Evolutionary Environmental Physiology (IB 150, 3 units, Spring 2016)

Department of Integrative Biology, University of California, Berkeley

COURSE INFORMATION

COURSE FORMAT	Two lectures (1.5h/lecture, 9:30 – 11am Tue/Thu, 110 Wheeler) and one discussion per week (2h, room and time TBA).
INSTRUCTOR	Caroline Williams Office: 5120 VLSB, (510) 643-9775, office hours to be advised Email: cmw@berkeley.edu Webpage: cmwilliamslab.com bCourses site: to be advised
GSI	To be advised (1 requested)
PREREQUISITES	Bio1A and Bio1B or equivalent
ENROLLMENT	Capped at 50 students for first year (8 Teams of 6-7 students), aiming to expand in future years
COURSE OVERVIEW	Evolutionary physiology studies how physiological traits arise and are modified during adaptation to the environment. An integrative understanding of the origin and maintenance of physiological traits, encompassing levels of biological hierarchy from molecular to ecological and biogeographic, is essential for improving human health and stewarding the natural world through the current era of rapid environmental change. This course consists of three parts: 1) big questions in evolutionary physiology and how they are addressed; 2) a student-led exploration of how environmental factors have shaped physiological evolution; and 3) predicting responses to global change using evolutionary physiology. This course will be taxonomically broad and will encompass aquatic and terrestrial systems.
LEARNING OBJECTIVES	This course aims to foster both content-specific knowledge and scientific enquiry and reasoning skills. As a result, this course will stimulate interest in the field of evolutionary physiology, and will also provide a solid preparation for the new (2015) MCAT examination. The specific learning objectives are listed below. **Content-Specific Skills**: Develop the ability to answer the following questions, and illustrate with examples: • What is evolutionary physiology, what unique perspectives does it bring to the study of evolution, and what tools does it employ?

LEARNING OBJECTIVES CONT…

- How is genetic variation transformed into phenotypes, via biochemical and physiological processes; and how do those phenotypes influence fitness and thus genotype frequencies in the next generation?
- How do natural and sexual selection drive physiological evolution, and how are these processes modulated by phenotypic plasticity, resource trade-offs, or physiological constraints?
- What transformations has physiology undergone as organisms have evolved and diversified and as their environments have changed?
- How have organisms responded to some of the primary environmental selective pressures? Are evolutionary responses to these selective pressures predictable? What are the mechanisms and consequences of these responses?

Scientific Enquiry and Reasoning Skills:

- Integrate and synthesize material from a variety of sources
- Analyze evidence, form inferences, evaluate strength of inferences
- Graphical analysis and interpretation
- Interpret common inferential statistics used in this field

METHODS OF INSTRUCTION

Lecture, discussion, team work, student-led seminars, independent study.

ASSESSMENT

	% of Final Grade	Due date
Pre-lecture exercises	10	Every lecture
Topic synthesis exercises	10	After each discussion
Midterm	15	Week 6
Team seminars on physiological adaptation	15 (grade weighted by team maintenance score)	Week 6 - 11
Discussion section exercise (on seminar topic)	10 (grade weighted by team maintenance score)	Week of seminar
Essay (on seminar topic)	15 (individual)	Week 13
Final exam	25	Finals week

STRUCTURE OF TEAM SEMINARS AND ASSIGNMENTS	Diverse teams will be formed at the beginning of the course and will select a topic from the following list: (1) Hypoxia and hyperoxia, (2) Ocean acidification, (3) Thermal tolerances, (4) Thermal effects on energetics, (5) Regulation of dormancy, (6) Cross-seasonal consequences of fluctuating selection, (7) Desiccation tolerance in terrestrial organisms, (8) Osmoregulation in aquatic animals. Up to four discussion periods are available throughout the semester for teams to meet to synthesize literature and prepare a one hour presentation on the topic that will be presented during lecture periods (see schedule). Out of class time can also be used for preparation. Presentation must be evaluated by instructor one week before presentation date. Presentations will be evaluated based on the learning outcomes above, and weighted by team maintenance scores assigned by team members (contributions to the team). The team will provide a discussion exercise to accompany that unit which they will lead the class through during one discussion period. Individual essays on the seminar topic will be due at the conclusion of the course, and will be evaluated for fulfillment of learning outcomes.
REQUIRED READING	No single text is adequate for this course. Instead, weekly readings will be made available via bCourses (consisting of textbook chapters, review articles, and primary literature articles, listed after the schedule below). Worksheets must be completed prior to each class to assess comprehension of this material (10% total grade).
SUPPLEMENTARY READING	Two textbooks will be placed on closed reserve at the library and will be available for purchase from the bookstore if desired: Hill RW, Wyse GA, Anderson M (2012) Animal Physiology. Sinauer Associates, Sunderland, MA, USA. Martin LB, Ghalambour CK, Woods A (2015) Integrative Organismal Biology. John Wiley and Sons, Hoboken, NJ, USA.

COURSE SCHEDULE

1 Big questions in evolutionary physiology

1.1 Introduction to evolutionary physiology

Guiding questions: What is evolutionary physiology, what unique perspectives does it bring to the study of evolution, and what tools does it employ?

WEEK 1 Lecture 1 – Introduction to evolutionary physiology and its role in medicine[1,2]
Lecture 2 – Evolutionary physiology toolkit 1 – understanding how genotype and environment influence physiological traits (textbook?)
Discussion – Form teams, choose topics

WEEK 2 Lecture 3 - Evolutionary physiology toolkit 2 – the comparative method[3]

1.2 Interactions among genotype, phenotype, physiological performance, and fitness

Guiding question: How is genetic variation transformed into phenotypes, via biochemical and physiological processes; and how do those phenotypes influence fitness and thus genotype frequencies in the next generation?

Lecture 4 – Enzyme polymorphisms – controlling nutrient flow through pathways[4]
Discussion – Meet in teams (seminar prep)
WEEK 3 Lecture 5 – Regulatory polymorphisms – controlling when, where and how much genes are expressed[5]

1.3 Role of evolutionary processes in engendering or limiting physiological evolution

Guiding question: How do natural and sexual selection drive physiological evolution, and how are these processes modulated by phenotypic plasticity, resource trade-offs, or physiological constraints?

Lecture 6 – Detecting adaptation[6,7]
Discussion – Meet in teams (seminar prep)
WEEK 4 Lecture 7 – Physiological plasticity[8]
Lecture 8 – Trade-offs and constraints in physiological evolution[9]
Discussion 1 – Mapping genotype to phenotype using evolutionary physiology

1.4 Historical, ecological and phylogenetic patterns of physiological evolution

Guiding question: What transformations has physiology undergone as organisms have evolved and diversified and as their environments have changed?

WEEK 5 Lecture 9 – Major physiological transitions (endothermy, flight, multicellularity)[10-13]
Lecture 10 – Evolution of quantitative traits (locomotor performance, growth and development, energetics)[14]

2 Environmental influences on physiological evolution

Guiding questions: How has physiology responded to some of the primary environmental selective pressures? Are evolutionary responses to these selective pressures predictable? What are the mechanisms and consequences of these responses?

2.1 Oxygen and carbon dioxide

WEEK 6 Lecture 11 – Physiological and evolutionary responses to oxygen and carbon dioxide (Animal Physiology textbook chapter?)
Lecture 12 – Hypoxia and hyperoxia (Team 1 presentation)[8,15]
Discussion – Meet in teams (seminar prep)
WEEK 7 Lecture 13 – Ocean acidification (Team 2 presentation) [16-18]
Midterm

2.2 Temperature

Lecture 15 – Thermal physiology[19]
Discussion 2 – Evolutionary impact of oxygen and carbon dioxide

WEEK 8 Lecture 16 - Thermal tolerances (Team 3 presentation)[20]
Lecture 17 – Thermal effects on energetics (Team 4 presentation)[21-23]
Discussion 3 – Evolutionary responses to temperature

2.3 Seasonality

WEEK 9 Lecture 18 – Physiological responses to seasonal fluctuations
Lecture 19 – Regulation of dormancy (Team 5 presentation)[24-26]
Discussion – Meet in teams (seminar prep)

WEEK 10 Lecture 20 – Cross seasonal consequences of fluctuating selection (Team 6 presentation)[27,28]

2.4 Water balance

Lecture 21 – Osmoregulation and water balance physiology (Animal Physiology chapter?)
Discussion 4 – Evolutionary responses to seasonality

WEEK 11 Lecture 22 – Desiccation tolerance in terrestrial organisms (Team 7 presentation)[29]
Lecture 23 – Osmoregulation in aquatic animals (Team 8 presentation) (sticklebacks etc)
Discussion 5 – Evolutionary water balance optimizations

3 Global change – can evolutionary physiology help predict the future?

WEEK 12 Lecture 24 – Global change predictions and impact on physiological systems[30]
Lecture 25 – Mechanistic models[31,32]
Discussion 6 – Predicting biotic impacts of climate change

WEEK 13 Lecture 26 – Case study: Willow leaf beetles in the Sierra Nevada mountains[33]
Lecture 27 – Final review session
Discussion – Exam preparation

READINGS

1 Feder, M. E., Bennett, A. F. & Huey, R. B. Evolutionary Physiology. *Annu.Rev.Ecol.Syst.* **31**, 315-341, doi:10.2307/221735 (2000).

2 Garland, T., Jr. & Carter, P. A. Evolutionary physiology. *Annu Rev Physiol* **56**, 579-621, doi:10.1146/annurev.ph.56.030194.003051 (1994).

3 Rezende, E. L. & Diniz-Filho, J. A. Phylogenetic analyses: comparing species to infer adaptations and physiological mechanisms. *Compr Physiol* **2**, 639-674, doi:10.1002/cphy.c100079 (2012).

4 Dalziel, A. C., Rogers, S. M. & Schulte, P. M. Linking genotypes to phenotypes and fitness: how mechanistic biology can inform molecular ecology. *Mol Ecol* **18**, 4997-5017, doi:10.1111/j.1365-294X.2009.04427.x (2009).

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9 Zera, A. J. & Harshman, L. G. in *Mechanisms of Life History Evolution: the genetics and physiology of life history traits and trade-offs* (eds T. Flatt & A. Heyland) (Oxford University Press, 2011).
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12 Paweł Koteja. The Evolution of Concepts on the Evolution of Endothermy in Birds and Mammals. *Physiological and Biochemical Zoology* **77**, 1043-1050, doi:10.1086/423741 (2004).
13 Dudley, R. The evolutionary physiology of animal flight: paleobiological and present perspectives. *Annu Rev Physiol* **62**, 135-155, doi:10.1146/annurev.physiol.62.1.135 (2000).
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15 Milo, R., Hou, J. H., Springer, M., Brenner, M. P. & Kirschner, M. W. The relationship between evolutionary and physiological variation in hemoglobin. *Proceedings of the National Academy of Sciences* **104**, 16998-17003, doi:10.1073/pnas.0707673104 (2007).
16 Pan, T.-C. F., Applebaum, S. L. & Manahan, D. T. Experimental ocean acidification alters the allocation of metabolic energy. *Proceedings of the National Academy of Sciences*, doi:10.1073/pnas.1416967112 (2015).
17 Clarkson, M. O. *et al.* Ocean acidification and the Permo-Triassic mass extinction. *Science* **348**, 229-232, doi:10.1126/science.aaa0193 (2015).
18 Sunday, J. M. *et al.* Evolution in an acidifying ocean. *Trends in Ecology & Evolution* **29**, 117-125, doi:http://dx.doi.org/10.1016/j.tree.2013.11.001 (2014).
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20 Barrett, R. D. H. *et al. Rapid evolution of cold tolerance in stickleback.* (2010).
21 Clarke, A. Costs and consequences of evolutionary temperature adaptation. *Trends Ecol.Evol.* **18**, 573-581, doi:10.1016/j.tree.2003.08.007 (2003).
22 Frazier, M. R., Huey, R. B. & Berrigan, D. Thermodynamics constrains the evolution of insect population growth rates: "Warmer is better". *American Naturalist* **168**, 512 (2006).
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33 Dahlhoff, E. P. *et al.* Effects of temperature on physiology and reproductive success of a montane leaf beetle: implications for persistence of native populations enduring climate change. *Physiological and biochemical zoology : PBZ* **81**, 718-732, doi:10.1086/590165 (2008).