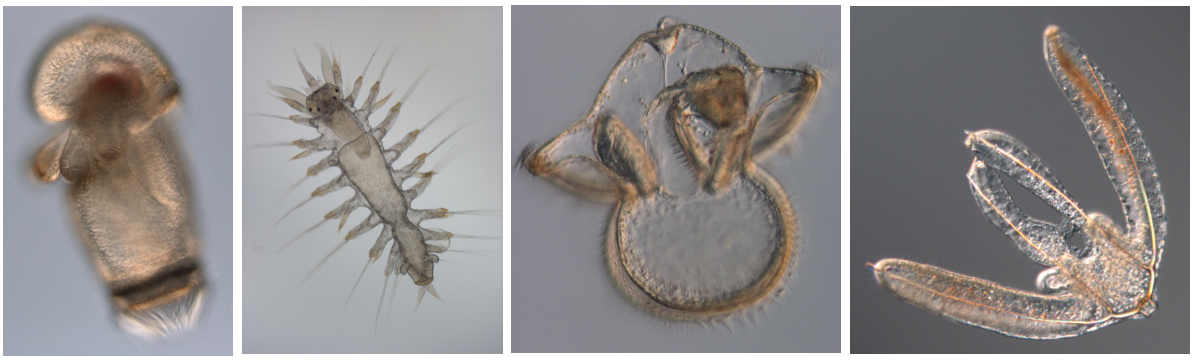

Comparative Embryology and Larval Biology
BI 457/557
OIMB Spring 2022 Term (March 28 - June 10)

In this class we survey embryonic and larval development in a broad selection of marine invertebrate phyla, including but not limited to Cnidaria (jellyfish), Ctenophora (comb jellies) Platyhelminthes (flatworms), Annelida (segmented worms), Mollusca (snails, clams etc.), Nemertea (ribbon worms), Phoronida (horseshoe worms), Echinodermata (starfish, sea urchins etc.), Bryozoa, Arthropoda (crustaceans), and Urochordata (sea squirts etc.). Lectures cover major developmental concepts and processes such as fertilization, cleavage and cell fate specification, morphogenesis, reproductive strategies, developmental modes, and larval function. Students explore the diversity of marine embryos and larvae by culturing dozens of representative species in the laboratory. Almost every week we go on field trips to visit local marine habitats and collect live material for the class. Students become proficient in using microscopes, and hone their observation and scientific illustration skills.

Learning outcomes

1. Demonstrate the ability to:
• culture embryos and larvae of a wide variety of marine invertebrates in the laboratory
• effectively use a microscope for observation and documentation
• identify and compare key developmental features of marine invertebrate groups covered by the course
2. Create a comprehensive notebook of biologically accurate and informative drawings of the developmental stages of species covered by the course

Instructor: Dr. Svetlana Maslakova svetlana@uoregon.edu
Teaching Assistant: Nicole Nakata nnakata@uoregon.edu

Meets: Wednesdays 8:30 am - 5:00 pm, McConnaughey Lab, OIMB (1 hr lunch break at noon).

Important notes about the schedule:

- The schedule below is tentative because embryological lab work depends in part on reproductive timing of animals, which we do not control. Changes in schedule for unexpected opportunities or disappointments are likely.

Office Hours: Drop by any time, or by appointment.

Required reading: See CANVAS for handouts, study guides, lecture notes, and required reading. Students are responsible for downloading and reading weekly assignments.

Especially helpful books on the subject (a few copies available in class, much of the required reading on Canvas comes from (1), (2), and (3)

1) M. F. Strathmann (1987) Reproduction and Development of Marine Invertebrates of the Northern Pacific Coast. Univ. Washington Press.
2) S. F. Gilbert and A. M. Raunio, eds (1997) Embryology: Constructing the Organism. Sinauer.
3) Young, Sewell and Rice (Eds). 2006. Atlas of Marine Invertebrate Larvae. Academic Press.
4) Shanks, A, ed. (2002) An identification guide to the larval marine invertebrates of the Pacific Northwest. Oregon State University Press. Individual chapters are available as pdfs from UO Scholar's Bank: https://scholarsbank.uoregon.edu/xmlui/handle/1794/6123

ASSESSMENT

1. Notebook (42%) All students are expected to maintain a high-quality laboratory notebook. The notebook should contain labeled drawings of eggs, embryos, and larvae raised by you, and organized by species. The notebook should also include notes on where and how the animals were collected, and the techniques used to procure embryos. The notebook should not contain lecture notes, handouts, or reading assignments. The drawings must be sufficiently detailed and well-labeled to demonstrate understanding of the subject, and must include indications of size. For more information refer to a separate handout about keeping a notebook, and examples of good embryology notebooks in the class. During second week of class the instructor will review notebooks, and offer individualized advice.

2. Weekly quizzes (18%). Every week (except week 1 and the final's week) we will have a 15-min quiz based on the material learned the previous week. Each of the nine quizzes is worth 2% of the total grade.

3. Final Exam (20%). Cumulative.

4. Participation in class (20%). Students are expected to keep track of class schedule and participate in all class activities. If you are unable to attend some activity for a respectable reason, notify the instructor as soon as possible, and discuss how you will make up for it. Tardiness and absences without a good reason will negatively effect the grade.

5. Extra credit (up to 5%). See extra credit assignment on Canvas.

Topics by week	**Grading scale**
April 3 Echinoderms I (echinoids) **April 10** Echinoderms II (asteroids, ophiuroids) **April 17** Spiralians I (mollusks and annelids) **April 24** Spiralians II (bryozoans) **May 1** Spiralians III (nemerteans and flat worms) **May 8** Plankton **May 15** Spiralians IV (phoronids) **May 22** Crustaceans **May 29** Cnidarians and Ctenophores **June 5** Ascidians **June 12** Final Exam, Notebooks due	97-100 A+ 93-96.9 A 90-92.9 A- 87-89.9 B+ 83-86.9 B 80-82.9 B- 77-79.9 C+ 73-76.9 C 70-72.9 C- 67-69.9 D+ 63-66.9 D 60-62.9 D- <59.9 = F

Detailed class schedule

Day	Tide	Time	Activities
Week 1 Apr 3	0.7 ft 18:14	8:30	Course orientation: introductions, handouts, Canvas, grading, keeping a notebook.
		9:00	**Lab.** Inject sea urchins *Strongylocentrotus purpuratus* and sand dollars *Dendraster excentricus* with KCl to induce spawning. Inject starfish *Pisaster ochraceus* with 1-methyl adenine to induce spawning.
		9:30	**Lab.** Fertilization on the slide. Students start individual cultures of both echinoid species.
		10:30	**Lecture.** Fertilization and development in echinoids.
		13:00	**Lab.** Use and care of microscopes. Making slide preps. Using ocular micrometer. Documenting *normal* development. Observe and draw: cleavage stages up to 16-cell stage to observe micromere formation (from morning cultures), and more advanced stages (from cultures started 1-2 days ahead by instructor: blastula, mesenchyme blastula, gastrula, prism).
		14:00	**DEMO:** crowd control, changing water, cleaning bowls, feeding (TA).
		15:00	**Lab.** Continue observation, draw developmental stages of echinoids **CLEAN, FEED, OBSERVE YOUR CULTURES EVERY 2-3 DAYS FOR THE REST OF THE COURSE**
Week 2 Apr 10	0.0 ft 10:31	8:30	**Quiz 1.** Fertilization and development of echinoids. (Instructor: mature and fertilize some excised seastar oocytes).
		8:45	mini-**Lecture.** Oocyte maturation, fertilization in starfish.
		9:00	**Lab.** Excise ovaries and testis from *Pisaster ochraceus*. Inject some with 1-MA to demonstrate spawning. Students: observe immature oocytes, GVBD, fertilization. Inject sea cucumber *Parastichopus* with spawning-inducing peptide, if available. Start cultures of sea stars (*Pisaster* and *Patiria*)
		11:00	**Lecture.** Larval development in asteroids.
		13:00	**Lecture.** Larval development of other echinoderms.

Day	Tide	Time	Activities
		14:00	**Lab**. Dissect and observe internally brooded embryos of brittle star *Amphipholis squamata*, externally brooded larvae of six-armed starfish *Leptasterias hexactis,* ophioplutei from plankton, as available. Observe cleavage (note the difference between seastar and sea urchin 16-cell stage), and more advanced stages of *Pisaster* or *Patiria*: blastula, gastrula, mouth and coelom formation (cultures started earlier by instructor) **Notebook advice:** students meet individually with instructor to get feedback on their notebooks.
Week 3 April 17	0.0 ft 17:31	8:30	**Quiz 2.** Larval development in echinoderms.
		8:45	**Lecture.** Spiral cleavage and its nomenclature. **Lab.** During lecture: **"**bowling for *Calliostoma"* (a gastropod mollusk) to induce spawning.
		9:45	**Lab.** Start cultures of *Calliostoma ligatum.* Avoid polyspermy and overcrowding!
		10:30	**Field trip to the large boat basin docks** (bring gardening or diving gloves to protect hands against barnacle cuts) to collect polychaete *Serpula sp.*, nudibranchs (and their egg masses), and sample plankton. Look for the polyclad *Pseudoceros* and its egg masses on the colonial ascidian *Distaplia.* Upon returning dilute plankton to keep alive till afternoon. Start cultures of *Serpula.*
		13:00	**Lab**. Observe equal spiral cleavage in *Calliostoma,* and identify cells according to spiralian nomenclature. Start cultures of *Serpula,* if have not already done so. Look through plankton for bryozoan cyphonautes, spiralian trochophores, metatrochophores, nectochaetes, gastropod and bivalve veligers, and other planktonic curiosities (see 'extra credit' list).
		14:00	**Lecture.** Equal vs. unequal cleavage. Development of annelids and mollusks.
		15:00	**Lab**. Follow cleavage in *Calliostoma* until 16-cell stage (observe and draw a side view and an animal pole view in dark field). Gastropod egg masses (*Nucella, Lacuna, Nassarius,* various nudibranchs, as available). Continue looking at plankton, examine at least two different polychaete and molluscan larvae. Check for cleavage in *Serpula*.

Day	Tide	Time	Activities
			Note: *Calliostoma* has lecithotrophic (non-feeding) development. Its cultures are especially prone to bacterial and ciliate infestations, but the shell is very pretty, so they are worth it! Avoid overcrowding, and clean them regularly and diligently, transferring individual normally-looking embryos into a clean bowl at each water change. These veligers do not swim well - normal ones usually rest on the bottom until they begin to crawl.
Week 4 April 24	-0.1 ft 10:42	8:30	**Field trip to South Cove** to collect bryozoans (*Crisia, Flustrellidra, Dendrobaenia*), polyclad flatworms *Notocomplana*, externally brooding anemonies *Epiactis* (if on small rocks). Assemble and be ready to depart WITH RAIN GEAR, RUBBER BOOTS, BUCKETS, BUTTER KNIVES, gardening GLOVES, in front of the open tank area by 8:30.
		11:00	**Lecture**. Bryozoan development. TA: set up bright lights, and watch for larval release from *Bugula* and *Schizoporella.*
		13:00	**Quiz 3.** Basics of spiral cleavage
		13:15	**Lab.** Observe released coronate larvae (*Schizoporella*, *Bugula*) and save a few larvae to observe metamorphosis and colony formation. Polyembryony in *Crisia*, pseudocyphonautes of *Flustrellidra,* planktonic cyphonautes, as available. Catch up on echinoderm cultures. Don't forget to look at *Serpula* (it has a classic trochophore larva!), and take care of and observe *Calliostoma.*
Week 5 May 1	1.2 16:55	8:30	**Quiz 4.** Bryozoan development
		8:45	**Lecture.** Marine zooplankton.
		9:30	**Field trip** to Charleston Marina to sample plankton off the docks.
		10:30	Dilute plankton, begin sorting. **Extra credit given for particularly interesting specimens** (see the list on Canvas). In order to receive credit you have to find it, save it, and give it to the instructor alive and undamaged, so everyone gets to see it.

Day	Tide	Time	Activities
		13:00	**Lab.** Continue looking at plankton with particular attention to the developmental stages of marine invertebrates. Identify and draw at least five different organisms you have not otherwise seen during the course.
Week 6 May 8	-1.1 ft 9:26	8:30	**Field trip to a mudflat in Charleston** to collect *Cerebratulus* and *Micrura* (nemerteans), *Phoronopsis harmeri* (phoronid) and *Owenia collaris* (polychaete).
		11:00	**Lecture.** Nemertean development. (TA: sort collected nemerteans, see if can start a culture of one or more species.)
		13:00	**Quiz 5.** Plankton
		13:15	**Lecture.** Flatworm development.
		14:00	**Lab.** Examine polyclad flatworm egg plates, Müller's larvae (as available). Students start cultures of *Micrura* or *Cerebratulus* (as available) and *Owenia*. Observe advanced pilidium larvae (cultures started by TA/instructor ahead of time or from plankton). Catch up on other cultures - echinoderms, *Calliostoma*, *Serpula,* observe young bryozoan colonies (*Bugula*, *Schizoporella*).
Week 7 May 15	0.7 ft 16:12	8:30	**Quiz 6.** Spiral cleavage (flatworms and nemerteans, larval development of annelids and molluscs)
		8:45	**Lecture.** Development of phoronids.
		9:30	**Lab.** Dissect females of *Phoronopsis harmeri*, and start cultures. Observe spermatophores and sperm.
		13:00	**Lecture**. General patterns in the evolution of life histories.
		14:30	**Lab.** Observe phoronid cleavage (morning cultures), advanced developmental stages from cultures started ahead of time, and actinotroch larvae from plankton (as available). Catch up on other cultures.

Day	Tide	Time	Activities
Week 8 May 22	-1.0 ft 9:27	8:30	**Field trip to Light House beach** to look for brooding crabs (*Cancer, Petrolisthes, Hemigrapsus, Emerita*), gooseneck barnacles (*Policipes polymerus*), and sand shrimp *Lyssocrangon stylirostris,* with a sexually dimorphic parasitic amphipod *Argeia pugettensis.*
		11:30	**Lecture.** Development of crustaceans.
		13:00	**Quiz 7.** Development of phoronids
		13:15	**Lab.** Dissect and examine egg lamellae and embryos of gooseneck barnacles, crab and shrimp embryos, females and dwarf males of *Argeia* parasitic on the sand shrimp.
		14:30	**Field trip to large boat basin docks** to collect caprellid amphipods and plankton (bring scoops for megalopae).
		15:30	**Lab.** Sort plankton and observe larval stages of crustaceans (nauplius, zoea, cyprid, megalopa). Examine broods of caprellid amphipods.
Week 9 May 29	1.6 ft 15:17	8:30	**Quiz 8.** Crustacean development. (Instructor and TA: check jelly beakers, pull out eggs, embryos, larvae)
		8:45	**Lab.** Eggs and embryos of hydrozoan medusae and ctenophores. Observe unilateral cleavage (cnidarians or ctenophores) and advanced developmental stages (holoblastula, gastrula, planula) from earlier spawnings of hydromedusae and ctenophores (various species, as available).
		9:45	**Lecture.** Development of cnidarians
		10:15	**Lab.** *Tubularia* - observe male and female gonophores, brooded and released actinula larvae. External brooding in anthozoan *Epiactis prolifera.*
		11:00	**Lecture.** Development of ctenophores
		13:00	**Field trip to boat basin** to collect scyphistomae of *Aurelia aurita,* various hydroids, and plankton (for medusae of Obelia)
		14:00	**Lab.** Observe *Obelia* medusae (from plankton) and hydroids (look for gonozooids at the base of larger colonies). Observe budding medusae in corned polyps (*Coryne* sp., *Sarsia* sp. or related species), as available.

Day	Tide	Time	Activities
Week 10 June 5	-1.9 ft 8:26	8:30	**Quiz 9.** Development of cnidarians and ctenophores.
		8:45	**Lecture.** Development of ascidians. (TA: set up *Distaplia* and other colonial ascidians under bright lights, watch for larval release)
		9:45	**Lab.** Start cultures of solitary ascidians (*Styela spp.*). Remove broods of *Molgula citrina* and *Corella inflata* (as available), and examine cleavage stages, tadpole larvae, metamorphosis. Look for released larvae of colonial ascidians, try to prompt metamorphosis.
		13:00	**Lab.** Observe cleavage in *Styela*. Catch up on other cultures. Polishing up the notebook (organization, labels, scales etc.).
		16:00	LAB CLEAN UP: release remaining healthy animals, wash glassware and set to dry, clean sea tables and desks, put away microscopes and lights, download any files from the class computer.
Week 11 June 12		**9:00**	**FINAL EXAM, NOTEBOOKS DUE**