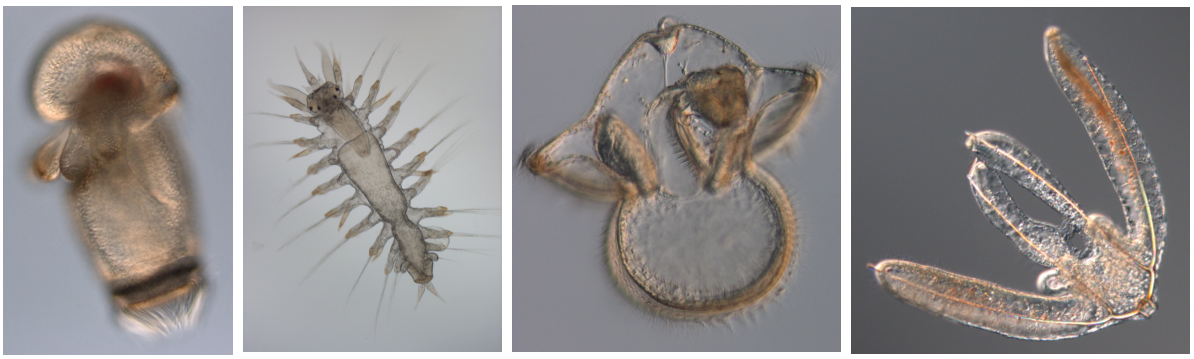

Comparative Embryology and Larval Biology
BI 457/557
OIMB Spring 2016

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, differentiation, morphogenesis, reproductive and developmental strategies, 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: Marie Hunt mhunt@uoregon.edu

Meets: Wednesdays, 8:30 am - 5:00 pm, McConnaughey Lab, OIMB.
We will have a 1 hour break for lunch at noon.

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.

Important note: 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. Because we only meet once a week, but the development goes on in between - students will only be successful in this course if they devote time to observing and caring for cultures outside of regular class hours.

March 30 Echinoderms I (echinoids)
April 6 Echinoderms II (asteroids, ophiuroids)
April 13 Bryozoans
April 20 Spiralians I (mollusks and annelids)

April 27 Spiralians II (nemerteans and flat worms)
May 4 Plankton (including crustaceans)
May 11 Phoronids
May 18 Cnidarians
May 25 Crustaceans
June 1 Ascidians
June 8 Final Exam, Notebooks due

Recommended texts: 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. A few copies will be available in class.

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 which techniques were 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 instructor will review notebooks, and offer individual advice.*

2. Weekly quizzes (18%). Every week we will have a short quiz based on the material learned the previous week. Each of 9 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.

Day	Tide	Time	Activities
March 28-29			*Instructor and TA: start cultures of echinoids (keep some at RT). Clean and set up microscopes, student work stations, imaging station etc.* ***BEFORE: collect sand dollars, urchins, sea stars.***
Week 1 Mar 30	1.0 ft 12:08	8:30	Course orientation: introductions, handouts, Canvas, grading, notebook. **Lab.** Inject sea urchins *Strongylocentrotus purpuratus* and sand dollars *Dendraster excentricus* with KCl to induce spawning. Use and care of microscopes. Making slide preps. Using ocular micrometer. Documenting *normal* development.
		9:30	**Lab.** Fertilization on the slide. Students start individual cultures of both species. TA: start a class culture of *Dendraster* right before lunch and leave at RT.
		10:30	**Lecture.** Fertilization and development in echinoids.
		13:00	**Lab.** Observe and draw: early cleavage stages, micromere formation and advanced stages (started days ahead by instructor and TA: blastula, primary mesenchyme, gastrula, prism).

Day	Tide	Time	Activities
		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
April 4-5			*Instructor and TA: start cultures of asteroids*
Week 2 April 6	0.0 ft 18:25	8:30	**Quiz 1.** Fertilization and development of echinoids.
		8:45	**Lecture.** Oocyte maturation, fertilization in starfish.
		9:00	**Lab.** Inject starfish *Pisaster ochraceus and Evasterias troschelii* with 1-methyl adenine to induce spawning. Excise ovaries and testis. Observe GVBD, fertilization. Start cultures (students choose one or the other, TA - use both).
		10:00	**DEMO:** Taking pictures through the microscope.
		11:00	**Lecture.** Larval development in asteroids, and other echinoderms.
		13:00	**Lab**. Dissect and observe internally brooded embryos of brittle star *Amphipholis squamata.* Externally brooded larvae of six-armed starfish *Leptasterias hexactis*. Observe cleavage in asteroids. **Notebook advice:** students meet individually with instructor to get feedback on their notebooks.
April 11, 12			*Instructor and TA: collect and set aside cyphonautes from plankton, collect Bugula and Schizoporella from Charleston docks. Check for ascidians, flatworms and egg masses. Keep bryozoans in the dark overnight. Keep pilidia from plankton, start pilidial cultures if pilidiophorans are available.* ***TA: ARRANGE WITH DINING HALL - SACK LUNCHES for April 13***
Week 3 April 13	-0.2ft 12:25	8:30	**Quiz 2.** Larval development in echinoderms. *TA: set Bugula, Schizoporella under bright lights, watch for larval release.*
		8:45	**Lecture**. Bryozoan development.
		9:45	**Lab.** Brooded coronate larvae (*Schizoporella*, *Bugula*), planktotrophic cyphonautes larvae, as available

Day	Tide	Time	Activities
		11:00	**Field trip to South Cove** to collect bryozoans (*Crisia sp., Flustrellidra corniculata, Dendrobaenia lichenoides*), gastropod *Calliostoma*, nudibranchs, *Nucella* egg massess, other mollusks as available, polyclad flatworms, *Epiactis*. Assemble WITH RAIN GEAR, RUBBER BOOTS, BUCKETS, BUTTER KNIVES, gardening GLOVES, and SACK LUNCH in front of the open tank area at 11:00.
		14:00	**Lab.** Continue with bryozoans, *Crisia* - polyembryony, brooded pseudocyphonautes of *Flustrellidra* as available. Catch up on echinoderm cultures. *Instructor and TA: set flatworms to lay eggs in clean plastic bags.*
Week 4 April 20	0.5 ft 6:20	8:30	**Quiz 3.** Bryozoan development
		8:45	**Lecture.** Spiral cleavage and nomenclature. **Lab.** During lecture: "bowling" for *Calliostoma* (a gastropod) to induce spawning.
		9:30	**Lab.** Start cultures of *Calliostoma ligatum.* Avoid polyspermy and overcrowding!
		10:30	**Field trip to the large boat basin docks** (bring gloves to protect hands against barnacle cuts) to collect polychaete *Serpula sp.*, nudibranchs (and their egg masses); sample plankton to look for bryozoan cyphonautes, spiralian trochophores and veligers, and various planktonic curiosities (see 'extra credit' list). **Small boat basin** to look for *Pseudoceros* and its egg masses on *Distaplia; collect Styela, Corella, as available.*
		13:00	**Lab**. Observe equal spiral cleavage in *Calliostoma,* and identify cells according to spiralian nomenclature. Start cultures of *Serpula.* Look through plankton.
		14:00	**Lecture.** Equal vs. unequal cleavage. Development of annelids and mollusks.
		15:00	**Lab**. Continue with spiralian cultures. Follow cleavage in *Calliostoma* until 16-cell stage. Gastropod egg masses (*Nucella, Lacuna, Nassarius,* others as available). Observe polar lobe (if available). Continue looking at plankton, examine a trochophore and a veliger. **Note:** *Calliostoma* has non-feeding development. Its cultures are especially prone to bacterial and ciliate infestations and die off. Transfer normal embryos into a clean bowl at each water change. But the shell is very pretty, so they are worth it! These veligers do not swim well - normal ones usually rest on the bottom until they begin to crawl.

Day	Tide	Time	Activities
Week 5 April 27	0.0 ft 10:39	8:30	**Quiz 4.** Spiral cleavage (basics)
		8:45	**Lecture. Flatworm development.**
		9:30	**Lab.** Examine polyclad flatworm egg plates, müller's larvae (as available).
		10:00	**Field trip** to a Mudflat in Charleston to collect *Cerebratulus* and *Micrura* (nemerteans), *Phoronopsis harmeri* (phoronid) and *Owenia collaris* (polychaete).
		13:00	**Lecture. Nemertean development.** *TA - sort nemerteans, and start lab cultures of nemerteans (Micrura, Cerebratulus as available), Owenia.*
		14:00	**Lab.** Students start individual cultures of *Micrura* or *Cerebratulus* (as available) and *Owenia*. Observe advanced pilidium larvae *(started by TA/instructor ahead of time.* Catch up on other cultures - echinoderms, *Calliostoma*, encapsulated veligers, *Serpula*.
Week 6 May 4	0.1ft 5:05	8:30	**Quiz 5.** Spiral cleavage (larval development)
		8:45	**Lecture.** Marine zooplankton.
		9:30	**Boat trip** to collect plankton (led by instructor). Those intolerant of boats — sample plankton off the docks at Charleston Marina (led by TA).
		11:00	Dilute plankton, begin sorting. **Extra credit given for rarities -** finding and keeping alive particularly interesting specimens for show and tell (see the list).
		13:00	**Lab.** Continue looking at plankton with particular attention to the developmental stages of marine invertebrates. Draw at least three different organisms (eggs, larvae) you have not otherwise seen in the course.
May 9-10			*Instructor and TA: check phoronids, collect more of needed (good low tides both days at 9-10 am), start cultures, separate males to release spermatophores.*
Week 7 May 11	-1.0ft 10:55	8:30	**Quiz 6.** Plankton

Day	Tide	Time	Activities
		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 cleavage (morning cultures), advanced developmental stages from cultures started ahead of time, and actinotroch larvae from plankton (as available). Catch up on other cultures.
May 16-17			*Instructor and TA: collect Cnidarians (Tubularia, Obelia, other hydroids, Aequorea, Polyorchis, Phialidium, Mitrocoma, Proboscidactyla, Sarsia; ctenophores, esp. Beroe, Bolinopsis), set in beakers, bowls for eggs, medusae, actinulae. Separate larvae. Collect Styela, Corella, Molgula as available and keep under constant light.*
Week 8 May 18	0.5 ft 5:22	8:30	**Quiz 7.** Development of phoronids
		8:45	**Lecture.** Development of cnidarians
		9:30	**Lab.** Look for eggs and embryos of hydrozoan medusae. Observe unilateral cleavage, as available. Observe advanced developmental stages (holoblastula, planula) from earlier spawnings of hydromedusae.
		11:00	**Field trip to large boat basin docks** to collect hydrozoan polyps (*Tubularia sp., Obelia sp.,* corynids*), Aurelia* scyphistomae, and plankton.
		13:00	**Lecture.** Development of ctenophores
		14:00	**Lab.** Observe *Obelia* medusae (from plankton) and hydroids (look for gonozooids at the base of larger colonies). *Tubularia* - observe male and female gonophores, brooded and released actinula larvae. External brooding in anthozoan *Epiactis prolifera,* as available. Observe budding medusae in corynid polyps (*Coryne* sp., *Sarsia* sp. or related species).
Week 9 May 25	-0.8ft 9:33	8:30	**Quiz 8.** Cnidarian and ctenophore development.
		8:45	**Field trip to Light House beach** to look for brooding crabs (*Cancer spp., Petrolisthes, Hemigrapsus, Emerita analoga*) and gooseneck barnacles (*Policipes polymerus*).

Day	Tide	Time	Activities
		11:00	**Lecture.** Development of crustaceans.
		13:00	**Lab.** Dissect and examine egg lamellae of gooseneck barnacle *Pollicipes polymerus.* Examine crab broods.
		14:00	**Field trip to large boat basin docks** to collect caprellid amphipods and plankton (bring scoops for megalopae).
		15:00	Observe and document larval stages of crustaceans (nauplius, zoea, cyprid, megalopa), brooding copepods and caprellids.
May 31			*Instructor and TA: collect ascidians Distaplia, Botryllus, Botrylloides and keep in the dark. Collect Corella (as available), suspend on floats.*
Week 10 June 1	0.4 ft 3:56	8:30	**Quiz 9.** Crustacean development. *TA: set colonial ascidians under bright lights.*
		8:45	**Lecture.** Development of ascidians.
		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,* metamorphosis in *Molgula*, *Distaplia* and *Botrylloides* (as available). Catch up on other cultures. Polishing up the notebook (organization, labels, scales etc.). LAB CLEAN UP
Week 11 June 8		9:00	**FINAL EXAM, NOTEBOOKS DUE**