialization into tissues and organs of the animal body.

10. Examine the prepared slides and then match them to the diagrams in Figure UIII-12.

- Fill in the figure caption with the correction information.
- Fill in the Phylum, Class, and Genus.
- Match the structures on the diagram with the listed terms.
- What is the ploidy level of each cell depicted in the diagram? _____

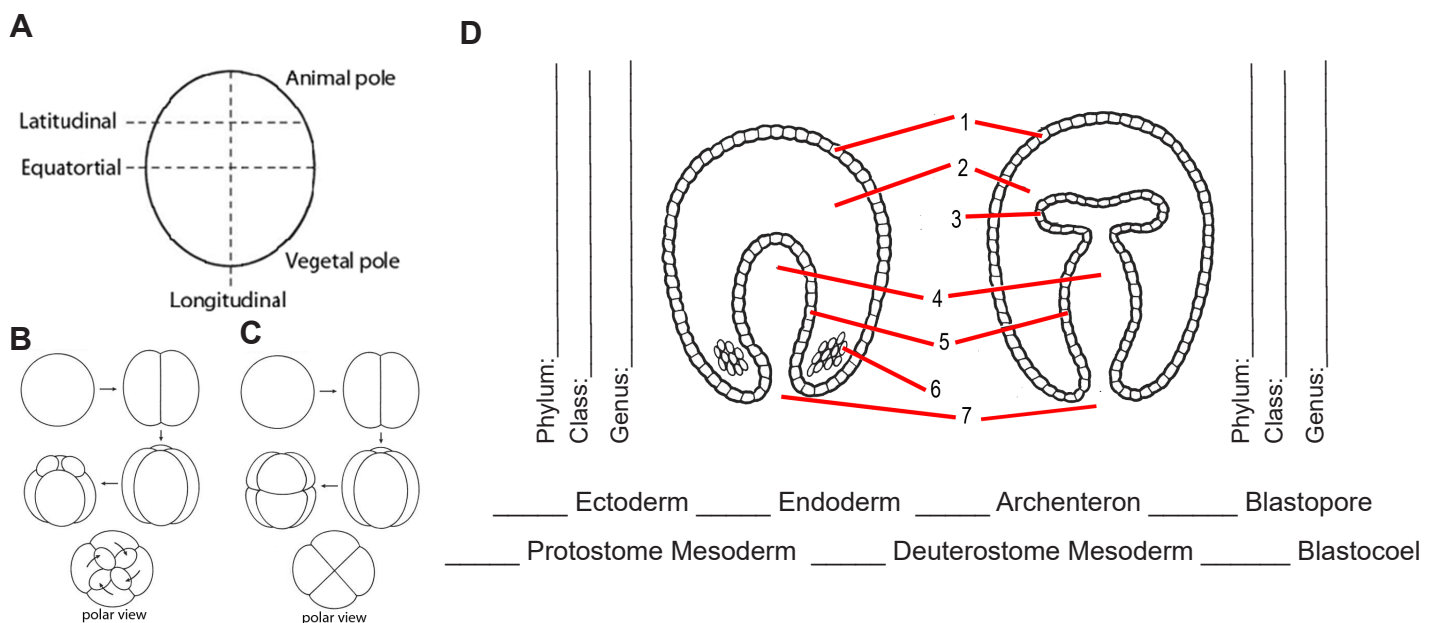


Figure UIII-12. **A)** Animal-vegetal axis with cleavage planes. **B)** _____ cleavage of _____ a _____, involves longitudinal divisions and then the following divisions result in blastomeres arranged in an alternating pattern. **C)** _____ cleavage of _____ a _____, involves both longitudinal and transverse divisions producing rows of blastomeres. **D)** Mesoderm formation of the gastrula stage; left, a _____ and right a _____.

11. Observe the flatworm specimen (Phylum Platyhelminthes, Class Trematoda, Species *Schistosoma japonicum*) available and Figure UIII-13.
- In the life cycle figure, sketch the adult.
 - What type of nuclear division (include ploidy level) produces the organism's gametes? _____
 - At what stage is sperm released that will fuse with an egg to produce a zygote (fertilized egg) that will develop into a larvae? _____
 - Once a zygote is formed and a fertilized egg is shed by the female organism what type of nuclear division occurs to allow the organism to grow and develop into different stages? _____
 - What type ploidy level does this organism have at each stage? _____
 - What is(are) the infective stage? _____, the diagnostic stage? _____.
 - What animals are the hosts? _____.
 - What type of triploblastic animal is this flatworm _____ and what is its cleavage pattern? _____

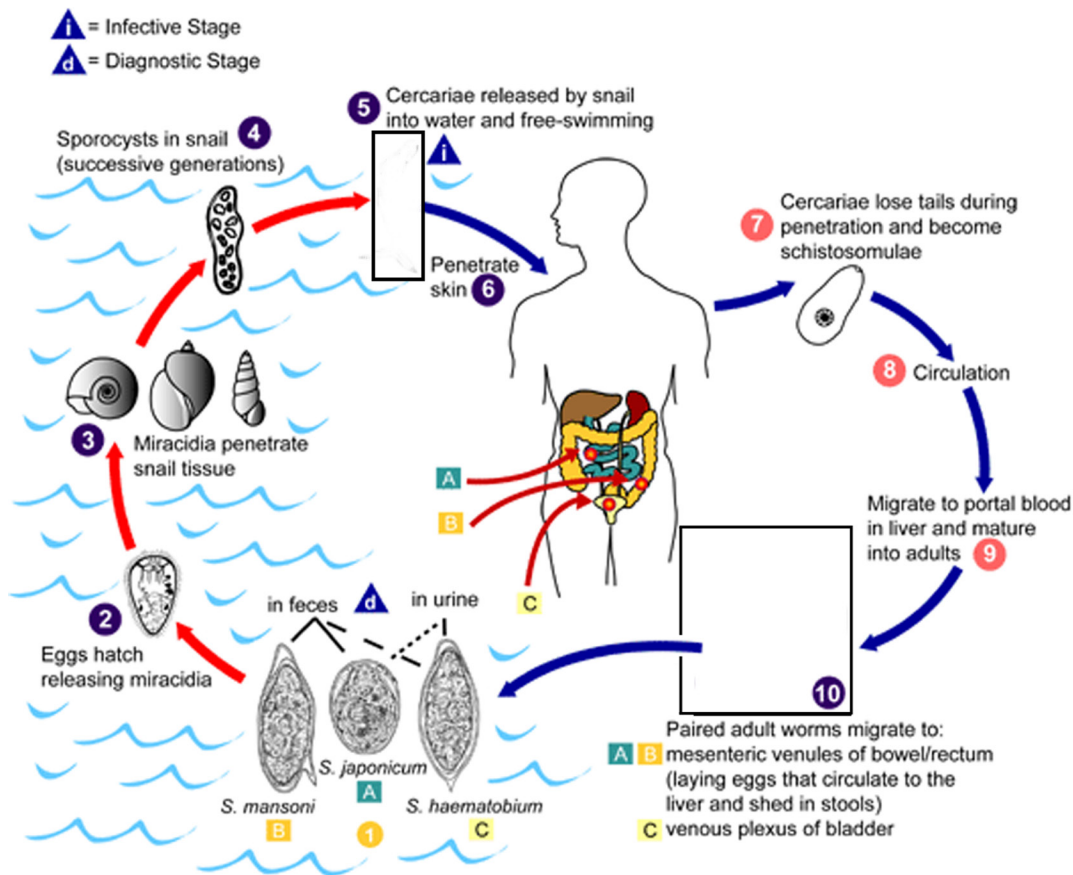


Figure UIII-13 Life cycle of the blood fluke *Schistosoma japonicum*. Eggs are eliminated with feces or urine (1). Under optimal conditions the eggs hatch and release miracidia (2), which swim and penetrate specific snail intermediate hosts (3). The stages in the snail include 2 generations of sporocysts (4) and the production of cercariae. Upon release from the snail, the infective cercariae swim (5), penetrate the skin of the human host (6), and shed their forked tail, becoming schistosomulae (7). The schistosomulae migrate through several tissues and stages to their residence in the veins (8 & 9). Adult worms in humans reside in the mesenteric venules in various locations (10), which at times seem to

be specific for each species. Pathology of *S. japonicum* schistosomiasis includes: Katayama fever, hepatic perisinusoidal egg granulomas, Symmers' pipe stem periportal fibrosis, portal hypertension, and occasional embolic egg granulomas in brain or spinal cord.

12. Observe the roundworm specimens (Phylum Nematoda, Class Adenophorea, Species *Trichinella spiralis*) available and Figure UIII-14.

A. In the life cycle figure, sketch the adult and the larvae.

B. What type of triploblastic animal is this roundworm _____ and what is its cleavage pattern? _____.

C. What type of nuclear division (include ploidy level) produces the organism's gametes? _____

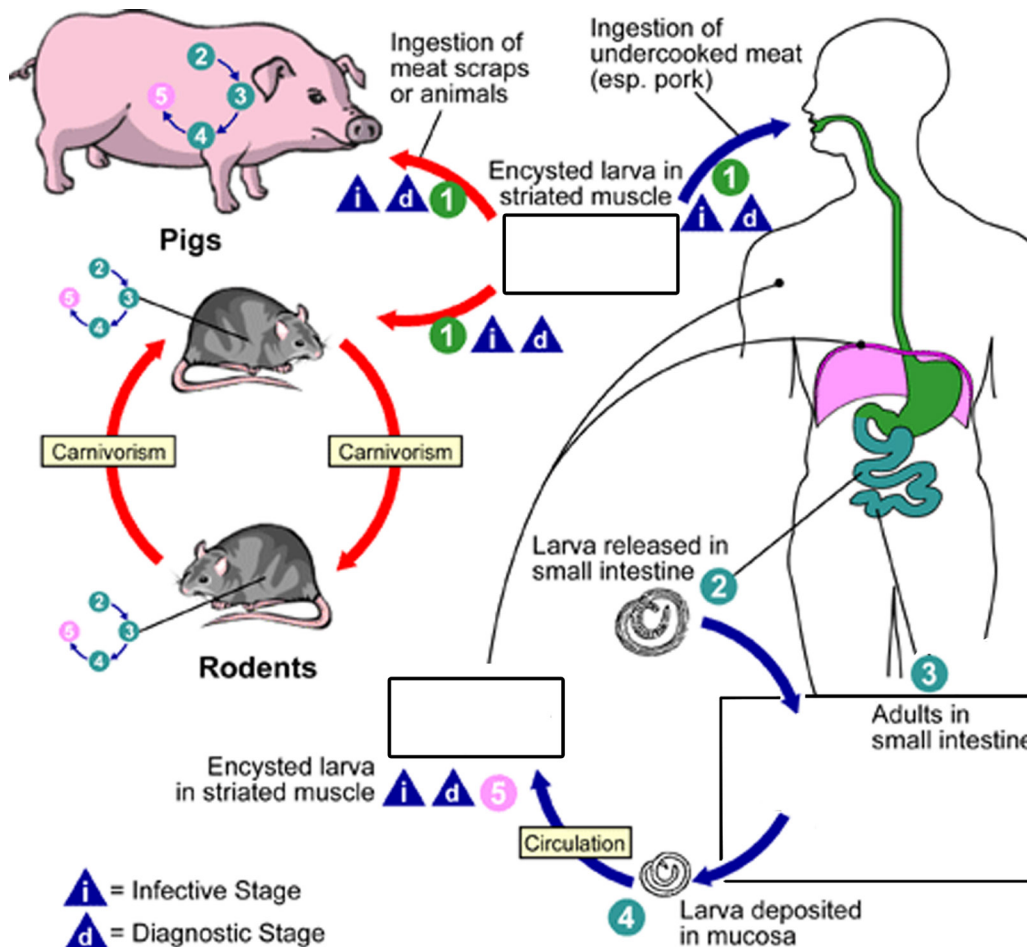
D. At what stage is sperm released that will fuse with an egg to produce a zygote (fertilized egg) that will develop into a larvae? _____

E. Once a zygote is formed what type of nuclear division occurs before the larva is released by the female organism? _____

F. What type ploidy level does this organism have at each stage? _____

G. What is(are) the infective stage? _____, the diagnostic stage? _____.

H. What animals are the hosts? _____.



this infection. Carnivorous/omnivorous animals, such as pigs or bears, feed on infected rodents or meat from other animals. Different animal hosts are implicated in the life cycle of the different species of *Trichinella*. Humans are accidentally infected when eating improperly processed meat of these carnivorous animals (or eating food contaminated with such meat).

13. Observe the insect development plastomounts in lab and match them to Figure UIII-15 A) and B).

Label each diagram:

A. Type of metamorphosis.

B. Name of each life stage.

C. Adult bees; drone (male ♂) and queen and worker (female ♀).

D. Phylum, class and genus names.

E. What type of nuclear division (include ploidy level) produces the organisms's gametes?

F. At what stage are egg and sperm produced? _____

G. Once a zygote is formed and a fertilized egg is laid by the female insect what type of nuclear division occurs to allow the organism to grow and develop into the different stages? _____ Where is the exception? _____

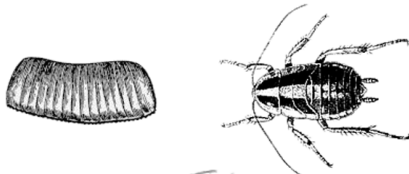
H. What type ploidy level does this organism have at each stage? _____ Where is the exception? _____

I. What type of triploblastic animals are insects _____ and what are their cleavage patterns? _____.

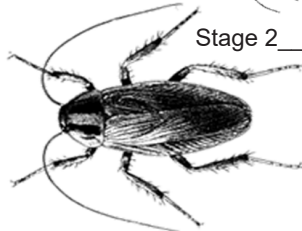
A Metamorphosis: _____
Phylum: _____
Class: _____
Genus: _____

B Metamorphosis: _____
Phylum: _____
Class: _____
Genus: _____

Stage 1 _____

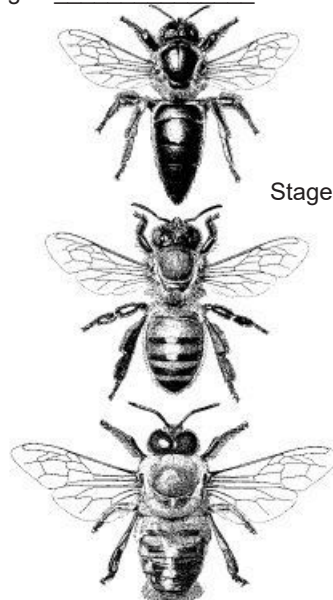


Stage 2 _____

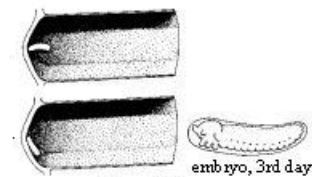


Stage 3 _____

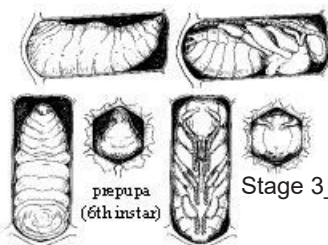
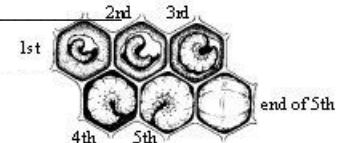
Stage 4 _____



Stage 1 _____



Stage 2 _____



Stage 3 _____

Figure UIII-15. Life cycle of **A)** a common house cockroach and **B)** a honey bee. Both insects have internal fertilization and the eggs laid by the female are zygotes or newly developing embryos (oviparity.) The ootheca of the cockroach is filled with fertilized eggs at varying stages of embryogenesis. The bee drone develops from an unfertilized egg whereas the eggs that will develop into workers and future queens are fertilized from the sperm of a haploid drone.

14. Observe the frog development plastomount (Phylum Chordata, Class Amphibia, Genus *Lithobates*) in lab and match them to Figure UIII-16:

A. Label the diagram with the name of each life stage.

B. What type of nuclear division (include ploidy level) produces the gametes? _____

C. At what stage are egg and sperm produced? _____

D. Once a zygote is formed what type of nuclear division occurs to allow the organism to grow and develop into the different stages? _____

E. What type of ploidy level does this organism have at each stage? _____

F. What type of triploblastic animal is a frog _____ and what is its cleavage pattern do they have? _____.

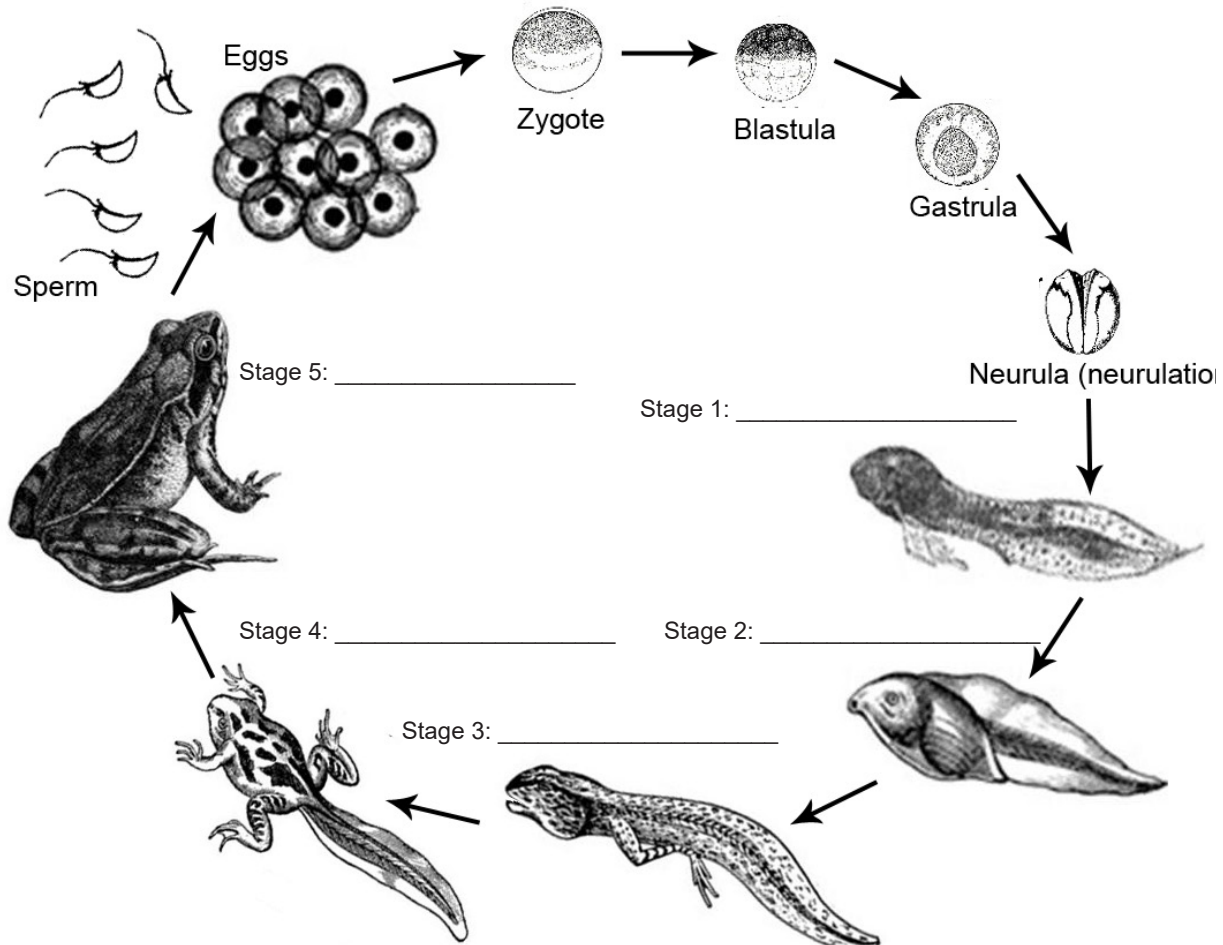


Figure UIII-16. Life cycle of *Lithobates*. Females lay eggs in water and males release sperm into water over eggs (oviparity.) Fertilization and development occurs in water outside of the female body.

15. To which life cycle do the plant specimens from questions 1-4 belong? _____

16. To which life cycle does the fungi from question 5 belong? _____ Do all fungi have that life cycle? _____ If not, what other life cycles do they have? _____

17. To which life cycle do the animal specimens from questions 7-14 belong? _____

Unit IV. Animals

Objectives

- Name, identify, and define the various cells, tissues, organs, and systems of the major animal taxa.
- Become familiar with the diversity of animal life.
- Dissect an invertebrate species and give an informal group presentation on that species.
- Compare the morphology of a selection of chordates using dissection, informal group presentation, and measurement.
- Analyze the collected measurements using Excel and R.
- Take a comparative morphology exam using the information from the presentations and the analyzed data.

Terms & Definitions

Ampullae - a muscular sac at the base of each tube foot of an echinoderm; used to store water.

Antennae - sensory organs found on the heads of certain arthropods such as hexapods and crustaceans.

Carnassials - paired upper and lower teeth modified in such a way as to allow enlarged and often self-sharpening edges to pass by each other in a shearing manner. The last premolar in the upper jaw has an elongated blade, which shears past a similar one on the first lower molar like scissors. This adaptation is found in carnivorans.

Carnivorans - members of a diverse order of placental mammals, the Carnivora. The majority have large, sharp teeth and powerful jaws, and prey on other animals.

Carnivore - an ecological term for any meat-eating animal including the non-carnivorans such as dolphins and non-mammals such as crocodiles.

Chordata (Phylum) - animals having at least at some stage of development a notochord, dorsally situated central nervous system, and gill slits and including the vertebrates, lancelets, and tunicates

Cephalization - the localization of a brain and sensory structures at the anterior end of the body of animals.

Cephalothorax - the fused head and thorax structure in species of the class Arachnida and Crustacea.

Cyclostomata (Superclass) – jawless vertebrates

Circulatory system - a system that transports necessary material to all cells of an animal's body and transports waste products away from cells. Three basic systems exist (A-C).

- Gastrovascular cavity - in certain invertebrates (cnidarians) a body cavity with a single opening to the outside functions as both a digestive and circulatory system.
- Open - a circulatory system in which hemolymph (not the same as interstitial fluid) flows throughout the body and is not confined to special vessels.
- Closed - a circulatory system in which blood flows throughout an animal entirely within a series of vessels and is kept separate from the interstitial fluid:
 - Single - type of circulatory system that occurs in fishes, in which the blood passes only once through the heart in each complete circuit of the body.
 - Double - in which the blood passes through the heart twice in each complete circuit of the body:
 - Pulmonary - the portion of the closed system transporting deoxygenated blood away from the right ventricle of the heart, to the lungs, and returns oxygenated blood to the left atrium and ventricle of the heart.
 - Pulmocutaneous - part of the amphibian circulatory system that directs blood from the heart to the gas exchange organs (skin and lungs).
 - Systemic - the portion of the closed system transporting oxygenated blood away from the heart through the aorta from the left ventricle where the blood has been previously deposited from pulmonary circulation, to the rest of the body, and returns oxygen-depleted blood back to the heart.
- Structures:
 - Aorta - in vertebrates, a large blood vessel that exits a ventricle of the heart and leads to the systemic circulation.
 - Atria - heart chambers that collect blood from the tissues.
 - Heart – a muscular structure that pumps blood through blood vessels.
 - Vein – blood vessel that returns blood to the heart OR a bundle of vascular tissue in a leaf.
 - Ventricles – a chamber that pumps blood out of the heart.

Crop - a storage organ that is a dilation of the lower esophagus; found in most birds and many invertebrates, including insects and some worms.

Dentition - the development of teeth and their arrangement in the mouth

- Dental formula - the number of teeth of each type is written as a dental formula for one side of the mouth, or quadrant, with the upper and lower teeth shown on separate rows. The number of teeth in a mouth is twice that listed, as there are two sides.
- Elodont - teeth that continuously grow
- Incisors - slicing teeth
- Canines - tearing teeth
- Premolar - grinding teeth
- Molars - grinding teeth

Digestion - the process of breaking down nutrients in food into smaller molecules that can be absorbed across the intestinal epithelia and directly used by cells.

Digestive system – the system that take in food and liquids, breaks them down into substances that the body can use for energy, growth, and tissue repair, and remove waste products. The system is made up of the gastrointestinal tract (GI tract), liver, pancreas, and gallbladder:

- Gallbladder – a small, pear-shaped organ on the right side of the abdomen, just beneath the liver storing bile produced by the liver.
 - Cystic Duct – a tube that carries bile from the gall bladder.
- GI tract – a series of hollow organs joined in a long, twisting tube from the mouth to the anus.
 - Pharynx – a portion of the vertebrate alimentary canal; also known as the throat.
 - Esophagus - the part of the gastrointestinal tract that connects the mouth to the stomach; the gullet. In humans and other vertebrates it is a muscular tube lined with mucous membrane.
 - Intestine:
 - Large (cecum, colon, rectum and anus) – portion of the GI tract most responsible for absorption of water from the indigestible residue of food.
 - Small – most of the end absorption of nutrients and minerals from food takes place.
 - Duodenum - the first part of the small intestine immediately beyond the stomach, leading to the jejunum.
 - Jejunum – the part of the small intestine between the duodenum and ileum.

- c. Ileum – the third portion of the small intestine, between the jejunum and the cecum.
- D. Stomach – a muscular, hollow organ in the gastrointestinal tract of humans and many other animals, including several invertebrates.
 - i. Chief Cells – a type of gastric gland cell that releases pepsinogen and gastric lipase.
 - ii. Circular fold – large valvular flaps projecting into the lumen of the small intestine.
 - iii. Fundus – the upper part of the stomach, which forms a bulge higher than the opening of the esophagus (farthest from the pylorus).
 - iv. Gastric Gland – any of the branched tubules in the inner lining of the stomach that secrete gastric juice and protective mucus
 - v. Gastric Pits - indentations in the stomach which denote entrances to the tubular shaped gastric glands.
 - vi. Pylorus – connects the stomach to the duodenum.
 - vi. Pylorus Sphincter – a band of muscle that marks the junction between the stomach and the duodenum.
- E. Rectum – the final straight portion of the large intestine in humans and some other mammals, and the gut in others.
- F. Anus – the final portion of the alimentary canal through which solid wastes are expelled.
- 3. Liver – accessory digestive organ used to produce bile.
- 4. Pancreas – an organ of the digestive system and endocrine system of vertebrates; it is a mixed or heterocrine gland, i.e. it has both an endocrine and a digestive exocrine function
 - A. Pancreatic Islets – the regions of the pancreas that contain its endocrine cells.
- 5. Villi – fingerlike or threadlike projections from the surface of certain membranous structures, typically serving to increase surface area and facilitate the passage of fluid or nutrients.
 - A. Microvilli – microscopic cellular membrane protrusions of simple cuboidal and simple columnar epithelium that increase the surface area for diffusion and minimize any increase in volume, and are involved in a wide variety of functions, including absorption, secretion, and cellular adhesion.
 - B. Brush-border membrane – the microvilli of the enterocytes that line the intestinal villi

Elodont – continuously growing teeth that do not develop anatomical roots.

Eyes – the visual organ in animals that detects light and sends signals to the brain.

Gizzard – the muscular portion of the stomach of birds and some reptiles that is capable of grinding food into smaller fragments.

Gnathostomata – opposing jaws vertebrates

Herbivore – an ecological term for any plant-eating animal.

Integumentary system – the set of organs forming the outermost layer of an animal's body. It comprises the skin and its appendages, which act as a physical barrier between the external environment and the internal environment:

- A. Chromatophore/chromatocyte – a pigment cell is a cell that contains pigment granules.
- B. Corpuscle/mechanoreceptors:
 - Herbst – a nerve-ending similar to the Pacinian corpuscle, in the mucous membrane of the tongue, in pits on the beak and in other parts of the bodies of birds. It differs from the Pacinian corpuscle in being smaller, in its capsules being more closely approximated, and in that the axis-cylinder in the central clear space is coated with a continuous row of nuclei. In many wading birds, a large number of Herbst corpuscles are found embedded in pits on the mandibles that are believed to enable birds to sense prey under wet sand or soil.
 - Pacinian – is one of the four major types of mechanoreceptors (specialized nerve ending with adventitious tissue for mechanical sensation) found in mammalian skin.
 - Meissner's – a type of nerve ending in the skin that is responsible for sensitivity to light touch. In particular, they have their highest sensitivity (lowest threshold) when sensing vibrations between 10 and 50 hertz. They are rapidly adaptive receptors. They are most concentrated in thick hairless skin, especially at the finger pads.
- C. Dermal papillae – fingerlike projections arranged into double rows, increasing the surface area between the epidermis and dermis, thereby strengthening the juncture with the epidermis and increasing the amount exchange of oxygen, nutrients, and waste.
- D. Dermis – the thick layer of living tissue below the epidermis that contains blood capillaries, nerve endings, sweat glands, hair follicles, and other structures.
- E. Epidermis – outermost layer that provides a barrier to infection from environmental pathogens and regulates the amount of water released from the body into the atmosphere.
- F. Feather – the epidermal growths that form the distinctive outer covering, or plumage, on birds. Feathers are formed in tiny follicles in the epidermis, or outer skin layer, that produce keratin proteins:
 - Barb –series of branches fused to the rachis of a feather.
 - Barbule – series of branches fused to the barb of a feather which have hooks that lock the barbs together.
 - Bulb – the base of the hair follicle.
 - Calamus –the short, hollow, tubular, unpigmented end of the mature feather inserted into the feather follicle and thus present below the skin level.
 - Rachis – the long solid, tubular extension of the calamus above the skin of a bird. The rachis contains pith, which is composed of air-filled keratinized epithelial cells surrounded by a solid keratinized outer cortex.
- G. Follicle (skin appendage) – an organ subunit in the skin that gives rise to cutaneous appendage.
- H. Gland:
 - Mucous – a microscopic exocrine gland in the skin composed of cells that secrete mucus. In amphibians, this is the smaller of the two types of gland, the other being the poison (granular) gland. In these species the mucous gland is a cluster of cells that release secretion into a common duct.
 - Poison (granular) – a microscopic exocrine gland in the skin composed of cells that secrete toxic chemicals within the lumen. In amphibians, this is the larger of the two types of gland, the other being the mucous gland.
 - Sebaceous – a microscopic exocrine gland in the skin that opens into a hair follicle to secrete an oily or waxy matter, called sebum, which lubricates the hair and skin of mammals.
- I. Hair:
 - Root – the enlarged basal part of a hair within the skin. The root of the hair ends in an enlargement, the hair bulb, which is whiter in color and softer in texture than the shaft, and is lodged in a follicular involution of the epidermis called the hair follicle.
 - Shaft – the main part of the hair which is composed of trichocytes and is divided into the cortex and medulla
- J. Hypodermis – layer of cells lying immediately below the dermis. This layer connects the dermis layer to your muscles and bones, insulates, helps regulate body temperature, and produces fat cells to store energy.
- K. Scales:
 - Dermal – dermal bone that is thin, flexible, and platelike, and that develops in overlapping skinfolds that cover the body and often the head of fish and the bases of the fins.
 - Ctenoid – scale that possesses cteni (discrete spines).
 - Cycloid – scale that is smooth-edged, round or oval and composed of acellular dermal bone lacking small spines on the posterior exposed edge.

- **Epidermal** – a fold in the surface epidermis composed of keratin.
- **Ganoid** – thick, rhomboid-shaped integumentary skeletal element composed of multiple tissues including ganoine and bone.
- **Placoid** – multi-tissue structure composed of enameloid, dentine surrounding a pulp cavity, and bone of attachment anchoring the element into the dermis.

L. Stratum:

- **Basale** – the deepest layer of the five layers of the epidermis, the external covering of skin in mammals.
- **Corneum** – the outermost layer of the epidermis.
- **Granulosum** – a thin layer of cells in the epidermis lying above the stratum spinosum and below the stratum corneum (stratum lucidum on the soles and palms)
- **Lucidum** – a thin, clear layer of dead skin cells in the epidermis named for its translucent appearance under a microscope.
- **Spinosum** – a layer of the epidermis found between the stratum granulosum and stratum basale.

Madreporite – a sieve-like plate on the dorsal surface of an echinoderm where water enters the water vascular system.

Mantle – a fold of skin draped over the visceral mass of a mollusk that secretes a shell in those species that form shells.

Mantle cavity – the chamber in a mollusk mantle that houses delicate gills.

Morphology – the structure or form of a body part or an entire organism.

Nervous system – groups of cells that sense the internal and external environmental changes and transmit signals that enable an animal to respond in an appropriate way.

A. Central (CNS) – the central nervous system (CNS) consists of the brain and spinal cord organs. Because they are so vitally important, the brain and spinal cord, located in the dorsal body cavity, are encased in bone for protection. The brain is in the cranial vault, and the spinal cord is in the vertebral canal of the vertebral column. Although considered to be two separate organs, the brain and spinal cord are continuous at the foramen magnum.

- **Brain** – organ of the central nervous system of animals that functions to process and integrate information:
- **Cerebrum** – a region of the forebrain that is responsible for the higher functions of conscious thought, planning, and emotions as well as control of motor function.
- **Corpus Callosum** – a large bundle of more than 200 million myelinated nerve fibers that connect the two brain hemispheres.
- **Cerebellum** – the hindbrain along with the pons, responsible for monitoring and coordinating body movements.
- **Hypothalamus** – a region of the forebrain below the thalamus which coordinates both the autonomic nervous system and the activity of the pituitary, controlling body temperature, thirst, hunger, and other homeostatic systems, and involved in sleep and emotional activity.
- **Medulla oblongata** – a region of the hindbrain that coordinates many basic reflexes and bodily functions, such as breathing.
- **Midbrain** – one of three major divisions of the brain; the other two being hindbrain and forebrain.
- **Pons** – the region of the hindbrain, along with the cerebellum that is responsible for monitoring and coordinating body movements.
- **Thalamus** – a region of the forebrain that plays a major role in relaying sensory information to appropriate parts of the cerebrum and, in turn, sending outputs from the cerebrum to other parts of the brain. Parasympathetic - Postganglionic parasympathetic fibers (oculomotor, facial, glossopharyngeal, and vagus cranial nerves) release acetylcholine that regulates resting response.
- **Spinal cord** – the structure that connects the brain to all areas of the body and together with the brain constitutes the CNS.
- **Cerebrospinal fluid (CSF)** – fluid that exists in ventricles within the CNS and surrounds the exterior of the brain and spinal cord; it absorbs physical shocks to the brain resulting from sudden movements or blows to the head.

B. Glia cells - cells that surround the neurons; a major class of cells in nervous systems that perform various functions.

C. Neuron – a highly specialized cell found in the nervous system that communicates with other cells by electrical or chemical signals.

- **Axon** – an extension of the plasma membrane of a neuron that is involved in sending signals to neighboring cells.
- **Axon hillock** – the part of the axon closest to the body; typically where an action potential begins.
- **Axon terminal** – the end of the axon that sends the electrical or chemical messages to other cells
- **Cell body (soma)** – a part of a neuron that contains the cell nucleus and other organelles.

D. Perineurium – a protective sheath that surrounds a nerve fascicle.

E. Peripheral (PNS) – The peripheral nervous system (PNS) consists of nerves and ganglia. Nerves are bundles of nerve fibers, much like muscles are bundles of muscle fibers. Cranial nerves (ventral/inferior from brain) and spinal nerves (lateral from spine) extend from the CNS to peripheral organs such as muscles and glands. Ganglia are collections, or small knots, of nerve cell bodies outside the CNS.

- **Autonomic** – motor impulses to cardiac muscle, smooth muscle, and glandular epithelium (involuntary or automatic functions).
- **Enteric (ENS)** – control of; 1) movements of the gastrointestinal tract (GIT) by detecting chemical and mechanical stimuli from ingestion coordinating peristalsis, 2) gastric acid secretion, 3) GIT hormone release, and local blood flow. It also interacts with the GIT immune system. Primary afferent neurons.
- **Sympathetic** – postganglionic sympathetic fibers release norepinephrine producing an acute response that activates the blood flow in skeletal muscles and lungs, dilates lungs and blood vessels, and raises the heart rate.
- **Ganglion** – a group of neuronal cell bodies in the PNS that is involved in a similar function.
- **Neurolemmocyte** – the principal glia of the peripheral nervous system (PNS).
- **Neurilemma** – the outermost nucleated cytoplasmic layer of the neurilemmocytes that surrounds the axon of the neuron

F. Myelin fatty sheath – an insulating layer made up of specialized glial cells wrapped around axons.

G. Nerve – a structure found in the PNS that is composed of multiple myelinated neurons bound by connective tissue; carries information to or from the CNS.

H. Nerve impulse – a signal transmitted along a nerve fiber. It consists of a wave of electrical depolarization that reverses the potential difference across the nerve cell membranes.

I. Net - interconnected neurons with no central organ.

J. Neurocranium – the upper and back part of the skull, which forms a protective case around the brain

K. Neurotransmitter – a small signaling molecule that is released from an axon terminal and diffuse to a postsynaptic cell where it elicits a response.

Nerve cord – in many invertebrates a ventral structure that extends from the anterior end to the tail; a dorsal nerve cord is found in chordates.

Neurulation – the embryological process responsible for initiating central nervous system formation.

Notochord – a defining characteristic of all chordate embryos; consists of a flexible rod that lies between the digestive tract and the nerve cord.

Omnivore - an ecological term for any animal that has the ability to eat and survive on both plant and animal matter including the carnivorans such as bears.

Proventriculus – the glandular portion of a bird stomach.

Respiratory system - the organs involved in the exchange of carbon dioxide and oxygen:

A. Insect:

- Spiracle – opening of the tracheal system on the surface of the body.
- Trachea – a sturdy tube arising from the spiracles of an insect's body; involved in respiration. Or the tube leading to the lungs of air-breathing vertebrates.
- Tracheal system – respiratory system of insects consisting of finely branched air tubes. Air enters the spiracles into the trachea.

B. Fishes:

- Gill – a respiratory organ found in aquatic animals that allows for the exchange of dissolved oxygen from water into the blood stream. Lie in a branchial chamber covered by a bony operculum.
- Gill raker – bony or cartilaginous processes that project from the branchial arch (gill arch).
- Gill filament – the fleshy part of the gills. Each filament has thousands of lamellae.
- Lamellae – thin plate-like structures with open space between used to increase the surface area in contact with the environment to maximize gas exchange (both to attain oxygen and to expel carbon dioxide) between the water and the blood.
- Operculum – a protective flap that covers the gills of a bony fish.

C. Tetrapods:

- Alveoli – spherical outcroppings of the respiratory bronchioles and primary site of gas exchange with the blood. Alveoli are particular to mammalian lungs. Different structures are involved in gas exchange in other vertebrates.
- Atria – the dead-end air vesicles of the honeycombed walls of the parabronchi which project radially from the parabronchi.
- Bronchus(i) – the upper conducting airways of the lung; these airways arise from the terminus of the trachea.
- Bronchiole(s) – the minute branches into which a bronchus divides.
- Lung – internal paired structures used to bring O₂ into the circulatory system and remove CO₂.
- Parabronchus(i) – tertiary bronchus in the avian lung
- Trachea – the portion of the airway that attaches to the bronchi as it branches

Tube feet – echinoderm structures that function in movement, gas exchange, feeding, and excretion.

Vertebrae – a bony or cartilaginous column of interlocking structures that provides support and also protects the nerve cord, which lies inside its tube-like structure.

Vertebrates – chordates that typically having a bony or cartilaginous spinal column which replaces the notochord, a distinct head containing a brain which arises as an enlarged part of the nerve cord; Subphylum: Vertebrata (or Craniata).

Urinary system - the structures that collectively act to filter blood or hemolymph and excrete wastes, while recapturing useful compounds. Relating to or denoting the system of organs, structures, and ducts by which urine is produced and discharged, in mammals comprising the kidneys, ureters, bladder, and urethra; maintain fluid and electrolyte balance, purify blood and excrete liquid waste (urine):

Arteries - blood vessels that deliver oxygen-rich blood from the heart to the tissues of the body:

- A. Interlobar/Cortical radial - vessels of the renal circulation which supply the renal lobes. The interlobar arteries branch from the lobar arteries which branch from the segmental arteries, from the renal artery.
- B. Arcuate - are vessels of the renal circulation. They are located at the border of the renal cortex and renal medulla.
- C. Interlobular - renal blood vessels given off at right angles from the side of the arcuate arteries looking toward the cortical substance.

Arterioles - a small branch of an artery leading into capillaries:

- A. Afferent - group of blood vessels that supply the nephrons in many excretory systems.
- B. Efferent - supply the blood for the extensive network of capillaries that surround the cortical and medullary tubular system of the kidneys, known as the peritubular capillary network. Urinary Bladder - a muscular sac in the pelvis, just above and behind the pubic bone.

Calyx - a cuplike structure of the kidney through which urine passes:

- A. Minor - surround the apex of the renal pyramids.
- B. Major - urine passes before continuing through the renal pelvis into the ureter.

Capsular Space - slit like space between the visceral and parietal layers of the capsule of the renal corpuscle

Collecting Duct - the final component of the kidney to influence the body's electrolyte and fluid balance.

Filtrate - to liquid which has passed through the process of filtration

Glomerular:

- A. Capsule - A double-walled, cup-shaped structure around the glomerulus of each nephron of the vertebrate kidney. It serves as a filter to remove organic wastes, excess inorganic salts, and water.

B. Filtration - the process by which the kidneys filter the blood, removing excess wastes and fluids.

C. Capillaries - a network of small blood vessels (capillaries) known as a tuft, located at the beginning of a nephron in the kidney.

Glomerulus - a network of small blood vessels (capillaries) known as a tuft, located at the beginning of a nephron in the kidney.

Loop of Henle - is the portion of a nephron that leads from the proximal convoluted tubule to the distal convoluted tubule. Creates a concentration gradient in the medulla of the kidney:

A. Descending - low permeability to ions and urea while being highly permeable to water. The loop has a sharp bend in the renal medulla going from descending to ascending thin limb.

B. Ascending - impermeable to water, but it is permeable to ions.

Kidney - of organs located in the right and left side of the abdomen. The kidneys remove waste products from the blood and produce urine. As blood flows through the kidneys, the kidneys filter waste products, chemicals, and unneeded water from the blood.

Nephron - is the minute or microscopic structural and functional unit of the kidney.

Peritubular capillary - tiny blood vessels, supplied by the efferent arteriole, that travel alongside nephrons allowing reabsorption and secretion between blood and the inner lumen of the nephron.

Renal:

A. Artery - paired arteries that supply the kidneys with blood.

B. Capsule - a tough fibrous layer surrounding the kidney and covered in a layer of perirenal fat known as the adipose capsule of kidney.

C. Corpuscle - the blood-filtering component of the nephron of the kidney.

D. Cortex - the outer portion of the kidney between the renal capsule and the renal medulla.

E. Medulla - the innermost part of the kidney.

F. Pelvis - is the funnel-like dilated part of the ureter in the kidney.

G. Tubule - a long pipe like structure containing the tubular fluid filtered through the glomerulus

H. Vein - veins that drain the kidney. They connect the kidney to the inferior vena cava. They carry the blood filtered by the kidney.

Tubules:

A. Proximal - the segment of the nephron in kidneys which begins from the renal pole of the Bowman's capsule to the beginning of loop of Henle.

B. Distal Convoluted - a portion of kidney nephron between the loop of Henle and the collecting tubule.

Tubular:

A. Reabsorption - a passive process whereby drugs are reabsorbed into the systemic circulation from the lumen of the distal tubules

B. Secretion - the transfer of materials from peritubular capillaries to the renal tubular lumen and occurs mainly by active transport and passive diffusion.

Ureter - the duct by which urine passes from the kidney to the bladder or cloaca.

Urine - filtrate after it has passed through the nephron and undergone filtration, reabsorption, and secretion.

Vasa Recta - the capillary networks that supply blood to the kidney medulla.

Veins - blood vessels that carry blood towards the heart. Most veins carry deoxygenated blood from the tissues back to the heart; exceptions are the pulmonary and umbilical veins, both of which carry oxygenated blood to the heart. In contrast to veins, arteries carry blood away from the heart.

A. Interlobar - drain the renal lobes.

B. Arcuate - located at the border of the renal cortex and renal medulla.

C. Interlobular - run alongside the interlobular arteries and collect venous blood from the capillary plexus of the cortex.

Zona - zones of the adrenal cortex:

A. Fasciculata - the middle and also the widest zone of the adrenal cortex, sitting directly beneath the zona glomerulosa. Constituent cells are organized into bundles.

B. Glomerulosa - the most superficial layer of the adrenal cortex, lying directly beneath the renal capsule. Its cells are ovoid and arranged in clusters or arches.

C. Reticularis - the innermost layer of the adrenal cortex, lying deep to the zona fasciculata and superficial to the adrenal medulla. The cells are arranged cords that project in different directions giving a net-like appearance.

Name: _____

Group #: _____

Section #: _____

Part 1. Animal Organization & Morphology

Morphology is defined as the structure or form of a body part or an entire organism. Functional morphology is the study of the design of tissues and organ systems, the principles of physics affecting animals, and the mechanisms of the body. Physiology is the study of how living organisms adjust to their environments and regulate critical functions at the system, organ, tissue, cellular, and molecular levels. Together the two related fields include a broad range of topics such as feeding mechanics, digestion, locomotion, muscle contraction, circulatory design, oxygen exchange and other topics focused on animal function. Most animals (excluding the sponges which have a cellular level of organization) are made from cells which are organized into tissues and these are themselves combined to form organs and systems. The bodies of animals with a tissue level of organization have four tissue types; **1)** epithelial tissues that form linings, coverings and glands, **2)** connective tissues for transport and support, **3)** muscle tissues for movement, and **4)** nervous tissues for carrying messages. Their functional morphology can be divided into eleven organ systems; **1)** integumentary, **2)** lymphatic, **3)** endocrine **4)** nervous **5)** urinary, **6)** circulatory, **7)** skeletal, **8)** reproductive, **9)** respiratory, **10)** digestive and **11)** muscular.

A. Integumentary System

The integumentary system consists of skin and its appendages (i.e. hair, feathers, nails, sweat glands, sebaceous glands, scales) and is the heaviest organ in the human and most animal bodies. It accounts for approximately 16% of human body weight. This system has four major functions; **1)** protect the body from various kinds of damage (water loss, ultraviolet light, mechanical, chemical, or thermal damage), **2)** provide sensory information using receptors for touch, pressure, pain, and temperature, **3)** regulate temperature using integument appendages, sweat glands (in certain animals like humans), and subcutaneous adipose tissue, and **4)** aid in metabolic functions such as triglyceride storage in the subcutaneous adipose tissue, waste excretion, and Vitamin D synthesis. In order to accomplish this task, the system is composed of several tissues. The **epidermis** is the outer keratinizing stratified squamous epithelium. The ectoderm germ layer gives rise to the epidermis during embryo development. It is made of four or five layers of epithelial cells, depending on its location in the body. It does not have any blood vessels within it (i.e., it is avascular). Reptile and bird scales develop from epidermal tissue. Hair and feather follicles, sebaceous glands, sweat glands, apocrine glands, and mammary glands are considered epidermal glands or epidermal appendages, because they develop as invaginations of the epidermis into the dermis. Hair, feathers, and scales are made of keratin that is produced by the epidermis. The **dermis** is made of two layers of connective tissue that compose an interconnected mesh of elastin and collagenous fibers, produced by fibroblasts. The dermis is derived from the mesoderm germ layer. The dermis contains blood and lymph vessels, nerves, and other structures, such as the epidermal follicles and glands. Dermal papillae are projections of dermis into the epidermis. Fish scales develop from dermal tissue and, in many fishes, age can be determined by counting scale growth rings. The **hypodermis** consists of well-vascularized, loose, areolar connective tissue, and adipose tissue, which functions as a mode of fat storage and provides insulation and cushioning for the integument. Hypodermis is also derived from the mesoderm germ layer.

Specimen: _____

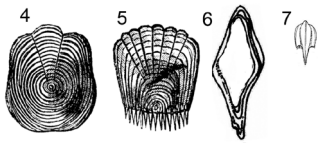
Class: _____

Species: _____

Total Magnification: _____

1. Examine the prepared slides of chordate (Phylum Chordata) integument.
 - A. Match the slides with correct diagrams.
 - B. Label the class and order names on each diagram.
 - C. Label the total magnification on each diagram.
 - D. Match the term with the correct structure.





Specimen: _____

Total Magnification: _____

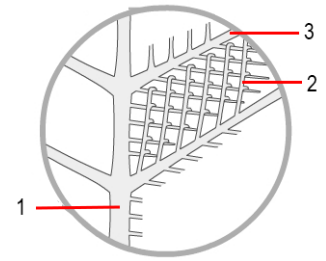


Specimen: _____

Class: _____

Genus: _____

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Specimen: _____

Class: _____

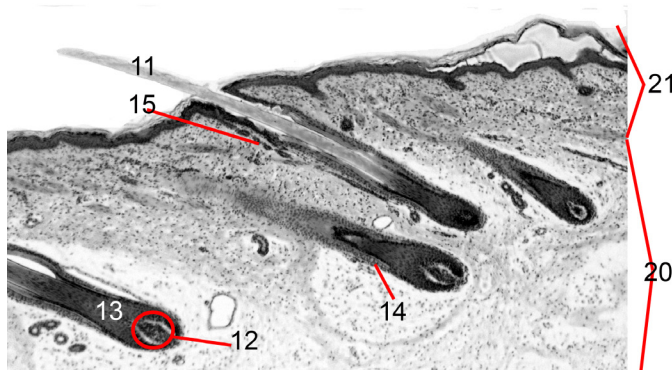
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Class: _____

Species: _____

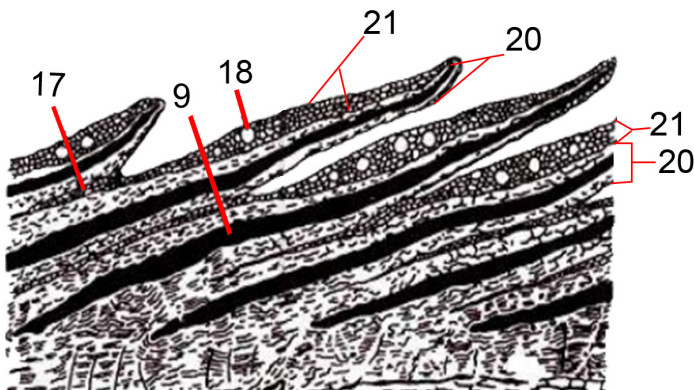
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Specimen: _____

Class: _____

Total Magnification: _____

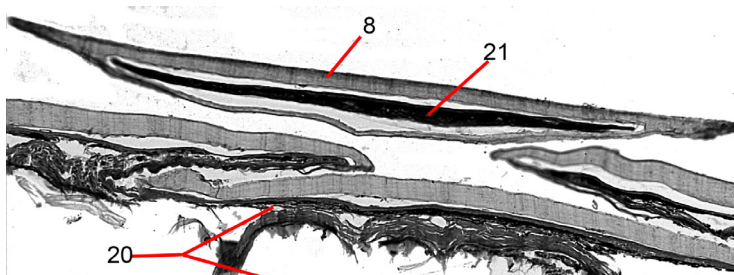


Specimen: _____

Class: _____

Genus: _____

Total Magnification: _____



- _____ barb
- _____ barbule
- _____ **calamus** (feather root)
- _____ chromatophore
- _____ ctenoid dermal scale
- _____ cycloid dermal scale
- _____ dermal papilla
- _____ dermal scale
- _____ dermis
- _____ epidermal scale
- _____ epidermis
- _____ follicle
- _____ ganoid dermal scale
- _____ hair root
- _____ hair shaft
- _____ hypodermis
- _____ mucous gland
- _____ placoid dermal scale
- _____ poison gland
- _____ **rachis** (feather shaft)
- _____ sebaceous gland

B. Circulatory System

The circulatory system consists of the blood vascular system and the lymphatic system. The blood vascular system includes: **1)** a heart, a muscular organ that pumps blood into arteries; **2)** arteries, thick-walled vessels that direct blood to capillary beds; **3)** capillaries, a fine network of thin-walled vessels across which the exchange of substance between blood and other tissues occurs; **4)** veins, which return blood from the capillaries to the heart. The lymphatic system consists of lymphatic capillaries and various-sized lymphatic vessels. the capillaries of this system are blind-ended tubules that collect lymph from tissue spaces. Lymph then passes through lymphatic organs and is carried back to the blood vascular system via vessels.

2. Figure UIV-1:

- Match the term with the correct structure.
- Color the oxygen-rich blood red.
- Color the oxygen-poor blood blue.
- Circle the Pulmocutaneous system in green.
- Circle the Pulmonary circuits in yellow.
- Circle the Systemic circuits in orange
- On the reptile (lizards, snakes, and turtles) diagram, draw in the second aorta that connects to the systemic circuit; indicate the direction of blood flow.

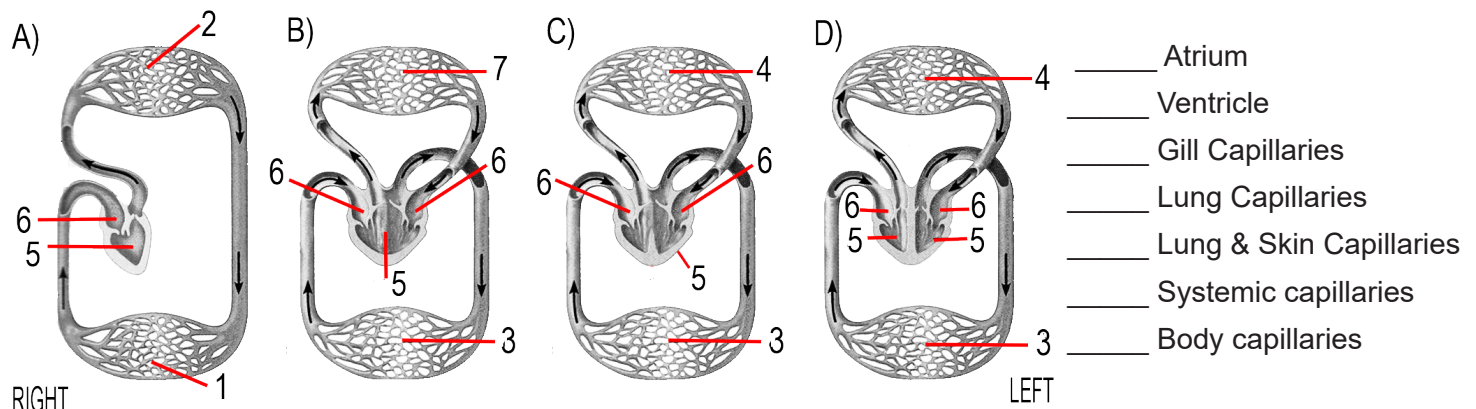


Figure UIV-1. Vertebrate blood vascular system; A) single circulation, B) double circulation with three chambers, C) double circulation with three chambers (variably partitioned ventricle), and D) double circulation with four chambers. **NOTE:** the systems are shown as if the body were facing you. The right side of the heart is shown on the left, and vice versa.

3. Observe the comparative heart plastomount and models:

A. Determine to which circulatory system (A, B, C, or D) each plastomount heart belongs. _____

B. Look at the fish heart model: the venous blood flows from the body tissues through two venae cavae and the hepatic veins to the _____, then into the _____ and finally the muscular _____. Ventricular contraction forces the blood into the bulbus arteriosus, to which the truncus arteriosus with its afferent branchial arteries is attached.

C. Look at the amphibian heart model: Venous blood (and sometimes arterial blood from the skin) flows to the _____ via two anterior and one posterior vena cava which unite to form the sinus venous. It is separated by a septum from the _____ which received arterial blood from the lungs via the _____.

D. Look at the bird heart model: the venous blood of the systemic circulation flows through two superior venae cavae and one inferior vena cava into the _____ atrium and from here into the _____ ventricle, which pumps the blood through the pulmonary circulation.

E. Look at the human mammal heart model: the venous blood flows through the superior and inferior vena cava to the right atrium. During the _____ phase of the heartbeat the _____ muscle relaxes and allows the _____ ventricle to fill with blood. The _____ phase the contraction of this chamber forces the blood into the _____ artery.

C. Nervous System

The nervous system can be divided into central (CNS) and peripheral (PNS). Both the CNS and PNS are composed of nervous tissue which consists of neurons and glia cells. The CNS consists of the nervous tissue of the brain and spinal cord whereas the PNS is composed of all other nervous tissue outside of the CNS. The PNS collects information from the integumentary system and the other sense organs and transmits the signals to the CNS using neurons and synaptic contacts. A **neuron (nerve)**, is an electrically excitable cell that receives, processes, and transmits information through electrical and chemical signals. It is the structural and functional unit of nervous tissue. It is composed of a **cell body**, and **protoplasmic extensions**. Each neuron can have one or more **dendrites** (receive signals for the cell body) but only one **axon** (transmit signals from the cell body). Some types of neurons have no axon and transmit signals from their dendrites. In some species, axons can emanate from dendrites and these are known as axon-carrying dendrites. No neuron ever has more than one axon; however in invertebrates such as insects or leeches the axon sometimes consists of several regions that function more or less independently of each other. **Glia cells** are more numerous than neurons and support, protect, and nourish the neurons.

4. Figure UIV-2:

- Color the telencephalon blue.
- Color the cerebellum orange.
- Color the medulla oblongata pink.
- Label where the spinal cord begins.

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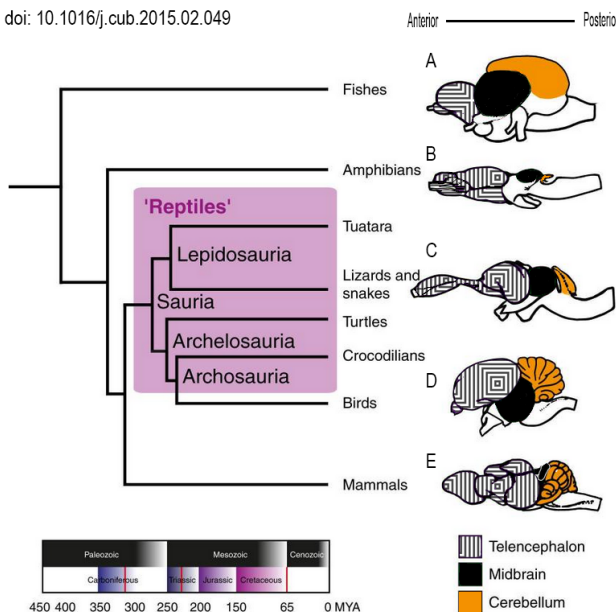
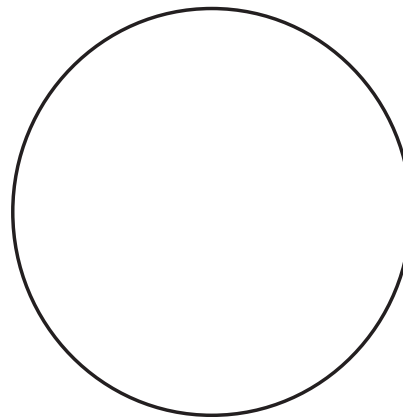


Figure UIV-2. Phylogenetic tree of vertebrates and time line of major events in amniote evolution. Shaded area in the phylogenetic tree indicates 'reptiles'. Red lines (lower panel) indicate the origin of amniotes (320 million years ago), the origin of dinosaurs (230 million years ago) and their extinction (65 million years ago). Right panel: schematic drawings showing brains (lateral view, anterior left) of vertebrate representatives: from top to bottom, A) fish, B) amphibian, C) reptile, D) bird, and E) mammal.

- Observe the comparative brain plastomount, determine to which animal taxon (A, B, C, D, or E) each brain belongs. _____

6. Observe the motor neuron slide.

- Sketch.
- Label a glia cell and a neuron.
- Label the cell body of a neuron.
- Label several dendrites and one axon coming from a cell body.
- Draw arrows in red along the dendrites and axon you labeled showing the transmission of signals to and from the cell body.
- Label the specimen name and total magnification.



Specimen: _____

Total magnification _____

D. Respiratory System

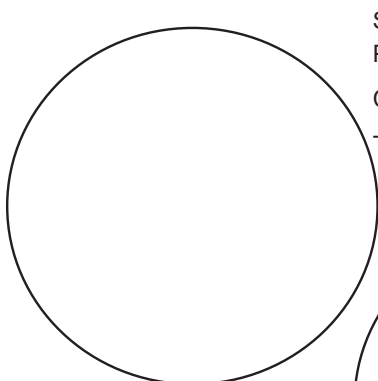
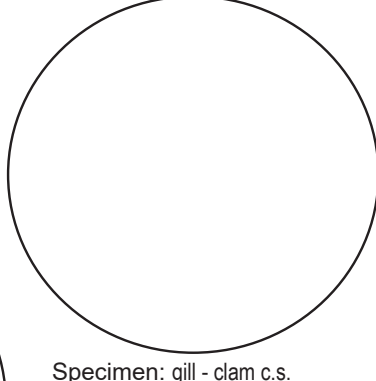
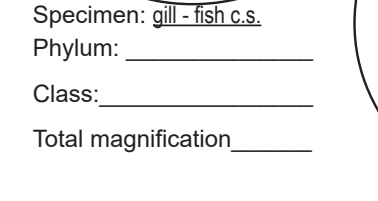
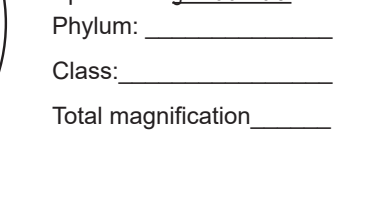
The respiratory system is a biological system consisting of specific organs and structures used for gas exchange in animals. The system varies greatly, depending on the size of the organism, the environment in which it lives and its evolutionary history. In tetrapods, the respiratory surface is internalized as linings of the lungs. Gas exchange in the lungs occurs in millions of small air sacs called alveoli in mammals and reptiles, but atria in birds. These microscopic air sacs have a very rich blood supply, thus bringing the air into close contact with the blood. These air sacs communicate with the external environment via a system

of airways, or hollow tubes, of which the largest is the **trachea**, which branches in the middle of the chest into the two main **bronchi**. These enter the lungs where they branch into progressively narrower secondary and tertiary bronchi that branch into numerous smaller tubes, the **bronchioles**. In birds the bronchioles are termed **parabronchi**. It is the bronchioles, or parabronchi that generally open into the microscopic **alveoli** in mammals and **atria** in birds. Air has to be pumped from the environment into the alveoli or atria by the process of breathing which involves the muscles of respiration. Skin plays a vital role in the amphibian **pulmocutaneous circuit**. In most fish, and a number of other aquatic animals (both vertebrates and invertebrates) the respiratory system consists of **gills**, which are either partially or completely external organs. Water flows over the gills by a variety of active or passive means. Gas exchange takes place in the gills which consist of thin or very flat filaments and **lamellae** which expose a very large surface area of highly vascularized tissue to the water.

7. Observe the slides available.

A. Sketch each.

B. Label the correct phylum and class names and total magnification.

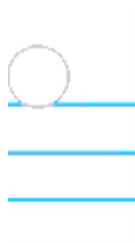
	Specimen: <u>trachea - mammal c.s.</u> Phylum: _____ Class: _____ Total magnification _____		Specimen: <u>trachea & spiracle - roach w.m.</u> Phylum: _____ Class: _____ Total magnification _____
	Specimen: <u>gill - fish c.s.</u> Phylum: _____ Class: _____ Total magnification _____		Specimen: <u>gill - clam c.s.</u> Phylum: _____ Class: _____ Total magnification _____

Part 2. Comparing Animal Systems

8. Study the location of the buccal funnel, horny teeth, mouth, and tongue on the dissected lamprey.

A. What is the purpose of these structures and, specifically, how are they used.

B. Is this animal in the Gnathostoma taxonomic group? Explain its taxonomic position.

	
---	--

9. On all following diagrams (where available) color the following:

A. Esophagus green

- bird - esophagus and crop

B. Trachea purple

C. Intestine brown- small (duodenum, jejunum, ileum), large (colon), rectum

D. Heart red

E. Stomach orange

- sea star - color pyloric stomach, duct, and cecum orange & cardiac stomach yellow
- bird - color both the gizzard and proventriculus orange

10. Figure UIV-3 A & B, using the perch plastomount and skeleton mount on display:
- Label the dorsal, ventral, anterior, and posterior regions of the fish on both A and B.
 - Match the term with the correct structure.
 - Draw a long ellipse where the kidney should be.

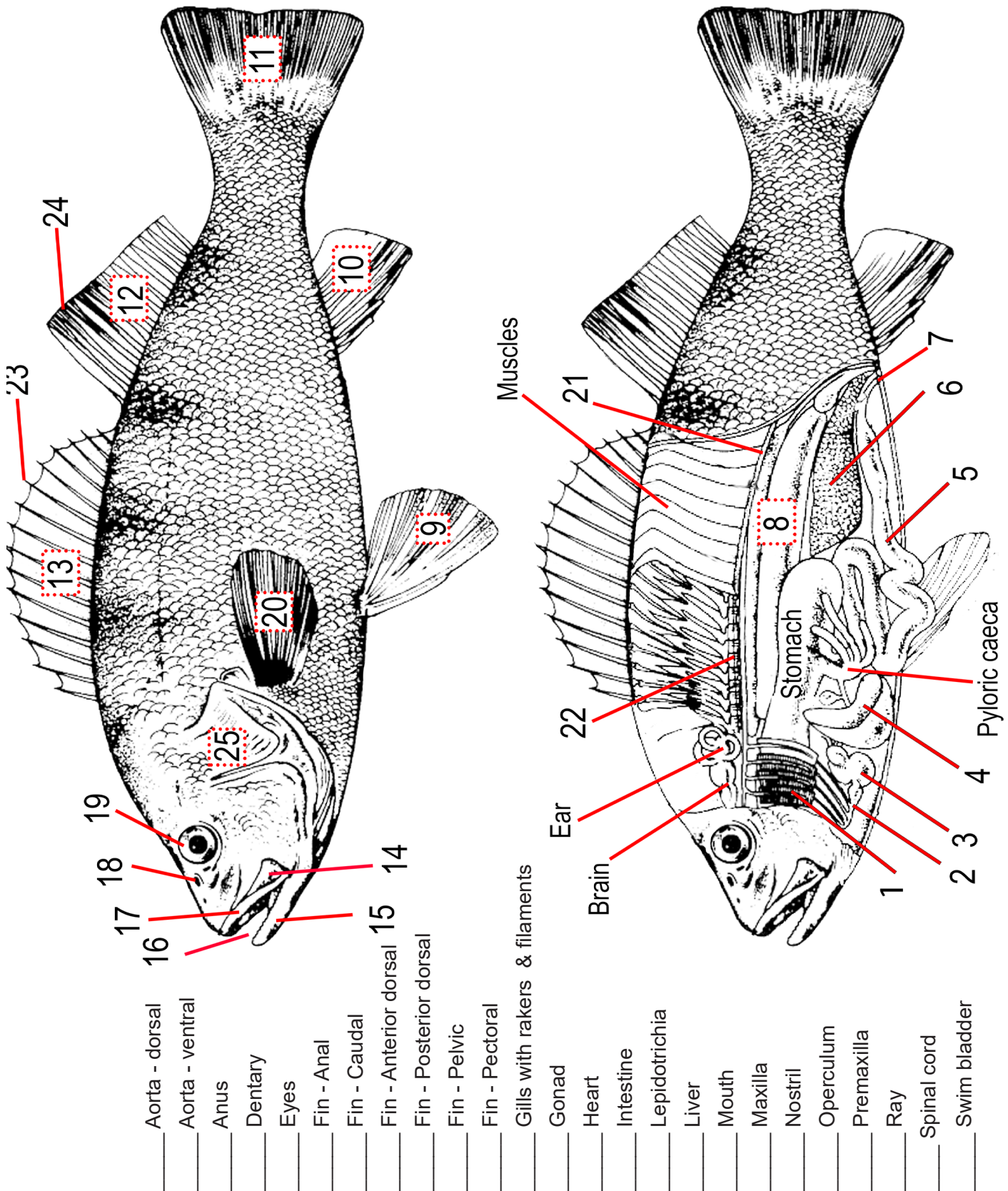


Figure UIV-3. Dissected perch (Phylum Chordata, Class Actinopterygii, Genus *Perca*); A. external and B. internal anatomy

11. On Figure UIV-4, using the sea star plastomount as a guide.
- Label the dorsal and ventral region of the starfish.
 - Match the term with the correct structure on Figure UIV-4.
 - What type of symmetry does this animal have as adults (larvae are bilateral)? _____
 - Does this animal have tissues and organs? _____
 - Label the phylum, class, order, genus name.

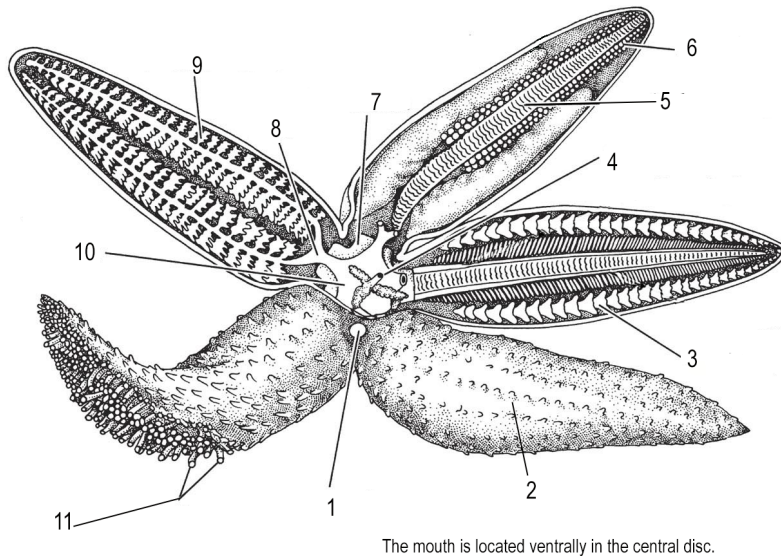
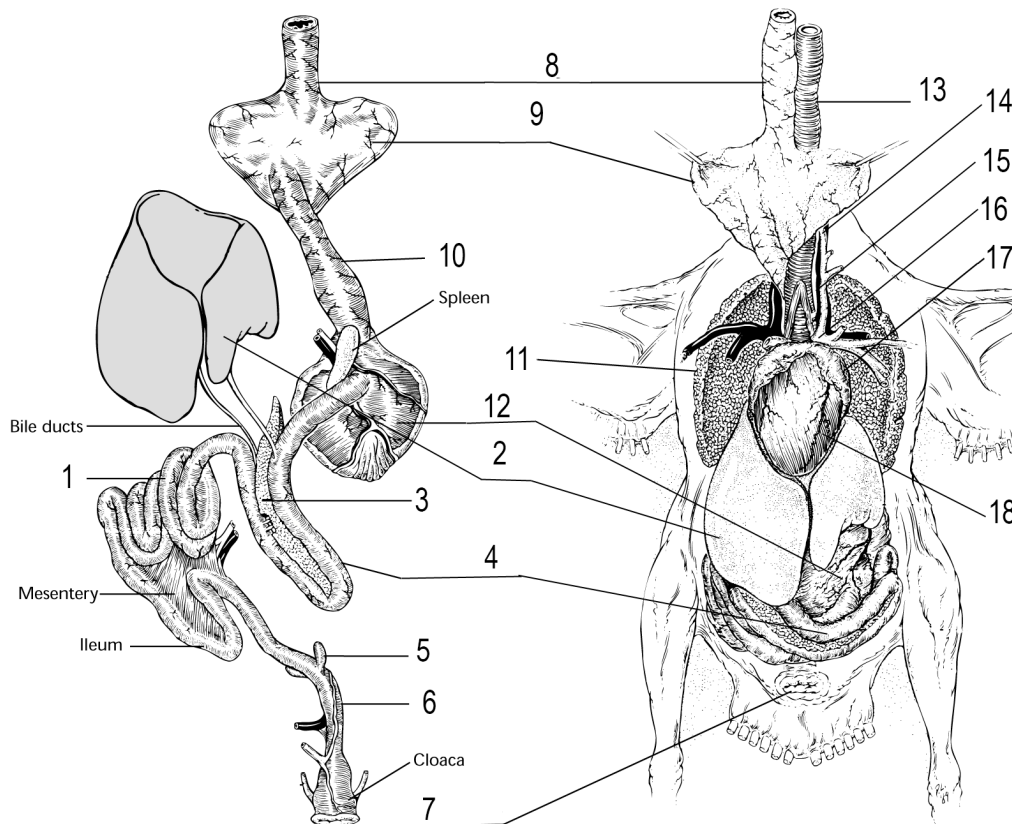


Figure UIV-4. Dissected sea star (Phylum Echinodermata, Class Asteroidea, Genus *Asterias*) showing internal and external anatomy.

- _____ Cardiac stomach
- _____ Pyloric stomach
- _____ Pyloric duct
- _____ Pyloric cecum
- _____ Radial water canal
- _____ Tube feet (lay in the ambulacral groove)
- _____ Madreporite (leads down the stone canal)
- _____ Anus
- _____ Arm
- _____ Ampullae
- _____ Skeletal plates (ossicles)

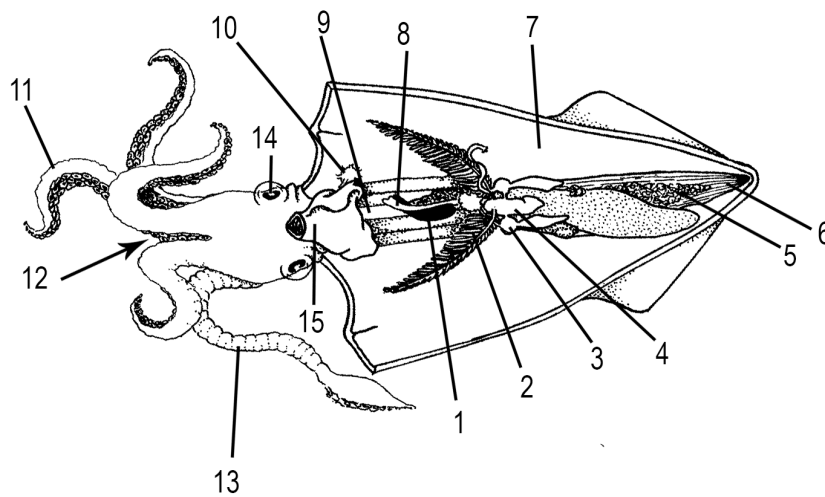
12. Using the pigeon plastomount on display, match the term with the correct structure in Figure UIV-5



- _____ Carotid artery
- _____ Gizzard
- _____ Jugular vein
- _____ Lung
- _____ Trachea
- _____ Proventriculus
- _____ Esophagus
- _____ Pancreas
- _____ Crop
- _____ Duodenum
- _____ Aorta
- _____ Jejunum
- _____ Left atrium
- _____ Colon
- _____ Left ventricle
- _____ Colic Caeca
- _____ Liver
- _____ Anus

Figure UIV-5. Dissected pigeon (Phylum Chordata, Class Aves, Order Columbiformes). *Columba livia* (common pigeon or feral rock pigeon) was originally native to Europe, North Africa, and Western Asia. Feral pigeons are derived from domestic pigeons that have returned to the wild. The domesticated and feral types are found worldwide and are reared by people for food and for laboratory research. It has morphology similar to that of many other birds,

13. Using the squid plastomount on display, match the term with the correct structure in Figure UIV-6.



- | | |
|-------------------------|----------------|
| _____ Branchial heart | _____ Eye |
| _____ Siphon | _____ Arm |
| _____ Systemic heart | _____ Tentacle |
| _____ Gill | _____ Mantle |
| _____ Ink sac | _____ Gonad |
| _____ Esophagus | _____ Pen |
| _____ Rectum | _____ Mouth |
| _____ Stellate ganglion | |

Figure UIV-6. Dissected squid (Phylum Mollusca, Class Cephalopoda). *Loligo* lives at depths of 33 to 1,640 ft. It attains sexual maturity at about one year old with a maximum life span of 3 years. The male delivers sperm into the mantle of the female using structures on a specialized tentacle. The female will spawn up to 100,000 eggs.

14. On Figure UIV-7, using the rat plastomount on display.

- A. Sketch and label the rat morphology.
B. Label the phylum, class, order, species name.

Phylum: _____

Class: _____

Order: _____

Species: _____

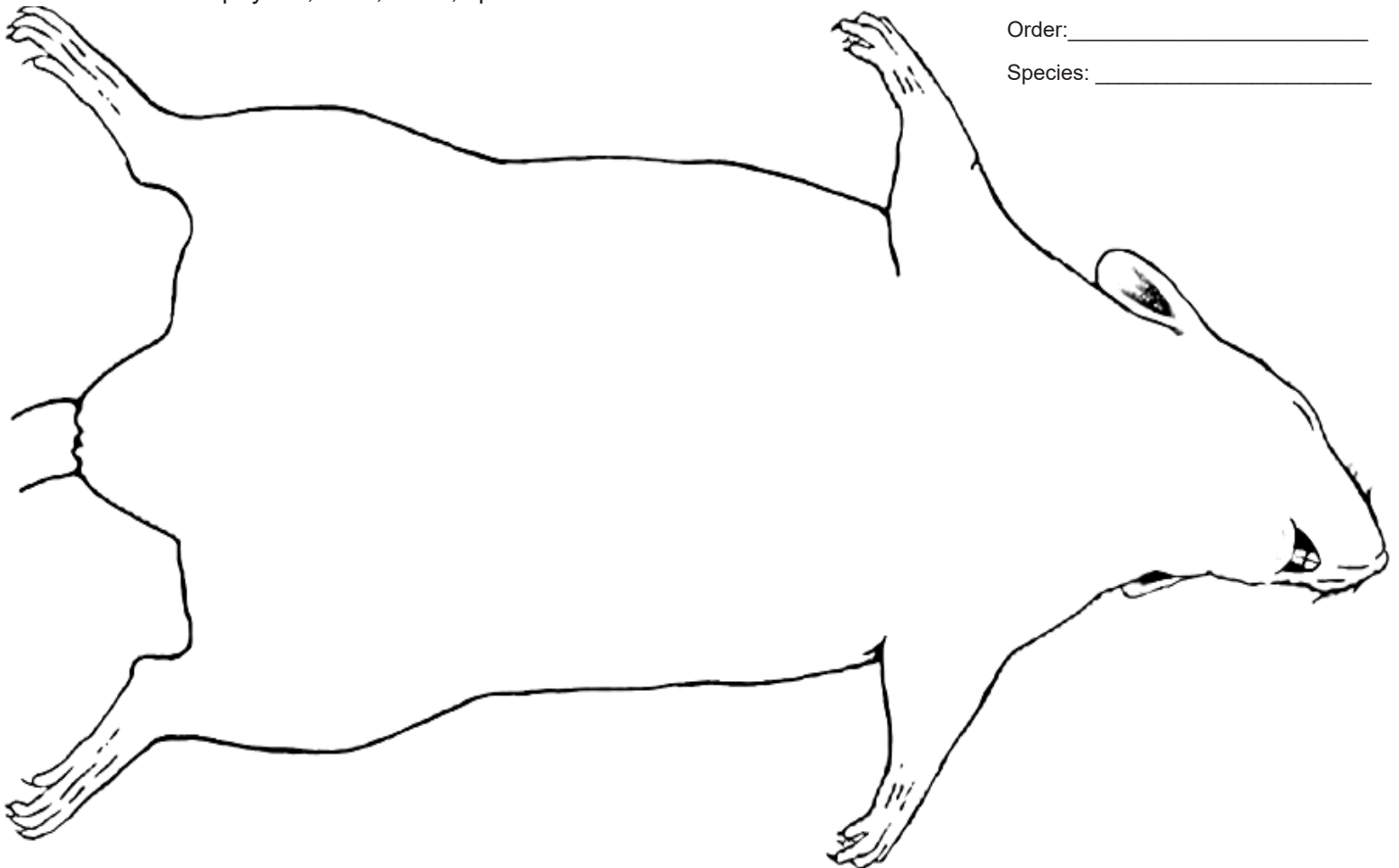


Figure UIV-7. Dissected rat (Phylum Chordata, Class Mammalia, Order Rodentia). *Rattus norvegicus* is native to China but is now established in most urban settings of the world. Recent selective breeding of this rat has produced the laboratory rat which is an important model organism in biology. It has morphology similar to that of many other mammals.

Name: _____

Group #: _____

Section #: _____

Part 3. Dissection of Invertebrates

1. Your group will be given one animal specimen to dissect. You can use the available manuals, the information you learned in the previous labs, and internet searches to help you dissect the organism and create an informal informative group presentation on the specimen. **You must be able to present the morphology to the other students and connect the morphology to content in the rubric (Figure UIV-9).**

A. Research; as a group:

- ☐ Learn the terms for the external morphology.
- ☐ Learn the terms for the internal morphology.
- ☐ Answer all the question Q1-11 in the rubric.
- ☐ Determine HOW to dissect the animal before you begin dissecting.
- ☐ **Read and study the Dissections web page A-D: <https://www.isu.edu/biology/biolab/instructor-training/lab-maintenance/dissections/>**

B. Dissection; as a group:

- ☐ Study the external morphology of your specimen BEFORE you cut the specimen open.
- ☐ Dissect the specimen in an organized and tidy manner using the information you gathered.
- ☐ Study the internal morphology of your specimen.
- ☐ Connect your understanding of Qs 5-11 of the rubric to the internal and external morphology of the specimen.

C. Presentation

- ☐ Review Qs12-16.
- ☐ Each student in the group will need to present an equal amount of content.
- ☐ Presentation should take 7 minutes.
- ☐ Present an introduction of the specimen (Qs1-4).
- ☐ Present your understanding of Qs5-11 and connect it to the internal and external morphology of the specimen **using a document camera and the specimen as a prop.**

Specimen Common Name _____			Points	
			Possible	Acquired
Content	1.	Genus name and common name	2	
	2.	Taxonomic Classification: order, class, phylum, kingdom	4	
	3.	Habitat	3	
	4.	Geographic location	3	
	5.	What does the animal eat and how does it eat it?	3	
	6.	How does food pass through the animal?	4	
	7.	How are waste products collected and expelled by the animal?	4	
	8.	Describe the respiratory system and how it works.	4	
	9.	Describe the circulatory system (open, closed, pulmonary, pulmocutaneous, systemic, double, single)?	4	
	10.	Where do eggs/sperm develop and how do they reach one another to form a zygote?	2	
	11.	Where do the offspring develop?	2	
Present	12.	Dissected animal was used as prop.	5	
	13.	Each student presented equally.	4	
	14.	Presentation was organized.	2	
	15.	Presentation could be understood.	2	
	16.	Each student turned in notes.	2	
Total			50	

Figure UIV-9. Informal presentation rubric. Fill in your name and the common name of the animal on this rubric and staple each student's rubric from your lab group together. Give them to your lab instructor before giving your informal presentation.

Name: _____ Group #: L10 _____, L11 _____, & L12 _____ Section #: _____

The science of comparative morphology is the study of structure and function and how that varies across evolutionary history. More than just naming veins or bones, comparative morphology tries to make sense of morphology (anatomical shape) by comparing closely related creatures with one another. Alternately, if an organism's identity is unknown (as it is in many fossils), we can compare the morphology to other species with known diet, habitat preference and evolutionary heritage. Comparative morphology bridges the disciplines of physiology and evolution.

An understanding of comparative morphology requires that we think about the evolutionary process. A trait needs to vary and be heritable (i.e., controlled at least in part by DNA) to be shaped by evolutionary forces. Some variants have allowed greater survival and reproduction through natural selection, allowing some genetic lineages to prosper in ways different than their ancestors. Natural selection acts upon whole organisms and their genomes, not upon an individual trait. Neutral traits vary but do not make a difference in fitness; others might be slightly deleterious but as long as the offspring are not out competed by a more adaptive lineage, they will continue to be passed on to successive generations. For example, humans have many adaptive traits (spines and hips adapted for walking upright), neutral traits (earlobes that may or may not be attached to the side of the head) and slightly deleterious traits (the arches of our feet are still not perfectly adapted for upright walking).

You will master the names, functions and relative locations of major chordate organs and structures in the digestive and cardiovascular systems in species from several chordate groups. You will learn how to orient yourself when describing morphology, increase gross and fine dissection skills, appreciate the connection between organismal form and function, and understand major evolutionary trends among, and specializations within chordate groups.

Part 4: Comparative Morphology

A. Hypothesis & Experimental Design (complete outside of lab time before Lab 12)

Biology is the science of life. It is a field of study that addresses the extraordinary complexities of how individual organisms and species come into existence, perpetuate themselves, change, and interact with one-another other and their environment. **Science is both a system for acquiring knowledge and the cumulative body of knowledge acquired using that system.**

☐ Go to Biolab > Training > Learning Environment > Research > Scientific Method & Experimental Design (<https://www.isu.edu/biology/biolab/instructor-training/learning-environment/research/#d.en.218210>) and study the content at that web page.

1. What is one question you have about the relationship between the **genera under study (or groupings of the genera) and the relative percent size of its organs?**

2. Determine your variables:

A. Which is your response (dependent) variable? *Relative percent mass (heart, liver, intestine) and length (intestine)*

Are the variables categorical and/or quantitative? _____

B. Which is your predictor (independent) variable? _____

Are the variables categorical and/or quantitative? _____

3. Develop a hypothesis.

4. What is your prediction as to the outcome of your experiment.

5. What result would cause you to conclude that your hypothesis was supported?

6. What result would cause you to conclude that your hypothesis was rejected?

B. Research

- ☐ Learn the terms for the external morphology.
- ☐ Learn the terms for the internal morphology.
- ☐ Answer all the question Q1-11 in the rubric.
- ☐ Determine HOW to dissect the animal before you begin dissecting.
- ☐ **Read and study the Dissections web page sections A-C: <https://www.isu.edu/biology/biolab/instructor-training/lab-maintenance/dissections/>**

7. Fill in Table UIV-3 with accurate taxonomic information for the animals you will be dissecting.

Table UIV-3. Taxonomic classification of dissected animals.

	Lab 10	Lab 11	Lab 12
Common name			
Genus name			
Order name			
Class name			

C. Specimen Preparation

- ☐ Study the external morphology of your specimen BEFORE you cut the specimen open.
- ☐ Dissect the specimen in an organized and tidy manner using the information you gathered and take measurements.
- ☐ Study the internal morphology of your specimen.
- ☐ Connect your understanding of Qs 5-11 of the rubric to the internal and external morphology of the specimen.

☐ Read and study the Dissections web page A-D: <https://www.isu.edu/biology/biolab/instructor-training/lab-maintenance/dissections/>  Put on goggles, face mask, gloves, and lab coat 

☐ Remove your specimen from its container and place it in your tray.

☐ Your specimen's preservative may have accumulated in open spaces, such as in the throat or abdomen, and this will have to be drained.

- In the middle of the abdomen, just to the right of the midline, make a 1 cm incision either 2 mm (for fish and amphibians) or 4 mm (for birds, reptiles, mammals) deep.
- Hold the specimen over the sink and gently squeeze the abdomen from anterior to posterior. Not all specimens will have excess fluid; do not squeeze so hard that tissues are pushed out of your incision!
- Use gently running tap water to rinse the external surface and mouth (without filling the stomach) in the sink, and towel dry the specimen.

☐ Using a ruler, obtain a straight-line length from the most anterior tip of the upper jaw to the anus/cloaca. This is known as a snout-vent length (SVL).

8. What is the SVL to the nearest millimeters (mm) of the animal? Fill in Table UIV-4 with this information.

9. What is the mass to the nearest 0.01 grams (g) of the animal? Fill in Table UIV-4 with this information.

Table UIV-4. Length to the nearest millimeters (mm) and mass to the nearest 0.1 grams (g) of three different genera.

	Genus	Length (mm)		Mass (g)		
		SVL	GI	Entire Animal	Heart	Liver
Lab 10						
Lab 11						
Lab 12						

D. Digestive System

All animals, including vertebrates, need both macronutrients and micronutrients to live. The macronutrients are water, proteins, carbohydrates, lipids and nucleic acids. The micronutrients include vitamins, minerals and ions. The acquisition of these compounds involves food capture, mechanical digestion (e.g., crushing or tearing tissue), biochemical digestion (breaking polymers into smaller molecules), absorption of nutrients and elimination of indigestible waste. Most vertebrates use the same organs for the biochemical processes, but size and specialization may differ slightly according to diet. For example, vertebrates that eat foods rich in indigestible cellulose must physically crush their food over and over, and they require a much lengthier digestive system than vertebrates that eat muscle and organs. Herbivores (plant-eaters) have many large crushing molars that grow constantly as they grind plant material, multiple stomachs to churn the vegetable matter and extremely long intestines to extract the nutrients that make up (by weight) relatively little of the mass of food ingested. Carnivores (meat-eaters) would not need any of these adaptations, but would need specialized teeth for prey capture. Omnivores feed upon both plants and animals and should show features of both herbivores and carnivores.

☐ Use the dissection guides and/or the internet to help you navigate your specimen and follow the general rules below:

- Place the dissecting pins to secure the specimen firmly onto the tray.
- Grip your dissecting blade firmly and lightly.
- Outline the dissection region by cutting using easy, shallow strokes.
- Remove the tissue by using forceps and a blunt probe. The forceps should be gripped by your non-dominant hand and used to gently grip a corner of skin.

- Lift up this corner by 1-2 mm only, and with your dominant hand use the blunt probe to brush away the tissue from the underside of the specimen. This might be difficult to do on some specimens, but blunt probes are very useful in separating the connective tissue that binds structures together.
- As you continue your dissection, practice lifting and separating using different arm and wrist positions to find what gives you both control and comfort.
- You will dissect your specimen and remove the digestive system taking care not to disturb the other tissues and organs.

10. Organs of the digestive system (3 lists, one per animal). Anterior to posterior order from anterior to posterior and name:

Lab 10

Lab 11

Lab 12

11. Determine the length to the nearest millimeters (mm) of the gastrointestinal tract from as close to the mouth as possible to the anus/cloaca. Fill in Table UIV-4 with this data.

12. Determine the mass of the liver to the nearest 0.1 grams (g). Fill in Table UIV-4 with this data.

☐ Add your data to the spreadsheet on the instructor computer.

E. Heart and Major Vessels

Before you begin dissection the circulatory system there is some terminology you need to master if you are to understand how circulation evolves in vertebrates. Remember that by convention, an artery is any vessel carrying blood away from the heart and a vein is one carrying blood back to the heart. These names do not have anything to do with oxygen (e.g., pulmonary arteries carry deoxygenated blood from the heart to the lungs). Just like the parts of the digestive system, identifying vessels is best done by looking what a vessel is connected to and where it goes. Arteries receive a large volume of blood at high pressure, but they receive it in pulses, and these vessels must be able to withstand this alternation of high force and relaxation. Alternately, blood moving through veins has relatively less pressure driving it, and may actually need help to keep moving in long vessels against gravity (accomplished by the presence of one-way valves). Don't forget the capillaries where these vessels meet each other.

- ☐ Note the pericardium, a membrane that surrounds the beating heart, holding fluid to reduce friction.
 - ☐ Remove the pericardium and study the external heart and note the blood vessels leading in and out of it. **Do not remove the heart until you know you can identify the external features!**
 - ☐ Remove the heart taking care not to disturb the other tissues and organs.
 - ☐ Use the dissection guide available to help you navigate your specimen's heart.
13. Determine the mass of the heart to the nearest 0.1 grams (g) . Fill in Table UIV-4 with this information.
14. Add your data to the spreadsheet on the instructor computer.

Part 5. Informal Presentations

- ☐ Review Qs12-16.
 - ☐ Each student in the group will need to present an equal amount of content.
 - ☐ Presentation should take 15 minutes.
 - ☐ Present an introduction of the specimen (Qs1-4).
15. Each group will give an informal presentation on the information as required by the rubric (Figure UIV-10) as well as that collected for Table UIV-5 **using the document camera and their dissected animal as a prop.**
- Present an introduction of the specimen (Qs1-4).
 - Present your understanding of Qs5-11 and connect it to the internal and external morphology of the specimen **using a document camera and the specimen as a prop.**
 - In detail, fill in Table UIV-5 for your dissected specimen (as well as all class specimens as the other students present the information).
- ☐ Listen to the presentation and observe the dissected specimens of the other groups in your class:
 - Take notes in the blue examination booklets provided.
 - Fill in Table UIV-5 with relevant information that your classmates provide.
 - **With a gloved hand feel the teeth, skin, gizzard, etc. of the specimens.**
 - ☐ **For clean-up, read and study the Dissections web page section D: <https://www.isu.edu/biology/biolab/instructor-training/lab-maintenance/dissections/>**

			Points	
			Possible	Acquired
Content	1.	Genus and common name AND classification.	1	
	2.	Habitat / geographic location	1	
	3.	How did you dissect the animal?	1	
	4.	What does the animal eat and how does it eat it?	1	
	5.	How does food pass through the animal?	1	
	6.	How are waste products collected and expelled by the animal?	1	
	7.	Describe the respiratory system and how it works.	1	
	8.	Describe the circulatory system (open, closed, pulmonary, pulmocutaneous, systemic, double, single) and how it works.	1	
	9.	Where do eggs/sperm develop and how do they reach one another to form a zygote?	1	
	10.	Where do the offspring develop.	1	
	11.	Table UIV-5 content was presented.	5	
Present	12.	Dissected animal was used along with the document camera.	1	
	13.	Each student presented equally.	1	
	14.	Presentation was organized.	1	
	15.	Presentation could be understood.	1	
	16.	Each student turned in notes.	1	
Total			20 PER ANIMAL	

Figure UIV-10 Informal presentation rubric. Fill in your name and the common name of the animal. Give to your lab instructor before giving your informal presentation.

Table UIV-5. Similarities and differences with respect to morphology (continued on next page) of dissected animals (lab 10).

	Lamprey	Chondrichthyes: _____	Chondrichthyes: _____	Osteichthyes: _____
Skin (scaled or smooth, hair or feathers attached, resistant to dessication)				
Heart (# and type of chambers, location in body)				
Ecto- or endothermic?				
Circulatory system (open, closed, pulmonary, pulmocutaneous, systemic, double, single)				
Respiratory system: Gills (# of openings, location) OR Lungs (location, paired)				
Jaws (size, articulated)				
Teeth (location, shape, size)				
Gastrointestinal tract (shape, location, connected to cloaca or anus/urethra)				
Stomach (location, shape) OR Crop and Gizzard				
Liver (location, shape)				
Kidneys (shape, location, could they be seen on dissected animal)				
Reproductive system (gonad location, shape, etc., were eggs present)				

Table UIV-5. Similarities and differences with respect to morphology (continued on next page) of dissected animals (lab 11).

	Urodela:_____	Anura:_____	Squamata:_____	Bird:_____
Skin (scaled or smooth, hair or feathers attached, resistant to dessication)				
Heart (# and type of chambers, location in body)				
Ecto- or endothermic?				
Circulatory system (open, closed, pulmonary, pulmocutaneous, systemic, double, single)				
Respiratory system: Gills (# of openings, location) OR Lungs (location, paired)				
Jaws (size, articulated)				
Teeth (location, shape, size)				
Gastrointestinal tract (shape, location, connected to cloaca or anus/urethra)				
Stomach (location, shape) OR Crop and Gizzard				
Liver (location, shape)				
Kidneys (shape, location, could they be seen on dissected animal)				
Reproductive system (gonad location, shape, etc., were eggs present)				

Table UIV-5. Similarities and differences with respect to morphology of dissected animals (lab 12).

	Bat	Mink	Rat	Rabbit
Skin (scaled or smooth, hair or feathers attached, resistant to dessication)				
Heart (# and type of chambers, location in body)				
Ecto- or endothermic?				
Circulatory system (open, closed, pulmonary, pulmocutaneous, systemic, double, single)				
Respiratory system: Gills (# of openings, location) OR Lungs (location, paired)				
Jaws (size, articulated)				
Teeth (location, shape, size)				
Gastrointestinal tract (shape, location, connected to cloaca or anus/urethra)				
Stomach (location, shape) OR Crop and Gizzard				
Liver (location, shape)				
Kidneys (shape, location, could they be seen on dissected animal)				
Reproductive system (gonad location, shape, etc., were eggs present)				

Name: _____

Section #: _____

Part 6 is due at the end of lab 13. Any form of academic dishonesty (including generative AI) will result in a zero on the entire assignment.

Part 6: Analysis & Questions

The CM.csv file includes the data from ALL lab sections after calculating the relative length of the GI tract and mass of the heart, liver, and GI tract for each INDIVIDUAL by:

- Dividing the length of the GI tract of each INDIVIDUAL by the original length (SVL) of that INDIVIDUAL.
- Dividing the mass of each organ of each INDIVIDUAL by the original mass of that INDIVIDUAL.
- Multiplying by 100 to get a percent of body length or mass.

A. Setting Up R

1. Log into Moodle.
2. Under "Lab Materials" you will find a 'Comparative Morphology' assignment that links to three files (CM.R, CMLength.csv and CMmass.csv.)
3. Download and Save all three files to the desktop.
4. Go to Windows Start > All Programs.
5. Scroll to 'R', click on the 'R' Folder, select the latest version of R X64.
6. In R open the 'File' tab and click on 'Open script'. A window will open.
7. Select the CM.R file from where you saved it on the desktop.
8. In the open CM.R in the R program:
 - Highlight the first line of code 'install.packages("asbio")'
 - Right click on the code.
 - Select 'Run line or selection' from the pop up menu.
9. In the 'CRAN mirror' pop up menu, select a USA mirror from the list and click on 'OK'.
10. In the open CM.R file highlight the code 'library(asbio)' and select 'Run line or selection'.
11. The library is loaded.
12. In the open CM.R file highlight the code

```
cm.length<-read.csv(file.choose())  
intL <- with(cm.length,paste(Genus,Organ))
```
13. Select 'Run line or selection'. A window will open.
14. Select the CMLength.csv file from where you saved it on the desktop.
15. Repeat steps 12-14 for the CMmass.csv data.
16. In the open CM.R file highlight the code 'names <- c("")' and select 'Run line or selection'.
17. The class data is now loaded into R.

B. Table and Figure by Genera

Relative mean and standard error (mean $\pm$ SE) was calculated using the 1) relative GI length for each genus and 2) relative organ mass for each genus. R calculated mean $\pm$ SE but use the tutorial to see the math behind it.

Table 1

1. In the open CM.R file highlight ALL code under the #----- Table 1 -----# heading until you get to the #-----Figure 1 -----# heading.
2. Right click on the code.
3. Select 'Run line or selection'.
4. Open Excel.
5. Highlight the farthest upper left cell.
6. Click the 'Control' and 'V' buttons at the same time on your keyboard.
7. Your data was pasted into Excel.
8. Highlight the column the data is in; column A.
9. Click on the 'Data' Tab.
10. Click on 'Text to columns'.

11. Select Delimited > 'Next' > check 'Tab' and 'Comma' > 'Next' > Finish
12. Format the table in Excel. Then:
13. Insert the table into a Word document and create a table caption (Above table 1). In the caption include;
 - 1) one introductory sentence that describes what the table is showing.
 - 2) describe how relative mass and length were initially calculated and changed into a percent, and
 - 3) describe how mean and SE were calculated.

Figure 1

1. In the open CM.R file highlight ALL code under the #----- Figure 1 -----# heading until you get to the #----- Table 2 -----# heading.
2. A window will appear with a figure composed of three graphs, right click on the figure. Copy as a bitmap.
3. Paste the figure into the Word document.
 - Label each graph A-C.
 - Create a figure caption (Below figure 1). In the caption describe;
 - 1) what each graph represents in one introductory sentence
 - 2) how relative mass and length were initially calculated and changed into a percent, and
 - 3) how mean and SE were calculated.

C. Table and Figure by Category

Table 2

1. Highlight the code under #-----Table 2 -----#. Right click on the code. Select 'Run line or selection'.
2. Repeat Table 1: steps 2 through 12.
3. Insert the table into a Word document and create a table caption (Above table 2). In the caption include;
 - 1) one introductory sentence that describes what the table is showing.
 - 2) describe how relative mass and length were initially calculated and changed into a percent, and
 - 3) describe how mean and SE were calculated.

Figure 2

1. Highlight the code under #-----Figure 2 -----#. Right click on the code. Select 'Run line or selection'.
2. A window will appear with a figure composed of three graphs, right click on the figure. Copy as a bitmap.
3. Paste the figure into the Word document.
 - Label each graph A-C.
 - Create a figure caption (Below figure 1). In the caption describe;
 - 1) what each graph represents in one introductory sentence
 - 2) how relative mass and length were initially calculated and changed into a percent, and
 - 3) how mean and SE were calculated.

D. Hypothesis

1. Copy your hypothesis from **UIV:Part 4A**. Rewrite the hypothesis if you missed points.
2. In the word document reject or support your hypothesis.
3. In detail, discuss why you were able to reject or support your hypothesis; be sure to refer to and cite your tables and figures.

E. Assignment (last hour of lab 13)

4. Send the document you created following the direction in Part 6A-D to question 1 to your lab instructor.
5. Answer the rest of the questions. Use:
 - task sheets Labs 10-12,
 - all of the tree diagrams you filled in,
 - notes you took in your blue examination booklet during labs 10-12,
 - and the tables and figures you just created.
6. Be sure to refer to and cite your tables and figures and the notes as you answer the questions.
7. Turn the blue book into you lab instructor.

Important Notes:

- **R** is a programming language and free software environment (www.r-project.org) for statistical computing and graphics supported by the non-profit **R** Core Team and the **R** Foundation for Statistical Computing.
- RStudio is a for-profit, third-party Integrated Development Environment (IDE) that was created as a graphical user interface for **R** (www.rstudio.com) and is completely dependent on the **R** programming language/free **R** software. RStudio, known as both a for-profit Public Benefit Corporation and B Corporation, is not affiliated with the non-profit R Foundation and core team.
- RBASE is a for-profit relational database program that has nothing to do with **R**.
- **R** is just called **R** because it is its own software environment and language. You can use **R** without having RStudio; however, you can't use RStudio without **R**.
- The program size once installed on your computer is as follows: **R** = 0.004 MB and RStudio = 156.89 MB.

Tables/Figures			Points	
			Possible	Acquired
Tables	1	Two tables composed of all analyzed data.	4	
	2	Proper labeling of columns and rows.	4	
	3	Table captions included above table and are numbered (Table 1 and Table 2).	2	
	4	Captions include an introductory statement of what the table is showing.	4	
	5	Captions include how relative mass and length were initially calculated and changed into a percent.	2	
	6	Captions include how mean and standard error of the relative mass and length were calculated.	2	
	7	Tables are formatted correctly.	2	
Figures	8	Two figures each with three graphs (each graph has a label A-C) .	10	
	9	Figure captions included below figures and are numbered (Figure 1 and Figure 2) .	2	
	10	Captions include introductory statements of what each figure is showing; each graph is referred to in the figure.	4	
	11	Captions include how relative mass and length were initially calculated and changed into a percent.	2	
	12	Captions include how mean and standard error of the relative mass and length were calculated.	2	
All captions include sample size.			2	
Hypothesis include and discussed in detail with tables and figures referenced.			8	
Total			50	

Figure UIV-12. This grading rubric will be used to grade your table and figures. Leave blank for your instructor.

Unit V. Conclusion

Objectives

- Learn about the species diversity of Idaho.
- Review the 1102L organisms and the tree diagrams.

Terms & Definitions

Ancestor - a plant, animal, or object that is related to one existing at a later point in time. Autotroph - an organism that has a metabolic pathways that use energy either from inorganic molecules or light to make organic molecules.

Evolution - the phenomenon that populations of organisms change from one generation to the next. As a result, some organisms become more successful at survival and reproduction.

A. Convergent - the process whereby two different species from different lineages show similar characteristics because they occupy similar environments.

B. Divergent evolution - the process whereby two different species from the same lineages show different characteristics because they occupy different environments.

Evolutionary trees - a model of evolutionary relationships among groups of organisms that is based on similarities and differences in their DNA, physical features, biochemical characteristics, or some combination of these. It maps the relationships between ancestral groups and their descendants, and it clusters the most closely related groups on neighboring branches.

A. LUCA - last universal common ancestor is the most recent population of organisms from which all organisms now living on earth are descended.

B. Most recent common ancestor - the most immediate ancestor that two lineages shares.

C. Node - the point in an evolutionary tree indicating the moment in time when an ancestral group split, or diverged, into two separate lineages. The node represents the most recent common ancestor of the two lineages in question.

D. Root - in an evolutionary tree a root represents the ancestral lineage, and the tips of the branches represent the descendants of that ancestor.

Gene - a unit of heredity that contributes to the characteristics or traits of an organism. At the molecular level, a gene is composed of organized sequences of DNA. Every person has two copies of each gene, one inherited from each parent.

A. Equilibrium - is a condition where a gene pool is not changing in frequency across generations.

B. Expression - gene function both at the level of traits and at the molecular level.

C. Flow - occurs when individuals migrate between different populations and results in changes in the genetic composition of the resulting populations.

D. Pool - all of the genes found in a population.

E. Sex-linked - refers to genes that are found on one sex chromosome but not the other.

F. X-linked - a gene found on the x chromosome but not on the y.

G. Y-linked - a gene found on the y chromosome but not on the x.

Genetic drift - the random changes in a population's allele frequencies from one generation to the next that is attributed to chance. It occurs more quickly in small populations.

A. Bottleneck - an effect caused by adverse environmental conditions.

B. Founder - an effect caused by geographic separation of a subset of the population.

Genotype - the alleles or variants an individual carries for a particular gene:

A. Allele - one of two or more versions of DNA sequence (a single base or a segment of bases) at a given gene locus. An individual inherits two alleles, one from each parent, for any given gene where such variation exists. If the two alleles are the same, the individual is homozygous for that allele. If the alleles are different, the individual is heterozygous.

B. Heterozygous - two different alleles at the same gene.

C. Homozygous genotype - two identical alleles at the same gene.

Life - a monophyletic group (refers to a group that consists of an ancestor and all of its descendants) that includes all known organisms. Characterized by a nucleic acid based genetic system (DNA or RNA), metabolism, and cellular structure. Some parasitic forms have secondarily lost some of these features and rely on the cellular environment of their host.

Lineage concept:

A. General - a species is an independently evolving lineage which is defined by morphology, reproductive isolation, DNA sequences, and ecology among other things

B. Evolutionary - a species is defined by its separate evolutionary lineage.

Species concept - different approaches for distinguishing species.

A. Biological - a species is a group of individuals that can interbreed and produce fertile offspring but typically cannot breed with members of another species.

B. Ecological - a species is defined by the ecological niche to which it belongs in its native environment and its influence on its environment and other species.

C. Morphological - definition of a species that relies on differences in physical characteristics among them.

Natural selection - the process that eliminates those individuals that are less likely to survive and reproduce in a particular environment, while allowing other individuals with traits that confer greater reproductive success to increase in numbers.

A. Balancing - a type of natural selection that maintains genetic diversity in a population.

B. Diversifying - natural selection for individuals at both ends of a range of phenotype but against the "average" phenotype.

C. Sexual - a type of natural selection that is directed at certain traits of sexually reproducing species that make it more likely for individuals to find or choose a mate and/or engage in successful mating.

D. Stabilizing selection - a pattern of natural selection that favors survival of individuals with intermediate phenotypes.

Phylogeny - evolutionary history of a group of organisms.

A. Monophyletic - a group of species, a taxon, consisting of the most recent common ancestor and all of its descendants.

B. Paraphyletic - a group of organisms that contains a common ancestor and some, but not all, of its descendants.

Population - a group of individuals of the same species that occupy the same environment and can interbreed with one another.

- A. Biological - individuals of the same species that live and breed in the same geographic area.
- B. Ecological - the study of how populations grow and what factors promote or limit growth.
- C. Genetics - study of the factors in a population that determine allele frequencies and their change over time.

Speciation - formation of new species

- A. Allopatric - evolution of a new species from biological populations that have become geographically isolated from each other to an extent that prevents or interferes with gene flow.
- B. Sympatric - evolution of a new species from a surviving ancestral species while both continue to inhabit the same geographic region.

Trait/character - a characteristic of an organism, such as the appearance of seeds, flowers, or stems; an identifiable characteristic; refers to a variant:

- A. Adaptive - a genetic trait that helps an organism to maximize its reproductive success
- B. Homologous - a feature that is similar across species because of common descent. Homologous traits may begin to look different from one another over time.
- C. Quantitative - a trait that shows continuous variation over a range of phenotypes.
- D. Shared derived - a trait that is shared by a group of organisms but not by a distant common ancestor.
- E. Shared ancestral - a trait shared with a distant ancestor.

Name: _____

Section #: _____

Part 1. Idaho Museum of Natural History☐ Meet your lab instructor at the IMNH during your lab section time with this task sheet and a pencil.☐ Fill in the task sheet as you visit the following regions of the 'This is Idaho' exhibit.**A. Snake River Plain**

1. Describe the location of this region.



2. Find the juniper tree cross-section and the tree ring labeled 1431. What happened on this date when the tree was living? _____

3. What was 'Elmer' ? _____ and how tall was 'Elmer'? _____.

4. What was 'Haroldine'? _____

B. Northern Basin and Range

5. Describe the location of this region.



6. How many hot springs are in Idaho? _____

7. How many species of sagebrush are there in the USA? _____

8. Name three animals that are dependent on sagebrush. _____,

_____, _____

9. The nuts of which species of pine tree was an important food source for the Indigenous peoples of the region? _____

10. To which mountain range can you find all 14 Idaho bat species? _____

11. The Snake River Plain used to be a body of water called _____

12. How many species of fossil fish have paleontologists found from this body of water? _____

C. Idaho Batholith

13. Describe the location of this region.



14. Which plant was so essential to the Indigenous peoples of the region that it was featured in origin stories and myths. _____

15. How many individual mountain goats can you find in Idaho? _____

16. What is an anadromous fish? _____

17.  What happened to the beavers of Payette and McCall lake areas?

D. Middle Rockies

18. Describe the location of this region.



19. What interesting fossils can you find on Mt. Borah? _____

20. What is the highest elevation found here? _____

21. Which range in the Middle Rockies show S-folds? _____

22. The Northern Flying Squirrel is diurnal or nocturnal?

23. What is the common and species name of the living animals in the aquariums; choose one species?

_____, _____

24. What is the name 'very rare, critically imperiled, endemic insect' found Idaho steppe habitats?

25. How many individual mountain lions can you find in Idaho? _____

E. Northern Rockies

26. Describe the locations of this region.



27. How many bear species can you find in this region; what are they? _____

28. This native grassland is one of the rarest bioregions in the US. _____

29. Lake Coeur d'Alene has how many nesting pairs of what species of animal? _____,

F. All Regions

30. What is the species name and common name of the animal fossil found in Hagerman, Idaho?

_____, _____

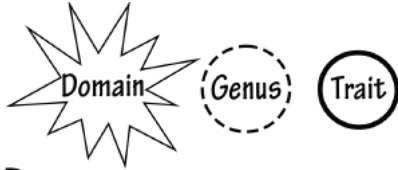
31. What was your favorite part of the IMNH? Why?



Part 2. Tree of Life

- ☐ No computers, phones, tablets, or any mobile devices can be used while in the laboratory.
- ☐ Legibly print your name, section #, and instructor name on pages 1, 3, and 5 where indicated on the assignment that will be handed out to you during lab.
- ☐ You can use Appendix B & your graded task sheets as guides.
- ☐ Work as individuals.
- ☐ Fill in the tree on page 2 with the Organisms and Traits listed on pages 4 and 6 on the assignment that will be handed out to you during lab. Most of these organisms were observed during the semester.

1. Fill in the numbers and letters for the:



2. Once completed, staple all six pages together.

- ☐ Before leaving the lab, turn in the:

3. Appendix A: C-Fern

4. Lab 15 - Tree of Life Assignment (all six pages stapled together).

Name _____

Section _____

Throughout the semester (Table A-1) you will sow *Ceratopteris* (Phylum Pteridophyta) spores and then carefully observe these spores and what happens to them. Each week, when you arrive in lab you will be required to check your C-Fern cultures.

Background:

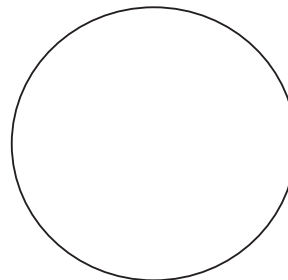
Table A-1. Schedule of fern culture and care.

The life cycle of land plants is characterized by an alternation between two phases or generations that are morphologically and functionally distinct. The gametophyte generation is the sexual phase of the life cycle. Gametophytes produce eggs and/or sperm (gametes) and house and nourish the product of fertilization, the embryo. Gametophytes may be extremely small or the dominant phase of the life cycle. Although fern gametophytes are quite small, they are free-living and independent from the much larger spore-producing plant that you are familiar with. In ferns, seed plants and other vascular plants, the sporophyte is the dominant phase of the life cycle and produces spores by meiosis. Spores are haploid cells and the plant that produces spores, the sporophyte, must be diploid. A spore is a single cell. Under the right conditions, spores grow by mitotic divisions and differentiate into multicellular plants that eventually produces gametes. See task sheet 5 for more information about the fern life cycle.

Labs	Days	Topic
2	1	Sow spores
3	8	Observe germinating spores.
4 & 5	15 & 22	Observe germinating spores and developing gametophytes.
6	29	Identify the two morphologically distinct kinds of gametophytes, observe sperm, initiate mating.
7 - 14	36 -92	Observe sporophyte development.
15	99	Observe spores made by the sporophyte. Take <i>Ceratopteris</i> plants home.

Lab 2 (day 1)

- ☐ Your instructor will give you a plant tissue culture tube with a lid filled half full of basic nutrient agar media.
- ☐ Using a permanent marker, write your initials, date, and section number on the side of the culture tube.
- ☐ Your instructor will have a sterile transfer pipette and a sterile microfuge tube of spores suspended in sterile water.
- ☐ Resuspend the spores by inverting the microfuge tube several times then draw up several drops into the sterile transfer pipette.
- ☐ Partially lift the lid from the culture tube and expel the spores onto the culture tube agar.
- ☐ After everyone has inoculated their culture tubes with spores, your instructor will prepare a wet mount of some of spores remaining in the microfuge tube. Observe this wet mount of spores under the microscope at different powers.
 1. Draw a few spores showing the wall pattern or ornamentation.
 2. Note variations in the spore wall ornamentation on different surfaces of the spores.
 3. Note the size, color, and distribution of the spores in your culture tube.
- 4. What is the ploidy level of the spore? _____
- 5. Is the spore multicellular? _____
- ☐ Place your culture tube upright in the correct terrarium for your lab section.



Spores

Phylum: _____

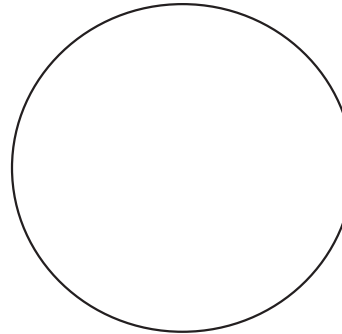
Genus: _____

Total Magnification: _____

Lab 3 (day 8)

☐ Using a **stereo microscope** observe the germinating spores. You might see a small projection coming from the spore coat called a rhizoids and a bump that is the developing gametophyte with photosynthetic cells (with chloroplasts).

6. Draw several of the spores and label:
- spore wall
 - rhizoid(s)
 - photosynthetic cells (with chloroplasts)



Germinating spore

day 8

Phylum: _____

Genus: _____

Total Magnification: _____

Labs 4 & 5 (days 15 & 22)

7. Compare and contrast the spores in your culture tube with the observations you made during the last two weeks. The spores will be germinating. You might see a small projection coming from the spore coat called a rhizoid.

8. What could be the reasons for germination of some spores and not others?

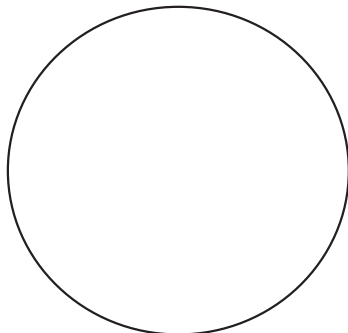
☐ Using a **stereo microscope** observe the germinating spores. You might see a small projection coming from the spore coat called a rhizoids and a bump that is the developing gametophyte with photosynthetic cells (with chloroplasts).

9. Draw several of the spores and label:
- spore wall
 - rhizoid(s)
 - photosynthetic cells (with chloroplasts)

10. What is the ploidy level of the immature plant germinating from the spore? _____

11. Is the plant multicellular? _____

12. What type of mitosis is the plant going through to add cells to its body? _____



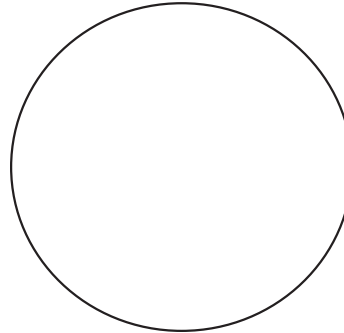
Germinated spore

day 15

Phylum: _____

Genus: _____

Total Magnification: _____



Germinated spore

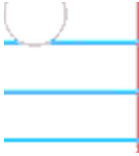
day 22

Phylum: _____

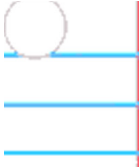
Genus: _____

Total Magnification: _____

13. Describe how the spore wall has changed from day 1?



14. What is the function of rhizoids in a plant that is composed of only a few cells?



Lab 6 (day 29)

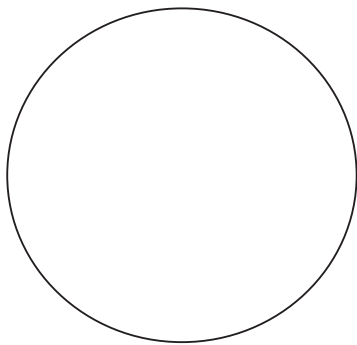
Important Notes: The larger mitten-shaped gametophytes (hermaphrodite) produce both male and female sex organs. The male sex organs (antheridia, sing. antheridium) are found around the margins of the plant and near the rhizoids at the lower part of the plant. The female sex organs (archegonia, sing. archegonium) are aggregated near the growing notch, usually on the underside of the plant. Among these larger hermaphroditic gametophytes should be numerous small, exclusively male plants. Each male gametophyte consists of numerous antheridia that give a bumpy appearance to the plant. These males develop in response to the presence of a special chemical (antheridogen) in the medium that is secreted by older gametophytes.

☐ Make a wet mount on a slide that includes a few gametophytes of both types.

☐ Using a **compound microscope** observe your slide.

15. Draw one of each type of gametophyte and label:

- spore wall
- rhizoids
- photosynthetic cells
- growing notch (hermaphrodite only)



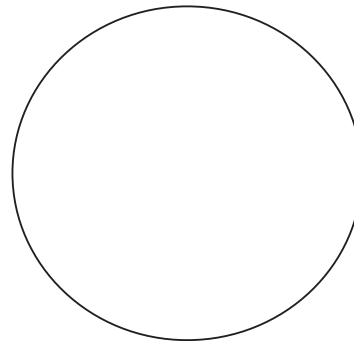
Gametophyte **hermaphrodite**

day 29

Phylum: _____

Genus: _____

Total Magnification: _____



Gametophyte **male**

day 29

Phylum: _____

Genus: _____

Total Magnification: _____

16. Describe the morphological differences between the two gametophytes?



17. What ploidy level do the gametophytes have? _____

18. Sperm cells come from what structure on the male and hermaphroditic gametophyte plants? _____

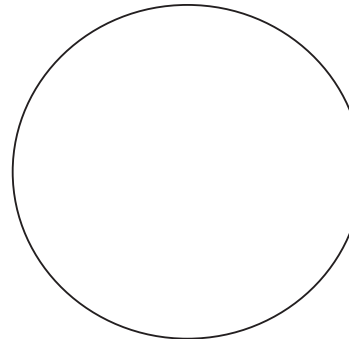
19. What does water do to these structures and how does it aid the sperm? _____

- ☐ Over the next 5 minutes continually observe the antheridia with the compound microscope.
- ☐ When you see movement, increase the magnification and observe these small, flagellated gametes. Be very patient - give it some time. The sperm cells can move very quickly and are hard to examine unless they are caught on something or slow down.

20. Draw the shape of the sperm cells.

- ☐ Once you have observed swimming sperm cells, locate the archegonia on another gametophyte. If you are patient and lucky, you will see the sperm cells swimming down the neck of the archegonium on its way to fertilize the egg inside.

21. Sperm and eggs are gametes. The gametes are _____ and are produced by cellular division called _____ mitosis.



Sperm

day 29

Phylum: _____

Genus: _____

Total Magnification: _____

22. What type of reproduction requires that two nuclei fuse to produce a zygote? _____

23. What is the ploidy level of a zygote? _____

- ☐ **IMPORTANT:** Water the plants in your plant tissue culture tube using the sterile water bottle labeled for your lab section and a sterile transfer pipette. This water will allow the sperm cells to easily swim to the eggs in the archegonia.

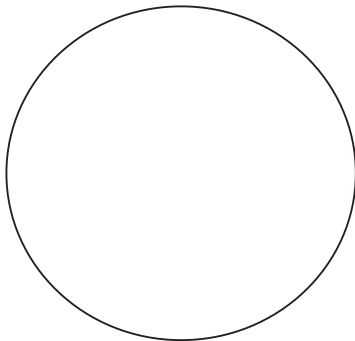
☐ Return your culture tube to the growth chamber.

Labs 7-12 (days 36-92)

- ☐ Using a **stereo microscope** observe the region close to the growing notch. If fertilization was successful last week, you may be able to the first leaves of the sporophyte growing from the gametophyte.

24. Draw a young sporophyte growing from the gametophyte during labs 7 & 8. Label:

- gametophyte
- sporophyte
- rhizoids



Immature sporophyte on gametophyte

day ____ (lab 8)

Phylum: _____

Genus: _____

Total Magnification: _____

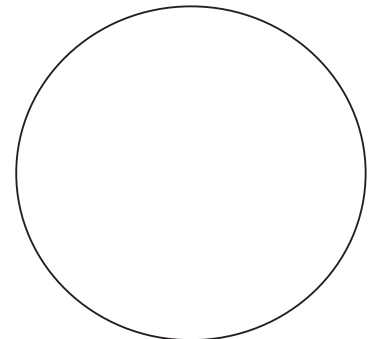
Immature sporophyte on gametophyte

day 36 (lab 7)

Phylum: _____

Genus: _____

Total Magnification: _____



25. In what structure on the hermaphroditic gametophyte did the sperm find the egg? _____

26. Once the sperm nuclei fuses with the egg nuclei a _____ is formed. What is the ploidy level of this cell? _____

27. What type of mitosis does this cell go through to grow into a multicellular sporophyte plant? _____

28. Is the sporophyte haploid or diploid? _____.

29. Draw the developing sporophyte during each lab. Label:

- Phylum & Genus.
- Vegetative leaves each week.
- Sporulating leaves each week.
- Measure the height (mm) of the sporophyte from the agar up each week.

30. How did the morphology of the fern change between over the semester?

Sporophyte development

Phylum: _____

Genus: _____

day ____ (lab 9)

height (mm) _____

day ____ (lab 10)

height (mm) _____

day ____ (lab 11)

height (mm) _____

day ____ (lab 12)

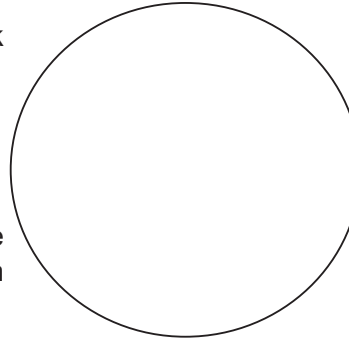
height (mm) _____

Lab 15 (day ____)

☐ Observe your mature fern sporophyte and check for sporangia filled with spores.

31. Draw the sporophyte. Label:

- Vegetative leaves
- Sporulating leaves
- Measure the height (mm) of the sporophyte from the soil up. The ruler should be placed on the outside of the tube.



Sporangia housing spores

day ____ (lab 15)

Phylum: _____

Genus: _____

Total Magnification: _____

☐ Using a **compound microscope**, observe a section of a leaf with sporangia containing spores. Break open one sporangia.

32. Draw a sporangia and its spores found on a sporulating leaf. Label:

- Leaf
- Sporangia
- Spores

33. What is the ploidy levels of the:

- A. Leaf _____
- B. Sporangia _____
- C. Spore _____

34. What will a spore from this plant develop into once it finds a suitable environment for germination? _____ What will its ploidy level be? _____ What type of mitosis does it use to go from the unicellular stage to the multicellular stage? _____

35. What type of life cycle is this? _____ .

36. In your own words, **describe** the type of life cycle the plant has:



37. In your own words, **describe** the type of life cycle mammals have:



Name _____

Section _____

Classification

Biological classification , as you might remember for BIOL 1101L, is a system for comparing and grouping organisms, and the naming of those groups. It encompasses both taxonomy and systematics relying heavily on many other fields of biology. Over the last 250 years, biological classification has made it possible for the description, naming, and organization of 1.2 million species into three domains (Figure B-1) with those species catalogued into a central database. However, it is estimated that there are another 7.5 species that have yet to be described. With the current rate of 6,200 eukaryote species described per year, describing Earth’s remaining species could take as long as 1,200 years and would require 303,000 taxonomists at an approximated cost of \$364 billion. With extinction rates now exceeding natural background rates by a factor of 100 to 1,000, species will become extinct before we know they even existed.

A. Taxonomy

The discipline of classification encompasses the field of **taxonomy** which is the classification, description, and naming of groups of organisms. Since the 18th century, biologists have subscribed to a standard protocol for the description, naming, and classification of organisms. In formal biological classification, species are grouped according to estimates of their similarity or relatedness. Such groups are called taxa (singular, taxon). The taxa are listed in a hierarchical pattern. The most commonly used groups in the system of biological classification are shown in Table B-1 (listed from the most inclusive to the most exclusive). In this system, the animal kingdom is divided into a number of phyla (singular, phylum). Each phylum is divided into classes, classes into orders, orders into families, families into genera (singular, genus) and genera into species. A classification developed for a taxon will be affected by the particular characters used, the relative weight given, and how they are analyzed. If different characters or weighting is used a different classification will arise. Animals have two types of names, common and scientific. Every animal taxon has a unique scientific name that is used throughout the world. Common names are less precise and can cause confusion because the name can be used for several different species. Also, the majority of species do not have a common name. The scientific name of a species is binomial and is always italicized. The name consists of two words the genus name and the specific name. For example the American Elk’s scientific name is *Cervus canadensis*. A dichotomous key (Figure UI-2) is a device used to identify an organism through several steps. At each step (called a couplet) a choice must be made between two alternatives based on the presence of certain characters. Usually the characters are morphological (that is they are based on the form or shape of an organism). Each alternative will lead to another couplet or to the name of the identified organism.

B. Systematics

The study of the diversity of organism and of the relationships between them is the scientific field of **systematics**. Phylogenetic systematics provides methods for inferring evolutionary relationships. Relationships are inferred by distinguishing between characters that represent a **primitive** condition for the organisms in question and those that represent the **derived** condition. Organisms are grouped together on the basis of common ancestry; this classification represents patterns of evolutionary diversification and the **Tree of Life**. **Shared derived characters/trait** among organism are evidence of common ancestry. A **phylogenetic tree** is graphical representation of the evolutionary relationship between taxa. Each **node** along a branch of the phylogenetic tree represents a population that lived at a particular point in time. The **root** is the original population. Nodes mark the population that split to produce two daughter populations or two separate species (known as **speciation**). The tips represent the populations that are currently living (extant).

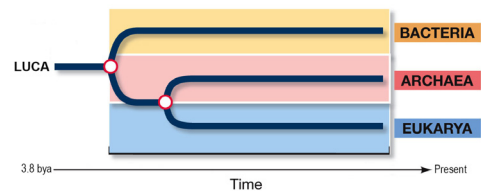


Figure B-1. Tree diagram with three domains of life.

Table B-1. Example of a taxonomic classification.

Taxa		Syringa	American Elk
Domain		Eukarya	Eukarya
Kingdom		Plantae	Animalia
Phylum or Division		Magnoliophyta	Chordata
Class		Magnoliopsida	Mammalia
Order		Rosales	Artiodactyla
Family		Hydrangeaceae	Cervidae
Genus + specific name	= species name	<i>Philadelphus lewisii</i>	<i>Cervus canadensis</i>

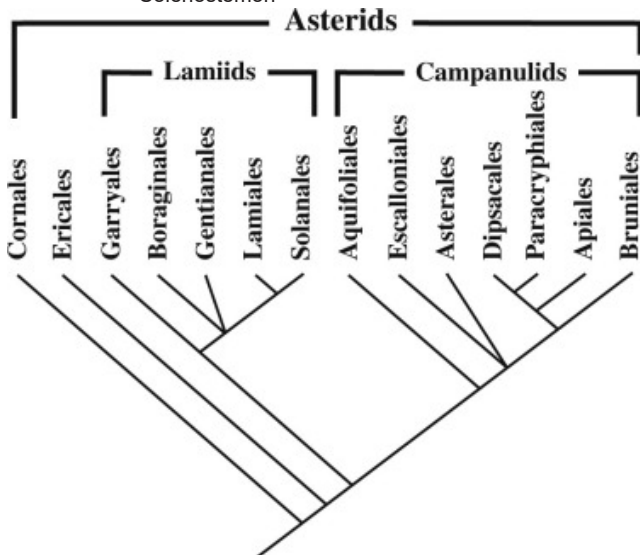
The **last universal common ancestor** (LUCA) is the most recent population of organisms from which all organisms now living on Earth are descended. LUCA should not be assumed to be the first living organism on Earth but the most recent common ancestor of all current life on Earth. The LUCA is estimated to have lived some 3.5 to 3.8 billion years ago. The composition of the LUCA is not directly accessible as a fossil, but can be studied by comparing the genomes of its descendants, all organisms living today.

Throughout the semester you will construct tree diagrams of the specimens viewed for each unit.

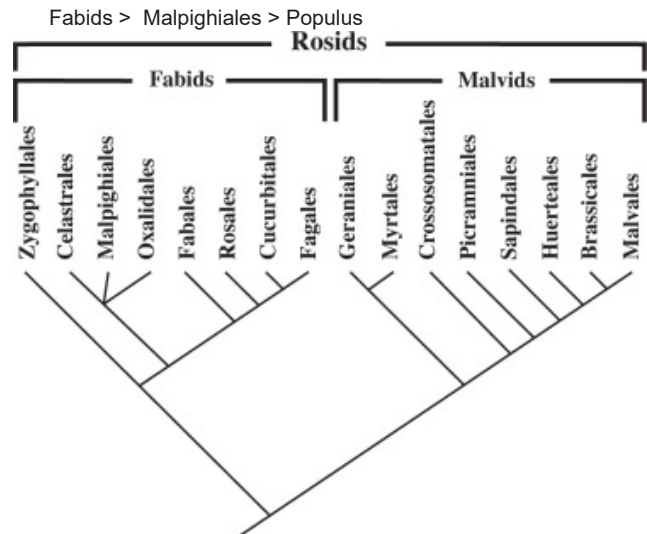
C. Extra Hints

Major eudicot plant clades:

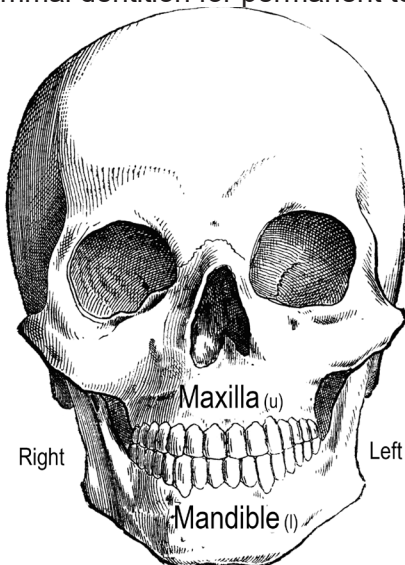
Angiosperm > Dicotyledons > Asterids >
 Asterales > Helianthus
 Lamiales > Mentha
 > Solenostemon



Angiosperm > Dicotyledons > Rosids >
 Malvids >
 Brassicales > Capsella
 Malvales > Tilia
 Sapindales > Acer



Mammal dentition for permanent teeth:



GENERAL: $2 \times (\text{INCISORS (u+l)} + \text{CANINES (u+l)} + \text{PREMOLARS (u+l)} + \text{MOLARS (u+l)}) = \text{TOTAL TEETH}$
 HOMO SAPIENS: $2 \times (\text{INCISORS (2+2)} + \text{CANINES (1+1)} + \text{PREMOLARS (2+2)} + \text{MOLARS (3+3)} \text{ OR } (2+2)) = 32 \text{ OR } 28$
 SUS: $2 \times (\text{INCISORS (3+3)} + \text{CANINES (1+1)} + \text{PREMOLARS (4+4)} + \text{MOLARS (3+3)}) = 44$
 RATTUS: $2 \times (\text{ELODONT INCISORS (1+1)} + \text{CANINES (0+0)} + \text{PREMOLARS (0+0)} + \text{MOLARS (3+3)}) = 16$
 ORYCTOLAGUS: $2 \times (\text{ELODONT INCISORS (2+1)} + \text{CANINES (0+0)} + \text{PREMOLARS (3+2)} + \text{MOLARS (3+3)}) = 28$
 NEOGALE: $2 \times (\text{INCISORS (3+3)} + \text{CANINES (1+1)} + \text{PREMOLARS (3+3)} + \text{MOLARS (1+2)}) = 34$
 MYOTIS: $2 \times (\text{INCISORS (2+3)} + \text{CANINES (1+1)} + \text{PREMOLARS (3+3)} \text{ OR } (2+3) + \text{MOLARS (3+3)}) = 38 \text{ OR } 36$

$2 \times (\text{Incisors (u + l) + Canines (u + l) + Premolars (u + l) + Molars (u + l)}) = \text{total teeth}$

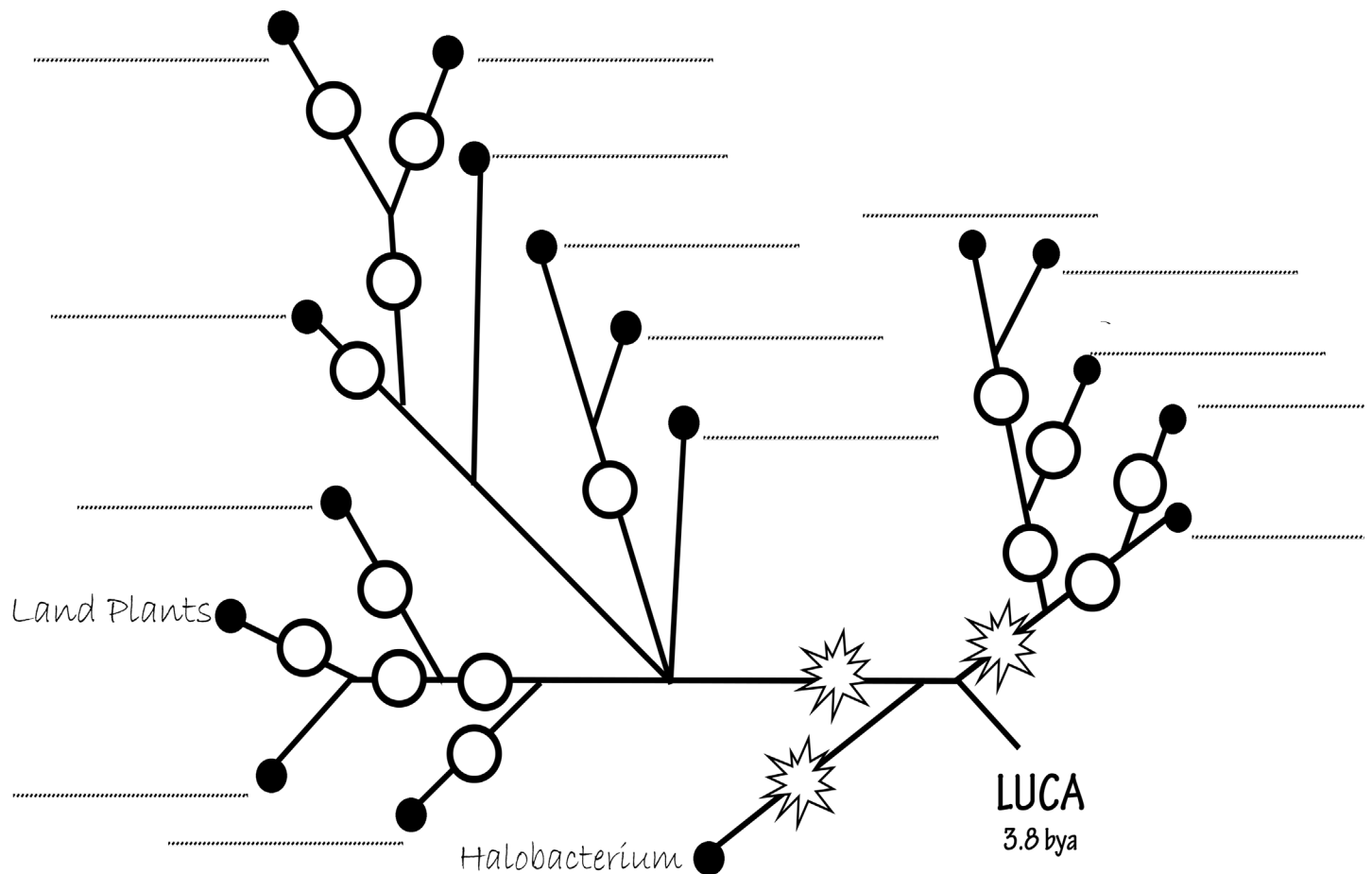


Figure B-2. Phylogeny of the organisms viewed in Unit I (Introduction to Life).

1. Fill in the phylogeny (Figure B-2) with the domain letters, *genus* names, and trait letters:
? = Common ancestor

Domains

- A. Eukarya - unicellular and multicellular with cell compartmentalization and membrane-bound organelles
- B. Bacteria - unicellular with membranes composed of unbranched fatty acid chains attached to glycerol by ester linkages; cell walls with peptidoglycan
- C. Archaea - unicellular; with membranes composed of branched hydrocarbon chains attached to glycerol by ether linkages; cell walls without peptidoglycan

Genera with Taxonomy

- P: Amoebazoa: *Amoeba*
- P: Euglenozoa: *Euglena*
- P: Rhodophyta: *Polysiphonia*
- P: Charophyta: *Chara*
- P: Ochrophyta: *Laminaria*
- P: Chlorophyta: *Scenedesmus*
- P: Ascomycota: *Penicillium*
- P: Basidiomycota: *Agaricus*
- P: Kinetoplastea: *Trypanosoma*
- P: Cyanobacteria: *Oscillatoria*
- P: Pseudomonadota: *Acetobacter aceti*
- P: Bacillota: *Lactobacillus delbrueckii* subsp. *bulgaricus*.
- P: Bacillota: *Streptococcus thermophilus*
- P: Bacillota: *Bacillus cereus*
- P: Euryarchaeota: *Halobacterium*
- P: Nematoda: *Turbatrix aceti*

Traits

- a. Chloroplast thylakoids contain chlorophylls a and phycobiliproteins; starch is stored in the cell
- b. Chloroplast thylakoids contain chlorophylls a and b; starch is stored in the chloroplast
- c. Chlorophytes
- d. Heterotrophs; chitinous cell walls
- e. Sexual spore-producing structure found on the reproductive bodies in fungi called the Basidia.
- f. Sexual spore-bearing cell produced in fungi called the Ascus.
- g. Similar flagellar apparatus
- h. Streptophytes/Charophytes
- i. Complex multicellular autotroph with specialized reproduction organs.
- j. Non-sporulating
- k. Sporulating with endospores
- l. Thylakoid membranes that contain chlorophylls, carotenoids, and phycobiliproteins pigments
- m. Gram-negative
- n. Gram-positive
- o. Heterotrophs; non-rigid cells

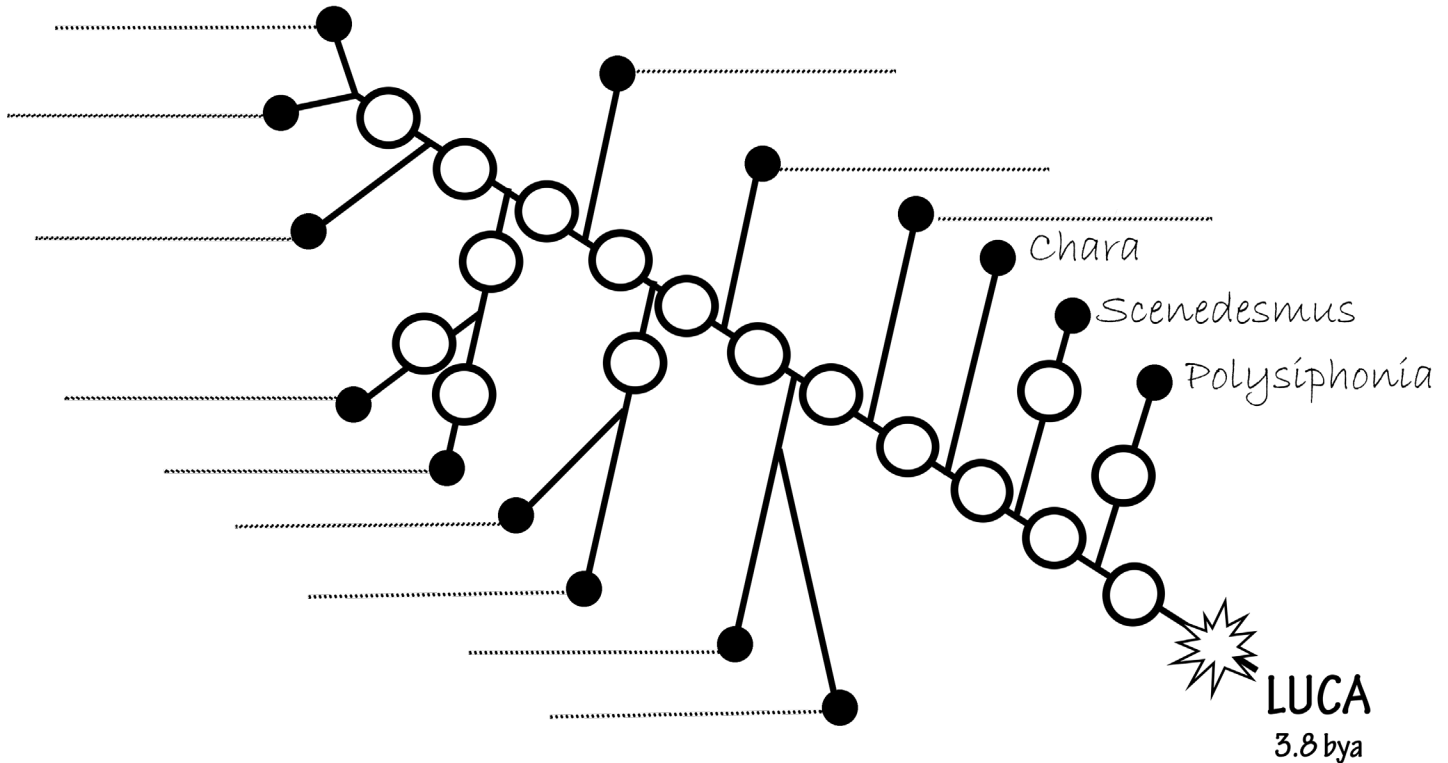


Figure B-3. Phylogeny of the organisms viewed in Unit II Parts 1-3 (Plant Anatomy).

2. Fill in the phylogeny (Figure B-3) with the domain letter, *genus* names, and trait letters:

Domain

A. Eukarya

Genera with Taxonomy

- P: Angiosperm, C: Dicotyledones, *Ranunculus* (buttercup)
- P: Angiosperm, C: Dicotyledones, *Helianthus* (sunflower)
- P: Angiosperm, C: Dicotyledones, *Solenostemon* (coleus)
- P: Angiosperm, C: Dicotyledones, *Mentha* (mint)
- P: Angiosperm, C: Dicotyledones, *Tilia* (linden)
- P: Angiosperm, C: Dicotyledones, *Acer* (maple)
- P: Pinophyta, C: Pinopsida, *Pinus* (pine tree)
- P: Angiosperm, C: Monocotyledones, *Zea* (corn)
- P: Angiosperm, C: Monocotyledones, *Allium* (onion/garlic)
- P: Pteridiophyta, O: Polypodiales, *Pteridium* (brake fern)
- P: Pteridiophyta, O: Psilotales, *Psilotum* (whisk fern)
- P: Bryophyta, O: Bryales, *Mnium* (moss)

Traits

- a. Autotrophs; cell walls; chloroplasts bound by two membranes derived from primary endosymbiosis of a cyanobacteria and cells have walls made of cellulose (usually).
- b. Chloroplasts contain chlorophylls a and phycobiliproteins; starch is stored in the cell
- c. Chloroplasts contain chlorophylls a and b; starch is stored in the chloroplast
- d. Complex multicellular autotroph with specialized reproduction organs.

- e. Vascular tissue
- f. Flowers
- g. Seeds contain only one cotyledon
- h. Seeds contain two cotyledons and pollen that has three furrows or pores (tricolpate)
- i. Five sepals, five petals, one whorl of five stamens, often another whorl of five stamens, and finally a whorl of three or five carpels
- j. Rosids
- k. Asterids
- l. Lamiales
- m. Malvales
- n. Sapinales
- o. Streptophytes/Charophytes
- p. Chlorophytes
- q. Seeds

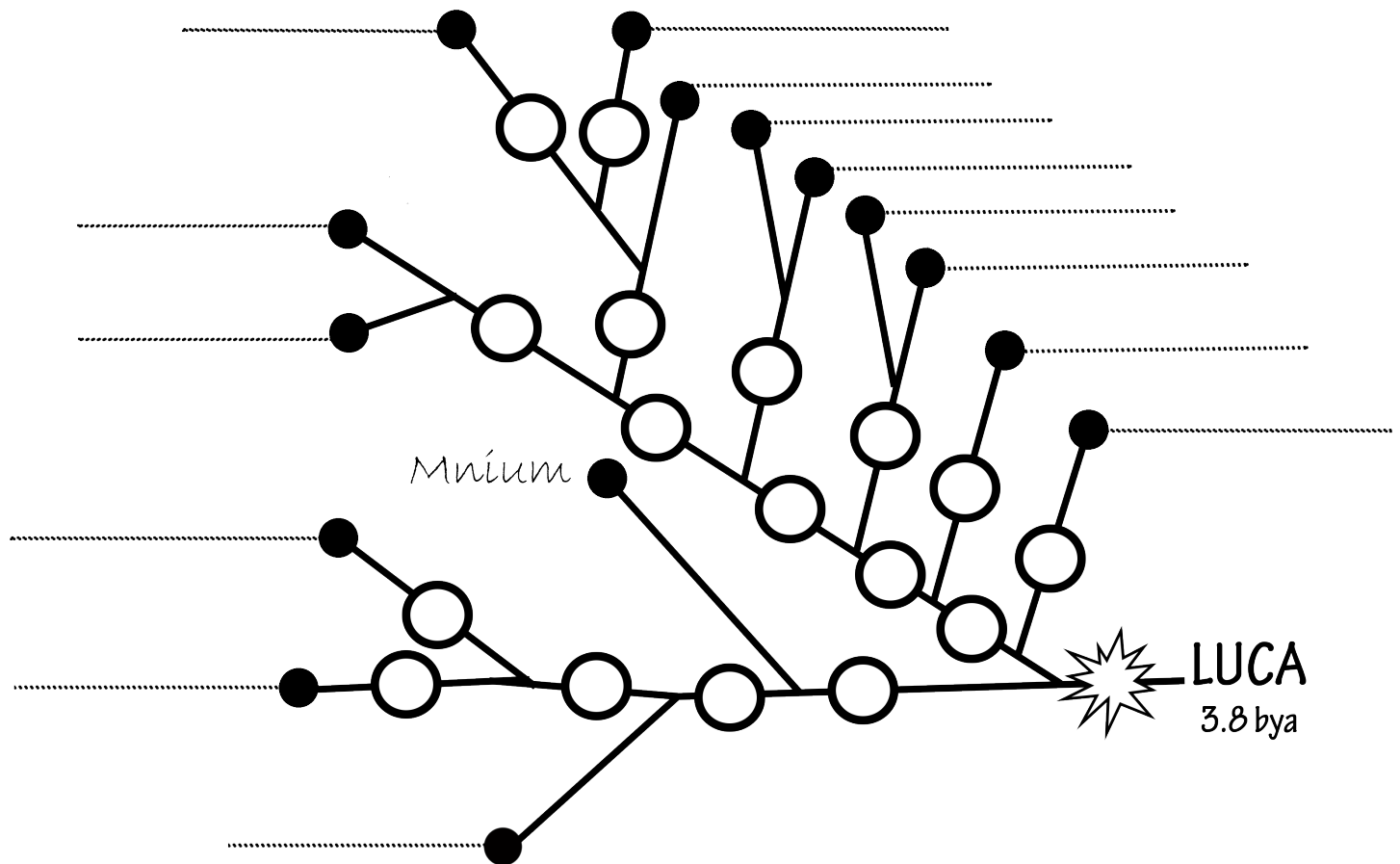


Figure B-4. Phylogeny of the organisms viewed in Unit III Parts 1-3 (Reproduction & Development)

3. Fill in the phylogeny (Figure B-4) with the domain letter, *genus* names, and trait letters:

Domain

A. Eukarya

Genera with Taxonomy

- P: Pteridiophyta, *Polypodium* (rock cap fern)
- P: Angiosperm, C: Monocotyledones, *Lilium* (lily)
- P: Angiosperm, C: Dicotyledones, *Capsella* (Shepard's purse)
- P: Zygomycota, *Phycomyces*
- P: Porifera, C: Calcarea, *Grantia* (sponge)
- P: Cnidaria, C: Scyphozoa, *Aurelia* (moon jelly)
- P: Ctenophora, C: Tentaculata, G: *Pleurobrachia* (comb jelly)
- P: Chordata, C: Amphibia, O: Anura, *Lithobates* (frog)
- P: Echinodermata, C: Asteroidea, *Asterias* (sea star)
- P: Nemertea, C: Anopla, *Cerebratulus* (ribbon worm)
- P: Platyhelminthes, C: Trematoda, *Schistosoma* (fluke)
- P: Nematoda, C: Adenophorea, *Trichinella* (nematode)
- P: Arthropoda, C: Insecta, O: Blattodea, *Blattella* (house cockroach)
- P: Arthropoda, C: Insecta, O: Hymenoptera, *Apis* (honey bee)

Traits

- a. Complex multicellular autotroph with specialized reproduction organs
- b. Heterotrophs; non-rigid cells
- c. Diploblastic; radial, biradial symmetry
- d. Organ systems composed of tissues
- e. Cellular level of organization; no tissues
- f. Triploblastic; bilateral symmetry
- g. Indeterminate radial cleavage
- h. Determinate spiral cleavage
- i. Complex cuticle with ecdysis
- j. Flower and seeds contain only one cotyledon
- k. Flowers and seeds contain two cotyledons and pollen that has three furrows or pores (tricolpate)
- l. Complete metamorphosis (holometabolous)
- m. Incomplete metamorphosis (hemimetabolous)
- o. Heterotrophs; chitinous cell walls
- p. Lophotrochozoa
- q. Seeds
- r. Vascular tissue

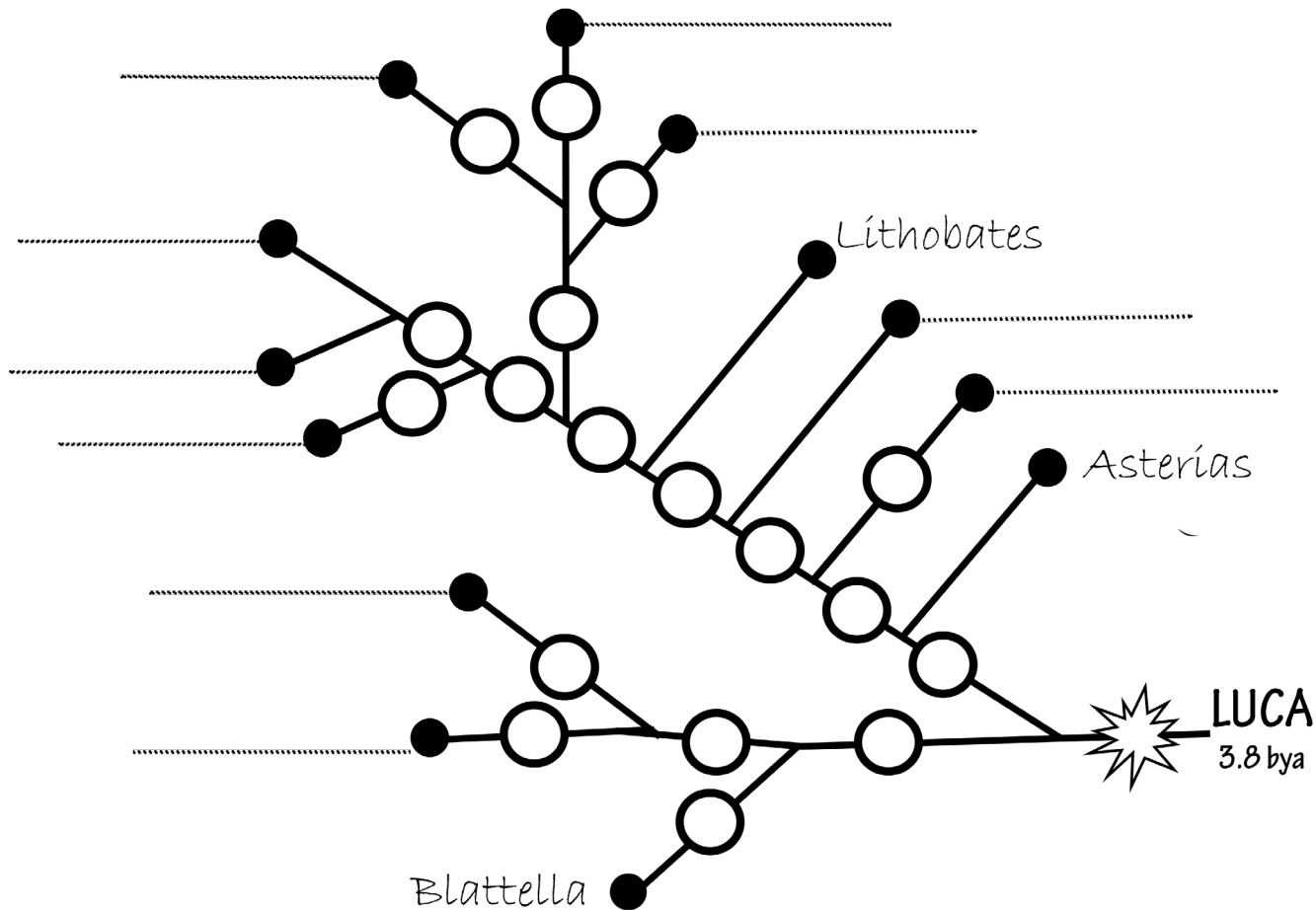


Figure B-5. Phylogeny of the organisms viewed in Unit IV Parts 1-2 (Animal Anatomy).

4. Fill in the phylogeny (Figure B-5) with the domain letter, *genus* names, and trait letters:

Domain

A. Eukarya

Genera with Taxonomy

- P: Mollusca, C: Bivalvia, *Mya* (clam)
- P: Mollusca, C: Cephalopoda, *Loligo* (squid)
- P: Chordata, C: Hyperoartia, *Petromyzon* (lamprey)
- P: Chordata, C: Actinopterygii, *Perca* (perch)
- P: Chordata, C: Reptilia, O: Squamata, *Pituophis* (snake)
- P: Chordata, C: Reptilia, O: Galliformes, *Gallus* (chicken)
- P: Chordata, C: Reptilia, O: Columbiformes, *Columba* (pigeon)
- P: Chordata, C: Mammalia, O: Artiodactyla, *Sus* (pig)
- P: Chordata, C: Mammalia, O: Rodentia, *Rattus* (rat)
- P: Chordata, C: Mammalia, O: Primates, *Homo sapiens* (human)

Traits

- a. Embryo with four separate extraembryonic membranes, thoracic breathing, desiccation-resistant skin, internal fertilization
- b. Foot; visceral mass; mantle and cavity; gills
- c. Shells with two halves
- d. Tentacles; siphon for propulsion; closed circulatory system
- e. Determinate spiral cleavage
- f. Complex cuticle with ecdysis
- g. Indeterminate radial cleavage
- h. Chordata
- i. Horny teeth; no jaw
- j. Opposing jaws
- k. Four limbs
- l. Scales/feathers – epidermis derived
- m. Hair; four-chambered heart
- n. Kinetic jaw; three-chambered heart
- o. Elodont incisors
- p. Feathers; four-chambered heart
- q. 8 incisors; 4 canine teeth
- r. 12 incisors; 4 canine teeth

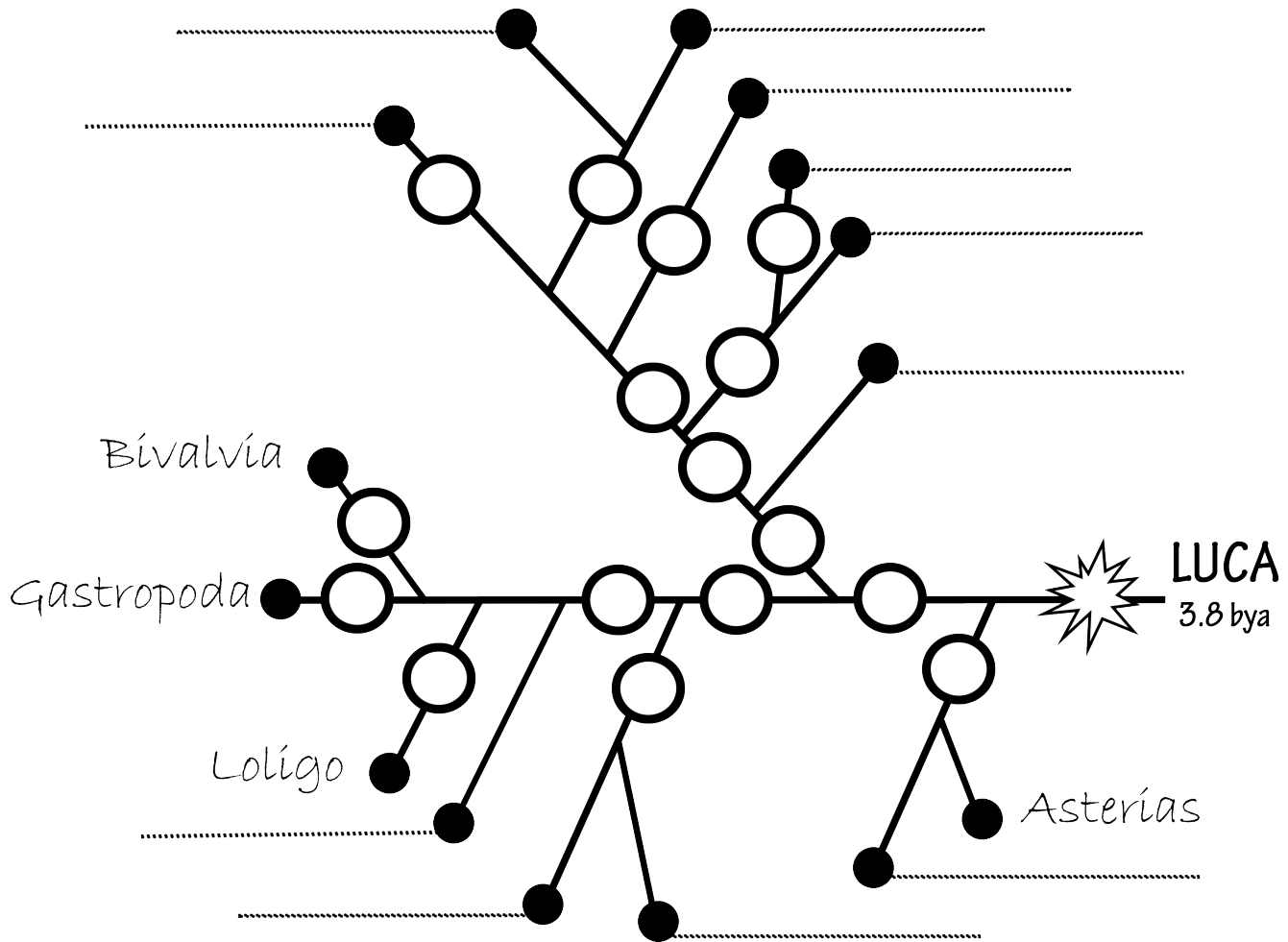


Figure B-6. Phylogeny of the organisms viewed in Unit IV Part 3 (Comparative Morphology - Invertebrates).

5. Fill in the phylogeny (Figure B-6) with the domain letter, *genus* names, and trait letters:

Domain

A. Eukarya

Genera with Taxonomy

P: Mollusca, C: Bivalvia:

- *Mya* (clam)
- *Mytilus edulis* (blue mussel)
- *Argopecten irradians* (scallop)
- *Crassostrea virginica* (Eastern oyster)

P: Mollusca, C: Gastropoda:

- *Ariolimax* (banana slug)
- *Otala lactea* (Land snail)

P: Mollusca, C: Polyplacophora, O: Chitonida, *Chiton* (chiton)

P: Annelida, O: Lumbriculida, *Lumbriculus* (earthworm)

P: Annelida, O: Phyllodocida, *Nereis* (clam worm)

P: Nematoda, O: Ascaridida, *Ascaris* (roundworm)

P: Arthropoda, C: Merostomata, *Limulus* (horseshoe crab)

P: Arthropoda, C: Arachnida, O: Uropygi, *Mastigoproctus* (whipscorpion)

P: Arthropoda, C: Chilopoda, *Scolopendra* (giant centipede)

P: Arthropoda, C: Insecta, O: Orthoptera, *Romalea* (lubber grasshopper)

P: Arthropoda, C: Malacostraca, O: Decapoda, *Callinectes* (blue crab)

P: Arthropoda, C: Malacostraca, O: Decapoda, *Cambarus* (crayfish)

P: Echinodermata, C: Holothuroidea, *Cucumaria* (sea cucumber)

Traits

- a. Determinate spiral cleavage
- b. Complex cuticle with ecdysis
- c. Exoskeleton (external skeleton); jointed appendages; segmented body
- d. Mandibular mouthparts on head
- e. Head (2 antennae), thorax (six legs, four wings), abdomen
- f. Head (2 antennae), trunk with many legs
- g. Head (4 antennae), thorax (more than six appendages that are biramous), abdomen
- h. Chelicerae mouthparts on prosoma
- i. Eight legs on opisthosoma
- j. Lophotrochozoa
- k. Segmented worms
- l. Foot; visceral mass; mantle and cavity; gills
- m. Shells with two halves
- n. Visceral mass rotates 180° moving anus above head
- o. Tentacles; siphon for propulsion; closed circulatory system
- p. Indeterminate radial cleavage

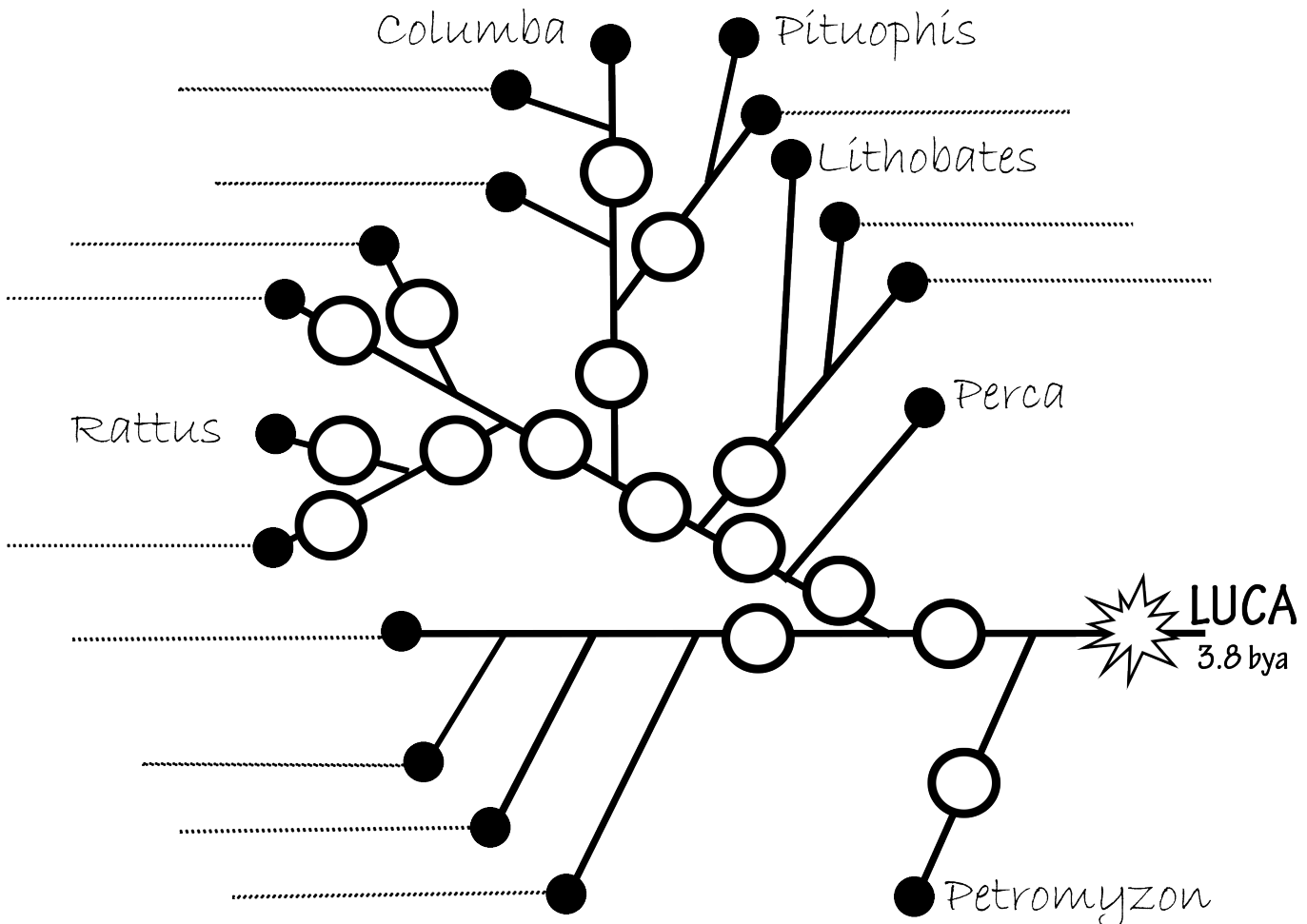


Figure B-7. Phylogeny of the organisms viewed in Unit IV Part 4-6 (Comparative Morphology - Chordates).

6. Fill in the phylogeny (Figure B-7) with the domain letter, *genus* names, and trait letters:

Domain

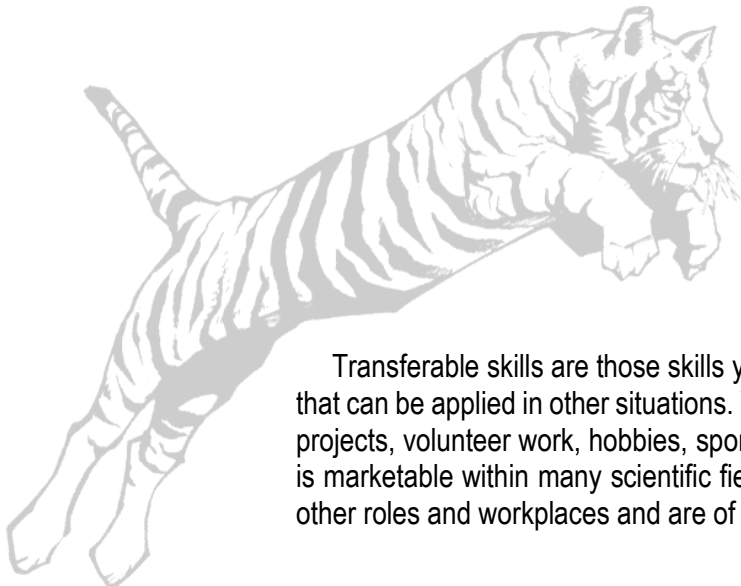
A. Eukarya

Chordata Genera with Taxonomy

- C: Chondrichthyes, O: Chimaeriformes, *Chimaera* (ratfish)
- C: Chondrichthyes, O: Myliobatiformes, *Dasyatis* (ray)
- C: Chondrichthyes, O: Rajiformes, *Dipturus* (skate)
- C: Chondrichthyes, O: Squaliformes, *Squalus* (dog shark)
- C: Amphibia, O: Urodela, *Amphiuma* (2-or-3 toed salamander)
- C: Amphibia, O: Urodela, *Necturus* (Common mudpuppy salamander)
- C: Reptilia, O: Testudines, *Trachemys* (turtle)
- C: Reptilia, O: Squamata, *Iguana* (iguana)
- C: Reptilia, O: Passeriformes, *Sturnus* (starling)
- C: Mammalia, O: Carnivora, *Neogale* (American mink)
- C: Mammalia, O: Chiroptera, *Myotis* (bat)
- C: Mammalia, O: Lagomorpha, *Oryctolagus* (domestic rabbit)

Traits

- a. Gnathostomata – opposing jaws
- b. Cartilaginous fishes
- c. Bony skeletons
- d. Four limbs
- e. Moist skin; external fertilization; three-chambered heart
- f. Embryo with four separate extraembryonic membranes, thoracic breathing, desiccation-resistant skin, internal fertilization
- g. Scales/feathers – epidermis derived
- h. Hair; four-chambered heart
- i. Feathers; four-chambered heart
- j. Kinetic jaw; three-chambered heart
- k. Elodont incisors
- l. 12 Incisors with 4 canines
- m. 10 Incisors with 4 canines
- n. 6 incisors with no canines
- o. 4 incisors and no canines
- p. Horny teeth; no jaw



TRANSFERABLE SKILLS

Transferable skills are those skills you acquire during any activity in your life - not just your studies - that can be applied in other situations. You can acquire skills through all sorts of activities: employment, projects, volunteer work, hobbies, sports, virtually anything. The knowledge you will develop in biology is marketable within many scientific fields. You will also gain skills that are transferable to a variety of other roles and workplaces and are of interest to a wide variety of employers.

Four types of skills that **all undergraduates** (regardless of major) are expected to develop:

- ✓ **Intellectual** – comprehension, critical reasoning, analytical, evaluation, planning and information-gathering, report writing.
- ✓ **Communication** – clarity of writing, layout and presentation of oral and written material, referencing, use of appendices, bibliographies, glossaries, indexes, and figures/tables.
- ✓ **Organizational** – prepare for exams, organize and complete assignments, time management, working under pressure.
- ✓ **Interpersonal** – negotiation, diplomacy, flexibility, adaptability, teamwork as well as independent work, delegation, and self-motivation.

Four types of skills (in addition to those above) that **all biology students** are expected to develop:

Foundational knowledge – structure/anatomy, function, physiology, reproduction, growth/development, origin, ecology, evolution, and distribution of organisms.

Applied knowledge

- ✓ **Research** – use primary sources (read, understand, and cite scientific literature) to develop questions that are innovative, novel, and creative; use the scientific method to answer these questions by constructing hypotheses and predictions, design experiments to test the hypotheses and predictions; monitor, record, and manage data; statistical analysis of the data; and conduct a critical analysis of the results.
- ✓ **Numeracy** – mathematical ability is necessary in most fields, and it is important that all students maintain at least a rudimentary comprehension of numeracy.
- ✓ **Computer literacy** – typing speed and accuracy, text formatting, spreadsheet use, formal presentation construction, academic and professional use of search engines, email, and other types of software and web applications.

BENGAL SURVIVAL SKILLS



BE PREPARED AND RESPONSIBLE

EMBRACE POSITIVE CHOICES

NURTURE A POSITIVE ATTITUDE

GIVE RESPECT TO SELF AND OTHERS

ACT ON TIME AND ON TASK

LABOR FOR SUCCESS

