Zoology 300: Invertebrate Biology and Evolution

Instructor: Prashant Sharma
(608) 890-2346 • psharma37@wisc.edu
Office: 352 Birge Hall
Office hours: By appointment

Teaching Assistant: TBA

3 credits (spring term)

Lectures: Tuesdays and Thursdays 11 AM-12:15 PM

Grading (100 points)

25 pts	Midterm exam
75 pts	Final exam

Grading scale: A (93-100%), AB (87-92%), B (83-86%), BC (77-82%), C (70-76%), D (60-70%), F (<60%).

Overview

This course provides an introduction to invertebrate diversity and biology, with emphasis on anatomy, development, and systematic relationships of the main animal phyla. Phyla are discussed in the context of major themes in animal evolution, such as the origin of tissue layers, the diversity of feeding mechanisms, the evolution of terrestrialization, patterns of diversification through time, and the conservation of transcriptional circuitry. The aim of this course is to understand animal diversity from a phylogenetic and developmental perspective.

Prerequisites: Zoology 101/101, 151/152 or Biocore 381

Course enrollment limit: None.

Learning outcomes

Four major learning outcomes are established for this course.

1. Students will be able to describe the major macroevolutionary trends spanning animal evolution through the Phanerozoic
2. Students will be able to interpret and analyze phylogenetic trees
3. Students will be able to interpret and analyze a gene regulatory network
4. Students will be able to design and execute a statistical test using R programming language

Readings
Mandatory textbooks: None.

Recommended textbooks: The following texts are strongly recommended as helpful resources and/or background reading. These will be placed on reserve at the Memorial and Steenbock Libraries.

Brusca, R. C., Moore, W., and S. M. Schuster. 2016. Invertebrates, 3rd edition. Sinauer Associates, Sunderland.

Gilbert, S. F. and A. M. Raunio. 1997. Embryology: Constructing the Organism. Sinauer Associates, Sunderland.

Minelli, A. 2009. Perspectives in Animal Phylogeny & Evolution. Oxford University Press, Oxford.

Nielsen, C. 2012. Animal evolution: interrelationships of the living phyla, 3rd edition. Oxford University Press, Oxford.

Lectures

Lecture 1: Introduction and general concepts in systematics and evolution

- What are animals?
- Classification and taxonomy
- Themes in metazoan diversity

Readings (mandatory):

Smith, S. A., Wilson, N. G., Goetz, F. E., Feehery, C., Andrade, S. C. S., Rouse, G. W., et al. (2011). Resolving the evolutionary relationships of molluscs with phylogenomic tools. Nature 480, 364–367.

Readings (recommended):

Invertebrates, Chapter 2

Lecture 2: The Cambrian Explosion

- Animal architecture and body plans
- The end of the Ediacaran biota
- Oxygen and complexity

Readings (mandatory):

Sperling, E.A., Wolock, C.J., Morgan, A.S., Gill, B.C., Kunzmann, M., Halverson, G.P., Macdonald, F.A., Knoll, A.H., Johnson, D.T. (2015). Statistical analysis of iron geochemical data suggests limited late Proterozoic oxygenation. Nature doi: 10.1038/nature14589

Readings (recommended):

Invertebrates, Chapter 4

Lecture 3: Multicellularity, complexity, and deep relationships

- Porifera: organization without nervous systems
- Cnidaria: complex life cycles, free-swimming stages, and nervous systems
- The problematic phylogenetic placement of Ctenophora

Readings (mandatory):

Moroz, L.L., Kocot, K.M., Citarella, M.R., et al. (2014) The ctenophore genome and the evolutionary origins of neural systems. Nature 510, 109-114.

Jekely, G., Paps, J., Nielsen, C. (2015). The phylogenetic position of ctenophores and the origin(s) of nervous systems. EvoDevo 6:1.

Readings (recommended):

Invertebrates, Chapters 6-8

Lecture 4: Triploblasty and bilateral symmetry

- Biology and genome of Ctenophora
- Further problematica: Placozoa and *Xenoturbella*
- Nemertodermatida

Readings (mandatory):

Rouse, G.W., Wilson, N.G., Carvajal, J.I., Vrijenhoek, R.C. (2016). New deep-sea species of *Xenoturbella* and the position of Xenacoelomorpha. Nature 530, 94-97.

Readings (recommended):

Invertebrates, Chapter 9

Lecture 5: Spiralia I: The evolution (and loss) of segmentation and appendages

- What is Spiralia?
- Annelids and *Notch* signaling
- Sipuncula and Echiura
- Polychaetes, oligochaetes, and leeches

Readings (mandatory):

Seaver, E.C. (2003). Segmentation: mono- or polyphyletic? Int. J. Dev. Biol. 47, 583-595.

Balavoine, G., Adoutte, A. (2003). The segmentated Urbilateria: A testable scenario. Integr. Comp. Biol. 43, 137-147.

Readings (recommended):

Invertebrates, Chapters 14-15

Lecture 6: Spiralia II: Radical reorganization of body axes

- Mollusca
- Left-right asymmetry and *nodal* signaling

Readings (mandatory):

Martindale, M.Q., Henry, J.Q. (1998). The development of radial and biradial symmetry: the evolution of bilaterality. Am. Zool. 38, 672-684.

Grande, C., Patel, N.H. (2009). *Nodal* signaling in involved in left-right asymmetry in snails. Nature 457, 1007-1011.

Readings (recommended):

Invertebrates, Chapter 13

Lecture 7: Spiralia III: How to survive a mass extinction (without really trying)

- Major mass extinctions and the Sepkoski Curve
- Brachiopods and bivalve mollusks
- Signatures of mass extinctions

Readings (mandatory):

Chen, Z.-Q., Kaiho, K., George, A.D. (2005). Survival strategies of brachiopod faunas from the end-Permian mass extinction. Palaeogeography, Palaeoclimatology, Palaeoecology 224, 232-269.

Readings (recommended):

Invertebrates, Chapter 17

Lecture 8: Spiralia IV: Suspension feeding

- Entoprocta, Phoronida, Bryozoa, and Brachiopoda

Readings (mandatory):

Pratt, M.C. (2008). Living where the flow is right: How flow affects feeding in bryozoans. Integr. Comp. Biol. 48, 808-822.

Readings (recommended):

Invertebrates, Chapter 17

Lecture 9: Spiralia V: Regeneration and resilience

- Platyhelminthes
- Gastrotricha
- Rotifera and Cycliophora

Readings (mandatory):

Baker, J.M., Giribet, G. (2007). A molecular phylogenetic approach to the phylum Cycliophora provides further evidence for cryptic speciation in *Symbion americanus*. Zoologica Scripta 36, 353-359.

King, R.S., Newmark, P.A. (2012). The cell biology of regeneration. J. Cell Biol. 196, 553-562.

Readings (recommended):

Invertebrates, Chapter 15

Lecture 10: Evolution of developmental mode

- Nemertea

Readings (mandatory):

Martindale, M.Q., Henry, J.Q. (1995) Modifications of cell fate specification in equal-cleaving nemertean embryos: alternate patterns of spiralian development. Development 121, 3175-3185.

Martín-Durán, J.M., Vellutini, B.C., Hejnol, A. (2015). Evolution and development of the adelphophagic, intracapsular Schmidt's larva of the nemertean *Lineus ruber*. EvoDevo 6, 28.

Readings (recommended):

Invertebrates, Chapter 12

Lecture 11: Ecdysozoa I

- What are ecdysozoans?
- Ecdysone and molting
- Nematoda, parasitology, and *Caenorhabditis*
- Nematomorpha, Kinorhyncha, Loricifera, and Priapulida

Readings (mandatory):

Matus, D.Q., Chang, E., Makohon-Moore, S., Hagedorn, M., Sherwood, D.R. (2014). Cell division and targeted cell cycle arrest opens and stabilize basement membrane gaps. Nature Commun. 13, 4184.

Readings (recommended):

Invertebrates, Chapters 18-19

Lecture 12: Ecdysozoa II: What is a segment?

- Tardigrada
- Onychophora

Readings (mandatory):

Smith, F.W., Boothby, T.C., Giovannini, I., Rebecchi, L., Jockusch, E.L., Goldstein, B. (2016). The Compact Body Plan of Tardigrades Evolved by the Loss of a Large Body Region. Current Biology 26, 224-229.

Murienne, J., Daniels, S.R., Buckley, T.R., Mayer, G. Giribet, G. (2014). A living fossil tale of Pangean biogeography. Proceedings of the Royal Society B: Biological Sciences 281, 1471-2954.

Readings (recommended):

Invertebrates, Chapter 20

Lecture 13: Ecdysozoa III: The evolution of terrestrialization

- Arthropoda
- The arachnid book lung
- The insect tracheal tubules
- The Malpighian tubule system

Readings (mandatory):

Damen, W.G.M., Saridaki, T., Averof, M. (2002). Diverse adaptations of an ancestral gill: a common evolutionary origin for wings, breathing organs, and spinnerets. Current Biology 12, 1711-1716.

Sharma, P.P., Kaluziak, S.T., Pérez-Porro, A.R., González, V.L., Hormiga, G., Wheeler, W.C., Giribet, G. (2014). Phylogenomic interrogation of Arachnida reveals systemic conflicts in phylogenetic signal. Molecular Biology and Evolution 31, 2963-2984.

Readings (recommended):

Invertebrates, Chapters 23, 24

Lecture 14: Ecdysozoa IV: Flight, co-diversification, and holometaboly

- Insects and mouthpart evolution
- The origin of insect wings
- Detecting co-diversification using dated phylogenies

Readings (mandatory):

Giorgianni, M., Patel, N.H. (2004) Conquering Land, Air and Water: The Evolution and Development of Arthropod Appendages. In: D.E.G. Briggs (ed.) *Evolving Form and Function: Fossils and Development*. New Haven: Peabody Museum of Natural History, Yale University, pp. 159-188.

Readings (recommended):

Invertebrates, Chapters 21, 22

Lecture 15: New axes of symmetry

- Chaetognatha
- Ambulacraria
- The organization of deuterostomes
- The water vascular system

Readings (mandatory):

Telford, M.J., Lowe, C.J., Cameron, C.B., Ortega-Martinez, O., Aronowicz, J., Oliveri, P., Copley, R.R. (2014). Proceedings of the Royal Society B: Biological Sciences 281, 20140479.

Readings (recommended):

Invertebrates, Chapters 11, 25

Lecture 16: The journey of the notochord

- Chordata
- Segmentation revisited
- Neurogenesis and the road to Vertebrata

Readings (mandatory):

Stach, T. (2008). Chordate phylogeny and evolution: a not so simple three-taxon problem. Journal of Zoology 276, 117-141.

Satoh, N., Rokhsar, D., Nishikawa, T. (2014). Chordate evolution and the three-phylum system. Proceedings of the Royal Society B: Biological Sciences 281, 20141729.

Readings (recommended):

Invertebrates, Chapters 26, 27

Lecture 17: Natural history collections and systematic biology in the 21st century

Assignment:

Self-guided tour of the Zoology Museum (complete the graded rubric before end of the week)

Lecture 18: Metazoan phylogeny and molecular techniques

Readings (mandatory):

Dehal, P., Boore, J.L. (2005). Two rounds of whole genome duplication in the ancestral vertebrate. PLoS Biology 3, e314.

Nosenko T., Schreiber, F., Adamska, M., et al. (2013). Deep metazoan phylogeny: When different genes tell different stories. Mol. Phylogenet. Evol. 67, 223-233.

Lecture 19: Metazoan habitat, ecology, and biogeography

Readings (mandatory):

Boyer, S.L., Clouse, R.M., Benavides, L.R., Sharma, P., Schwendinger, P.J., Karunarathna, I., Giribet, G. (2007). Biogeography of the world: a case study of globally distributed arachnids. Journal of Biogeography 34: 2070–2085.

Sharma, P.P., Giribet, G. (2012). Out of the Neotropics: Late Cretaceous colonization of Australasia by American arthropods. Proceedings of the Royal Society of London B: Biological Sciences 279: 3501–3509.

Lecture 20: Emerging non-model organisms in invertebrate evodevo

Readings (mandatory):

Abzhanov, A., Extavour, C.G., Groover, A., Hodges, S.A., Hoekstra, H.E., Kramer, E.M., Monteiro, A. (2008). Are we there yet? Tracking the development of new model systems. Trends in Genetics 24, 353-360.

Sharma, P.P., Schwager, E.E., Extavour, C.G., Wheeler, W.C. (2014). Hox gene duplications correlate with posterior heteronomy in scorpions. Proceedings of the Royal Society of London B: Biological Sciences 281:20140661.