INTEGBIO 177LF – Ichthyology: an introduction to the scientific process through research on fishes (4 units)

Letter grade.

Prerequisites: Basic background in ecology and evolution (e.g. AP Bio or BIO 1B) or permission of instructor. Open to first-year, non-major, and transfer students.

To be offered every: **Fall**
Course title: **Ichthyology: an introduction to the scientific process through research on fishes**
Abv Title: **Fish Research**
Unit Value: **4**
Instructor: **Christopher Martin**
Office: **3186 VLSB**
Office hours: Friday 2-4 or by appointment.
Please contact me if you cannot meet during the times listed here. I am happy to meet with you!
Email: chmartin@berkeley.edu
Instructional Format: **Lecture, Lab**
Tentative schedule: T/Thurs 10-11:30am lecture, Tuesday 2 – 5pm lab
Final Assessment: An individual written scientific research paper and group presentation, one midterm, one lab anatomy practical.
Reading Materials: No textbook required. Student discussion and presentation of weekly topical readings from the primary literature (attached below) including both classic and recent papers.
Prerequisites: *Basic background in ecology and evolution (e.g. AP Bio or BIO 1B) or permission of instructor.*

Course description:

Did you know that our closest living fish relative can build a cocoon and hibernate for three years? Or that some fish make a living by eating scales? This class will conduct publishable research in evolution, ecology, and behavior by doing actual science on fishes. We will attempt to answer unknown questions about the evolution of fascinating adaptations in diverse groups of fishes in both the laboratory and field.

Course objectives:

This class is meant to be an introduction to research through ichthyology: students are not expected to have any prior research experience. The primary focus throughout the semester will be on independent group projects conducting laboratory and field experiments testing hypotheses about our focal fish groups: scale-eating pupfish, sponge-eating cichlids, cocoon-building lungfish, Monterey kelp forest communities, and four-eyed fishes. By focusing on these diverse study systems, students will receive a broad perspective on how to investigate and test hypotheses about adaptation in the field and lab. The class will include three field trips, high-speed video of prey capture, and detailed studies of behavior, ecology, and functional morphology.

Student Learning Outcomes:

Students will be taught how to generate original hypotheses, collect and analyze data in the R statistical programming language, discuss scientific literature, present their research, and publish their results. Students will ask their own independent research questions and conduct experiments to answer them. Lecture topics will focus on the evolution, ecology, behavior, anatomy, and biodiversity of fishes, with an introduction to concepts including adaptationism, natural selection, convergent evolution, exaptation, tree thinking, evolutionary novelty, behavioral ecology, applications to human health, and conservation.

Assessment:
Lab Assignments/lab participation/weekly quizzes/lab and field notebook: 20%
Midterm: 20%
Lab practical (group anatomy project): 10%
Final Project: 50%

- individual written paper 25%
- group presentation and participation 25% (rubric: group data collection effort: 10%, group engagement: 10%, contribution to final presentation: 5%)

Instructor: Christopher Martin is broadly interested in the ecology and evolution of organismal diversity. In grad school he developed two new integrative case studies for studying speciation and adaptation genomics: adaptive radiations of Caribbean pupfishes and Cameroon crater lake cichlids. His work at Cal focuses on further study of the evolution, ecology, genomics, functional morphology, and quantitative genetics of these fascinating examples of evolution-in-action.

Readings: There is no required textbook. Readings from the primary literature and/or popular press for each week's discussion will be posted to bCourses.

In-class assignments: I will collect in-class assignments and assign online reading quizzes from time to time. These will often be based on the weekly assigned reading of a relevant scientific paper but will also sometimes relate directly to your research project (e.g., written brainstorming ideas, one-page specific research aims, and figure sketches).

There will also be a group anatomy/curatorial project (this is the lab practical) distinct from the research project to aid in learning fish anatomy, such as a labeled and prepared fish skull or μCT scan (e.g. here: https://sketchfab.com/3d-models/micropterus-salmoides-uf-34881-skull-01ad5b1d8ea540eda8d3a5777a3532d5), cleared and alizarin-stained specimen, or four-bar linkage model.

Final paper and presentation: You will write up your results in a scientific manuscript format (2,000 words main text, 2-4 figures) at the end of the semester. This final paper will take the place of a final exam in the course. In addition, your group will give a 15 minute scientific talk on your findings to the class and prepare a meme, gif, or infographic for social media to communicate your findings to the public.

Letter grades will be determined at the end of the semester. Course letter grades are based on total scores following the above rubric. Please note that this course is heavily weighted (50%) toward the final research project, which includes a written paper and group presentation, and in general overall participation and engagement in the laboratory group projects and discussion. Attendance at all labs is mandatory with excused absences allowed (preferably no more than one); however, students must attend to participate and contribute to the group efforts.

Final exam justification: No final exam is required for this course. This allows students to focus on writing their research papers, which is the main graded assignment for this course. The midterm (given in November) will cover all course material while the final weeks of the course will focus on preparing the final research project and paper.

Course Goals:
To introduce you to the process of science through the study of fishes.
The lecture and the reading material will provide the basic content. You will gain hands on experience with evolutionary ecology thinking, learn how to formulate testable hypotheses, design experiments to test them, and analyze the data that you collect in the R statistical programming language. You will read scientific literature and learn to write like a scientist. After this class, you will be prepared to do research in a lab on campus and to build upon this content with other advanced courses in Integrative Biology.

You will acquire basic laboratory techniques and skills needed to test hypotheses about adaptations in the field and laboratory. You will develop a novel, hypothesis-driven question, design an experiment that allows you to answer it, collect data, and interpret your findings.

You will learn scientific communication by writing a paper and giving a talk with your lab partners to the class about your science.

You will learn to communicate the relevance of the science. For example, you will read and discuss journal articles on evolutionary novelty to understand the bigger picture surrounding the science you are doing.

Final exam period:
The final paper and presentation will act in lieu of a final exam.
Papers due by email to instructor before the time of the final exam.

Course Policies:
Assignments turned in late, but before the correct answers are discussed, will incur a 25% penalty on the final grade. Homework turned in afterwards but before the final exam, will incur a 50% penalty on the final grade.

Honor code:
Students are encouraged to work together on discussing papers, collecting, analyzing, and interpreting data, but must submit an independent write-up of their final paper.

The student community at UC Berkeley has adopted the following Honor Code: “As a member of the UC Berkeley community, I act with honesty, integrity, and respect for others.” The hope and expectation is that you will adhere to this code.

Collaboration and Independence: Reviewing lecture and reading materials and studying for exams can be enjoyable and enriching things to do with fellow students. This is recommended. However, unless otherwise instructed, homework assignments are to be completed independently and materials submitted as homework should be the result of one’s own independent work.

Plagiarism: To copy text or ideas from another source without appropriate reference is plagiarism. For additional information on plagiarism and how to avoid it, see, for example:
https://www.lib.berkeley.edu/research-support/cite-sources#Plagiarism

http://gsi.berkeley.edu/teachingguide/misconduct/prevent-plag.html

Academic Integrity and Ethics: There is no tolerance for dishonesty in the academic world, for it undermines what we are dedicated to doing – furthering knowledge for the benefit of humanity. Your experience as a student at UC Berkeley is hopefully fueled by passion for learning and replete with fulfilling activities.

Tentative Course Schedule

08/27/2020	**Introduction to the class, grading, and fish study systems** Case study: San Salvador Island pupfishes (Cyprinodontidae: *Cyprinodon*) Reading: Moczek 2008. On the origins of novelty in development and evolution. ***Bioessays.***
LAB	Generating scientific hypotheses: Krogh's principle, applied vs. basic science Practice focal observations of fishes in teams. Brainstorming research questions. Class divided into small groups. Supervised tour of fish facilities.
09/01/2020	**Discuss: Evolution, Natural Selection** Case study: scale-eating (lepidophagy) in fishes Generating scientific hypotheses: literature vs. fieldwork-inspired questions Reading: Darwin, Chapter 4, *On the Origin of Species* https://www.gutenberg.org/files/1228/1228-h/1228-h.htm#link2H_4_0006
09/03/2020	**Discuss: Adaptation** Case study: four-eyed fishes (Anablepidae and Mugilidae) Generating scientific hypotheses: Tinbergen's proximate vs. ultimate questions Reading: Janovetz 2005 Functional morphology of feeding in the scale-eating specialist *Catoprion mento*. ***Journal of Experimental Biology.***
LAB	Class divided into small groups. Rotating supervised measurements of prey capture kinematics, external anatomy, stomach content analysis. Data analysis: introduction to data entry in Google spreadsheets.
09/08/2020	**Discuss: Phylogenetics / Vertebrate (fish) tree of life** Case study: lungfish (Dipnoi) Class activities: explore the TimeTree app Generating scientific hypotheses: phylogeny-based questions Reading: Chen Mayden 2010. A phylogenomic perspective on the new era of ichthyology. ***BioScience.***
09/10/2020	**Discuss: Tree thinking** Case study: hagfish and lampreys (Craniata) Class activity: make a geneology/tree from a set of objects
LAB	Group research projects: brainstorming, pitch project ideas, divide into final groups. Preliminary data collection.

	Scientific process: how to read and search the literature.
Tentative Saturday field trip:	Field sampling of local stream/inshore fish diversity. Possibility: Codornices Creek. Use of seine net, waders, field identification of fishes, iNaturalist app.
09/15/2020	**Discuss: Exaptation** Case study: lungfish (Dipnoi) Generating scientific hypotheses: experiment vs. observation Reading: Gould and Lewontin 1979. The spandrels of San Marco and the Panglossian paradigm: a critique of the adaptationist programme. ***Proceedings of the Royal Society of London B.***
09/17/2020	**Discuss: Adaptive radiation** Case study: cichlids (Cichlidae) Generating scientific hypotheses: the case study approach Reading: Kocher 2004. Adaptive evolution and explosive speciation: the cichlid fish model. ***Nature Reviews Genetics.***
LAB	Preliminary data collection for group research projects. Informal research proposal pitch to instructor and GSI. *Scientific process: How to write a research grant proposal.*
09/22/2020	**Discuss: Homology** Case study: hyomandibula/mammalian inner ear Reading: excerpts from 'Your Inner Fish' by Neil Shubin Reading: Longo et al. 2013. Homology of lungs and gas bladders: insights from arterial vasculature. ***Journal of Morphology.***
09/24/2020	**Discuss: Convergent evolution** Case study: sawfish (Chondrichthyes: Rhinopristiformes), saw sharks (Pristiophoridae), and thresher sharks (Alopiidae) Reading: Muschick et al. 2012. Convergent evolution within an adaptive radiation of cichlid fishes. ***Current Biology.***
LAB	**One-page research proposals due: NIH specific aims format.** *Scientific process: peer-review, discuss examples.* In-class peer review of research proposals. Data collection for group research projects.
Tentative Saturday field trip:	Monterey Bay: tidepooling and underwater ROV transects.
09/29/2020	**Discuss: Evolution of novelty** Case study: internal fertilization in tetras (Characiformes: Glandulocaudinae) Introduction to clearing and staining specimens / skeletal preparation / fish skull anatomy.

	Reading: Martin and Wainwright 2013. On the measurement of ecological novelty: scale-eating pupfish are separated by 168 my from other scale-eating fishes. ***PLOS ONE.***
10/01/2020	**Discussion: Vertebrate animal research** Case study: ray-finned fishes (Actinopterygii) Guest visit from Office of Laboratory Animal Care staff. Reading: Christine Lattin: Animal rights group targets young researcher for first time. https://www.sciencemag.org/news/2017/09/peta-versus-postdoc-animal-rights-group-targets-young-researcher-first-time
LAB	Data collection for group research projects. Data analysis: Introduction to R programming environment / data import
Tentative Thursday laboratory trip:	California Academy of Sciences Ichthyology collection: guided tour, potential for data collection, and Steinhart Aquarium trip.
10/06/2020	**Discuss: Genome-Morphology-Performance-Fitness relationship** Case study: lobe-finned fishes (Sarcopterygii) Generating scientific hypotheses: 'completing the circle' Reading: Arnold 1983 Morphology, performance and fitness. ***American Zoologist.***
10/08/2020	**Discuss: Suction-feeding in fishes** Case study: slingjaw wrasse (*Epibulus insidiator*) and all teleost fishes Reading: Wainwright et al. 2007. Suction feeding mechanics, performance, and diversity in fishes. ***Integrative and Comparative Biology.***
LAB	Data collection for group research projects. Data analysis pipeline: high-speed videos of pupfish feeding using DLTdataviewer http://biomech.web.unc.edu/dltdv/
10/13/2020	**Discuss: the adaptive landscape** Case study: San Salvador Island pupfishes (Cyprinodontiformes: *Cyprinodon*) Data analysis: principles of data visualization Readings: Martin and Wainwright 2013. Multiple fitness peaks on the adaptive landscape drive adaptive radiation in the wild. ***Science.*** Carl Zimmer's popular press summary of this research: Watching Fish Climb Darwin's Mountain.
10/15/2020	**Discuss: speciation** Case study: stickleback (Gasterosteidae) Readings: Colosimo et al. 2005. Widespread parallel evolution in sticklebacks by repeated fixation of ectodysplasin alleles. ***Science.***

LAB	Data collection for group research projects. *Writing a scientific paper: methods/results*
10/20/2020	**Discuss: sympatric speciation** Case study: Cameroon/Nicaraguan/Tanzanian crater lake cichlids (Cichlidae) Readings: Richards et al. 2019. Searching for sympatric speciation in the genomic era. ***BioEssays.***
10/22/2020	**Discuss: water-to-land / fin-to-limb transition** Case study: Tiktaalik (Sarcopterygii: Elpistostegidae) Reading: Kawano and Blob. 2013. Propulsive forces of mudskipper fins and salamander limbs during terrestrial locomotion: implications for the invasion of land. ***Integrative and Comparative Biology.***
LAB	Data collection for group research projects. Data analysis: introduction to data visualization in R.
Tentative Saturday field trip:	American River fish sampling/collecting trip. Potential for sponge-sampling and invertebrate prey collection for class projects on dietary specialization and prey detection.
10/27/2020	**Discuss: Parental care in fishes** Case studies: Cichlidae, Kurtosidae, Syngnathiformes Reading: Sutton and Wilson. 2019. Where are all the moms? External fertilization predicts the rise of male parental care in bony fishes. ***Evolution.***
10/29/2020	**Discuss: sexual selection in fishes** Case study: bower-building cichlids and pufferfish (Cichlidae/ Tetraodontiformes) Reading: York et al. 2018. Behavior-dependent cis-regulation reveals genes and pathways associated with bower-building in cichlid fishes. ***Proceedings of the National Academy of Sciences.***
LAB	Data collection for group research projects. Data analysis: Introduction to statistical testing in R
11/03/2020	**Discuss: fish as models for human disease and aging** Case study: annual killifishes (Nothobranchiidae) Reading: Albertson et al. 2009. Evolutionary mutant models for human disease. ***Trends in Genetics.***
11/05/2020	**Discuss: fish novel sensory powers: lateral line system and electric sense** Case study: South American and African electric fishes (Gymnotiformes and Mormyridae) Reading: Carlson et al. 2011. Brain evolution triggers increased diversification of electric fishes. ***Science.***

LAB	Data collection for group research projects. Curatorial methods: extended fish skull anatomy, clearing and staining, microCT scans, and skeleton preparations.
11/10/2020	**Discuss: open discussion – student-selected topic at beginning of semester** Case study: priapium fish (Phallostethidae)
11/12/2020	**Discuss: many-to-one mapping / four-bar linkage** Case study: wrasses (Labridae) Reading: Wainwright et al. 2005. Many-to-one mapping of form to function: a general principle in organismal design? ***Integrative and Comparative Biology.***
LAB	Data collection for group research projects. Data analysis: R workshop (customized for each research group).
11/17/2020	Midterm review: vertebrate tree of life, tree-thinking, fish functional morphology and anatomy
11/19/2020	**Midterm**
LAB	Data collection for group research projects. *Writing a scientific paper: introduction/discussion* Data analysis: R workshop (customized for each research group).
11/24/2020	**Discuss: conservation genomics / ex situ conservation** Case study: Devil's Hole pupfish (*Cyprinodon diabolis*) Reading: Deacon and Williams 2002. Ash Meadows and the legacy of the Devils Hole pupfish. https://books.google.com/books?hl=en&lr=&id=6ScsDwAAQBAJ&oi=fnd&pg=PA69&dq=devils+hole+pupfish&ots=kEz4Gu_29o&sig=xvQNAUTGgB4CAs_WiF3PU97bVJk#v=onepage&q=devils%20hole%20pupfish&f=false
11/26/2020	Thanksgiving holiday.
LAB	Finish data collection for group research projects. Data analysis: Introduction to bootstrap resampling / null distributions in R
12/01/2020	**Discuss: sustainable fishing practices** Case study: bluefin tuna (Scombriformes: Scombridae) Writing a scientific paper: abstracts. Peer review: abstracts Reading: Meyers and Worm 2003. Rapid worldwide depletion of predatory fish communities. ***Nature.***
12/03/2020	**Discuss: climate change, ocean acidification**

	Case study: Mola mola (Tetraodontiformes: Molidae) **Gyotaku exercise** – the Japanese art of fish printing. 
LAB	Open lab
12/08/2020	Student research presentations
12/10/2020	Student research presentations
	Final research papers due during scheduled final exam time (TBD)