ANATOMY AND FUNCTION OF MARINE VERTEBRATES
SHOALS MARINE LABORATORY, BIOSM 321
GENERAL INFORMATION AND SYLLABUS, SUMMER 2011
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Introduction

Welcome to **Anatomy and Function of Marine Vertebrates (AFMV),** a 3-credit course on the structure, function, and evolution of vertebrates that live in or near marine environments. Rather than focusing only on the description of anatomical structure, the anatomy of structures will be integrated with analyses of function, biological role, and evolution. Marine vertebrates include hagfishes, lampreys, cartilaginous and bony fishes, sea turtles, crocodilians, marine lizards and snakes, many groups of birds, and marine mammals. Of the more than 50,000 living species of vertebrates, more than 15,000 species are marine or marine-associated. In this course, you will review the diversity of these animals and learn to think in terms of their 500 million year history.

Fieldwork includes an offshore trip to collect hagfish, local fishing, a whale watch, and seal study at Duck Island.

Laboratory exercises cover osteology, dissection, behavior and biomechanics. We study many species, possibly including hagfish (*Myxine*), sea lamprey (*Petromyzon*), sharks (*Squalus*, *Mustelus* and others), skates (*Leucoraja* or others), teleosts (*Gadus*, *Myoxocephalus*, *Pseudopleuronectes*, *Scomber* and others), sea turtles (*Caretta* or *Chelonia*), crocodilians (*Alligator*), seabirds (*Larus*, *Gavia*, *Phalacocrorax* and others), muskrats (*Ondatra*), mink (*Mustela*), seals (*Phoca*, *Halichoerus* and others), walrus (*Odobenus*), dolphins (*Lagenorhynchus*, *Tursiops* and others), porpoises (*Phocaena*) and whales (*Balaenoptera*, *Megaptera* and others). We explore how these animals are adapted for life in aquatic environments and how they meet basic functions for living, such as eating, breathing, swimming, flying and reproducing. Then, we will link these functions to their behavior and ecology.

This course uses a comparative systems approach, which means that we compare organ systems across the series of animals that we study. Lecture and laboratory materials are tightly integrated. We begin with vertebrate origins, diversity, and embryology and then study each of the ten organ systems: 1. integumentary; 2. skeletal; 3. muscular; 4. nervous; 5. endocrine; 6. digestive; 7. respiratory; 8. circulatory; 9. excretory; and 10. reproductive.

The daily schedule will be adjusted as needed to allow time for field trips, guest lectures, and other trips. We will actively collect vertebrate skeletal material. Bring a bucket or bag on all walking trips around the island.

Textbook and readings

The text is *Functional Anatomy of the Vertebrates* by K. F. Liem, W.E. Bemis, W.F. Walker, Jr. and L. Grande (3rd edition; 2001, Harcourt, Philadelphia). ***Reading assignments are listed in this handout.*** You will work through most chapters of the book during this course, so it is extremely important to learn how to use it. You cannot sit down and casually read this text: it requires effort and practice. Use its index and glossary. Do not become bogged down by terminology. If you cannot remember terms as you read them, then write them down. ***Learn to dissect words as well as animals.*** Your efforts will be rewarded now and in the future. If you have questions or problems, see us early!

We may assign articles in scientific journals and books that will either be available in the SML library or on — line from Cornell University.

Tentative Lecture and Laboratory Schedule

Day	Date	Topics [Chapter Assignments in FAOV]	
Mon	**July 25**	**Introduction and Vertebrate Phylogeny [1 — 3]**	
		3:30 — 3:45	Introductions and Welcome! (meet in Hamilton)
		3:45 — 4:30	Overview of Vertebrate Phylogeny (WEB)
		4:30 — 6:00	Get settled
		6:00 — 6:30	Dinner
		7:00 — 8:30	**Island tour**
		8:30 — 9:30	Perceptions of Anatomy (Commons)
Tue	**July 26**	**Development and Integument [4, 6]**	
		7:30 — 8:00	Breakfast
		8:00 — 9:00	Overview of Embryology (FEF)
		9:00 — 12:30	Lecture: Integument (FEF)
		12:30 — 1:00	Lunch
		1:30 — 2:30	Film: ***Signals for Survival*** (Hamilton; film and discussion)
		2:30 – 4:00	Project introductions
		4:00 — 6:00	Lecture: Hard Tissues (FEF)
		6:00 — 6:30	Dinner
		6:30 — 8:00	Lecture: Osteology (FEF)
		8:00 — 9:30	Study
Wed	**July 27**	**Skeleton [7 - 9]**	
		7:30 — 8:00	Breakfast
		8:00 — 10:30	**Hagfish pick up (RV Heiser)**
		10:30 — 11:00	Hagfish Preparation
		11:00 — 11:30	Quiz 1 (25 points)
		11:30 – 12:30	Lecture: Osteology (FEF)
		12:30 — 1:00	Lunch
		1:00 — 2:00	
		2:00 — 6:00	Seal Watch
		6:00 — 6:30	Dinner
		7:00 — 9:30	**Lab: Amphioxus, Hagfish and Fish External Anatomy (FEF)**
Thu	**July 28**	**Muscles [10 — 11]**	
		7:30 — 8:00	Breakfast
		8:00 — 10:30	Lecture: Osteology (FEF)
		10:30 — 12:30	Lecture: Muscles and movement (FEF)
		12:30 — 1:00	Lunch
		1:30 — 3:00	Lecture: Fluid Dynamics (FEF)
		3:00 — 6:00	Lab: Shark Dissection and Skeletal preparation
		6:00 — 6:30	Dinner
		7:00 — 9:00	Buoyancy and Locomotion (FEF)

Fri	**July 29**	**Locomotion [11]**	
		7:30 — 8:00	Breakfast
		8:00 — 8:30	Quiz 2 (25 points)
		8:30 — 12:30	Lecture: Locomotion (FEF)
		12:30 – 1:00	Lunch
		1:30 — 6:00	**Trawling**
		6:00 — 6:30	Dinner
		7:00 — 8:30	Study and Review
Sat	**July 30**	**Sensory [12 — 14]**	
		7:30 — 8:00	Breakfast
		8:00 — 11:00	Study and Review
		11:00 — 12:30	Exam I
		12:30 — 1:00	Lunch
		1:30 — 3:30	Lecture: Sensory Systems (WEB)
		3:30 — 6:00	Lecture: Biology and conservation of Coelacanths (WEB)
		6:00 — 6:30	Dinner
		7:00 — 9:00	**Fishing**
Sun	**July 31**	**Internal anatomy: Feeding and digestion [16]**	
		10:00 — 11:00	Brunch
		11:00 — 12:30	Evolution of Mammalian Teeth (WEB)
		12:30-1:00	Lunch
		2:00 — 3:00	Lecture: Bluefish teeth (WEB)
		3:00 — 5:00	Lab: Bird & Reptile Anatomy
		5:00 — 5:30	Dinner
		6:00 — 8:30	Seal Dissections
Mon	**August 1**	**Respiration and Circulation [18 - 19]**	
		7:30 — 8:00	Breakfast
		8:00 — 8:30	Quiz 3 (25 points)
		8:30 — 10:00	Respiration (WEB)
		10:00 — 11:30	Circulation (FEF)
		11:30 — 12:30	Study/project time
		12:30 — 1:00	Lunch
		1:00 — 3:00	Lab: Dolphin dissection
		3:00 – 4:00	Food capture, processing and digestion [FEF]
		4:00 — 6:00	Study/project time
		6:00 — 6:30	Dinner
		7:00 — 8:30	Project discussion time (one-on-one planning)
Tue	**August 2**	**Excretory and reproductive systems [20 — 21]**	
		7:30 — 8:00	Breakfast

		8:00 — 8:30	Quiz 4 (25 points)
		8:30 — 10:30	Lecture: Excretory systems (FEF)
		10:30 — 12:30	Lecture: Reproductive systems (FEF)
		12:30 — 1:00	Lunch
		1:30 — 3:00	Lecture: Diving Adaptations (FEF)
		3:00 — 4:30	**Seal Trip**
		4:30 — 6:00	Project time
		6:00 — 6:30	Dinner
		7:00 — 8:30	Project time
Wed	**August 3**	**Whale Watch**	
		7:30 — 8:00	Breakfast
		8:00 — 11:00	Study and review
		11:00 — 4:00	**Whale Watch**
		4:00 — 6:00	Project time
		6:00 — 6:30	Dinner
		7:00 — 8:30	Study and review
Thu	**August 4**	**Tern Colony**	
		7:30 — 8:00	Breakfast
		8:30 — 10:30	Exam 2
		10:30 — 12:30	Special topics in functional anatomy: Biomimetics (FEF)
		12:30 — 1:00	Lunch
		1:30 — 5:00	Lab: Trip to tern Colony, White Island
		6:00 — 6:30	Dinner
		7:00 — 8:30	Projects
Fri	**August 5**	**Special Topics**	
		7:30 — 8:00	Breakfast
		8:00 — 12:30	Special topics in functional anatomy: Whale Evolution (WEB)
		12:30 — 1:00	Lunch
		1:30 — 4:00	Preliminary project presentations
		5:00 — 6:00	Projects
		6:00 — 6:30	Dinner
		7:00 — 8:30	First Draft and Project Review Meetings
Sat	**August 6**	**Special Topics**	
		7:30 — Breakfast	
		8:00 — 12:30	Special topics in functional anatomy: Manta ray and marine mammal swimming
		12:30 — 1:00	Lunch
		1:30 — 6:00	Project time
		6:00 — 6:30	Dinner
		7:00 — 8:30	Projects

Sun	**August 7**	**Project Presentations**	
		10:00 — 11:00	Brunch
		11:00 — 1:00	Project Presentations
		3:00	Project papers due
		3:00 — 5:00	Lab cleanup
		5:00 — 6:00	Dinner
		6:00 — 8:30	**Star Island or fishing trip (rod and reel)**
Mon	**August 8**	**Students depart**	

Grading Schedule

Lecture exam I	150
Lecture exam II	150
Quizzes	100
Individual Projects	300
In Class/On Site Evaluations	100
TOTAL	**800**

Notes on Quizzes and Exams

It is hard to draw a sharp line between lecture and laboratory material. ***Therefore, assume that questions concerning any information covered in lecture may appear on a quiz or exam.*** The two lecture exams include essay, short answer and multiple choice questions based on information presented in lectures, laboratories, and readings. Quizzes focus on the diversity of marine vertebrates and on the identification of anatomical structures and functions.

Notes on Individual Projects

Each student will complete an independent project pertaining to some aspect of marine vertebrate anatomy and function. More details are given on the following pages and will be explained in class

Notes on In Class/On Site Evaluations

You are expected to participate fully in lecture, project discussions, discussions of readings, and laboratory exercises. This component of the grade is based on our subjective evaluation of your involvement in the course.

About the Instructors

Dr. **Frank Fish** is a Professor of Biology at West Chester University of Pennsylvania, where he has been on the faculty since 1980. He received a B.A. in Biology from SUNY Oswego in 1975. He completed a M.Sc. in 1977 and a Ph.D. in 1980 from the Zoology Department of Michigan State University, where he worked on the biomechanics, hydrodynamics and energetics of swimming in the muskrat.

Dr. Fish has published over 100 research articles, government reports, patents, and book chapters. He has served as chairperson of his department and was the chairperson of the Division of Vertebrate Morphology of the Society for Integrative and Comparative Biology. He is currently an associate editor for the journal *Marine Mammal Science* and he served on the editorial board of the journal *Bioinspiration and Biomimetics*.

Dr. Fish's research focuses on the energetics and hydrodynamics of aquatic locomotion by vertebrates. His research has been funded by the Defense Advanced Research Projects Agency (DARPA), National Science Foundation (NSF), and the Office of Naval Research (ONR). Recent projects have included examinations of the evolution of

swimming modes in aquatic mammals, energetics and maneuverability of aquatic animals, hydrodynamic design of biological control surfaces, biomimetic designs for propulsion control, energy conservation by formation movement, and swimming performance by batoid rays.

Dr. Fish has appeared on the PBS series *Evolution* and the production *Walking with Prehistoric Beasts* on the Discovery Channel, as well as other television broadcasts on the History Channel, Discovery Channel Canada, National Geographic Channel, and BBC.

Dr. **William (Willy) Bemis** studied zoology as an undergraduate at Cornell, as a masters student at the University of Michigan, and at the University of California Berkeley, where he earned his PhD for studies of fossil and living lungfishes. After postdoctoral training at the University of Chicago, Willy spent 20 years on the faculty at the University of Massachusetts Amherst, where he taught comparative anatomy, embryology, fish biology, and trained 40 graduate students. He was founding director of the UMass Graduate Program in Organismic and Evolutionary Biology and also served as Director of the UMass Zoological Collections and Chair of the UMass Research Council. After a brief stint as Program Director in the Division of Environmental Biology at the National Science Foundation in 2004, Willy accepted a professorship in Ecology and Evolutionary Biology at Cornell University, where he also serves as the John M. Kingsbury Director of Shoals Marine Laboratory (SML). SML trains about 190 undergraduates in marine science annually at SML's facilities on Appledore Island in the Isles of Shoals Archipelago. Over the last six years, Willy has worked to revitalize SML's undergraduate curriculum by developing new courses and internship programs in marine science, engineering, and conservation. He also has worked to define SML's long-term future, including plans for a shore base and teaching venue at Creek Farm Reservation in Portsmouth. He says: “SML offers world-unique experiences for our undergraduate students and college credit for some of the happiest, most productive, and most exciting days that these students will ever have anywhere. Period. It is a joy to be involved in the Shoals endeavor, which has such upside potential for so many people.”

Possible Projects for Anatomy and Function of Marine Vertebrates, 2009

A. Evolutionary Morphology

1. Odontocete teeth and the evolution of whale feeding systems
2. Comparative anatomy of phocid skulls with comparisons to terrestrial carnivores
3. Comparative anatomy of weasel, mink, badger, and sea otter skulls
4. Comparative anatomy and function of seabird skulls
5. Comparative anatomy/mechanics of coronoid and angular processes of marine mammal skulls
6. Comparative anatomy of skulls of marine birds
7. Strength of bird limb bones

B. Feeding Systems

1. Anatomy and function of the filter feeding tunicate, Ciona
2. Anatomy of hagfish teeth and feeding system
3. Anatomy of gill rakers and pharyngeal teeth in mackerel
4. Anatomy of teeth and tooth attachment in Lophius

C. Locomotor Systems

1. Flapping and soaring flight of gulls
2. Stride length and lever arms in walking gull chicks
3. Fledging flight of gull chicks
4. Anatomy and function of pectoral fin flipping by sculpins
5. Fast start performance: Sculpin versus flounder
6. Swimming kinematics of hagfish
7. Differences in flight feather morphology

Respiratory Systems

1. Comparative anatomy of respiration in sculpins and flounders

Behavioral Systems

1. Anatomy and dynamics of calling by gulls
2. Sound production by sculpins
3. Preening mechanics of gulls

Developmental Anatomy

1. Development of feathers and feather barbules of gulls
2. Allometry of gull leg and wing bones