Syllabus
Bio 0410: Invertebrate Zoology (2016)

Lectures: Martinos Auditorium (Room 110)
Granoff Center
Monday, Wednesday 11:00 – 11:50

BioMed Building Room 081
Friday 11:00 – 11:50

Laboratory: Wednesday 1:00-3:50
BioMed Center 112C

Monday 1:00-4:00
Granoff Multimedia Lab
(optional, for those preparing animations)

Instructor: Prof. Casey Dunn
http://dunnlab.org
Office: 301 Walter Hall
Email: casey_dunn@brown.edu . Begin the subject of each course related e-mail with "inverts:".
Office hours: Monday 1:00-2:30 pm

Teaching assistants: Alex Damian (alejandro_damianserrano@brown.edu)
Afra Rahman (fnu_afra@brown.edu)
Tristan Reinecke (tristan_reinecke@brown.edu)
Office hours: TBD

Online resources: Canvas - https://canvas.brown.edu/courses/1070424
Course Wiki - http://goo.gl/HqMLh
CreatureCast - creaturecast.org

Readings:
Lecture text: Biology of the Invertebrates, Jan Pechenik (7th edition). Estimated price $218
Lab manual: Instructions for each lab are posted on Canvas by the Monday before the lab
Optional text: Field Guide to the Atlantic Seashore, K.L. Gosner (copies available in lab)
Papers: Several papers will be assigned for class discussion. Links for these papers will be provided one week in advance of discussion.

Course Description
General Orientation to the course
This course focuses on the awesome diversity of animals (all animals are invertebrates, vertebrates are just invertebrates that happen to have a spine). Much of the focus will be

on general themes and concepts that are applicable to the study of any group of organisms, such as phylogenetics (the analysis of relationships between organisms), the study of evolutionary patterns in a comparative context, and the interaction of organisms with their environments. It is, however, an –ology course, these themes will be explored in the context of the actual diversity of animal life on Earth. This course is about both marine and terrestrial animals, though most animal groups live predominantly or exclusively in the ocean.

Animal diversity will be systematically surveyed from a phylogenetic perspective. The animal tree of life provides a biologically relevant organizational framework for what could otherwise seem a laundry-list of facts about worms you never heard of before. Rather than independently consider the attributes of each species, a tree-thinking approach will allow you to organize your knowledge of diversity through a birds-eye view of animal relationships in combination with the examination of where particular changes have occurred on this tree. Throughout this survey, and in dedicated classes that follow it, we will explore a variety of themes that cut across this tree. These include the evolution of lifecycles (including the extremely complex life cycles of many parasites), organ systems (such as the nervous system), and ecological interactions.

The course wiki includes notes from lectures, study guides that TA's and students have contributed to, information about the organisms and sites that we will see on the fieldtrip, and much more. You are encouraged to use it to take notes and organize information while you study. Since it is a derivative resource (based on the lectures and other sources) it is important to evaluate the information in the wiki critically. If there is a mistake in the wiki and you propagate this mistake on an exam, points will be taken off.

Course Goals

At the end of this course you will have a broad perspective on the morphological, functional, and ecological diversity of animals. This will provide a concrete foundation for understanding macro-evolutionary patterns and processes. Beyond animals, this provides a rich framework for approaching and understanding biological diversity in general. The core ideas could be applied to any group of organisms. In particular, the course illustrates phylogenetic biology and evolutionary "tree thinking" through the application of these concepts to animal diversity.

Learning activities and assessments

Class attendance and participation: You are expected to attend all classes, labs, and fieldtrips, and to complete the reading assigned for each day. You are expected to be engaged in the lectures, and be ready to both ask and answer questions on the readings and lecture material.

Book reading assignments: Readings from the textbook will supplement and reinforce the material covered in the lecture. There is a massive body of knowledge regarding animal diversity, and you are not expected to have an encyclopedic knowledge of every bristle on each arthropod limb or tentacle count on jellyfish. But you are expected to use the reading to steep yourself in general broad-scale patterns, and to familiarize yourself with the fundamental attributes of the various groups of organisms we address.

Paper reading assignments: Several papers from the primary literature will be assigned for reading during the course. These will then be discussed in class. You will get a link to the paper one week before we discuss it. These papers will serve to highlight the unique biologies of particular groups of animals, explore their form and function in greater detail, and to introduce you to the structure of a peer-reviewed scientific study and paper.

Exams: There will be three exams, all scheduled during lectures. You will be held responsible for lecture material, reading assignments, and subjects addressed during lab exercises. The subject of the exams will be drawn mostly from the material since the previous exam (or the start of the course, in the case of the first exam), though earlier material may be covered when essential to evaluating newer material. Be sure to have your Banner ID handy to write on your exam.

Quizes: Three 15 minute quiz will be provided. It will have the same scope as the exams in terms of subject material, and will be announced two classes in advance. Be sure to have your Banner ID handy to write on your exam.

Labs: Labs are held weekly, and are a critical component of the class. It is essential that you thoroughly read the exercises that will be performed in the lab, which are outlined in the course reader, before coming to lab.

We will work with live and preserved animals in the lab. It is required that you treat the animals respectfully; no gratuitous harm to the animals will be tolerated. Given the broad diversity of species, mechanisms for anesthesia and euthanasia will vary from lab to lab. The principle mechanisms will rapid chilling by ice, immersion in Magnesium Chloride, and physical methods such as pithing. Buckets with autoclave bags will be provided in each lab for disposal of animal material. These will be autoclaved after the labs. Procedures will be consistent with those described by the American Veterinary Medical Associations (https://www.avma.org/KB/Policies/Pages/Euthanasia-Guidelines.aspx).

The Invertebrates by Sherman and Sherman (S&S) will be used as a reference and source of anatomical diagrams. Some copies are available for sharing in the lab. Field Guide to the Atlantic Seashore by K. Gosner, and Marine Animals of Southern New England and New York by H. Weiss will be used to identify organisms observed on the field trips and in the lab. Invertebrate Zoology Online (http://lanwebs.lander.edu/faculty/rsfox/invertebrates/) will be a source for some lab activities.

You will keep a lab notebook that is distinct from your lecture notes. The content, organization, and presentation of this notebooks will be part of your grade. We will discuss what is expected of a lab notebook during the first lab period. Laboratory notebooks will be collected for grading at the last exam. I suggest using an artist sketchbook as a lab notebook.

Field trips: There will be two field trips. Your participation in these trips will be evaluated in the same way as for labs. The bus for each trip will depart from the corner of Brown St. and Olive St.

Final project: There are two options:

Research paper- A fully cited research paper 6-8 pages in length (do not exceed 8 pages), double spaced in 12-point font. The lists of references do not count towards the page limit (*ie* a 7 page paper could have 3 additional pages of references). For a paper of this length, you should have at least 20 citations. Formatting guidelines, including citation and reference format, should follow those of *American Naturalist*, as described at http://goo.gl/T3fPa. You can browse published articles at http://goo.gl/ixDus to better understand the reference formatting and get a sense of the tone and organization of scientific papers.

Animation- A video episode (1-3 minutes in length) explaining some aspect of invertebrate biology to a general audience. Some videos may be selected for public distribution via creaturecast.org. Visit the site to familiarize yourself with the format. Information on producing a video is available at http://creaturecast.org/making-a-creaturecast-episode. Be sure to take a look at previous episodes (you can browse them at https://vimeo.com/user1747626 as well as http://creaturecast.org) to see what topics have been done before (there is much room for exploring different aspects of stories that have already been covered, but we want to avoid telling the same story in the same way twice). Production quality, as well as content and effectiveness at communicating with the target audience, will be evaluated. Along with the episode, you submit a caption for a general audience (80-300 words) that includes links to music and other resources (see http://creaturecast.org for example captions) and a list of citations to the primary scientific literature that back up each factual assertion in your story.

You must submit a plan for your final project for preliminary evaluation. This is due at the beginning of class on the date indicated on the schedule below. For the paper, the project plan consists of the abstract (250-400 words), with citations for 5 sources from the primary literature that will be used in support of the paper. For an animation, the project plan will consist of a script, the caption, and your citations.

Any content that is included in any final project (be it music in an animation or a figure in a paper) must be original, or available under a license that allows its reuse, such as a http://creativecommons.org license that allows derivative works. You must also attribute the work, *i.e.* by providing a link for music or specifying the source of a figure. It is fine to cite references, such as copyrighted journal articles, that are available under stricter licenses. The license covers the media itself (i.e., the text, sound, or images), not the ideas in the media.

Students are encouraged to discuss their proposed topics with the professor and the TA's in advance of submitting their plan. The topic can be the functional biology or natural history of an organism, the evolution of a particular character or suite of characters, a

review of the state of phylogenetic knowledge of a group, or an ecological examination of a clade or other grouping of animals. Other topics may also be considered if they are discussed well in advance of submitting the project plan. The final projects are due at the beginning of class on the date indicated on the schedule.

Assessment:

Lecture:	3 hour-long exams	20% each
	2 quizzes	1% total
	Final project	20%
	Class participation	2%
Laboratory:		
	Lab participation	5%
	Lab notebook	12%

Credit Hours

Total time spent in and out of class for this course is estimated at ~180 hours. This estimate is based on the following approximation:

Description	**Hours**
Lectures and exams	32
Labs	30
Fieldtrips	13
Final project	45
Reading	45
Material review	15
Total time	**180**

Academic Support

Accessibility and Accommodations: Brown University is committed to full inclusion of all students. Please inform me early in the term if you have a disability or other conditions that might require accommodations or modification of any of these course procedures. You may speak with me after class or during office hours. For more information, please contactStudent and Employee Accessibility Services at 401-863-9588 or SEAS@brown.edu. Students in need of short-term academic advice or support can contact one of the deans in the Dean of the College office.

Campus resources: A list of campus resources can be found at https://www.brown.edu/about/administration/sheridan-center/teaching-learning/teaching-brown/academic-support-brown

Lecture Schedule
Reading is from Pechenik unless otherwise noted. Additional papers from the primary will be assigned throughout the semester.

Date	Class	Reading
7-Sep	Introduction- what are animals?	
9-Sep	Tree thinking- phylogeny and classification	Ch 2, www.sciencemag.org/content/310/5750/979.full.pdf, link.springer.com/article/10.1007%2Fs12052-008-0035-
12-Sep	Animals in their environments	Ch 1
14-Sep	The context: Eukaryotes	Ch 3
16-Sep	A bird's eye view of animal phylogeny and anatomy	
19-Sep	Ctenophores	Ch 7
21-Sep	Sponges	Ch 4
23-Sep	Placozoa, Cnidaria	p. 89-90, Ch 5,6
26-Sep	Cnidaria	Ch. 6
28-Sep	Bilateria Introduction, Acoelomorpha	
30-Sep	Deuterostome Introduction, Hemichordates	Ch 21
3-Oct	Echinoderms	Ch 20
5-Oct	Echinoderms	Ch 20
7-Oct	**Exam One (Through Cnidaria)**	
10-Oct	**No Class (Fall Weekend)**	
12-Oct	Chordates	Ch 23
14-Oct	Chordates; **FINAL PROJECT PLAN DUE**	Ch 23
17-Oct	Biomechanics	Ch 5
19-Oct	Protostome Introduction, Chaetognaths	p. 461-467
21-Oct	Ecdysozoa Introduction, Scalidpohora	Ch 17
24-Oct	Nematoida	Ch 16
26-Oct	Tardigrades and Onychophorans	Ch 15
28-Oct	Arthropods	Ch 14
31-Oct	Arthropods	Ch 14
2-Nov	Predators and Prey	
4-Nov	**Exam Two (through arthropods)**	
7-Nov	Comparative embryology	Ch 24

9-Nov	Spiralia Introduction, Platyhelminthes	Ch 8
11-Nov	Platyhelminthes, Gnathifera, and friends	Ch 10, p. 459-460
14-Nov	Nemerteans, Lophophorates	Ch 11, 19
16-Nov	Annelids	Ch 13
18-Nov	Annelids	Ch 13
21-Nov	Life Cycle Evolution	Ch 24
23-Nov	**No Class (Thanksgiving)**	
25-Nov	**No Class (Thanksgiving)**	
28-Nov	Molluscs	Ch 12
30-Nov	Molluscs; FINAL PROJECT DUE	Ch 12
2-Dec	Animals in Earth History	
5-Dec	Evolution of organ systems	
7-Dec	CreatureCast showing	
9-Dec	**Exam Three**	

Lab and Field Trip Schedule

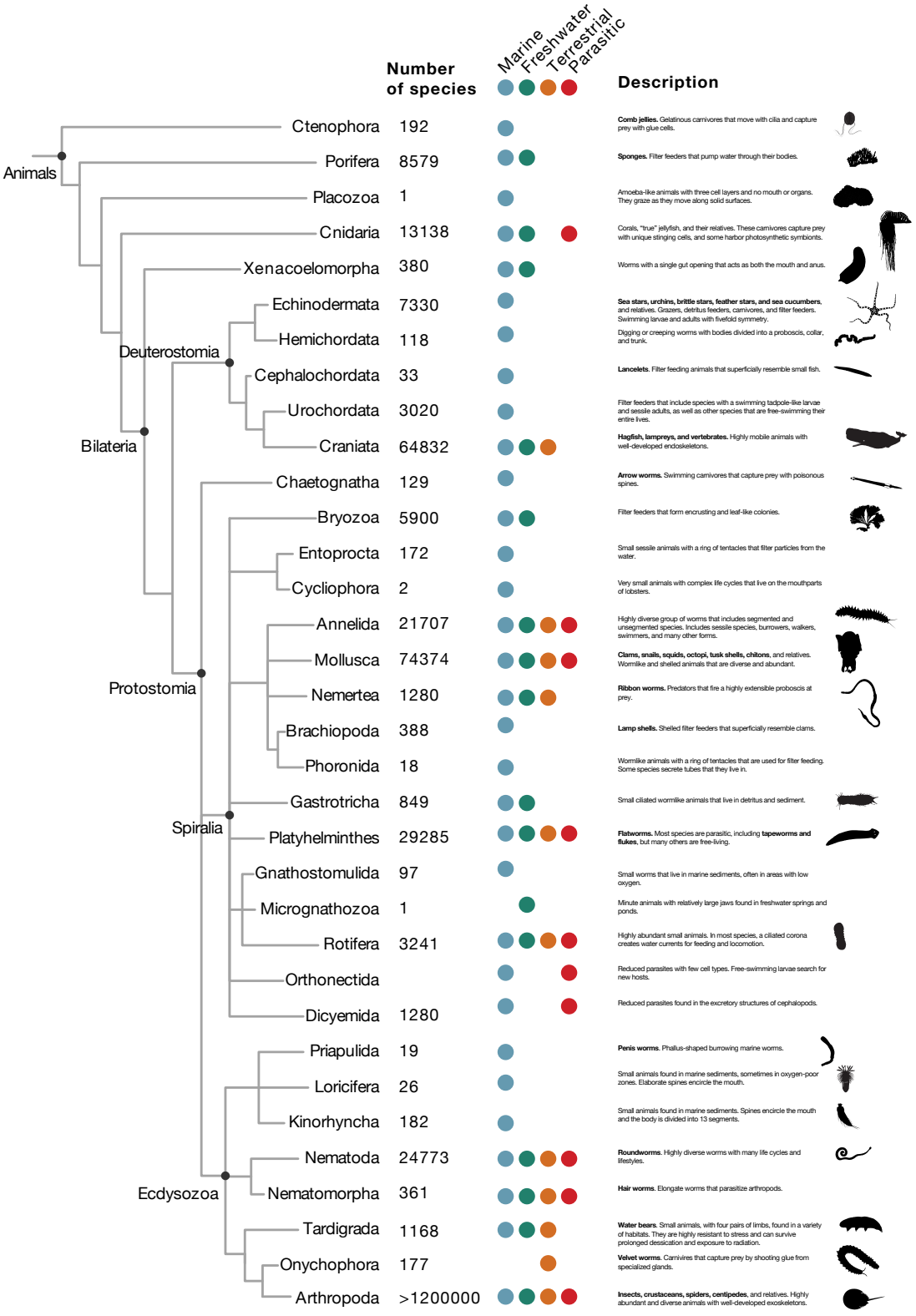
Date	**Lab**	**Notes**
14-Sep	Eukaryotes	
21-Sep	Porifera (Sponges)	
28-Sep	Cnidaria and Ctenophora	
1-Oct (Saturday)	FIELD TRIP TO NARRAGANSETT (low tide 2:10 PM)	Depart from corner of Brown and Olive Street at 11:15 AM, arrive Haffenreffer ~12:00PM, depart 4:00, arrive Brown ~4:45
5-Oct	Environmental samples	
8-Oct (Saturday)	FIELD TRIP TO NAHANT (low tide 10:51 AM)	Depart from corner of Brown and Olive Street at 9:00AM, arrive at Nahant ~10:30AM, Depart 3:00PM, arrive Brown 4:30PM
12-Oct	Deuterostomia	
19-Oct	No lab	
26-Oct	Nematodes, Tardigrades, and Onychophora	
2-Nov	Arthropods	
9-Nov	Flatworms	

16-Nov	Annelids
23-Nov	No lab - Thanksgiving
30-Nov	Molluscs
7-Dec	no lab

The Animal Tree

A phylogeny depicting animal relationships that are broadly supported across studies. Higher resolution image available at http://goo.gl/yNFDTG . From:

Dunn, CW, G Giribet, GD Edgecombe, A Hejnol (2014) Animal Phylogeny and its Evolutionary Implications. Annual Review of Ecology, Evolution, and Systematics 45:371–395.doi:10.1146/annurev-ecolsys-120213-091627.


Marine
Freshwater
Terrestrial
Parasitic
Number of species
Description
Animals
Bilateria
Deuterostomia
Protostomia
Spiralia
Ecdysozoa
Ctenophora 192
Comb jellies. Gelatinous carnivores that move with cilia and capture prey with glue cells.
Porifera 8579
Sponges. Filter feeders that pump water through their bodies.
Placozoa 1
Amoeba-like animals with three cell layers and no mouth or organs. They graze as they move along solid surfaces.
Cnidaria 13138
Corals, "true" jellyfish, and their relatives. These carnivores capture prey with unique stinging cells, and some harbor photosynthetic symbionts.
Xenacoelomorpha 380
Worms with a single gut opening that acts as both the mouth and anus.
Echinodermata 7330
Sea stars, urchins, brittle stars, feather stars, and sea cucumbers, and relatives. Grazers, detritus feeders, carnivores, and filter feeders. Swimming larvae and adults with fivefold symmetry.
Hemichordata 118
Digging or creeping worms with bodies divided into a proboscis, collar, and trunk.
Cephalochordata 33
Lancelets. Filter feeding animals that superficially resemble small fish.
Urochordata 3020
Filter feeders that include species with a swimming tadpole-like larvae and sessile adults, as well as other species that are free-swimming their entire lives.
Craniata 64832
Hagfish, lampreys, and vertebrates. Highly mobile animals with well-developed endoskeletons.
Chaetognatha 129
Arrow worms. Swimming carnivores that capture prey with poisonous spines.
Bryozoa 5900
Filter feeders that form encrusting and leaf-like colonies.
Entoprocta 172
Small sessile animals with a ring of tentacles that filter particles from the water.
Cycliophora 2
Very small animals with complex life cycles that live on the mouthparts of lobsters.
Annelida 21707
Highly diverse group of worms that includes segmented and unsegmented species. Includes sessile species, burrowers, walkers, swimmers, and many other forms.
Mollusca 74374
Clams, snails, squids, octopi, tusk shells, chitons, and relatives. Wormlike and shelled animals that are diverse and abundant.
Nemertea 1280
Ribbon worms. Predators that fire a highly extensible proboscis at prey.
Brachiopoda 388
Lamp shells. Shelled filter feeders that superficially resemble clams.
Phoronida 18
Wormlike animals with a ring of tentacles that are used for filter feeding. Some species secrete tubes that they live in.
Gastrotricha 849
Small ciliated wormlike animals that live in detritus and sediment.
Platyhelminthes 29285
Flatworms. Most species are parasitic, including tapeworms and flukes, but many others are free-living.
Gnathostomulida 97
Small worms that live in marine sediments, often in areas with low oxygen.
Micrognathozoa 1
Minute animals with relatively large jaws found in freshwater springs and ponds.
Rotifera 3241
Highly abundant small animals. In most species, a ciliated corona creates water currents for feeding and locomotion.
Orthonectida
Reduced parasites with few cell types. Free-swimming larvae search for new hosts.
Dicyemida 1280
Reduced parasites found in the excretory structures of cephalopods.
Priapulida 19
Penis worms. Phallus-shaped burrowing marine worms.
Loricifera 26
Small animals found in marine sediments, sometimes in oxygen-poor zones. Elaborate spines encircle the mouth.
Kinorhyncha 182
Small animals found in marine sediments. Spines encircle the mouth and the body is divided into 13 segments.
Nematoda 24773
Roundworms. Highly diverse worms with many life cycles and lifestyles.
Nematomorpha 361
Hair worms. Elongate worms that parasitize arthropods.
Tardigrada 1168
Water bears. Small animals, with four pairs of limbs, found in a variety of habitats. They are highly resistant to stress and can survive prolonged dessication and exposure to radiation.
Onychophora 177
Velvet worms. Carnivires that capture prey by shooting glue from specialized glands.
Arthropoda >1200000
Insects, crustaceans, spiders, centipedes, and relatives. Highly abundant and diverse animals with well-developed exoskeletons.