BIOL 4480/6480 Evolutionary Developmental Biology – How to Build an Organism

Monday 3:05 – 4:55 PM; ES&T #L1105

Instructor
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Honor Code: Students are expected to abide by the Academic Honor Code (viewed online at http://www.honor.gatech.edu/).

Course Summary: Evolutionary Developmental Biology

Nobel Laureate Sydney Brenner, recalling Friedrich Nietzsche, said two decades ago that 'genetics is dead.' He meant that biologists have solved the major questions of genetics – what DNA is made of, how it is replicated, transcribed and translated into proteins. He said further that the major questions remaining to solve in Biology were: (i) How does consciousness work? and (ii) How do organisms develop? Our class deals with this latter fundamental question. We are concerned not only with why things stay the same in development (i.e., why a bird develops like a human), but significantly, why and how things are different (i.e., why cavefish populations lack eyes and pigment).

So how does development shape evolution? We can think of evolution as consisting of two steps: 1) the generation of organismal variation in form and function, and 2) the differential survival of variants within a population. The "Modern Synthesis" of the 1930s and 1940s united evolutionary biology and population genetics to explain the origin and maintenance of adaptive variation within populations of species. It's focus, in other words, was on step 2, or the "survival of the fittest." The Modern Synthesis did not, however, identify the specific genetic changes that underlie evolutionary change (or adaptive variation), nor could it account for the origin of novel forms and functions. Evolutionary developmental biology (evo-devo) seeks to compliment the Modern Synthesis by identifying the developmental genetic changes that underlie evolution. The emphasis of evo-devo is on step 1, or the "arrival of the fittest," and is grounded by the idea that changes in evolution are caused by heritable changes in development.

Evo-devo is motivated by many of the same questions first asked by biologists in the late 1800s. How does nature make wings, fins, heads and flowers? What goes wrong in development when disease occurs? Significant technological advances in genomics, molecular biology and developmental genetics have allowed biologists to begin to understand how genes control development, and how development drives evolution.

How This Class Works

1st hour: presentation of general topic from targeted research

2nd hour: detailed discussion of 2-3 focal papers (presenters during first hour are the *de facto* experts for the day).

Class Discussions

Most of our meetings will be devoted to in-class discussion of that day's assigned topic. Thus, all readings should be done before the date for which they are assigned. Assigned research articles will be available for download from T-Square, or will be sent by email. Each day, one group of students will be in charge of leading class. Discussion leaders should come to class with a list of 3-5 main points and 3-5 questions related to that day's topic. These will be used to guide class discussion. Please note that your class participation grade will be based on my assessment of your preparation for, and participation in, class discussions regardless of whether or not you are leading discussion that day. In other words, be prepared for class every day. It is, after all, 20% of your grade!

Undergraduate Student Research Papers

Undergraduate students must turn in a 5-7 page (1.5 line spacing) research paper. Topics for research papers may be an extension of the one you chose for your presentation or it may be entirely separate. Research papers should (i) be a written evaluation of a body of literature, (ii) assess the questions addressed, the underlying assumptions, methods, basis for conclusions, and (iii) provide a synthesis of broader impacts.

Graduate Student Research Papers

Graduate student research paper guidelines will differ from those for undergraduate students as follows:

1. The paper must be 7-10 pages (1.5 line spacing) long.
2. Topics for research papers may be an extension of the one you chose for your presentation or it may be entirely separate; the topic may be close to one's dissertation/thesis topic.
3. The paper must be more than a simple review – one way to do this is to include a specific section titled 'what should be done next' – where the student outlines critical experiments that should logically follow the present state of knowledge.
4. Graduate students will submit drafts of their papers to at least one other graduate student in the class for 'peer review.' Students must turn in their final papers, as well as the comments they received from peer review and a brief outline of how they have responded to comments.

For those of you who are feeling a bit more creative, here is another option for a research paper – *Build me a hypothetical animal*. Take me from the developmental blueprint, through morphogenesis, and finally the production of

the phenotype. This endeavor should be scientifically grounded and based on real processes covered in class or in your readings. **Topics are due October 22, Introduction/Literature reviews are due November 12, and full papers are due December 10.**

Grading

Class Participation and Discussion	**20 points**
Oral Presentation	**20 points**
Research Papers – Intro and Lit Review	**20 points**
Research Papers – Final	**40 points**
Total	**100 points**

The final class grades will be standardized and assigned as follows: A = 90-100%; B = 80-89%; C = 70-79%; D = 60-69%; F = < 60%.

Texts for General Reference

-- *From DNA to Diversity: Molecular Genetics and the Evolution of Animal Design, 2nd edition* (2005) – Carroll SB, Grenier JK, and Weatherbee SD.
-- *Cells, Embryos, and Evolution: Toward a Cellular and Developmental Understanding of Phenotypic Variation and Evolutionary Adaptability* (1997) – Gerhart J, Kirschner M.
-- *The Evolution of Developmental Pathways* (2001) – Wilkins AS.

Schedule (dates, topics and **possible** readings)

August 20 --- Major themes, syllabus, short day (JTS)

August 27 --- **Why things stay the same, why things differ** (JTS)
Readings:
-- Nichols SA, Dirks W, Pearse JS, King N. 2006. Early evolution of animal cell signaling and adhesion genes. *Proc Natl Acad Sci USA* 103:12451-6.
-- Greer JM, Puetz J, Thomas KR, Capecchi M. 2000. Maintenance of functional equivalence during paralogous Hox gene evolution. *Nature* 403:661-5.
-- Streelman JT, Peichel CL, Parichy DM. 2007. Developmental genetics of adaptation in fishes: the case for novelty. *Ann Rev Ecol Evol Syst.* 38:655-681.

September 3 --- **HOLIDAY**

Students lead discussion from here.
September 10 --- **Micro-RNAs and development**
Readings:
-- Plasterk RHA. 2006. MicroRNAs in animal development. Cell 124:877-881.
-- Hornstein *et al*. 2005. The microRNA *miR-196* acts upstream of Hoxb8 and Shh in limb development. Nature 438:671-674.

-- Yekta *et al*. 2004. Micro-RNA-directed cleavage of HOXB8 mRNA. Science 304:594-596.

September 17 --- **Limbs and fins**
Readings:
-- Sears KE, Behringer RR, Rasweiler JJ 4th, Niswander LA. 2006. Development of bat flight: morphologic and molecular evolution of bat wing digits. *Proc Natl Acad Sci USA* 103:6581-6.
-- Panganiban *et al*. 1997. The origin and evolution of animal appendages. *Proc Natl Acad Sci USA* 94:5162-6.

September 24 **--- The evolution of butterfly wing patterns**
Readings:
-- Keys DN *et al*. 1999. Recruitment of a hedgehog regulatory circuit in butterfly eyespot evolution. *Science* 283:532-4.
-- Beldade P, Brakefield PM, Long AD. 2002. Contribution of Distal-less to quantitative variation in butterfly eyespots. *Nature* 415:315-8.

October 1 --- **The evolutionary origin of jaws**
Readings:
-- Gans C, Northcutt RG. 1983. Neural crest and the origin of vertebrates: a new head. *Science* 220:268-74.
-- Cohn MJ. 2002. Lamprey Hox genes and the origin of jaws. *Nature* 416:386-387.
-- Helms JA, Cordero D, Tapadia MD. 2005. New insights into craniofacial morphogenesis. *Development* 132:851-861.

October 8 --- **Snakes**
Readings:
-- Vonk *et al*. 2008. Evolutionary origin and development of snake fangs. *Nature* 454:630-633.
-- Cohn MJ, Tickle C. 1999. Developmental basis of limblessness and axial patterning in snakes. *Nature* 399:474-9.

October 15 --- **HOLIDAY, Fall Break**

October 22 --- **Phenotypic plasticity, induced development**
-- Whitfield *et al*. 2003. Gene expression profiles in the brain predict behavior in individual honey bees. *Science* 302:296-299.
-- Moczek AP, Rose DJ. 2009. Differential recruitment of limb patterning genes during development and diversification of beetle horns. *PNAS* 106:8992-8997.
Paper topics DUE

October 29 --- **How fish get their stripes, bars and spots**
Readings:

-- Parichy DM. 2006. Evolution of danio pigment pattern development. *Heredity* 97:200-10.
-- Maderspacher F, Nusslein-Volhard C. 2003. Formation of the adult pigment pattern in zebrafish requires *leopard* and *obelix* dependent cell interactions. *Development* 130:3447-57.
-- Roberts *et al*. 2009. Sexual conflict resolved by invasion of a novel sex determiner in Lake Malawi cichlid fishes. *Science* 326:998-1001.

November 5 **--- Teeth, feathers, hair**
Readings:
-- Houghton L, Lindon C, Morgan BA. 2005. The ectodysplasin pathway in feather tract development. *Development* 132:863-872.
-- Plikus *et al*. 2008. Cyclic dermal BMP signaling regulates stem cell activation during hair regeneration. *Nature* 451:340-344.
-- Fraser *et al*. 2009. An ancient gene network is co-opted for teeth on old and new jaws. *PloS Biology* 7(2):e31.

November 12 **--- Development of trait loss (fish without fins, fish without eyes and pigmentation)**
Readings:
-- Shapiro *et al*. 2004. Genetic and developmental basis of evolutionary pelvic reduction in threespine sticklebacks. *Nature* 428:717-23.
-- Protas *et al*. 2006. Genetic analysis of cavefish reveals molecular convergence in the evolution of albinism. *Nat Genet*. 38:107-11.
-- Yamamoto Y, Stock DW, Jeffery WR. 2004. Hedgehog signaling controls eye degeneration in blind cavefish. *Nature* 431:844-7.
Paper introductions/literature reviews DUE

November 19 --- **Evolutionary development of the brain (GUEST – Jon Sylvester)**
-- Sylvester *et al*. 2010. Brain diversity evolves via differences in patterning. *PNAS* 107:9717-9723
-- Kiecker C, Lumsden A. 2005. Compartments and their boundaries in vertebrate brain development. *Nature Reviews Neuro*. 6:553-564.
-- Menuet *et al*. 2007. Expanded expression of Sonic Hedgehog in *Astyanax* cavefish: multiple consequences on forebrain development and evolution. *Development* 134:845-855.

November 26 --- **How to make strong bird beaks and fish jaws**
Readings:
-- Abzhanov A, Protas M, Grant BR, Grant PR, Tabin CJ. 2004. *Bmp4* and morphological variation of beaks in Darwin's finches. *Science* 305:1462-5.
-- Albertson RC, Streelman JT, Kocher TD, Yelick PC. 2005. Integration and evolution of the cichlid mandible: the molecular basis of alternate feeding strategies. *Proc Natl Acad Sci USA* 102:16287-92.

December 3 --- **Man's best friend: Diversification of dogs**

Readings:
--- Sutter *et al*. 2007. A single IGF1 allele is a major determinant of small size in dogs. *Science* 316:112-115.
-- Cardieu *et al*. 2009. Coat variation in the domestic dog is governed by variants in three genes. *Science* 326:150-153.

December 7 --- LAST DAY OF CLASS

December 10 --- FINAL EXAMS BEGIN
Research papers due, 5PM

December 17 --- GRADES DUE