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**
Group: **B (Ecology, Behavior, and Diversity)**
Instructor: **Christopher Martin**, Assistant Professor and Curator of Ichthyology, Department of Integrative Biology and Museum of Vertebrate Zoology, lab website: http://ib.berkeley.edu/labs/martin/
pronouns: he/his
Office: **3186 VLSB**
Office hours: by appointment Monday, Thursday, or Friday afternoons.
Please feel free to contact me any time. I am happy to meet with you!
Course Fee: **$0**
Email: chmartin@berkeley.edu
Instructional Format: **Lecture, Lab**
Course Schedule: Two lectures per week, 1.5 hours per lecture, 3-hour lab
Schedule: T/Thurs 10-11:30am lecture, Tuesday 2 – 5pm lab
Location: VLSB 3030
Final Assessment: An individual written scientific research paper and group presentation. Please see the course document 'Individual and group assignments' for all assignments for this class.
Target enrollment: 1 section, 20 students (1 GSI).
Classroom: wet lab with bench space for experiments for both lecture and lab (planned for VLSB 3030)
Reading Materials: No textbook required. Student discussion of weekly topical readings from the primary literature 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 experiments testing hypotheses about focal fish groups: scale-eating pupfish, sponge-eating cichlids, cocoon-building lungfish, four-eyed fish, flying fish, and more. 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 four field trips and detailed studies of evolution, behavior, biomechanics, and ecology.

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 evolutionary concepts including adaptationism, natural selection, convergent evolution, exaptation, tree thinking, evolutionary novelty, behavioral ecology, applications to human health, and conservation.

Assessment:
Individual assignments:
1. Written project proposal (10%) leading to 10-page double-spaced final research paper (20%)
2. Classroom/group participation and contributions to research (10%)
3. Quizzes/short answers on the weekly readings (15%)
4. Fish identifications during participation in 2 out of 3 field trips (10%)

Midterm: short answers covering selection, adaptation, phylogenies, statistics (15%)
Group assignments:
1. Research proposal presentation (15 min) (5%)
2. Final class presentation (15 min) (5%)
3. Final 'curatorial' project: preparing and labeling a fish skull (10%)

Instructor: Chris Martin is broadly interested in the ecology and evolution of organismal diversity. His lab has developed new integrative case studies for studying speciation and adaptation: 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, developmental 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: There will be approximately weekly quizzes or assignments related to discussion during class or lab periods.

One-page individual research proposal: NIH specific aims format. You will write a research proposal summary following the format of the National Institutes of Health. This will include a one-paragraph introduction to the topic, citing 10 references, a second paragraph with a clear statement of your hypothesis, and then 2-3 specific 'aims' or research objectives, stating the data you plan to collect and the methods used to collect and analyze your data in a few sentences. This proposal should be limited to one page for full credit.

Final paper and presentation: You will write up your results in a scientific manuscript format (at least 2 figures, one statistical analysis, and 20 references cited) 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 12 minute scientific talk on your findings to the class and prepare a meme 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 weighted 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. It is important to attend as many lab periods as possible to successfully participate and contribute to the group efforts, however, no one will be penalized for absences due to sickness, quarantine, fires, or other reasons and we will come up with alternate assignments if needed.

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 the majority of the course material while the final weeks of the course will focus on R statistical programming and writing the final research 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 experimental design 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 your 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 on bcourses or by email to instructor before end of exam week.

Course Policies:
Request an extension if you need to turn in an assignment late. If you are too sick or without access to email, it is also ok to not send an email and we can figure out alternate assignments when you return. I will reach out if you are missing from class/lab for an extended period.

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 research proposal and final paper and complete the midterm independently in class.

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.” My 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 should be the result of one’s own independent work (e.g. answers to quiz questions on the assigned readings).

Course policy on AI: AI chatbots and all other forms of machine learning are acceptable and encouraged for drafting your research proposals and writing code. However, you are still responsible for the accuracy of your writing, references, and code. A final paper generated entirely by AI is essentially zero effort and a failing grade, so you will need to substantially revise and use the AI as a tool to improve your writing and code.

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
For the purposes of this course, I do not consider AI-generated text to be plagiarism, however you should always acknowledge your use of AI. Please note that other

professors may consider AI-generated text or code to be plagiarism so please always ask and check the policies for each course.

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 a passion for learning.

Tentative Course Schedule:

Class 1	**Introduction to the class, grading, and fish study systems** Case study: San Salvador Island pupfishes (Cyprinodontidae: *Cyprinodon*)
LAB	**Brainstorming research questions.** Generating scientific hypotheses: Krogh's principle, Tinbergen's proximate vs. ultimate questions, integrative case studies ('building the pyramid') Reading: Tinbergen's questions Class divided into small groups. Individual meetings with teams interested in different research topics.
2	**Discuss: Evolutionary novelty** Case study: Naso unicornfishes and scale-eating (lepidophagy) in fishes *Scientific process: how to read and search the literature.*
3	**Discuss: Why study fishes?** Case study: Deep-sea anglerfishes (Lophiiformes: many families!) Reading: Darwin, Chapter 4, *On the Origin of Species* https://www.gutenberg.org/files/1228/1228-h/1228-h.htm#link2H_4_0006
LAB	Continued brainstorming sessions. Small group discussions with instructor. Class divided into small groups. Data analysis: introduction to data entry in Google spreadsheets.
4	**Discuss: Phylogenetics / Vertebrate (fish) tree of life** Case study: lungfishes (Dipnoi) Class activities: explore the TimeTree app, Treebase, UCSC genome browser Generating scientific hypotheses: phylogeny-based questions

	Reading: Smith et al. 2005. Tree-thinking. Chen Mayden 2010. A phylogenomic perspective on the new era of ichthyology. ***BioScience.***
5	**Discuss: Convergent Evolution** Case study: four-eyed fishes (Anablepidae and Mugilidae) 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.*** Reading: Arnold 1983 Morphology, performance, and fitness. ***American Zoologist.*** Reading: Stayton 2019
LAB	Group research projects: brainstorming, pitch project ideas, divide into final groups. Preliminary data collection for group research projects. Informal research proposal pitch to instructor and GSI.
6	**Discuss: Adaptation/Exaptation** Case study: lungfish (Dipnoi) *Scientific process: How to write a research grant proposal.* 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.***
7	**Discuss: Adaptive radiation** Case study: cichlids (Cichlidae) [time for group proposal presentations] **INDIVIDUAL RESEARCH PROPOSALS DUE (5-minute lightning talks): suggested due date today.** **One-page NIH specific aims format.** *Scientific process: peer-review, discuss examples.* Peer review of research proposals.

	Reading: Kocher 2004. Adaptive evolution and explosive speciation: the cichlid fish model. ***Nature Reviews Genetics.***
8	Research group progress meetings with instructor and GSI. [additional time for group presentations]
9	**Discuss: Suction-feeding, jaw protrusion, and pharyngeal jaws.** Case study: Percomorphs, moray eels, cichlidae Introduction to fish skull anatomy. Reading: Janovetz 2005. Scale-biting. Mehta 2007. Science.
10	**Discuss: Homology / morphospace occupation / many-to-one mapping / four-bar linkage** Case study: hyomandibula/mammalian inner ear Case study: hagfish and lampreys (Craniata) 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.*** 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.***
LAB	Research group progress meetings with instructor and GSI.
11	**Discuss: Kelp forest community ecology and trophic cascades** Case study: sheepshead 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.***
12	**Discussion: Vertebrate animal research** Case study: ray-finned fishes (Actinopterygii) Guest lecture 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	Research group progress meetings with instructor and GSI. Data analysis: Introduction to R programming environment / data import
13	**Discuss: Conservation genetics / Devil's Hole pupfish** Case study:
14	**Special guest lecture:** **Dr. Jennifer Gumm, U.S. Fish and Wildlife Refuge manager for the Devil's Hole Pupfish in Death Valley National Park** **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	Research group progress meetings with instructor and GSI.
15	**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.
LAB	Special lab session: Joint class with Professor Ashton Wesner **Anti-colonialism in field research** with focus on Cameroon crater lake cichlids.
16	**Discuss: speciation** Case study: stickleback (Gasterosteidae) Readings: Colosimo et al. 2005. Widespread parallel evolution in sticklebacks by repeated fixation of ectodysplasin alleles. ***Science.***

17	**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.*** *Writing a scientific paper: methods/results*
18	**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	Research group progress meetings with instructor and GSI.
19	**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.*** *Writing a scientific paper: methods/results* Data analysis: introduction to data visualization in R.
20	**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.*** Data analysis: Introduction to statistical testing in R
LAB	Research group progress meetings with instructor and GSI.

21	**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.***
22	**Discuss: fish superpowers: 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	Research group progress meetings with instructor and GSI.
23	**Discuss: open discussion – student-selected topic** Case study: priapium fish (Phallostethidae) *Writing a scientific paper: introduction/discussion*
24	
LAB	Research group progress meetings with instructor and GSI. Data analysis: R workshop (customized for each research group).
25	Open class – flexible.
26	Open class – flexible.
LAB	Research group progress meetings with instructor and GSI. Data analysis: R workshop (customized for each research group).
27	**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 Guest lecture: Dr. Jennifer Gumm, U.S. Fish and Wildlife Service. Director of the Ash Meadows Fish Conservation Facility containing the only refuge population of the Devil's Hole pupfish.

	Thanksgiving holiday.
LAB	Research group progress meetings with instructor and GSI. Data analysis: Introduction to bootstrap resampling / null distributions in R **Discuss: climate change, ocean acidification** Case study: Mola mola (Tetraodontiformes: Molidae)
28	Student research presentations
29	Student research presentations
LAB	 **Gyotaku exercise** – the Japanese art of fish printing.
	Final research papers due on bcourses or by email to me by the final day of the exam period.