American Museum of Natural History

Richard Gilder Graduate School

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Course Catalog
Fall 2024 - Summer 2025

Comparative Biology PhD Program

CORE COURSES

Core courses give students a broad overview of the conceptual basis for studying life and provide them with a common language and essential set of tools and methods for research. The annual organization, content, and flow of each core course are developed by the course director (in consultation with and approval by the AMNH Comparative Biology Ph.D. Program Committee), who oversees the implementation of the course throughout the semester. Course directors and faculty vary, but teaching of all core courses is performed by faculty representing the broad spectrum of research disciplines of the AMNH.

RGGS501 Systematics and Biogeography

Credits: 3
This one-semester class will explore the principles of systematics, the science of classifying organic diversity, contemporary systematic methods, and biogeography.

- **Section 1**—Introduction and background: history of systematics and classification, applications of systematics, schools of thought, and philosophical underpinnings of systematics.
- **Section 2**—Systematic data: homology, types of data, characters, weighting, and molecular data.
- **Section 3**—Analytical methods: alignment of nucleotide characters, inferring trees, distance algorithms, parsimony algorithms, likelihood, measures of support, consensus methods, optimization, and missing data.
- **Section 4**—History of biogeographic inquiry: dispersalist and vicariance perspectives, analytical methods in biogeography, and relation to conservation biology.
- **Section 5**—History and importance of classification; phylogenetic classification, applications of classifications, DNA “bar-coding,” and Assembling the Tree of Life initiatives.

RGGS501L Systematics and Biogeography Lab

Credits: 1
Lab component for Systematics and Biogeography course.

RGGS502 Grantsmanship, Ethics, and Communication

Credits: 3
This course will be offered in a workshop format and focused on how scientists operate within the broader range of society.

- **Section 1**—Grantsmanship: preparing grants, identifying granting agencies, developing and maintaining grant budgets, and practical development of a grant application (e.g., Predoctoral Fellowship or Doctoral Dissertation Improvement Grant).
- **Section 2**—Ethical issues in science, including scientific misconduct, interpersonal responsibilities, institutional responsibilities, mentoring, peer review of papers and grants, serving on panels and boards, and use of animals in research.
- **Section 3**—Communication: writing quality papers, targeting papers to particular journals, crafting press releases, dealing with the media, and giving high-quality presentations.

RGGS503 Evolution

Credits: 3
This one-semester course will include historical and critical reviews of evolutionary theory and will cover the basic principles of contemporary evolutionary biology.

- **Section 1**—Evidence of evolution: the historical development of evolutionary biology; evolution in modern biology; evolution outside of biology
- **Section** 2—Basic principles of evolutionary biology: e.g., population and species concepts), fitness, adaptation, selection, species, clade, phylogeny, hierarchy, homology, and constraint.
- **Section 3**—Evolution of genes: population genetics; quantitative genetics; molecular evolution; molecular tools in evolutionary analyses.
- **Section 4**—Microevolution: fitness, natural selection, sexual selection, analysis of adaptation; nonadaptive causes of pattern, coevolution, complex adaptations.
- **Section 5**—Evolution of Development: molecular, cellular, and anatomical origin and transformation of form and function; developmental genetics, expression patterns, lineage analysis, and developmental analysis.
- **Section 6**—Macroevolution and major transitions in the history of life: speciation, cospeciation, tempo and mode in evolution, phyletic evolution in lineages, kin selection, clade dynamics, evolution of cells, and evolution of sex.
- **Section 7**—History of Life and the Earth: paleobiology, phylogenetic radiations, extinction, Earth history, tectonics, climate and environmental change, and interaction of biological and physical processes.

RGGS503L Evolution Lab

Credits: 1
The lab component for Evolution course.

ELECTIVE COURSES

Elective courses consist of a combination of lecture, workshop, lab, and fieldwork, as appropriate to the specific topic or discipline, and are offered on either a semester-long or immersive schedule to maximize fulfillment of the learning objectives of each course. Elective courses are meant to be flexible and to assist students in achieving a concentration and a depth of knowledge in an area of individual interest.

RGGS601 Applied Phylogenetics

Credits: 1-3
This course is designed to teach students how to consider questions in evolution and ecology in a statistically rigorous manner using phylogeny as a key component for addressing hypotheses. The course will cover methods of molecular evolution, phylogenetic inference using species tree methods, biogeographic reconstruction, trait inference and correlation, species diversification, and community assembly using Bayesian inference and maximum likelihood modeling methods. Importantly, the course will provide a strong background in ecological and evolutionary theory and how to practically address major questions intersecting both of these fields using and modifying existing packages and developing novel code needed.

RGGS602 GIS Methods and Applications

Credits: 2
This course will focus on the application of Geographic Information Systems (GIS) to address questions relating to evolution and conservation. Students will gain hands-on experience with multiple GIS software packages, and will learn the fundamentals of species distribution modeling and remote sensing. The

course will combine lectures and computer lab exercises, and each student will undertake an individual project.

RGGS603 Marine Zoological Biodiversity Surveys and Inventory

Credits: 3

This course will familiarize students with the nature of the DEB-BSI granting panel priorities at the National Science Foundation with a focus on the broad zoological diversity in marine and associated environments. Passamaquoddy Bay, at the mouth of the Bay of Fundy, exhibits a tidal range of 30 feet. From low water to high water takes about 6.2 hours and in that time, up to 2-1/4 billion tons of water swill into Passamaquoddy Bay through the passages. Few places on this planet have such a huge tidal variation and, consequently, few offer as great a diversity of marine organisms and habitats. Lectures will cover basic principals of physical oceanography, biological oceanography, marine taphonomy, phylum-by-phylum marine metazoan diversity (from sponges to mammals), marine protozoology, and parasitology. Field work will focus on survey-based marine sampling strategies from l-meter plots, to transects and trawling effort across a range of habitats that includes benthic, pelagic, inshore, meiofaunal, intertidal, salt marshes and rocky shores.

RGGS604 Understanding Biological Disparity

Credits: 3

Disparity analyses attempt to characterize and explain extreme differences in morphology and diversity in closely related groups of organisms. Through group discussion of a series of contemporary readings covering both the fossil record and modern organisms, students will explore the basic concepts of biological disparity and learn how to apply these in their own research.

RGGS609 Molecular and Genome Evolution

Credits: 3

The techniques and analytical approaches to examining the genomes of organisms will be the focus of this course. This course will begin with detailed examination of the high throughput approaches used to analyze and collect information on genomes. Such approaches include estimating genome size, obtaining genome level maps, estimating gene content in genomes, sequence alignment, and genome level shotgun sequencing approaches. This course will then proceed to annotation of genomes and discovery of ortholog/paraolog relationships. It will conclude with detailed examination of data basemanipulation, PERL scripting to mine the burgeoning database, and the incorporation of phylogenetic approaches into studying genomes.

RGGS611 Parasitism

Credits: 3

Parasitism is the most successful life history strategy on Earth. There are more and more varied species of parasites than there are free-living species hosting them. Students will discover a full range of eukaryotic parasites ranging from the protistan causative agents of malaria, sleeping sickness, Chagas disease, and leishmania to the metazoan tapeworms, flukes, nematodes, and arthropod parasites. Subject matter will include comparative anatomy, life cycles, pathology, phylogenetic relationships, and coevolutionary parasitology.

RGGS612 Biogeographic Analysis

Credits: 3

The course will explore historical biogeographic methods as well as how biogeography is relevant for answering questions within evolutionary biology, from speciation analysis to the origin of biotas and patterns of diversity. An ecological biogeographic approach will not be taken in this course, although the evolution of ecological assemblages and patterns of diversity will be discussed.

RGGS628 Systematic Ichthyology

Credits: 3

This course will be a taxonomic survey and introduction to the science of ichthyology. It will focus on the systematic relationships among the major clades of fishes, and will also include discussions focusing on ecology, biogeography, and the natural history of fishes. This course will consist of lectures, readings from the primary literature, and laboratory sections focusing on a taxonomic review

RGGS630 Mammalogy

Credits: 3

This course will provide an integrative survey of the biology, diversity, and evolution of mammals with a focus on extant taxa. Class sessions will be topic-focused and will cover various aspects of mammalian phylogeny, biogeography, anatomy, physiology, functional morphology, reproduction, life histories, behavior, ecology, and conservation. Labs will be taxon-focused and will cover diversity and morphology of all of the extant mammalian orders.

RGGS637 How the Cosmos and Earth's History Affect Life

Credits: 1

The complex phenomenon that we call life has evolved on an average planet, orbiting an average star, in a very humdrum part of the Milky Way galaxy. Is this an accident? Are there other abodes for life in our galaxy? How has the Earth's history driven the evolution of life? These and related questions will be addressed by the museum's astrophysicists and planetary scientists. The focus will be on processes that constrained and drove evolution on Earth over the past 4.6 Billion years.

RGGS652 *Anolis* Lizards: Model System in Ecology and Evolution

Credits: 3

The *Anolis* lizards of the New World tropics are one of the best-studied groups of vertebrates in evolution and ecology, making them a model system for adaptive radiation and island biogeography. The literature on this group is rich and varied and includes both hundreds of primary journal articles and book chapters as well as a new synthetic volume, just published by Jonathan Losos. This course uses the *Anolis* lizards as a gateway to teach diverse topics in evolutionary biology, biogeography, systematics, behavior and ecology through readings and discussion and a field experience where students will design and conduct research on these lizards. This course would be appropriate for students interested in herpetology, West Indian biogeography, or who just want to expand their exposure to evolution, ecology and behavioral research in comparative biology.

RGGS655 Advanced Invertebrate Zoology

Credits: 3

The course will familiarize students with physiology, development and classification of each invertebrate phylum of the animal kingdom. The different topics will be discussed using scientific literature. Laboratory exercises will introduce students to diversity of invertebrate phyla and subgroups, and will comprise structure and function of representatives of each phylum as well as physiology and embryology of exemplar organisms. Students will also carry out two field trips to collect local invertebrates.

RGGS655L Advanced Invertebrate Zoology Lab

Credits: 1

Lab component for Advanced Invertebrate Zoology course.

RGGS656 Major Events in Evolution: Paleozoic-Mesozoic Transition

Credits: 2

This course will present major themes in terrestrial vertebrate evolution, using the Paleozoic-Mesozoic

transition as a source of case studies. The end of the Paleozoic was a time of important transitions in Earth history, with profound effects on vertebrates and their ecosystems. Discussion topics will address outstanding issues in research on this period, including causes of the Permo-Triassic mass extinction, biotic shifts and climate-mediated endemicity in the Triassic, and timing of origin of the major modern clades.

RGGS656L Major Events in Evolution: Paleozoic-Mesozoic Transition Lab

Credits: 0-3
Lab component for Major Events in Evolution (for the Paleozoic-Mesozoic Transition course, the lab is considered part of the main course, so no additional credits assigned).

RGGS658 Vertebrate Paleobiology

Credits: 3
Students will develop an understanding of the general morphology, phylogeny and evolutionary history of major vertebrate clades. These will be taught in association with current issues that convey knowledge of environment-organism interaction, evo-devo, Tree of Life, molecular-morphological views in divergence and phylogeny, paleobiogeography, and contemporary analytical methods in morphological studies (CTscans, microstructures, histology, etc.).

RGGS658L Vertebrate Paleobiology Lab

Credits: 1
Lab component for Vertebrate Paleobiology course.

RGGS659 Insect Taxonomy

Credits: 3
The primary objective is to increase knowledge of the diversity of insects down to the family level. Students will become familiar with the families that are commonly encountered, and be able to key out those which are not so common. Students will learn sight recognition of important North American groups (about 200), how to use keys and literature, and techniques for collection, preservation, and preparation. Students will also gain an understanding of insect phylogeny and biology.

RGGS659L Insect Taxonomy Lab

Credits: 0
Lab component for Insect Taxonomy course.

RGGS660 Extinction Science

Credits: 2
This course is concerned with explaining the causes and consequences of biological extinction through time. Importantly, perspectives from both the physical and organismic sciences will be employed throughout. This survey course will use a broad historical perspective, i.e., the vicissitudes of life on this planet during the past 600 million years, with a special focus on three events that illustrate many of the most important phenomena and puzzles connected with major losses—the Permo-Triassic, Cretaceous-Paleogene, and Late Quaternary extinctions. Topics covered include: the fossil record of extinction; “mass” vs. “background” extinction; extinction rates: computation and meaning; assessing causation in theory and practice; biotic and abiotic factors in extinction; understanding modern-day biotic losses.

RGGS661 Reptile Biology and Diversity

Credits: 3
Reptile Biology and Diversity is a course in the systematics, life history, morphology and anatomy, and evolution of living reptiles and their immediate extinct ancestors.

RGGS662 Comparative Genomics I (formerly Next Generation Sequencing)

Credits: 2

This course covers genomics and genome analysis, with the goal of lowering the learning curve of, and increasing familiarity with, wet-chemistry and bioinformatic techniques as related to next-generation sequencing (NGS). While students will explore the different types of genetic material, the polymerase chain reaction, traditional Sanger sequencing, and some of the first methods of screening random pieces of the genome and/or transcriptome (cloning and colony picking), the major focus will be NGS technologies and applications.

RGGS662L Comparative Genomics I Lab

Credits: 1

Lab component for Comparative Genomics I course.

RGGS663 Biological Specimen Informatics

Credits: 3

Lectures and labs will focus on introducing students to various specimen databases and demonstrating the value of using a specimen database to manage research data. In addition, the course will offer best practices in specimen data acquisition, handling and management, georeferencing, imaging, basics of MySQL, and import and export tools.

RGGS664 Comparative Genomics 2 Informatics (formerly Next Generation Sequencing Informatics)

Credits: 3

The course will build on the extensive technical and lab oriented RGGS course, Next Generation Sequencing (RGGS-662). In that course students were exposed to next generation sequencing (NGS) approaches in the lab. In this course we will take up where that course left off and develop the necessary computational approaches that are required for NGS data processing – including data quality assessment, assembly, annotation and accessioning. The completion of Next Generation Sequencing (RGGS-662) is not, however, a prerequisite to taking this course.

RGGS666 The Tree of Life and Invertebrate Zoology

Credits: 2

This uniqueness of the course of lectures and labs will lie in its use of morphological and molecular characters to interpret the major groups of invertebrates on the planet. At the end of week two of the course, each student will choose a well-defined monophyletic phylum or a well-defined group of phyla and compile a phylogenetic matrix for the taxa in their chosen group. They will then rigidly analyze their matrices and extensively compare these to the published record on their chosen group.

RGGS668 Microscopy and Imaging Methods for Comparative Biology

Credits: 2

The course will introduce and demonstrate a variety of imaging and analyses tools used in comparative biology as well as in planetary science. These include light and epifluorescence microscopy, confocal microscopy, advanced stereoscopy, scanning and transmission electron microscopy, energy-dispersive and wavelength dispersive x-ray spectroscopy, x-ray diffractometry, high resolution x-ray CT scanning, and flow cytometry.

RGGS669 Geometric Morphometrics

Credits: 1

Lectures will focus primarily on methods of biological shape measurements, multivariate statistics and comparative methods associated with shape data. Labs will concentrate on application of the techniques

and methods presented during the lectures using either data provided during the course or student's personal data.

RGGS670 Algorithmic Approaches to Biological Data
***Credits**:* 4

An intensive introduction to programming in the Python programming language, culminating with an in-depth analysis of several biological topics and the algorithmic approaches needed to analyze the relevant data. Programming topics include the basic concepts of loops, decisions, strings, lists, interacting with files, functions, data collections, common libraries, and recursion. Biology topics are sequence alignment with dynamic programming, genome assembly with deBruijn graphs, and algorithms for phylogenetic tree reconstruction. No previous programming experience is required. This course is appropriate for students working with genomic or phenomic data and other collections-oriented work.

RGGS671 Next Generation Sequencing 3: Advanced Informatics
***Credits**:* 1

The course will help students transform their classroom-based understanding of next-generation sequencing data into the ability to independently analyze and interpret raw data. Students will spend most of their time working with their own data sets, and will, by the conclusion of the course, have produced preliminary results that are suitable for grant proposals. In addition, the analysis routines they develop should allow them to move forward independently to process and interpret the NGS data they produce over the course of their PhD work.

RGGS672 Foundations of Biological Classification
***Credits**:* 1

This course will provide students with a general understanding of the theoretical and philosophical foundations of biological classification. The course starts with an introduction to the goals, logic and uses of biological classifications. It follows with an historical analysis of the ideas and traditions that have influenced biological classifications, from the classics and the naturalists of the Enlightenment through the Linnaean, Darwinian, New Synthesis and Hennigian paradigms shifts. The historical analysis is followed by a brief introduction to the philosophy of classification in which we will analyze how the biological world and classifications are perceived and explained by different schools of thought. In the second part of the course we will delve into the units, working logic, and nomenclatural rules of current biological classification systems. This second part is divided into three blocks. The first block, provides a thorough analysis of the levels of complexity in the living world and how these levels relate to concepts such as characters, populations, species, taxa, clades, lineages, subspecies, varieties, ranks, etc. During this first block we will also analyze the relationship between phylogeny and the Linnaean system for extant and fossil taxa. The second block is about nomenclature. We will briefly analyze the logic of regulated actions by looking at different nomenclatural codes (botanical, zoological, bacteriological, and phylocode). We will then continue with a more detailed analysis the main rules that govern zoological nomenclature. This block will also include practical exercises to help students solve nomenclatural issues, build classifications, and understand the different causes of name changes. In the third and last block we will analyze how classifications relate to empirical inferences of clades and species and what that means for taxonomy as a scientific discipline and for users of biological classifications. The course will conclude with presentations and discussions of essays written by students.

RGGS672L Foundations of Biological Classification Lab
***Credits**:* 1

Lab component for Foundations of Biological Classification course.

RGGS673 Speciation
***Credits**:* 3

This course will provide a detailed review of the study of speciation, considering the historical literature, models of speciation, hybrid zones, empirical studies, and current trends and literature. These topics will considerably expand upon the following two lectures that are currently given in RGGS Core classes: Evolution Core lecture "Geographic variation and speciation" and Systematics Core lecture "Diversification".

RGGS674 Modern Techniques and Evo-Devo
***Credits**:* 1

The course will consist of a lecture part (3 hrs per week) and a lab part (3 hours per week). The lecture part will start by looking at the classical evo-devo literature and proceed to an examination of the techniques involved in establishing the field. Homology will be a running thread through the course and a focus of one of the week's lectures. How developing cell type systems and tissues can be studied and how information about the development of organisms can be incorporated into evolutionary studies. Comparative genomics can give us some idea of the genetic tool box (sensu Carroll) and so we will focus on the many comparative genomics studies that have made evo-devo claims. One of the major kinds of data that has been incorporated into evo-devo is transcriptomics and so we will spend some time on this topic, focusing on how the data are used to make inferences about development and evolution.

Labs: Labs will follow the treatment of samples from living organisms to genomic data for developmental stages of a specific organism - Trichoplax. This organism is fascinating because of its very basic bodyplan and phylogenetic placement. The goal is to obtain four RNAseq datasets from four different life stages of the animal, to analyze the RNAseq data, and to interpret the data in an evo-devo context. The goal is to produce a paper using these data that the participating students will co-author. The students will be responsible for the analysis of the transcriptome data and writing sections of the paper.

RGGS674L Modern Techniques and Evo-Devo Lab
***Credits**:* 1

Lab component for Modern Techniques and Evo-Devo course.

RGGS675 Spatial Bioinformatics
***Credits**:* 1

Spatial data and models are ubiquitous in modern comparative biology and ecology due to the vast amount of available data and ever developing modeling methods. This course will focus lectures on a series of "best-practices" in handling and modeling spatial biological data including data-mobilization, bias detection and reduction, geographic projection management, and comparative modeling frameworks. Labs will concentrate on demonstration of best-practices on a range of datasets including student's personal data. The course will culminate in student's working in "hackathon" style working groups to develop a spatial data analysis pipeline to address a question of mutual interest to be posted on appropriate code-sharing repositories.

RGGS676 Systematics of Symbiosis
***Credits**:* 1

This course will be rooted in systematics and have hands-on genomic projects and activities. Students will gain a strong theoretical framework, while also developing practical genomic skills. Finally, students will have a unique opportunity to apply foundational knowledge on symbiosis towards the development of an educational resource that can be used as an undergraduate recitation or laboratory activity, and which we will aim to publish in an education journal such as the American Biology Teacher. All students will be invited to co-author the resulting manuscript. Thus, students will not only gain practical research skills, but

also be immersed in best-practice pedagogical training, which will enhance their graduate training as scholars and educators.

RGGS677 Population Genetics Modeling and Inference in R
***Credits**:* 1

This course is an introduction to population genetics modeling and inference in R. We will cover an introduction to the R statistical platform, the coalescent model, simulation-based inference methods such as approximate Bayesian computation and supervised machine-learning; the software phrapl, PipeMaster and G-phocs. Each session will include lectures followed by hands-on practical training using real data to become familiar with the tools they are learning. They will also be assigned at-home tutorials for further practice.

RGGS678 Insect Diversity
***Credits:* 4**

Introduction to phylogenetic relationships, evolution and ecology of the major groups of arthropods, with emphasis on insects. Lab: identification of common families of insects of the northeastern United States.

RGGS 679 Foundational Papers in Ecology and Evolution: Then and Now
***Credits:* 2**

This course examines the classic papers describing seminal studies and important advances that have shaped current understandings of the fields of ecology and evolution, and contemporary papers that illustrate how understandings have shifted over time.

RGGS 680 Integrative Paleoanthropology I: Late Miocene through Early Pleistocene
***Credits:* 3**

This course provides a detailed overview of the early stages of human evolution from the Miocene to the early Pleistocene, focusing on the fossil and archaeological record of the earliest hominins up to and including early Homo in East and South Africa. It emphasizes the anatomical, phylogenetic, and behavioral traits of Plio-Pleistocene hominins in Africa. Special topics include: a critical review of recently described fossils purported to be early hominins from the late Miocene of Africa; an introduction to phylogenetic methods, geochronology, and the evidence used to reconstruct global climate change; comparative morphology and tool-using behavior of extant hominoids; the earliest tool industries; models of early hominin dietary behavior; functional morphology and locomotor behavior; and debates surrounding early hominin biogeography, taxonomy and phylogenetic relationships. Students will supplement their reading of the primary literature with the study of comparative skeletal materials and casts of early hominins in the laboratory.

RGGS681 Comparative Genomics 2 Informatics, 2 credits
***Credits:* 2**

The course will build on the extensive technical and lab oriented RGGS course, Comparative Genomics 1(RGGS-662). In that course students were exposed to next generation sequencing (NGS) approaches in the lab. In this course we will take up where that course left off, introducing the computational tools necessary for interpreting modern molecular sequencing data. It covers whole genome and transcriptome assembly, comparative analyses using both de novo and reference-based methods, and phylogenomic inference. Designed for non-model systems, the course emphasizes documentation, reproducibility, and proficiency with computational tools. Students will address experimental questions starting from raw data, aiming to lay a foundation for a publishable final product.. The completion of Comparative Genomics 1 (RGGS-662) is not a prerequisite to taking this course; however participants should have high throughput sequencing data (Illumina, PacBio, ONT) available for use in class. These may be the student's own data

or a publicly available dataset from NCBI's SRA database. Students will receive individual guidance on applying methods relevant to their research and data. This support will include using their own datasets for tutorials and homework assignments, as well as consultations with instructors to discuss their data and appropriate bioinformatic methods.

RGGS682 The Tree of Life --Marine Invertebrate Zoology
***Credits*: 2**

The course will take a modern and multidisciplinary approach to the study of marine Invertebrate Zoology, integrating classical anatomy, modern genomics and evo-devo. The course will cover all of the major marine invertebrate animal phyla and discuss common biological themes across taxa. Students will have the opportunity to use taxonomic and systematic knowledge to identify and describe field collected and museum specimens.

RGGS706 The Science of Effective Teaching and Learning
***Credits:* 1**

This course will center on discussion of selected key literature on the science of teaching and learning, and demonstration, review, and practice of a variety of teaching techniques so participants can develop a deeper knowledge of how active, student-centered, and evidence-based approaches can be effective in promoting student learning. Each class session will include both seminar and workshop-style activities, and students will develop a syllabus, a teaching unit/class session, and a teaching philosophy statement as course assignments, with input from their peers and the instructors.

RGGS707 Genome Assembly & Annotation
***Credits*: 1**

The aim of our course is to train the next generation of biologists in the skills necessary to assemble and annotate genomes, thus democratizing and accelerating the field of genomics. While first providing an overview of the algorithmic developments in the field, we will then focus on the practical aspects of genome assembly. We will discuss how genomic technologies such as Illumina paired-end sequencing, long-read sequencing (Oxford Nanopore Technologies and Pacific Biosciences), linked-reads (10X Genomics), optical maps (Bionano Genomics) and Hi-C scaffolding (Arima, Dovetail, and Phase Genomics) can be utilized effectively for both genome assembly and annotation. Participants will get hands-on training using real data to assemble a genome and become familiar with the tools used to annotate it.

RGGS708 Nature Conservation & Biodiversity Field Trip Crau/Camargue/Mediterranean Sea
***Credits*:** 3

La Crau is Europe's' last unimpaired "stone" steppe formation, the Camargue one of Europe's most fascinating nature reserves and the Mediterranean Sea a unique marine habitat. In less than 45 minutes we can travel between stony steppe, multifaceted wetlands and extended seashore to discover and observe completely contrasting ecological communities and unique biodiversity patterns. We will observe in highly striking ways the battle between human economic interests and nature conservation.

RGGS709 Programming in Bioinformatics, Data Analysis and Visualization
***Credits*: 1**

The course will be mostly Python-focused, but there will be some shell and R scripting too.

Topics

- Fundamentals of programming (with Python).
- Bio-sequence processing (with BioPython).
- Creating, parsing, and visualizing multiple-sequence alignments and phylogenetic trees.

- Introduction to data analysis and machine learning (with NumPy, Pandas, and Ski-kit learn).
- Interfacing Python with R and the Unix shell via Jupyter Notebooks.
- Introduction to data visualization (with Matplotlib, Seaborn, and Plotly)

RGGS 711 Speciation and Adaptation Genomics: a How-To
Credits: **1**
This course is an introduction to population genomic analyses related to understanding the processes of speciation and adaptation. Students will work through a complete bioinformatic pipeline from raw read data to reviewer-ready results while discussing seminal works from the literature. The course will include five modules: (1) read processing, mapping, and variant calling/filtering; (2) population genetic summary statistics and geographic/genomic clinal analysis, (3) genome-wide association mapping and statistical confidence, (4) scanning for selective sweeps, and (5) structural variant mapping. Over the span of each of these five modules, students will learn the skills required for data manipulation and the making of publication ready figures in R (Tidyverse). The course will also showcase the benefits of linked-read over short-read sequencing data for population genetics and structural variant discovery. Students will be assigned at-home tutorials for further practice and have a final project to demonstrate skill aptitude.

RGGS713 Readings in Natural Selection
Credits**: 1**

This seminar focuses on in-depth exploration of natural selection through critical reading and discussion of primary literature. Students will engage with current research across various biological fields, such as evolutionary biology, genetics, ecology, paleontology, and behavioral science, to understand the mechanisms and implications of natural selection.

The course will be taught by Dr. Brian Smith and will include readings each week that provide in-depth exploration of key concepts/questions related to natural selection. Each week one student will select a related paper to read and present formally in class, and lead discussion on that paper.

INDEPENDENT STUDY ELECTIVE COURSES

Comparative Biology Ph.D. Program students are invited to submit proposals for independent study courses to the Comparative Biology Ph.D. Program Committee.

RGGS726-301 Cichlid and Ponyfish Gas Bladder Evolution
Credits: 3
The objectives of the independent study are: (1) to learn how to use magnetic resonance imaging (MRI) and computed tomography (CT) technology to reconstruct three-dimensional images of gas bladders (in cichlids and ponyfishes) and associated light organs (in ponyfishes); (2) to learn reconstruction software for MRI and CT scan data, such as Amira; (3) to learn techniques for analyzing the morphological data using geometric morphometrics (as outlined in Zelditch et al.); and to (4) use these data in a phylogenetic context.

RGGS892 Morphological Character Coding in Phylogenetics
Credits: 2
In addition to a review of the philosophical and methodological basis of morphological character coding for phylogenetic analysis and a review of seminal papers published in the last 50 years, the course will study: the logical basis of morphological character coding; character definition and homology, and primary

homology statements; delimiting states: qualitative versus quantitative characters; practical application of character coding: phenotypic diversity; combined analysis of morphological and molecular datasets.

RGGS892 Python for Evolutionary Biology
Credits: 2
This course will use the Python programming language to teach bioinformatics and data science skills. It will cover both programming fundamentals and applied uses of Python for evolutionary biology, with a focus on manipulating DNA sequence data.

RGGS892 Hymenoptera Natural History and Identification
Credits: 2
The main objective of the course is to provide knowledge and experience in identifying parasitic and predatory wasps, sawflies, wood wasps, bees, and ants. This course will also present information on the natural history and biodiversity of wasps, bees, and ants, and that information will be reinforced with fieldwork. Techniques used to collect, rear, preserve, and curate wasps, bees, and ants will be presented in a hands-on manner to allow students to learn directly by doing. Following collection students will continue identification and examination of the taxa collected.

RGGS893 Metagenomics
Credits: 3
This course will focus on learning to process and analyze Next Generation Sequence (NGS) data for environmental samples of microbes and blood meals. The course will emphasize the creation of custom pipelines in R to streamline future use of these methods. Topics to be covered: Metagenomic/eDNA data processing; metagenomic/eDNA data analysis; metagenomic/eDNA literature, including the incorporate of phylogenetic information into microbial community studies; R scripting to produce automated pipelines.

RGGS893 Field Techniques, Identification, and Analysis of Bats and Parasites
Credits: 3
A study of obligate mammalian ectoparasites and the bats they rely on as hosts, with a focus on Neotropical host-parasite associations in Central America, Mexico, and the Caribbean. This course teaches how to capture, identify and analyze Neotropical bats to the species level; how to sample live bats for ectoparasites and preserve them for future study; how to identify and analyze bat flies and ticks to the genus level (species level when possible); and how to collect and record important natural history information associated with field captures of bats and ectoparasites. Course includes fieldwork, lab work, and an extensive literature review.

RGGS893 Comparative Osteology and Skeletal Ornamentation
Credits: 3
This course will cover the literature on comparative vertebrate anatomy and osteology, how to use imaging methods (such as CT) to score and describe morphological features, and how to formally describe morphological characters for taxa. We will utilize a CT dataset collected over the past year to examine the evolutionary history of vertebral ornamentation in Brookesia chameleons to produce a final paper.

RGGS893-301 Histology of the Recessus Orbitalis in Flatfishes
Credits: 3
This course will have two main goals: 1) Set-up a functional histology lab in the Department of Ichthyology, and 2) carry out comparative analyses based on the histology of the recessus orbitalis.

RGGS895 Genomics Software and Programming
Credits: 2
Hands-on learning about a wide suite of commonly implemented genomic software pipelines. Course topics will include DNA and RNA fixation/extraction/ sequencing; post-sequencing cleanup and genomic assembly; different classes and utilizations of BLAST; gene family creation; metagenomics and environmental DNA; phylogenetic matrix creation and analyses; data compilation and visualization; statistical analysis of data; and common computational languages that underlie all of the above (R, Python, SQL).

RGGS895 Nesting Biology and Development of Bees
Credits: 2
An introduction to solitary and cleptoparasite bee development, behavior, and morphology, through examining, describing, and imaging specimens from the AMNH collections and those obtained through fieldwork. Course aims include dissections and illustrations to learn solitary bee and cleptoparasite larval morphology and behavior, as well as nest structure and materials, and gaining proficiency with imaging techniques including SEM, photomicroscopy, CT, and confocal imaging.

RGGS895-101 Phylogeny and Behavior: Theory and Practice
Credits: 2
This course examines fifty years of primary and secondary literature concerning the interaction of phylogenetic theory with the study of behavioral evolution. Current and historical controversies, as well as various and competing methodological approaches are emphasized. Throughout, these studies are used to develop a deeper understanding for the student's own dissertation work.

RGGS895-301 Molecular Laboratory
Credits: 2
The generation and manipulation of DNA sequences is essential for a range of biological and evolutionary studies. The procedures required to generate and manipulate DNA sequences depend on specific training for laboratory work and specific molecular protocols in order to guarantee efficiency and safety. Knowledge of molecular protocols and lab work experience are indispensable for any biologist interested in molecular systematics and other evolutionary studies. Students will learn lab protocols to guarantee biosafety during lab work, and learn techniques for DNA extraction, DNA amplification (PCR), DNA purification, DNA sequencing, DNA samples storage, and DNA sequences manipulation.

RGGS896 Computational Species Delimitation Methods
Credits: 3
Using molecular data is critical when delimiting cryptic species. This course will cover the literature on computational species delimitation methods, as well as empirical studies that utilize these methods. Several programs will be used on an already existing molecular dataset and a final paper will be produced describing the (1) results from the different analyses, (2) pros and cons of each analysis, and (3) the utility of these programs.

RGGS896-101 Fossil Imaging Techniques and Methods
Credits: 3
The goal of this course is to develop a working knowledge of protocol, and the specification of protocol for different types of specimens, in various imaging techniques utilizing the CT scanner, SEM machines, and confocal light microscope in the AMNH imaging lab; develop a basic theoretical understanding of the physics behind these various imagining techniques; and solidify understanding of morphology (external and internal) of exemplar species representing research organisms.

RGGS896-301 Homology, Characters and Coding

Credits: 3

This course will cover the following concepts, using two systems for reference: neoscopelid nerves and myctophiform osteology. (1) Character individuation/ identification: definition of a morphological character and the numerical coding used (binary/multistate) to convey its information. (2) Homology concepts and tests: survey of Remane, Patterson, Wiley, De Pinna, Rieppel (homology concepts), and comparison of Remane and Herrick's criteria, considering nerves. (3) Nerves: ontogeny and pattern.

RGGS897 Biology and Current Research of Photosynthetic Protists

Credits: 1

The goal of the course is to become familiar with the physiology of the plastid, diversity of photosynthetic protists, their lifecycle, ecology, and current research in this field.

RGGS897-101 Biogeography of Southeast Asian Scorpions

Credits: 1

A comparative study on the biogeography of Southeast Asian scorpions that seeks to answer: Are biogeographical patterns congruent across multiple Southeast Asian scorpion taxa?

RGGS897-201 Advanced Taxonomy of Hymenoptera

Credits: 1

The course will help students to understand the diversity of the different groups of Hymenoptera and the characters and literature used to identify them.

RGGS897-301 NGS Applications and Data Analysis

Credits: 1

The goal of this course is to go beyond the *Next Generation Sequencing* (RGGS662-301) class content by participating and assisting with students' projects including multiplexing for barcoded mtDNA, ancient DNA shotgun, and transcriptome work.

RGGS898 Study of Solitary Bees

Credits: 2

This course emphasizes the classification and identification of more than sixty bee genera of North and Central America (both temperate and tropical). There will be a special focus on solitary bee nesting biology and the subfamily anthophorinae.

RGGS898 Study of Olfactory Apparatus in Congo Catfish

Credits: 2

As a training in fish olfactory biology, the student will section and stain the nasal and oral region of freshwater catfishes from the Congo region. The student will render a 3D reconstruction of the olfactory apparatus and will use this to describe the fishes' unique mechanics of smell and compare this with the olfactory apparatus of other fishes (both bony and cartilaginous).

RGGS898 Bioinformatics

Credits: 2

The massive amount of molecular data allowed by current technology presents both opportunity and challenge to biologists. Using Haddock and Dunn's "Practical Computing for Biologists" as a textbook, students will learn crucial skills such as regular expressions, multiple programming code languages, managing and manipulating large datasets, how to work with relational databases, combining and

automating analyses, how to create vector graphics, how to perform analyses on remote computers, and more.

RGGS898-301 Programming

Credits: 2
Learn how to access and use the technological resources available through the AMNH cluster (Darwin). Learn the fundamentals of programming (language structure, scripting, etc.) using the packages Pearl and R: (1) scripting for data acquisition (Genbank), (2) Blast and related tools for sequence comparison and investigation of orthology/ paralogy, (3) sequence manipulation (direction, translation, frame checking), (4) sequence alignment (clustal, kalign, maft, muscle, t-coffee), (5) phylogenetic analyses (parsimony, maximum likelihood and Bayesian analyses for phylogenetic reconstruction), (6) trees comparison (topology, structure, branch length and support), (7) natural selection investigations (Dn/Ds analyses).

RGGS898-301 Philosophy and Phylogenetic Inference
Credits: 2
In historical sciences, theories cannot be proved correct any more than they cannot be proven incorrect. Yet, we are in the midst of a race to build the Tree of Life, a "reconstruction" of the history of all life. Is this task attainable? What are the assumptions one must make to make phylogenetic inference even possible? How can you narrow the bridge between realism and scientific rigor? Readings will be geared towards the methods for comparison among competing phylogenetic hypotheses.

RGGS899 Neuroanatomy

Credits: 3
An intensive three-week course for students to become well-versed in the structure of the human brain by focusing on human neuroanatomy through lectures, conferences and laboratory sessions. All material will focus primarily on learning the structure of the human nervous system with related focus on function, as well. Laboratory sessions will include sheep and human brain dissections. Students will produce a Brain Atlas as a required course project.

RGGS899-101 Squamate Morphology with Digital Imaging

Credits: 3
The goal of this course is increased knowledge of squamate morphology, experience running phylogenetic and morphometric analyses, and training on CT software, including VGstudio Max.

RGGS899-101 Vertebrate Morphology and Specimen Description

Credits: 3
The goal of this course is to become familiar with anatomical terminology and methods of paleontological description. The methods learned will include techniques such as Micro-CT scanning and variable pressure SEM imaging.

RGGS899-102 Scaffolding and Annotating the Full Genome of *Riechenowia parasitica*

Credits: 3
Scaffolding will be done to separate the bacterial genome from that of its leech host and annotation of the scaffolded fragments will subsequently be performed.

RGGS899-103 Digital Morphology of the Cichlid Hindbrain

Credits: 3
This collaboratively taught elective course in conjunction with RGGS899-104, will bridge the gap between phylogeny, morphology, and physiology by: (1) continuing to teach the student how to utilize MRI

technology for comparative morphological studies; (2) specifically, employing previously acquired MRI scans of the brain to study hindbrain morphology; (3) working with a collaborator knowledgeable in brain morphology and MRI technologies (Dr. Rachel Berquist, UCSD); (4) examining the morphological evolution of the hindbrain in the context of the MSA-cichlid phylogeny; and (5) further fostering collaborations in order to build connections for future studies investigating fish audition and communication.

RGGS899-104 Introduction to Methodologies in Functional Neurophysiology

Credits: 3

This collaboratively taught elective course, in conjunction with RGGS899-103, will bridge the gap between phylogeny, morphology, and physiology by: (1) introducing the student to concepts and introductory literature in functional neurophysiology; (2) instructing the student in methodologies for studying brain function, specifically auditory evoked potentials, or AEP; (3) employing these methodologies in the context of the present study on MSA cichlids; and (4) further fostering collaborations in order to build connections for future studies investigating fish audition and communication.

RGGS899-201 Amphibian Anatomy

Credits: 3

This course will provide in depth experience with amphibian morphology, with a focus on Ranoides (a large clade of frogs in which Microhylidae is included).

RGGS899-301 Advanced Topics in the Evolution & Taxonomy of Insects

Credits: 3

A deep understanding of the evolutionary history of insects is a necessary prerequisite to order- and family-level specialization; at the same time, practical skills in identification and taxonomy enrich and expand a student's field work. Students will conduct in-depth explorations of insects (such as ants and apoid wasps), and will benefit from a semester-long immersion in insect evolution and taxonomy.

RGGS899-301 Understanding Neuroanatomy Using MRI

Credits: 3

This course focuses on the comparative neuroanatomy of fishes with an emphasis on flatfishes (Pleuronectiformes). The goal is to learn to generate and analyze useful MRI data for soft tissue morphology, and to learn how to use AMIRA to generate 3D segmented data from MRIs.

RGGS899-301 Morphology Across Hemiptera through Literature

Credits: 3

A morphological study of groups across Hemiptera will provide an overview of the diversity of structures for insects related to scale insects. Readings of the literature and discussions will help students understand how morphological studies are made.

RGGS899-301 Motor and Sensory Systems Neuroscience

Credits: 3

This course will help the student understand the physiological processes in the central and peripheral nervous system of vertebrates, thereby giving a deeper and broader understanding of neurological processes. This is vital to understanding the effect of anesthesia on the brain, which will affect the results of the PET scans the student is producing and analyzing for their thesis research. It will also help the student correlate physical behaviors to neurological patterns and neuroanatomical locations. This course will cover all the sensory and motor systems in the cortex, the areas to which they connect in the central and peripheral nervous systems, and how they affect the rest of the body through various systems of chemical and physical communication.

RGGS899-302 Comparative Brain Morphology and Hearing in Fishes

Credits: 3

The student will gain experience in histological techniques (embedding in paraffin and acrylics [JB-4]), microtome use, staining techniques, and most importantly comparative brain anatomy via examination of thin slices using light microscopy and gross dissection. As part of an NSF project to examine the evolution and diversification of anatomical hearing specializations and physiological abilities in Malagasy-S. Asian cichlids, the student focused previously on using MRI technology and gross morphology to investigate the otophysic (gas bladder-inner ear) connection unique to these fishes. As work progressed it was noticed that the hindbrain region appears to be enlarged/specialized in this assemblage relative to other cichlids, leading the student to become interested in comparative brain morphology and neuroanatomy.

RGGS899-303 Anthozoan Anatomy: Actiniaria as a Model

Credits: 3

Sea anemones (Anthozoa, Actiniaria) require the study of their anatomy and cnidom to identify them. Thus, histology is a basic tool to study the taxonomy of the group. The objective is to understand the diversity of the different groups of Anthozoan (Cnidaria), their anatomy, and characters and methods used to classify them. Actiniaria will be use as a model and the required morphological techniques to identify them will be learn.

RGGS899-401 Morphological Evolution

Credits: 3

New phylogenetic hypotheses can foster insights into the evolution of novel morphological structures. Unfortunately, few studies bridge the gap between phylogeny and morphological novelty, and fewer still explore those connections in the context of the ecological and behavioral circumstances. This course will provide an in-depth case study of one largely unexplored example of morphological novelty: the terminal abdominal structures (lamina, spines) that have evolved repeatedly within the bee family Megachilidae.

RGGS891-101 Whole Transcriptome Data Analysis

Credits: 1

This course will cover methods in processing transcriptome data -- from receipt of raw data to comparative genomic analysis. Participants will learn how to use transcriptome analysis software and compare efficacy of different methods with the goal of building a personal transcriptome analysis pipeline applicable to future data collection. Students will understand what their data mean at every step and be able to critically analyze the final results. Students will use their own dataset or one will be provided.

RGGS893-101 Functional Approaches to Genomics Algorithms

***Credits*:** 3

Many algorithms have been developed for computational genomics, but not all of them have been implemented in a functional language. This course will study previously implemented functional algorithms used in genomics and in graph searches and teach how create and implement new code modules for transcriptome sequence data analysis, including horizontal gene transfer and alternative splicing. Students will gain proficiency in Haskell programming while learning best practices for writing clear and efficient code.

RGGS898-101 Cophylogeny

Credits: 2

The course will focus on cophylogenetics from background through analysis. The course project will explore these topics with phylogenetic data on shipworms (reviewed from a broad phylogenetic and geographic sampling) and their bacterial endosymbionts.

RGGS892-301 Molluskan Taxonomy from the Cretaceous to the Present
Credits: 2
This course is meant to allow the student to familiarize herself with mollusk taxonomy and ecology. It will focus on molluskan families that persisted from the Cretaceous to the present. It will include hands-on taxa ID and various background readings on molluskan taxonomy, ecology, and evolution.

RGGS896-101 Phylodynamics of Rapidly Evolving Viruses
Credits: 3
Dynamical phylogenomics is the study of how phylogenetic relationships between genomes change over time. This can be applied to rapidly-evolving viral genomes to quantify the effect of medical treatments (viewed as mass extinction events) on the evolution of the virus population. This course will utilize well-curated time-series datasets for HIV populations, and emphasize continuous phylogenetic treespace methods.

RGGS896-301 Laboratory and Informatics Methods for Microbial Community Ecology
Credits: 2
This course will be a seminar reviewing the broad themes driving microbiome research, and the latest methods for sequencing and analyzing host-associated microbial communities. It will focus primarily on providing students with context in which to frame their research, and familiarizing students with the latest laboratory protocols and statistical tools for drawing meaningful inferences about microbial communities and their hosts.

RGGS894-101 Machine Learning
Credits: 4
Using a Coursera course (Machine Learning, from Stanford) as a foundation, student will learn the theoretical foundation behind many modern analytical techniques, learn a new programming language (MatLab), and become familiar with recent applications of the techniques to the biological literature.

RGGS891-301 Advanced Python for Ecological Data Analysis
Credits: 1
This course will focus on advanced data science and statistics in the Python programming language. The first part of this course will focus on using Python to manipulate and clean large data sets using Pandas to streamline data processing. The second part of this course will introduce databases and the SciPy library in Python in order to complete ordination analyses such as non-metric multidimensional scaling on the dataset in question.

RGGS897-301 Marine Viral Diversity and Interactions
Credits: 1
This independent study will survey the biology and ecology of microorganisms that inhabit the world's oceans. As a group, marine microbes are extremely diverse taxonomically, and extremely versatile with respect to their metabolic capabilities. This course will focus on four major themes: the diversity, ecology, and biogeochemistry of ocean microbes, as well as microbe-virus in the ocean. This course is in part adapted from the syllabus for Columbia's Microbial Oceanography EESC G6823 course from Fall 2018-2019.

RGGS895-101 Machine Learning Algorithms for Ecological Datasets
Credits: 2
This course will be a technical training in the intuition behind, construction of, and use of neural network algorithms for making predictions from ecological datasets. The key deliverable of this course will be a functioning script (written in both Python and R) to analyze the data from Melissa's final dissertation chapter on predicting parasite diversity in bats using host ecology, evolutionary history, and microbiomes.

RGGS893-301 Advanced Insect Physiology and Evolution
***Credits*: 3**
The plan is an intensive study of entomology, with an emphasis on the evolution and physiology of all major orders. This will include identification of major groups and "deep dives" into the evolution, anatomy, and physiology of selected orders. In addition, scientific content knowledge from this study will be applied to the revision of an entomology instructional module for Network of Conservation Educators and Practitioners.

RGGS892-301 Whole Transcriptome Data Analysis
***Credits*: 2**
This course will guide students through the transcriptomic analysis from study design, through statistical inference, differential expression analyses, and next steps. Participants will use relevant software and compare multiple methods in order to gain knowledge and perspective for designing a transcriptome analysis pipeline applicable to future data collection and analyses. Students will understand what their data means at every step and will be able to critically analyze the final results. Students will use their own dataset or one will be provided. Students will be asked to complete a variety of hands-on exercises and read primary literature throughout the course. This Independent Study will be open to one student at a time.

RGGS891-401 Bacterial Genetics and Genomics
***Credits*: 1**
This course will survey topics in Bacterial Genetics and Genomics drawing on a standard textbook for the subject matter, supplemented with readings which tie together broader topics with the specific areas of interest for the student's dissertation work. Weekly discussions of course readings will be capped by a term paper which can serve as the basis for the student's introduction to her dissertation.

RGGS893-401 Herpetology- Part II
***Credits*: 3**
This course will cover the phylogenetic relationships, geographic history, and characteristics of all squamates outside of Colubroides, which was covered last semester. The final project and course objectives will be similar, but instead of focused on the rest of Squamata.

RGGS893-201 Early Animal Evolution and Classification Systems
***Credits*: 1**
This course is designed to facilitate deep critical discussion of the history of two major scientific endeavors: The classification of nature in general, and research on early animal evolution. The scope of this course is aimed to be as close to all-encompassing as possible, with sections dedicated to the foundations of each discipline, critical discussion of publications that go against the mainstream with alternative classification schemes or unusual data types, and a special focus on all literature of the past 30 years. The course will incentivize critical thinking outside of the box to develop innovative approaches.

This Independent Study will be open to one student at a time. The student will present select publications in two weekly seminars, and critically discuss them with the instructors. The student will condense this information into a table showing the history of hypotheses on early animal evolution, and an essay on the developments of the field of classification.

RGGS892-301 Python for Genomic Data Analysis
***Credits*: 2**
This course will focus on manipulating genomic data using the Python programming language. The first section of the course will focus on reviewing the fundamentals of Python (data structures, loops, functions and variables) and introduce data-processing tools such as NumPy, Biopython and Pandas. The second

part of the course will focus on developing and optimizing a bioinformatic pipeline with Python code in Jupyter Notebook. The learning generated in this course will be beneficial to my dissertation progress since the bioinformatic work I am doing to understand beetle evolution requires the analysis of large genomic data sets.

RGGS893-201 Lab-based Comparative Osteology of Mammals
***Credits*: 3**
This is a lab-based course designed to give the student familiarity with the comparative osteology of mammals, with reference to other vertebrates as needed. Readings on anatomy, development, and genetics will supplement examination of specimens in the lab.

RGGS891-2-2021-4 Phylogenetic Analysis of Morphological Data
***Credits*: 1**
This course will cover phylogenetic and systematic methods for trilobites. More specifically, it will cover morphological character coding and character identification, models of morphological evolution (e.g. Lewis MK), and trilobite-specific applications of parsimony and Bayesian phylogenetic methods.
Physiology and Energetics of Insect Flight

RGGS896-1-2022-4 Physiology and Energetics of Insect Flight
***Credits*: 3**
This course is a deep dive into the biology, physiology, and energetics of insect flight. Concentrating on classical and contemporary readings, the goal is a deeper understanding of how insect physiology and metabolism, especially respiration, relates to weight relief, weight distribution, miniaturization, and other aspects of insect flight.

RGGS897-1-2023-1 Data Science: Manipulation and Reproducibility
***Credits*: 1**
This course will focus on manipulating, combining, and making available datasets generated during my PhD. The first section of the course will focus on learning SQL (Structured Query Language), a programing language used for communicating with and extracting data from databases, and other Python packages for data manipulation. The second part of the course will focus on creating and managing code in GitHub and Jupyter Notebooks for science reproducibility.

RGGS892-1-2023-1 Data Science: Manipulation and Reproducibility
***Credits*: 2**
This course will focus on manipulating, combining, and making available datasets generated during my PhD. The first section of the course will focus on learning SQL (Structured Query Language), a programing language used for communicating with and extracting data from databases, and other Python packages for data manipulation. The second part of the course will focus on creating and managing code in GitHub and Jupyter Notebooks for science reproducibility.

RGGS891-1-2023-1 Long bone internal structure
***Credits*: 1**
The course will focus on applied research methods for long bone internal structure analysis using microtomographic scans of extant primates. It will comprise of background readings on current research and hands-on work to process virtual data and virtually analyze and extract endostructural signals for comparative work with fossil specimens.

RGGS893-1-2023-4 Histological Techniques
Credits: 3
This course will cover the entire workflow necessary for learning histological techniques, including the differential staining of tissues to distinguish between various tissue types (eg cartilage/muscle). This

includes preparation of specimens (embedding), sectioning, staining, and interpretation of sections with light microscopy.

RGGS893-1-2023-3 New approaches to hominin phylogenetics
Credits: 3
This course will provide an in-depth understanding of approaches to hominoid phylogenetic studies through hands-on analyses of a 6 Mya dental specimen. The course will consist of background readings, new data collection from fossil and extant specimens, and focus on modern approaches to the phylogenetic analysis of hominoid craniodental characters. The course will result in a completed project with a conference-ready abstract.

TEACHING ASSISTANTSHIPS

The experience of teaching is an integral part of graduate training, especially in preparation for a career including academic service and teaching. After the first year, each student must complete mentored teaching assistantships in two courses or other educational programs; at least one of these must be in a formal university-level (undergraduate or graduate) classroom setting. A particular strength of the AMNH graduate program is the opportunity for a student to participate in AMNH pre-college, teacher training, life-long learning, and public outreach programs with the goal of enhancing the public understanding of science.

RGGS701 Teaching Assistantship I
Credits: 3

RGGS702 Teaching Assistantship II
Credits: 3

MUSEUM SEMINAR SERIES

Throughout the academic year, the AMNH presents a weekly Museum Seminar Series at which presentations on a variety of scientific topics will be given by leading scientists, educators and AMNH curators. During the first year, students are required to attend each program in the Series and meet with the speaker and course instructor(s) after each program for a discussion of the pertinent literature, which they will be expected to have read prior to the seminar, for a total of two hours each week. First year students will earn one credit per semester for a total of two credits.

RGGS703-101 Museum Seminar Series I
Credits: 1

RGGS704-301 Museum Seminar Series II
Credits: 1

STUDENT SYMPOSIUM

Second-year students organize and are required to attend a day-long Annual Symposium that features their research interests and the Graduate School curriculum. This informal retreat-like gathering, to which the faculty and the entire AMNH student community are invited, is intended to give new students access to faculty and other students, to share information about labs and research programs and activities, and to strengthen the Richard Gilder Graduate School community.

RGGS705-101 Student Symposium
Credits: 1

DIRECTED RESEARCH

Directed Research, Year 1: The aim of Directed Research in Year 1 is for the student, working with his/her advisors, to identify and refine a research area(s) for the dissertation proposal, including techniques to be used; field, collections, and laboratory components; identification of potential funding sources and preparation of grant proposals, with submission as a tangible outcome; and undertaking related pilot research. Specific supervised research opportunities include: experimental or project design, formulation of hypotheses and research questions, development of tests for specific hypotheses, acquisition of new techniques, generation and analysis of data, interpretation and discussion of results. Development of a written project is encouraged.

Directed Research, Years 2-4: The aim of Directed Research in Years 2-4 is for the student, working with faculty members, to carry out research on the chosen dissertation topic. Directed research work can include but is not limited to pilot analyses, development of expanded analytical data sets, transforming course projects/papers or directed research analyses into dissertation chapters and/or manuscripts to be submitted for publication. Specific supervised research opportunities include: experimental design, formulation of hypotheses and research questions, development of tests for specific hypotheses, acquisition of new techniques, generation and analysis of data, interpretation and discussion of results. Development of a written project is encouraged. Emphasis is placed on producing high quality dissertation chapters, suitable for publication, and development and submission of grant proposals.

RGGS801 Directed Research
Credits: 1

RGGS802 Directed Research
Credits: 2

RGGS803 Directed Research
Credits: 3

RGGS804 Directed Research
Credits: 2

RGGS805 Directed Research
Credits: 1

RGGS806 Directed Research
Credits: 2

RGGS807 Directed Research
Credits: 3

RGGS808 Directed Research
Credits: 2

American Museum of Natural History

Richard Gilder Graduate School

RGGS809 **Directed Research**
Credits: 1

RGGS810 **Directed Research**
Credits: 2

RGGS811 **Directed Research**
Credits: 3

RGGS812 **Directed Research**
Credits: 2

RGGS813 **Directed Research**
Credits: 1

RGGS814 **Directed Research**
Credits: 2