Lecturer: Dr. K. S. Cole (Office: Edmondson 416)
Contact: colek@hawaii.edu Office Phone: 808-956-8618
Lectures: Tues - Thurs TBA
Office Hours: Tuesday & Thursday, 9:00 AM-11:00 AM, and by appointment.
Credits: 3
Additional Material: Will be provided on the course web site as needed.
Required Items: Personal laptops will be useful for most class sessions.
Mandatory Academic Requirements: Pre-requisite: Biology 265.
Notes and Attendance: Attendance is mandatory. Students who miss more than 10% of the lectures may be barred from writing the final, and will automatically receive an incomplete grade.
Classroom Policies: Students are expected to support a safe, civil, learning and working environment in which the dignity of every individual, and the rights, privileges and property of others, are respected. Students are also expected to maintain standards of personal integrity that are in harmony with the educational goals of the institution. Cheating, plagiarism or other academic misconduct is grounds for immediate failure. Details of campus policies can be reviewed at: http://www.catalog.hawaii.edu/about-uh/campus-policies1.htm
Grading Scale: 90-100% = A; 80-89% = B; 70-79% = C; 60-69% = D; less than 59% = F.
Grading Apportionment: 2 midterms and a final exam
Midterm 1 - 25% (covers approximately first third of lecture-associated material)
Midterm 2 - 35% (covers approximately second third of lecture-associated material)
Final - 40% (cumulative from the beginning of the course, with an emphasis on untested material).

Preamble
Where did modern fishes come from and how did they get there? These are the questions that are addressed in this course. Unlike a fish systematics course, which surveys the biodiversity of all fishes according to their phylogenetic relationships, this course focuses on the origins of different lineages. Working through the geological time scale, this course examines the nature of morphological innovations that have led to divergence and adaptive radiation among early fishes. Each transition serves as a focal point for an in-depth discussion on how specific morphological innovations have arisen, and with what results. This provides the opportunity to explore not only evolutionary successes, but also evolutionary failures, as revealed in a detailed fossil record. By the end of this course, students will have a deeper understanding of the early history of fishes, and how novel character traits underlie the development of entirely new taxonomic lineages.
LECTURE SCHEDULE AND TOPICS

Week 1. The Geology of Fishes
- A review of the geological time scale; fossil dating and reconstruction
- The Burgess Shale and the GoGo Formation

Week 2. The Cambrian: Origins of the Chordates
- Protochordates and early chordates of the Cambrian
- What is the notochord and why is it important?
- Chordate-craniate transition: Haikouichthys, and Pikaia
- Candidate for the earliest vertebrate: Conodonta; the origin and function of the cranium; the importance of neural crest cells; HOX duplication

Week 3. Late Cambrian and Early Ordovician: Earliest Fishes – The Ostracoderms. Part 1
- Early agnathans: the ostracoderms - first fishes with well-developed bony tissues
- Construction, variation in morphology, and function of head shields
- Advanced agnathans: galeaspids and osteostracids; the advent of pectoral fins

Week 4. Late Cambrian and Early Ordovician: Earliest Fishes – The Ostracoderms. Part 2
- Hagfish and lamprey: primitive, or advanced with reductive loss? Uncertain origins within the Agnatha. Pharyngeal skeleton - origins and innovations
- Origins of jawed fishes: thelodonts versus osteostracants; a ontogenetic link between sclerotic eye bones and lower jaw formation
- The (late) Ordovician Extinction Event (OEE)

Week of first midterm

Week 5. Silurian-Devonian: First Jawed Fishes. Part 1
- Post-OEE reflooding of continental shelves and rebounding of biodiversity
- Early gnathostomes: the placoderms – first fishes with jaws (stem gnathostomes);
- Origins of the upper and lower jaw; morphological elements; embryonic origins; associated gene expression; placoderm jaws versus modern bony fish jaws

- Placoderm radiation in the Devonian. Origins of pectoral and pelvic fins and associated girdles. The first appearance of true teeth
- Internal fertilization, intra-uterine embryonic development and first placenta-like embryo support

Week 7. Silurian-Devonian: First Jawed Fishes. Part 3
- Basal antiarch Silurolepis, antiarchs and arthrodires
- Devonian: the Hangenberg event and the end of the placoderms; anoxic event possibly related to a rapid sea-level fall due to the last phase of the Devonian Southern Hemisphere glaciation
- Dermal exoskeleton fates

Week 8. Silurian: The Origins of Cartilaginous Fishes and their Major Lineages. Part 1
- The story of dermal denticles, shark teeth, and their fossil record: the earliest chondrichthyan
- Cartilage as the primary dense connective tissue: how do bone and cartilage differ?
- Are cartilaginous fish traits primitive or advanced?

- Early Devonian: the shark-form makes its first appearance; possible thelodont sister
relationship

- Late Devonian: internal fertilization, an independently evolved reproductive trait?
- Devonian-Permian 'shark' radiation; extraordinary body forms and morphological innovations

**Week of the second midterm**

Week 10. Silurian: The Origins of Cartilaginous Fishes and their Major Lineages. Part 3
- Carboniferous: rise of the holocephalans
- Jurassic: the flattening of the chondrichthyan body form into skates and rays
- Late Mesozoic formation of the modern shark taxa

Week 11. Silurian-Devonian: the Origins of the “Spiny Sharks", the Acanthodians
- Distinguishing morphological traits; armored and non-armored forms
- Hypothesized relationships and origins
- Divergent morphologies associated with active predation and filter-feeding

Week 12. Late Silurian: Origins & Radiation of Bony Fishes, the Osteichthyans. Part 1
- The development of a completely ossified internal skeleton
- New advances in the gill arches and associated musculature
- An esophageal diverticulum: swim bladders and lungs

Week 13. Late Silurian: Origins & Radiation of Bony Fishes, the Osteichthyans. Part 2
- The modern fish jaw
- Hypothesized stem Osteichthyans, *Andreolepis* and *Lophosteus*

Week 14. The Big Split: Lobe-finned and Ray-finned Fishes. Part 1
- Origins of ray-finned fishes, the actinoperygians
- Extensive adaptive radiation: why so successful?
- Reductionism and mobility

Week 15. The Big Split: Lobe-finned and Ray-finned Fishes. Part
- Origins of lobe-finned fishes, the sarcopterygians
- Rhipidistians, coelacanth and lungfish
- Lungfish innovations. A short walk to land

**FINAL EXAMINATION:** May __, 2015. Time TBA

**STUDENT LEARNING OUTCOMES**

As a result of participating in this course, students should be able to:

1. Identify major fish taxa according to shared traits (knowledge)
2. Describe morphological innovations associated with early evolutionary divergences among major fish lineages (knowledge)
3. Describe underlying processes associated with morphological changes discussed in class (comprehension)
4. Present supporting arguments for interpretations of, and current hypotheses for, the proposed evolutionary history of fishes (comprehension)
5. Critically evaluate information obtained from primary and secondary sources in independent assignments (evaluation) related to fish evolution