

COMPARATIVE INVERTEBRATE EMBRYOLOGY

Zool. 536b, Friday Harbor Laboratories

June 10 - July 13, 2002

Instructors: Billie J. Swalla, George von Dassow, Yale Passamaneck (T.A.)

Lectures: 9:40 AM and 4:00 PM in the Commons near Dorms

Required text:

M. F. Strathmann (1987) *Reproduction and Development of Marine Invertebrates of the Northern Pacific Coast*. Univ. Washington Press. (Royalties to FHL scholarships).

Recommended text:

S. F. Gilbert & A. M. Raunio, eds (1997) *Embryology, Constructing the Organism*. Sinauer.

Changes in schedule for non-spawning in some groups and unexpected opportunities are likely. Day starts about 8:30 on Mon to Sat in Lab 4 for maintenance of cultures or start of new ones.

<u>Tide</u>	<u>Date</u>	<u>Lecture and Lab</u>	<u>Instructors</u>
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(Port Townsend tide times, tide in feet below MLLW)

-2.1 10:25 Mon, 10 June

8:30	Lab Orientation and Purpose of the course in Lab 4	BJS, GvD
9:40:	Film in Commons "A Dozen Eggs"	
10:30	Tour of FHL	YP
11:00	Blanche Bybee on stockroom; buy books and tools	
11:30	Craig Staude on boat and computer use	
11:45	Library - Maureen	
1:00	Lab – Inducing spawning, handling of gametes and embryos, fertilization and first cleavage in sand dollars, <i>Dendraster excentricus</i>	GvD
4:00	Lecture: Echinoid Fertilization and Early Development	GvD
7:00 pm	Lab: Start more Dendraster cultures	

We will have a mixer 'round the sea-tables in Lab 4 while we work

-2.6 11:00 Tue, 11 June

8:30	Check cultures, draw embryos (and each morning hereafter, and every other spare moment between lectures, meals, labs, etc.!)	
9:40	Lecture: Overview of Metazoan Phylogeny	BJS
10:40	Field trip: Argyle Lagoon to collect various invertebrates, including brittle star <i>Amphipholis squamata</i> and turbellarian <i>Kaburakia</i> (take box lunches)	
1:00	Lab: fertilization and cleavage pattern in echinoids <i>Strongylocentrotus purpuratus</i> and <i>droebachiensis</i>	GvD
4:00	Lecture: Evolution of Echinoid Larval Development	BJS

-2.8 11:39 Wed, 12 June

- 9:40 **Lecture:** Oocyte Maturation, the Cell Cycle, and Cytokinesis GvD
10:40 **Field trip:** collect *Ophiopholis* at Snug Harbor (take box lunches) (also collect *Paranemertes* and *Cucumaria*, etc.)
1:00 Lab: asteroids *Orthasterias koehleri*, *Pisaster ochraceus*, *Luidia foliolata*, *Pteraster tesselatus*, as available GvD
4:00 **Lecture:** Fluorescent Probes and Confocal Microscopy GvD
Evening: start cultures of *Ophiopholis*

-2.8 12:20 Thurs, 13 June

- 9:40 **Lecture:** Development with Feeding vs. Non-feeding Larvae BJS
10:40 Lab: Dissect *Amphipholis* to recover brooded embryos
1:00 Lab: holothuroid *Parastichopus californicus*; possibly *Cucumaria*
4:30 **Paper discussion:** Raff, E.C., Popodi, E.M., Sly, B.J., Turner, F.R., Villinski, J.T. and R.A. Raff (1999) A novel ontogenetic pathway in hybrid embryos between species with different modes of development. *Development* 126: 1937-1945.

-2.5 1:05 Fri, 14 June

- 10:40 Lab: Plankton tows in the harbor to look for echinoderm larvae; continue working with echinoderm cultures
1:00 **Field trip:** Nugget trip to dredge for *Boltenia villosa*, *Terebratalia*, et al.

-1.9 1:54 Sat, 15 June

- 8:30 Lab: continue observations of echinoderm embryos and larvae
9:00 Get cars and van in ferry line
10:30 **Field trip:** Padilla bay to collect hemichordates (take box lunches)

Mon, 17 June

- 9:40 **Lecture:** Ascidian Larval Development BJS
10:40 Lab: Solitary ascidians *Boltenia villosa*, *Corella inflata*, et al. BJS
1:30 Lab: Ascidian dechoriation, blastomere separation, fixations BJS
Phalloidin staining, PI nuclear staining, etc. GvD
4:00 **Meeting with Dr. Margaret McFall-Ngai**
10:00 pm Night-light for larvaceans

Tues, 18 June

- 9:40 **Lecture:** Evolution of Tailed vs. Tailless Molgulid Ascidians BJS
10:40 **Field trip:** to Roche Harbor or Fisherman's Bay to collect *Botrylloides*
1:00 Lab: colonial ascidians *Aplidium*, *Distaplia*, *Botrylloides* BJS
Confocal viewing: phalloidin staining, PI nuclear staining, etc. GvD
4:00 Guest Lecturer – Dr. Ed Munro – Analysis of Notochord Morphogenesis in Ascidians

5:00 Discussion with Dr. Ed
10:00 pm Night-light for larvaceans

Wed, 19 June

9:40 **Lecture**: Evolution of Development of Deuterostomes BJS
10:40 Lab: Larvacean development; solitary ascidian metamorphosis BJS
4:00 Guest Lecturer – Dr. Anna DiGregorio – Promoter Analyses of Notochord
Development in *Ciona* Embryos
5:00 Discussion with Dr. DiGregorio

Thurs, 20 June

8:30 Lab: Begin *In situ* hybridization pretreatments BJS
Demonstration on antisense probe preparation
1:00 Lab: Hemichordate spawning and development
4:30 **Paper discussion**: Peterson KJ, Cameron RA, Davidson EH (2000) Bilaterian
origins: significance of new experimental observations. *Dev Biol.* 219:1-17

Fri, 21 June

8:30 Lab: Begin *In situ* hybridization Washes BJS
10:40 Lab: Continue Hemichordate spawning and development
4:00 **Lecture**: Hemichordate Development and Evolution BJS

-1.5 8:57 Sat, 22 June

8:30 Lab: Detection of *In situs* and discussion of results BJS
11:00 **Lecture**: Ascidian Metamorphosis BJS

-2.6 10:17 Mon, 24 June

8:30 **Field trip**: to False Bay to collect *Owenia fusiformis*, *Micrura alaskensis*,
Haminaea vesicula and *Melanochlamys diomedea* and their egg masses, etc.
1:30 Lab: nemertean *Micrura alaskensis*, if obtained in the morning; try spawning
Paranemertes; examine egg masses collected in the morning. GvD
4:00 **Lecture**: Spiral Cleavage and Spiralian Gastrulation GvD

-2.7 10:57 Tues, 25 June

9:30 **Field trip**: to Cattle Point or Lime Kiln for *Calliostoma ligatum*, limpets *Lottia*
and *Tectura*, chitons *Katharina* and *Mopalia*, et al.
1:00 Brief trip to Labs' beach to obtain *Littorina*; place them in tea-buoys
1:30 Lab: start cultures of limpets and *Calliostoma* GvD
4:00 **Lecture**: Variations on the Spiralian Early Developmental Theme among the
Molluscs GvD

-2.4 11:38 Wed, 26 June

9:40 **Lecture**: The Trochophore; Concepts of Larvae GvD

- 10:40 Lab: examine various egg masses and encapsulated eggs; prosobranchs *Fusitriton*, *Ceratostoma*, and *Littorina*, as available; opisthobranchs *Tritonia*, *Haminaea*, *Melanochlamys*, *Archidoris*, *Doridella*, as available
- 1:00 Lab: spawn bivalves *Chlamys* and *Crassostrea* and observe polar lobes; dissect *Transenella tantilla* to recover brooded embryos GvD
- 4:00 Guest Lecturer – Dr. Richard Strathmann – Functional biology of marine invertebrate larvae and evolution of larval forms
- 5:00 Discussion with Dr. Strathmann

-2.0 12:19 Thurs, 27 June

- 8:30 **Field trip**: Nugget trip to collect *Sabellaria cementarium*
- 1:30 Lab: try spawning chitons *Mopalia muscosa* and *Katharina tunicata*; try sipunculan *Phascolosoma* if available GvD
- 4:30 **Paper discussion**: Freeman, G. and J. W. Lundelius (1992) Evolutionary implications of the mode of D quadrant specification in coelomates with spiral cleavage. *J. Evol. Biol.* 5: 205-247
- 10:00 pm Night-light for polychaetes: nereid epitokes, syllids, *Armandia brevis*

-1.4 1:01 Fri, 28 June

- 9:40: **Lecture**: Segmentation and Coeloms GvD
- 10:40 Lab: *Sabellaria cementarium*, *Serpula vermicularis*, other polychaetes (e.g. *Owenia*, *Eudistalia*) if available GvD
- 1:00 Lab: dissect spirorbids to recover brooded embryos

-0.6 1:43 Sat, 29 June

- 8:30 "Field trip" – collect *Ulva* blades by rowboat, pan for acoel *Childia* and look for extruded eggs to see the biggest meiotic spindles in the world; observe *Notoplana* and *Kaburakia* eggs if available; hunt for egg masses of *Vorticeros* on colonies of *Dendrobenia*

Mon, 1 July

- 9:40 **Lecture**: Our Friends the Bryozoans and How to Know Them YP
- 10:40 "Field trip" to the docks to collect bryozoans *Membranipora*, *Dendrobenia*, et al. off the tires; start cultures of *Membranipora*
- 1:00 Lab: continue observations of bryozoans *Dendrobenia*, *Bugula*, *Schizoporella*, as available; observe metamorphosis in released larvae; examine entoprocts if we can find any

Tues, 2 July

- 9:40 **Lecture**: Development in Brachiopods and Phoronids YP
- 10:40 Lab: start cultures of brachiopod *Terebratallia* GvD
- 1:00 Lab: extract brooded embryos from *Phoronis vancouverensis* colonies; start cultures from embryos extruded from oviduct GvD

Wed, 3 July

- 9:40 **Lecture:** Metamorphosis, Cues and Mechanisms BJS
10:40 Lab: continue observations on lophophorate embryos and larvae
4:00 Guest Lecturer – Gary Freeman on evolution of brachiopods
5:00 Discussion with Dr. Freeman
10:00 pm Night-light for chaetognaths

Thurs, 4 July

- Holiday — meaning you get a chance to catch up on your notebook and cultures!
But let's still have a:
1:30 **Paper discussion:** Carre D, Djediat C, Sardet C (2002) Formation of a large Vasa-positive germ granule and its inheritance by germ cells in the enigmatic Chaetognaths. *Development* 129: 661-70
10:00 pm Fireworks! then night-light for chaetognaths with volunteers

Fri, 5 July

- 9:40 **Lecture:** Something Entirely Other, the Chaetognath BJS
10:40 Lab: group effort to find chaetognath *Sagitta elegans* eggs and embryos
4:00 **Lecture:** VASA and Germ Cell Determination BJS

Sat, 6 July

- 9:40 **Lecture:** Cladistic Phylogenetics, Why and How? BJS
10:40 Computer lab with MacClade – What are Chaetognaths?

SUNDAY: Collect ctenophores *Pleurobrachia* and *Bolinopsis* with volunteers, on the dock in daylight and at night light as well

-1.8 9:24 Mon, 8 July

- 9:40 **Lecture:** Development of Ctenophores BJS
10:40 Lab: group effort to find ctenophore embryos
1:30 "Field trip" to dock to collect medusae (including *Stomatoca*, *Proboscoidactyla*, *Phialidium*, *Aequorea*, *Aglantha*, etc. as available) by dipper, and to collect hydroid colonies from tires and straps
2:30 Lab: examine hydroids *Plumularia*, *Tubularia*, etc. as available
4:00 Guest Lecturer – Dr. Claudia Mills – Diversity of Gelatinous Zooplankton
5:00 Reception with Dr. Mills

-2.4 10:01 Tues, 9 July

- 9:40 **Lecture:** Development of Cnidarians GvD
10:40 Lab: observe embryos of hydrozoans
1:00 Lab: try to induce *Anthopleura* and *Stomphia* to spawn

-2.8 10:40 Wed, 10 July

- 9:40 **Lecture:** Early Development of Arthropods GvD

10:40 Lab: continue observations on cnidarian embryos

4:00 Guest Lecturer – Dr. Laura Corley – Polyembryonic Wasps

5:00 Discussion with Dr. Corley

-3.0 11:22 Thurs, 11 July

9:30 **Field trip**: last of the course, best tide of the year! We'll go to Cattle Point to get religion, plus a few specimens of the gooseneck barnacle *Pollicipes* and hopefully some brooding crabs (take box lunches)

2:30 Lab: examine brooded embryos of *Pollicipes*, other crabs as available

4:30 **Paper discussion**: Lartillot N, Lespinet O, Vervoort M, Adoutte A. (2002) Expression pattern of Brachyury in the mollusc *Patella vulgata* suggests a conserved role in the establishment of the AP axis in Bilateria. *Development* 129: 1411-21 – **and** – Arendt D, Technau U, Wittbrodt J. (2001) Evolution of the bilaterian larval foregut. *Nature* 409: 81-5

Fri, 12 July

9:40 LAST LECTURE – To Be Announced

BJS, GvD, YP

10:40 "Field trip" to take plankton tows in the harbor for copepods and crustacean larvae; some look for pycnogonids and brooding amphipods on the floats

Start lab clean up; examine notebooks

Sat, 13 July

Finish cleaning lab: both individual and group areas

(Attendance required until done!!)

11:30 Field trip to release cultures!