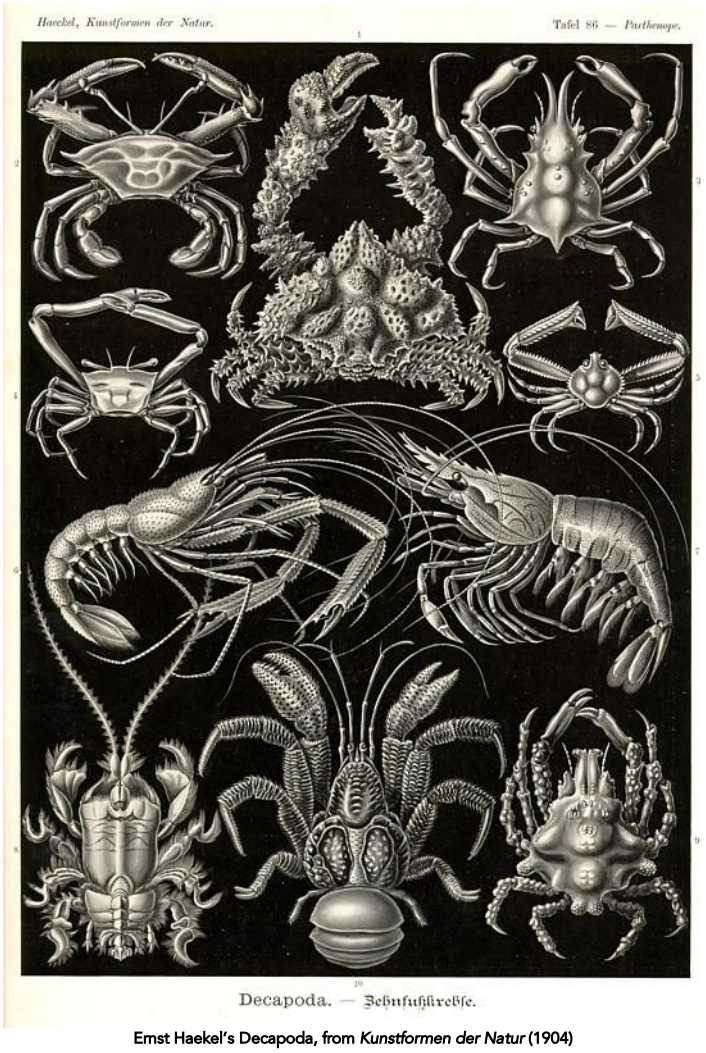

Ernst Haekel's Decapoda, from *Kunstformen der Natur* (1904)

FISH 310: Biology of Shellfishes

Instructor:
Dr. Jacqueline L. Padilla-Gamiño
office: 206-543-7878
jpgamino@uw.edu

Invert Wrangler:
Dr. Greg Jensen (gjensen@uw.edu)

TAs:
Lindsay Alma (lalma@uw.edu)
Laura Spencer (lhs3@uw.edu)

Course Outline

Lectures: Mondays, Wednesdays, and Fridays, 11:30am-12:20pm in FSH 107
Labs: Section AA meets Tu and Th, 1:30pm-4:20pm in FTR 124
Section AB meets M and W, 1:30pm-4:20pm in FTR 124

Office hours:
JPG – 2:00-3:00 pm on Fridays in FSH 204A and by appointment
Lindsay – 12:00-1:00 pm on Thursdays in FSH 264 and by appointment
Laura – 12:30-1:30 pm on Wednesdays in FTR 124 and by appointment

Pre-requisites: None

Credits: 5 credits + this course counts toward the UW Additional Writing (W) requirement

Required readings: Most readings come from the required textbook, Biology of the Invertebrates, Jan Pechenik, 7th edition (available to buy from $40 or to rent for the quarter from $20 on Amazon); additional reading material (including chapters of Karban and Huntzinger's book, see below) available as pdfs through Canvas

Optional readings: Richard Karban and Mikaela Huntzinger's book, How to Do Ecology: A Concise Handbook, will be an indispensable resource as you develop your term-project research proposal. You are required to read Chapters 1, 2, and 6, and these will be provided as pdfs on Canvas. But I encourage you to read the entire book, available on Amazon for ~$5 used.

Course Goals

This is a laboratory course on aquatic invertebrates, with emphasis placed on those of economic, ecological, and socio-cultural importance (i.e., the "shellfishes"). Inverts are dazzling in their diversity, and we will examine the sometimes surprising ways in which these organisms feed, reproduce, and persist in a changing environment. Focus will be on the morphology, physiology, ecology, and life history of arthropods and molluscs.

Because this is a biology course, we will survey invertebrate diversity in light of evolutionary diversification and phylogenetic relationships. The unique characters of each group will be emphasized, and we will compare how different groups carry out basic functions, such as feeding, dispersal, and reproduction. Phylogenetic relationships within and among groups will provide the framework for all of the specific biological details.

By the end of the semester, I expect you will be able to:

1. recognize each of the major groups of invertebrates,
2. recognize several important (mostly local, economically important) species within each of these groups,
3. know the basic anatomy, physiological and behavioral adaptations, and ecological role of each of these groups,
4. know the phylogenetic relationships among these groups,
5. read, interpret, evaluate, and synthesize primary literature in invertebrate biology,
6. communicate ideas about the biology of invertebrates effectively,
7. have an appreciation for the dazzling diversity of invertebrate life.

Evaluation

	Assessment	Due	Proportion of your final grade
Exams	Exam 1	6 May	20%
	Exam 2 (cumulative)	12 Jun, 2:30-4:20pm	20%
Lab reflections	Structured observations, creative thinking, and research skills assignments	At the end of each lab session	15% – We will have 17 labs over the course of the quarter (18 labs total minus the 1 lab in which you present your elevator pitches). Each carefully completed and correct lab reflection will earn 1 point. The lowest two lab reflection grades (e.g., if you miss a lab and therefore get a 0 on that lab reflection) are dropped.
Research proposal	You choose a general topic for your research proposal	In lab on Monday, 15 Apr or Tuesday, 16 Apr	0% – We will discuss these briefly in lab. Please bear in mind that no two students can work on the same topic.
	You pitch your ideas for your research proposal	In lab on Monday, 22 Apr or Tuesday, 23 Apr	0% – This is to encourage you to be as creative as possible! No ideas are too far-fetched. In our in-lab discussion, your colleagues will give feedback to improve your idea.
	You submit a first draft of your 10-page research proposal, which will be forwarded to a classmate	Via Canvas by 11:59pm on Wednesday, 1 May or Thursday, 2 May	n/a
	Classmate provides peer review of your draft	Via Canvas on Wednesday, 8 May or Thursday, 9 May	n/a
	You provide peer review of classmate's draft	Via Canvas by 11:59pm on Wednesday, 8 May or Thursday, 9 May	10% – Peer review makes the science world go 'round. Here, you get to practice providing constructive suggestions to colleagues.
	You revise and submit the second draft	Via Canvas by 11:59pm on Wednesday, 15 May or Thurdsay, 16 May	5% – You will submit another draft, revised after feedback from your peers, for more feedback from instructors. This should give you the opportunity to put together a stellar final proposal, and lets you experience the iterative process of scientific writing.
	I return second draft to you with feedback	Via Canvas by Wednesday, 22 May or Thursday, 23 May	n/a
	You give a 5-minute oral presentation describing your research idea (an "Elevator Pitch")	In lab on Wednesday, 29 May or Thursday, 30 May	5%
	You submit your final draft (≥10 pages double-spaced)	Via Canvas by 11:59pm on Friday, 7 June	15%
Participation	In-class and in-lab participation	n/a	10%

Grading Scale*

LETTER	PERCENT	GPA	NOTES
A	≥95	4.0	
A	94	3.9	
A–	93	3.8	
A–	92	3.7	
A–	91	3.6	
A–	90	3.5	
B+	89	3.4	
B+	88	3.3	
B+	87	3.2	
B	86	3.1	
B	85	3.0	
B	84	2.9	
B–	83	2.8	
B–	82	2.7	
B–	81	2.6	
B–	80	2.5	
C+	79	2.4	
C+	78	2.3	
C+	77	2.2	
C	76	2.1	
C	75	2.0	
C	74	1.9	
C–	73	1.8	
C–	72	1.7	
C–	71	1.6	
C–	70	1.5	
D+	69	1.4	
D+	68	1.3	
D+	67	1.2	
D	66	1.1	
D	65	1.0	
D	64	0.9	
D–	63	0.8	
D–	62	0.7	Lowest passing grade
E	<62	0.0	Academic failure, no credit earned

*Note that there will be no curve.

Exam Policy

There are no alternative exam times. Make-ups for exams will be available only for emergency situations that can be verified. If you miss an exam due to illness or other emergency, make sure that you or a friend contacts the instructor, Dr. Padilla-Gamiño, by email at jpgamino@uw.edu within 24 hours of the exam. Documentation of illness will be required for any missed exam. To preserve the academic integrity of the course, the instructor reserves the right to alter the content and/or format of the original test in creating a make-up exam.

Extra Credit

There will be bonus questions on exams that will require you to think hard, synthesize your knowledge across invertebrate taxa, and creatively generate hypotheses for patterns in invertebrate biology. These questions will draw heavily from the textbook and pdf readings and from content presented by Guest Speakers.

Regrade Policy

If you believe that an exam or assignment has been graded incorrectly, or that the grade entered is incorrect, you must contact me within one week of when the assignment was returned to you. Such a request must be submitted in writing (e-mail is fine) and must be accompanied by the original, unaltered assignment.

Academic Integrity

Students at the University of Washington are expected to maintain the highest standards of academic conduct, professional honesty, and personal integrity. Plagiarism, cheating, and other misconduct are serious violations of the University of Washington Student Conduct Code (WAC 478-120). I expect you to know and follow the university's policies on cheating and plagiarism. Any suspected cases of academic misconduct will be handled according to University of Washington regulations. For more information, see the University of Washington Community Standards and Student Conduct website.

I don't expect anyone in this class to engage in academic misconduct – invertebrate biology is a window into a new and exciting world, and cheating robs the cheater of the opportunity to explore and know that world. But university regulations require me to state up front my policy for addressing academic misconduct, so here it is: if you are caught cheating, falsifying data, plagiarizing, collaborating on assignments in a manner that is prohibited, or committing any other kind of academic misconduct as defined in the Student Conduct Code, you will receive an automatic zero on the assignment and the case will be referred to Community Standards and Student Conduct for a Student Conduct Process hearing. If you are caught twice, you will receive a zero in the course and the case will be referred for an additional hearing.

Posting of Grades

You will be able to access your grades via Canvas. All graded material (exams and essays) will be returned promptly during scheduled class or lab times. If you find that there is a clerical

error in a posted score, please contact me as soon as you notice the error. Exam scores will be posted no more than 10 days after the exam date.

Labs

Lab exercises are a key part of learning about invertebrates. You will work with a variety of living representatives of the groups discussed in lecture. We will also look at preserved specimens and slides. Please adhere to the following guidelines in lab:

- No food or drink, including gum
- Always wear close-toed shoes
- Put any sharp waste (scalpel blades, broken glass) in the sharps container
- Handle preserved specimens and shells carefully
- Rinse tools before and after use
- Rinse your hands well with water only to remove lotions or soaps before touching live animals
- Handle all animals gently
- Keep live animals in water and avoid temperature, oxygen, and light shock
- Don't feed the animals unless you are instructed to
- Don't let animals dry out
- Never place dead animals in the garbage – put them in the bags provided
- Put preserved animals back in the correct jar
- Don't mix instruments used with live and dead animals
- If you are unsure of what to do, ask before you act

Participation

Science education research has demonstrated that students who take an active role in their learning learn more and retain that knowledge longer; therefore, it is in your best interest to prepare for and actively participate in every class meeting – including small group activities and whole-class discussions. This is a relatively easy way to earn points toward your final grade. *One thing that may help you participate in class is bringing questions you have written out ahead of time*. I will also use a random name generator to call on students at random. Your class participation grade will be determined by how often you contribute, as well as the quality of your contributions. 10 points (of 10) = regular participation, usually well thought-out, useful contributions; 8 points = regular participation, sometimes useful, sometimes not; 6 points = occasional participation that is generally useful; 4 points = occasional participation, but generally non-substantive, adding little new information; 2 points = present but rarely contributed. I can provide feedback on your participation at any point in the semester, at your request.

Attendance Policy

Although attendance in lecture is the best way to ensure you absorb the material and perform well on tests and assignments, attendance in lecture will not be recorded. Attendance in labs is recorded. You may be excused from lab twice without a grade penalty. Additional absences on top of the first two absences will result in a 0% on the "lab reflections" assignment for each

missed lab and will reduce your overall participation grade. Aside from these effects on your final grade, absence from lab is to be absolutely avoided if at all possible, because you'll miss out on the opportunity to see demonstrations and slides that are designed to help you know the invertebrates well.

Guest Lectures

We will have visitors lecture on various topics. You are expected to show extra respect to our invited speakers by arriving early, if possible, for these presentations, remaining engaged throughout the class period, and asking thoughtful questions at the end. There will be at least one question on each exam about the material presented by these speakers.

E-mail

Any e-mail sent to me will receive a response within 48 hours. Detailed questions should be addressed to me in person – either after class or during office hours.

Late Assignments

Late assignments will not be accepted and will receive a grade of 0%. If you anticipate having trouble meeting one of the deadlines set out in this syllabus, please discuss with me beforehand.

Incomplete (I)

From UW's Faculty Resource on Grading: "An *Incomplete* is given only when the student has been in attendance and has done satisfactory work until within two weeks of the end of the quarter and has furnished proof satisfactory to the instructor that the work cannot be completed because of illness or other circumstances beyond the student's control… To obtain credit for the course, an undergraduate student must convert an *Incomplete* into a passing grade no later than the last day of the next quarter… An Incomplete grade not made up by the end of the next quarter is converted to the grade of 0.0 by the Office of the University Registrar… An *Incomplete* grade does not count for registered hours nor in computation of grade-point averages."

Classroom Climate

Diverse backgrounds, embodiments, and experiences are essential to the critical thinking endeavor at the heart of higher education. I expect you to follow the UW Student Conduct Code in your interactions with your colleagues and me in this course by respecting the many social and cultural differences among us, which may include, but are not limited to: age, cultural background, disability, ethnicity, family status, gender identity and presentation, citizenship and immigration status, national origin, race, religious and political beliefs, sex, sexual orientation, socioeconomic status, and veteran status. Please talk with me right away if you experience disrespect in this class, and I will work to address it. DCinfo@uw.edu is a resource for students with classroom climate concerns.

Access and Accommodations for Persons with Disabilities

Your experience in this class is important to me. If you have already established accommodations with Disability Resources for Students (DRS), please communicate your approved accommodations to me at your earliest convenience so we can discuss your needs in this course.

If you have not yet established services through DRS, but have a temporary health condition or permanent disability that requires accommodations (conditions include but not limited to; mental health, attention-related, learning, vision, hearing, physical or health impacts), you are welcome to contact DRS at 206-543-8924 or uwdrs@uw.edu or disability.uw.edu. DRS offers resources and coordinates reasonable accommodations for students with disabilities and/or temporary health conditions. Reasonable accommodations are established through an interactive process between you, your instructor(s), and DRS. It is the policy and practice of the University of Washington to create inclusive and accessible learning environments consistent with federal and state law.

Accommodations for Religious Observances

Students who expect to miss class or assignments as a consequence of their religious observance will be provided with a reasonable alternative opportunity to fulfill their academic responsibilities. Absence from class for religious reasons does not relieve students from responsibility for the course work required during the period of absence. It is the responsibility of the student to provide the instructor with advance notice of the dates of religious holidays on which they will be absent. Students who are absent will be offered an opportunity to make up the work, without penalty, within a reasonable time, as long as the student made prior arrangements. Pre-arranged absences for religious observances will not be counted against class participation.

FISH 310: Biology of Shellfishes

Schedule of Lectures and Labs: Spring 2019

You are expected to have read these materials *before* each lecture/lab. This schedule is subject to change. Pechenik = our required text, Biology of the Invertebrates, by Jan Pechenik. K&H = Karban and Huntzinger's How to Do Ecology: A Concise Handbook, pdfs of chapters available on Canvas.

Week	Date	Lecture	Lab	Reading and other assignments (*required*)
1	Monday 1 Apr	**Lecture #1: An introduction to shellfish biology**	**NO LAB**	
1	Tuesday 2 Apr		**NO LAB**	
1	Wednesday 3 Apr	**Lecture #2: Challenges and opportunities of life in the sea**	**Lab #1:** Introduction to shellfish biology (lab rules, microscopy tutorial, overview of invertebrates)	☐ Pechenik Chapter 1 ☐ Pechenik Chapter 5 ☐ Lab Reflection Guidelines (in this syllabus)
1	Thursday 4 Apr		**Lab #1:** Introduction to invertebrate biology (lab rules, microscopy tutorial, overview of invertebrates)	☐ Lab Reflection Guidelines (in this syllabus)
1	Friday 5 Apr	***Guest lecture by TAs: Laura and Lindsay***		☐ K&H Chapter 1
2	Monday 8 Apr	**Lecture #3: Invertebrate classification, relationships, and terminology**	**Lab #2:** Floating dock lab (held during regular lab time)	☐ Pechenik Chapter 2 ☐ Lord 2016
2	Tuesday 9 Apr		**Lab #2:** Floating dock lab (held during regular lab time)	

2	Wednesday 10 Apr	**Lecture #4: Invertebrate reproduction and development**	**Lab #3:** Invertebrate development and reproduction	☐ Pechenik Chapter 24
2	Thursday 11 Apr		**Lab #3:** Invertebrate development and reproduction	
2	Friday 12 Apr	**Lecture #5: Protozoa**		☐ Pechenik Chapter 3
3	Monday 15 Apr	**Lecture #6: Porifera**	**Lab #4:** Porifera (+ brief discussion of research proposal topics + primer on searching the scientific literature)	☐ Pechenik Chapter 4 ☐ Come to lab prepared to choose a topic for your research proposal
3	Tuesday 16 Apr		**Lab #4:** Porifera (+ brief discussion of research proposal topics + primer on searching the scientific literature)	☐ Come to lab prepared to choose a topic for your research proposal
3	Wednesday 17 Apr	**Lecture #7: Cnidaria 1**	**Lab #5:** Cnidaria + Ctenophora	☐ Pechenik Chapter 6 ☐ Sanz-Martin *et al.* 2016 ☐ K&H Chapter 2
3	Thursday 18 Apr		**Lab #5:** Cnidaria + Ctenophora	
3	Friday 19 Apr	**Lecture #8: Cnidaria 2 + Ctenophora**		☐ Pechenik Chapter 7 ☐ Simpson *et al.* 2017
4	Monday 22 Apr	**Lecture #9: Platyhelminthes 1**	**Lab #6:** "Worm stew" (+ discussion of research proposal pitches)	☐ Pechenik Chapter 8 ☐ Pechenik Chapter 11 ☐ Watch this 10-min video: https://vimeo.com/37282961

				☐ Read this comic strip: http://theoatmeal.com/comics/captain_higgins ☐ Come to lab prepared to pitch ideas for your research proposal
4	Tuesday 23 Apr		**Lab #6:** "Worm stew" (+ discussion of research proposal pitches)	☐ Come to lab prepared to pitch ideas for your research proposal
4	Wednesday 24 Apr	**Lecture #11: Mollusca 1 – Introduction to the molluscs**	**Lab #7:** Introduction to molluscs	☐ Pechenik Chapter 12 ☐ K&H Chapter 6 ☐ Quimby 2010 ☐ Glausiusz 1997
4	Thursday 25 Apr		**Lab #7:** Introduction to molluscs	
4	Friday 26 Apr	**Lecture #12: Mollusca 2 – Four molluscan classes: Polyplacophora, Gastropoda, Bivalvia, Cephalopoda**		☐ Duane 2006 ☐ Landman 1984
5	Monday 29 Apr	**Lecture #13: Annelida and other worms**	**Lab #8:** Bivalvia	☐ Pechenik Chapter 13
5	Tuesday 30 Apr		**Lab #8:** Bivalvia	
5	Wednesday 1 May	**Lecture #18: Echinodermata 1**	**Lab #9:** Gastropoda	☐ Pechenik Chapter 20 ☐ Via Canvas and by 11:59pm, submit first draft research proposal to swap with a

				classmate for peer review
5	Thursday 2 May		**Lab #9:** Gastropoda	☐ Via Canvas and by 11:59pm, submit first draft research proposal to swap with a classmate for peer review
5	Friday 3 May	**Exam Review**		☐ No readings ☐ Bring questions for exam review
6	Monday 6 May	**EXAM 1 (everything up to and including molluscs)**	**Lab #10:** Cephalopoda and mollusc reproduction	
6	Tuesday 7 May		**Lab #10:** Cephalopoda and mollusc reproduction	
6	Wednesday 8 May	***Guest lecture by Chelsea Wood on Snail abundance determines the burden of human schistosomiasis in Senegal, West Africa***	**Lab #15:** Echinodermata: Asteroidea	☐ No readings
6	Thursday 9 May		**Lab #15:** Echinodermata: Asteroidea	☐ Via Canvas and by 11:59pm, return your peer review comments on classmate's research proposal ☐ Via Canvas, collect classmate's peer review comments on your research proposal
6	Friday 10 May	**Lecture #19: Echinodermata 2**		
7	Monday 13 May	**Lecture #14: Arthropoda 1 – Crustacean intro + anatomy** (Lecture given by Greg Jensen)	**Lab #17:** Echinodermata: Holothuroidea and Ophiuroidea	

7	Tuesday 14 May		**Lab #17:** Echinodermata: Holothuroidea and Ophiuroidea	
7	Wednesday 15 May	**Lecture #15: Arthropoda 2 – Crustacean senses, feeding, and symbiosis** (Lecture given by Greg Jensen)	**Lab #11:** Introduction to arthropods	☐ Reaka 1981 ☐ Via Canvas and by 11:59pm, submit the second draft of your research proposal for professor's feedback
7	Thursday 16 May		**Lab #11:** Introduction to arthropods	☐ Via Canvas and by 11:59pm, submit the second draft of your research proposal for professor's feedback
7	Friday 17 May	**Lecture #16: Arthropoda 3 – Crustacean reproduction, development, and growth** (Lecture given by Greg Jensen)		☐ Wahle 1993 ☐ Jensen 1995
8	Monday 20 May	LECTURE CANCELLED FOR ALKI BEACH FIELD TRIP	**Lab #14**: Alki Beach field trip – depart at 11:30 (for a -2.26 foot low tide at 12:38pm), expect to arrive back at the lab by 4:30 pm.	
8	Tuesday 21 May	LECTURE CANCELLED FOR ALKI BEACH FIELD TRIP	**Lab #14**: Alki Beach field trip – depart at 11:30 (for a -2.26 foot low tide at 12:38pm), expect to arrive back at the lab by 4:30 pm.	
8	Wednesday 22 May	**Lecture #17: Arthropoda 4 – Aquatic insects** (Lecture given by Greg Jensen)	**Lab #12:** Arthropod anatomy and "shrimps"	☐ Via Canvas, collect professor's comments on your second-draft research proposal

8	Thursday 23 May		**Lab #12:** Arthropod anatomy and "shrimps"	☐ Via Canvas, collect professor's comments on your second-draft research proposal
8	Friday 24 May	NO LECTURE – JPG IN WORKSHOP IN OHIO		
9	Monday 27 May	NO LECTURE – MEMORIAL DAY	NO LAB - MEMORIAL DAY	
9	Tuesday 28 May		NO LAB - MEMORIAL DAY	
9	Wednesday 29 May	**Lecture #20: Hemichordates and the non-vertebrate chordates**	**Lab #16:** Elevator pitches	☐ Deliver your elevator pitch to the lab group ☐ Pechenik Chapter 21 ☐ Pechenik Chapter 23 ☐ Gould 1996
9	Thursday 30 May		**Lab #16:** Elevator pitches	☐ Deliver your elevator pitch to the lab group
9	Friday 31 May	**Lecture #21: Issues in shellfish biology – Parasitism and disease**	**Lab #13:** Planktonic crustaceans and larvae	☐ Pechenik Chapter 16 ☐ Weinstein and Kuris 2016
10	Monday 3 June	**Lecture #22: Issues in shellfish biology – Climate change and ocean acidification**	**Lab #13:** Planktonic crustaceans and larvae	☐ Reading TBD
10	Tuesday 4 June			
10	Wednesday 5 June	**Lecture #23: The big picture** (15 minutes will be set aside to allow you to fill out course evaluations)	**Lab #18:** Parasites	☐ Bring a device you can use to fill out your online course evaluation (laptop or smartphone)

10	Thursday 6 June		**Lab #18:** Parasites	☐ Bring a device you can use to fill out your online course evaluation (laptop or smartphone)
10	Friday 7 June	**Exam review**		☐ Via Canvas and by 11:59pm, submit the final version of your research proposal
11	12 June	**EXAM 2 (cumulative)**	**2:30-4:20**	

Lab Reflection Guidelines*

**Adapted from Kuris, Whitney, and McKenzie Parasitology Lab Exercises, UC Santa Barbara*

You are required to complete a "lab reflection" in each of our 16 lab sessions. These assignments are worth 15% of your final grade and will be collected and graded at the end of each lab. A major part of this lab course is the study of fresh material, and we are fortunate to have access to these animals. A good record of your observations will be useful to you for studying and review and for any future research that you may do in invertebrate biology.

Drawings: Artistic ability is not necessary to produce workable specimen drawings and don't worry, you will not be graded on the quality of your artwork. However, you will need to develop your observation skills. Even the smallest protozoa have morphological and anatomical details that facilitate their identification. Find a specimen that shows the details described by your instructor, adjust the focus and illumination for optimal viewing, and observe the specimen carefully before you draw. Drawings should be large enough to accommodate anatomical detail and clear labeling. Try sketching lightly in pencil and then trace over the lines that you want to keep for your finished drawing.

Drawings should include the following details:

1. Specimen identity (genus and species or lowest taxonomic level)
2. Specimen collection data (location and date of collection)
3. Specimen descriptors (age, sex, size)
4. Dissection description (what parts of the animal were examined? how did you dissect it?)
5. Scale bar or magnification (always use metric units)
6. Labeled specimen anatomy (notes and annotations are always useful)
7. Notes on natural history (feeding, reproduction, larval stages, etc.)
8. Notes on behavior (if working with a live specimen) – Describe any movement observed. Does the specimen respond to light, touch, or other stimuli?

The more detail that you include in your notes and drawings, the more you will learn and the more useful your lab reflections will be to you when it comes time to study for exams.

Research Proposal Guidelines

One of the most exciting and daunting challenges a scientist faces is to come up with a good research question. Good research questions are several things at once:

1. Novel – question has never been asked/answered before, is original
2. Important – answer to the question will matter to science, conservation, or natural resource management
3. Testable – question can be feasibly tested

The tough thing about research questions is that they are difficult to develop without an intimate understanding of the species, ecosystem, or problem of interest – but since, in science, the question must come before all the other steps in the research process, we are often in the position of posing questions about a species, ecosystem, or problem that is new to us. How are we supposed to proceed?

In this assignment, you will practice a skill that is fundamental in science – the ability to develop good research questions. This skill will serve you well no matter where your career takes you, because it will help you to think critically about many problems – not just problems in invertebrate biology. You will choose a topic of interest to you, with only one restriction: your topic must fall within the disciplinary boundaries of invertebrate biology. You will read the literature, get to know your topic, and develop a research question based on the current state of the research. You will then write a >10-page paper in the form of a research proposal, where you will:

1. Contextualize your question in the existing literature, with references to that literature,
2. State your question and explain why it is novel, important, and testable,
3. State the various hypotheses that might arise from your question,
4. Propose a feasible research project that tests your hypotheses,
5. Explain what results would support your hypotheses, and what results would falsify them.

The purpose of this assignment is: (1) to get you to think critically about the ecology and management of marine invertebrates, (2) to get you intimately familiar with at least one invertebrate taxon, (3) to have you practice generating hypotheses and designing experiments to explore invertebrate biology, and (4) to hone your scientific writing skills.

Choosing a topic:

This can be the most challenging part of performing scientific research! To help you in the process of narrowing your interests, we will be reading several chapters from Richard Karban and Mikaela Huntzinger's How to Do Ecology: A Concise Handbook. This book was written for beginning graduate students, but its sections on picking a question (Chapter 1), posing questions (Chapter 2), and communicating what you find (Chapter 6) are all very relevant to the development of your research proposal for this class. Depending on what kind of research you choose to propose, you might also want to read the chapters on using experiments to test hypotheses (Chapter 3) and analyzing patterns and data (Chapter 4). I will provide pdfs of these chapters, but I encourage you to buy the book and read it in full if you are interested in pursuing a career or further studies in scientific research.

Please note that **no two students may work on the same topic**. We will have two in-lab discussions to provide feedback on ideas and to ensure that there is no overlap in content between any two students.

Whatever topic you ultimately choose, you will need to wade into the scientific literature to understand what is known and what remains unknown. I primarily use two resources when searching the literature: Google Scholar and Web of Science. If you need help using these resources, please see me or your TA.

Pre-selected topics:

The most important criterion that you should bear in mind as you choose a research proposal topic is that it should be one that you are excited about! This goes for any original research project that you might work on – they are challenging and time-consuming undertakings, so they are a delight if you're invested in the research and a slog if you aren't. If you are having trouble coming up with an idea, you may consider the potential topics below as a starting point. However, using one of these "pre-selected topics" will automatically bump you down two points for the "creativity" criterion in the Research Proposal Grading Rubric. We designed the assignment this way to encourage you to exercise your research creativity muscles, but provide you with a starting point in case you get really stuck.

- How is the climate-driven invasion of king crabs (*Neolithodes yaldwyni*) affecting Antarctic food webs?
- Are Dungeness crab larvae adapted to local ocean pH?
- How is the ongoing invasion of Japanese horn snails (*Batillaria attramentaria*) changing community structure in Washington's estuaries?
- Do climate change and domoic acid exposure have synergistic effects on invertebrate physiology/growth?

- How does intertidal oyster aquaculture affect water quality and nutrient cycling in estuaries?
- Does infection by *Philometra* spp. nematodes change the behavior of infected English sole (*Parophrys vetulus*)?
- What are the indicators of senescence in bivalves?
- How will the opening of the Northwest Passage affect the dispersal of Arctic invertebrates?
- Does overfishing drive jellyfish blooms?

Example research proposals:

Several example proposals are provided for you on our Canvas page. These are proposals written by junior- and senior-level undergraduates. These example proposals should give you an idea of: (1) the kinds of questions you might choose, (2) how to contextualize your question within the existing literature, (3) an appropriate scope for the proposed research, and (4) how to pose research questions and state your hypotheses.

Formatting:

- 12-point, Times New Roman font, double-spaced with 1" margins
- At least 10 pages long
- At least 20 references to primary literature
- No references to sources other than the scientific literature (i.e., no Wikipedia, no encyclopedias, no textbooks) – a handful of websites (< 3) is okay if warranted
- Number your pages
- References formatted according to Reference Formatting Guidelines (end of this document)

Sections:

TITLE PAGE AND ABSTRACT

On the title page, give a concise (<200 word) summary of your proposal.

INTRODUCTION

Set the project in its appropriate context (e.g., ecological, behavioral, evolutionary). Where does the research fit into the field in general? Why is it important? The introduction is a place to convince the reader that the research is interesting and timely, and – frankly – worth your time to do and their time to read. So, you need to establish the "big picture" of why you should do the research, why it is interesting to scientists in general.

OBSERVATIONAL OR THEORETICAL MOTIVATION FOR RESEARCH

Explain the field observation or theoretical consideration that raised the question you will be studying. Is this research addressing a particular controversy? What is the background? What is known about the observed phenomenon? This is the place for you to discuss specific published papers that have addressed this or a similar research topic.

RESEARCH QUESTION(S)

Be specific! Draw on the general discussion and the background information to frame a specific, concise question.

HYPOTHESES

List the alternative hypotheses that are possible answers to your question(s). Note that there may be different sets of hypotheses that relate to different parts of your question.

EXPERIMENTAL DESIGN AND METHODS

How will you test your hypothesis? Your methods should be described in detail, including the number of replicates, quadrat sizes, focal animals, etc. Make sure you discuss the use of appropriate controls in your study, if needed.

ANTICIPATED RESULTS

Sketch out graphs of the main results that you expect. What findings would support your hypothesis? What findings would falsify your hypothesis?

DISCUSSION

How would you interpret the different possible results of your experiments or observations? What would each alternative result mean for science, conservation, or natural resource management?

Elevator Pitch Guidelines

Once you have crafted your plan for research on a fascinating aspect of invertebrate biology, you've got to convince people to fund it! Imagine that you are in a library on campus and you step into the elevator. Behind you, another person enters – and you turn around to see that this person is Bill Gates. What luck! The Bill and Melinda Gates Foundation just announced its intention to invest in invertebrate biology research! You have the length of an elevator ride to convince Bill that your project is a worthy investment – that it addresses a major research need, that it will work, and that it will mean big things for science, seafood, or conservation.

The purpose of this assignment is: (1) to get you comfortable with speaking about science to a variety of audiences, (2) to introduce some of the principles of excellent science communication, and (3) to have you practice boiling down complex scientific ideas.

Pitch requirements:

- No more than 5 minutes long (an **exceptionally** long elevator ride) – you'll be stopped at 5 minutes on the dot
- This can be a more colloquial talk than you might give for a scientific audience. For inspiration, see the 3-minute TED talks: https://www.ted.com/playlists/81/ted_in_3_minutes
- If you want to use a visual aid, it must be something that you might reasonably carry with you into an elevator, with no prior expectation of meeting Bill Gates.

Research Proposal Grading Rubric

Category	Exceeds expectations (9–10)	Meets expectations (7–8)	Nearly meets expectations (5–6)	Does not meet expectations (3–4)	Incomplete (0–2)
Title page, including abstract, and formatting of paper	Includes title and author's name. Abstract is concise and accurately reflects the content of the paper. Paper matches or exceeds minimum number of pages.	Includes title and author's name. Abstract is relatively concise and reflects the content of the paper, with some omissions or misrepresentations. Paper matches or exceeds minimum number of pages.	Includes title and author's name. Abstract is wordy OR only partially represents the content of the paper. Paper too short.	Includes title and author's name. Abstract is wordy AND only partially represents the content of the paper. Paper too short.	Any of the components (title, author's name, abstract) are missing.
Introduction + motivation for research	The introduction successfully "funnels" by providing a broad context and narrowing in to the purpose of the paper. Each paragraph has topic sentences and thoughtful supporting detail sentences that develop the main idea.	The introduction provides appropriate background context but does not "funnel". Each paragraph has topic sentences and sufficient supporting detail sentences that develop the main idea.	The introduction states the main topic but does not provide appropriate background context. Most paragraphs lack supporting detail sentences. Some topic sentences missing.	There is no clear introduction or main topic and no background context. Paragraphs wander, failing to support the main idea. Some topic sentences missing.	Absent
Research questions + hypotheses	Research question is novel, interesting, and testable, and hypotheses lay out many potential answers to the research question.	Research question is novel, interesting, and testable. Hypotheses lay out some potential answers to the research question.	Research question has two of these three traits: novel, interesting, testable. Hypotheses lay out limited potential answers to the research question.	Research question has one of these three traits: novel, interesting, testable. Hypotheses lay out few or illogical potential answers to the research question.	Absent
Experimental design and methods	Experimental design and methods would produce a convincing answer to the research question.	Experimental design and methods would suggest a possible answer to the research question.	Experimental design and methods would hint at a possible answer to the research question.	Experimental design and methods do not follow from the research question.	Absent
Anticipated results	Graphs and written language are used to describe a full suite of possible data outcomes.	Graphs and written language are used to describe some possible data outcomes.	Only graphs or only written language are used to describe some possible data outcomes.	Only graphs or only written language are used to describe a single possible data outcome.	Absent
Discussion	Anticipated outcomes are even-handedly interpreted in terms of their implications for science, conservation, or management.	Anticipated outcomes are interpreted in terms of their implications for science, conservation, or management.	Anticipated outcomes are partially mis-interpreted in terms of their implications for science, conservation, or management.	Anticipated outcome is mis-interpreted in terms of its implications for science, conservation, or management.	Absent
Creativity	Entirely original research idea.	Somewhat original research idea.	Research idea is derivative of ideas in the literature.	Research idea repeats ideas already well-established in the literature.	n/a
Organization – structural development of the idea	Writer demonstrates logical and subtle sequencing of ideas through well-developed paragraphs; transitions are used to enhance organization.	Paragraph development present but not perfected.	Logical organization; organization of ideas not fully developed.	No evidence of structure or organization.	n/a
Mechanics	No errors in punctuation, capitalization, spelling, sentence structure, or word usage.	Almost no errors in punctuation, capitalization, spelling, sentence structure, or word usage.	Many errors in punctuation, capitalization, spelling, sentence structure, or word usage.	Numerous and distracting errors in punctuation, capitalization, spelling, sentence structure, or word usage.	n/a
References	All references are cited in the correct format with no errors. All sources are legitimate.	Some references are cited in the correct format. All sources are legitimate.	Few references are cited in the correct format. Some illegitimate sources (e.g., websites).	No references are cited in the correct format. Reference list contains illegitimate sources.	Absent

Elevator Pitch Grading Rubric

Category	Exceeds expectations (9–10)	Meets expectations (7–8)	Nearly meets expectations (5–6)	Does not meet expectations (3–4)	Incomplete (0–2)
Content	The information included is accurate and completely addresses each component of the assigned topic.	The information included adequately addresses each component of the assigned topic.	The information included inadequately addresses the assigned topic. The information included is sometimes inaccurate.	The information included does not address the assigned topic.	There is no accurate content information.
Persuasiveness	The presenter effectively argues his/her case. Bill Gates is convinced to fund the project. He writes you a check on the spot.	The presenter's argument is somewhat convincing. Bill Gates says that he will discuss the project with Melinda and get back to you.	The presenter's argument is marginally convincing. Bill Gates thanks you for the information and goes on with his day.	The presenter's argument is weak. Bill Gates is visibly uncomfortable during the elevator ride.	There is no evident effort to persuade.
Delivery	The presenter effectively and creatively delivers the information while staying on topic. The presenter appears relaxed and self-confident. Body language, voice modulation, and eye contact are effectively used.	The presenter adequately delivers the information while staying on topic. The presenter appears relaxed and self-confident. Body language, voice modulation, and eye contact are mostly appropriate.	The presenter delivers the information but does not stay on topic. The presenter appears tense or nervous. Body language, voice modulation, and eye contact are inappropriate or lacking.	The presenter omits important information and does not stay on topic. The presenter appears tense or nervous. Body language, voice modulation, and eye contact are inappropriate or lacking.	The presenter does not effectively deliver the necessary information.
Organization	The presentation content has been organized using a logical sequence. The presentation is engaging and effective.	The presentation content has been mostly organized using a logical sequence, but some flaws exist. The presentation is adequate.	The presentation content has been organized using a somewhat logical sequence. The presentation is sometimes confusing.	The presentation content is disorganized, unclear, or confusing. The presentation is not adequate.	The presentation does not include evidence of organization.
Preparation	Presentation indicates detailed preparation.	Presentation indicates adequate preparation.	Presentation indicates minimal preparation.	Presentation indicates a lack of preparation.	Presentation shows no evidence of preparation.

Reference Formatting Guidelines*

*Adapted from Rutgers University Libraries Research Guide

In-text references

For references with one author: (First author's last name Date), e.g., (Abrams 1987)
For references with two authors: (First author's last name and Second author's last name Date), e.g., (Abrams and Menge 1987)
For references with three or more authors: (First author's last name *et al.* Date), e.g., (Abrams *et al.* 1987)

Journal article: one author

Last name First initial Second initial. Date. Title. *Journal Title* volume number: page range.
Example: Abrams PA. 1987. The functional responses of adaptive consumers of two resources. *Theoretical Population Biology* 32: 262–288.

Journal article: two or more authors

Last name First initial Second initial, First initial Second initial Last name, and First initial Second initial Last name. Date. Title. *Journal Title* volume number: page range.
Example: Hjalten J, K Danell, and P Lundberg. 1993. Herbivore avoidance by association: Vole and hare utilization of woody plants. *Oikos* 68: 125–131.

Chapter in a book

Last name, First initial Second initial, First initial Second initial Last name, and First initial Second initial Last name. Date. Chapter title. Pages *in* First initial Second initial Last name and First initial Second initial Last name, editors. Book Title. City of publication, State of publication, Country of publication: Publisher name.
Example: Abrams PA, BA Menge, and GG Mittelbach. 1995. The role of indirect effects in food webs. Pages 371–395 *in* G. Polis and K. O. Winemiller, editors. Food Webs: Integration of Patterns and Dynamics. New York, NY, USA: Chapman and Hall.

Book

Last name, First initial Second initial, First initial Second initial Last name, and First initial Second initial Last name. Date. Book Title. City of publication, State of publication, Country of publication: Publisher name.
Example: Drake JA, F DiCastri, and RH Groves. 1989. Biological Invasions: A Global Perspective. New York, NY, USA: Wiley.

Government document

Last name First initial Second initial, First initial Second initial Last name, and First initial Second initial Last name, editors. Date. Document title. Report number. City of publication, State of publication, Country of publication: Government agency, Agency division.
Example: Maschinski J, HD Hammond, and L Holter, editors. Southwestern rare and endangered plants: Proceedings of the second conference. General Technical Report RM-GTR-283. Fort Collins, CO, USA: US Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station.