

EARTH AND PLANETARY SCIENCES, PHD

Fields of Graduate Study and Research

The department offers a range of fields of study covering Earth, Space, and Environmental Sciences. In the past decade, the department has hired seven new assistant professors and two full professors spanning Planetary Sciences, Geosciences, and Environmental Science. What links all of these fields of research together is a focus on treating individual processes - ranging from the formation of rocks to the distribution of organisms - as part of a system, with implications for and feedbacks from other parts of the system. The description below provides a rough grouping of the research areas involved and the faculty associated with each one. Interested applicants are urged to consult individual group web sites for more detail as well as to view presentations made as part of the department's 50th Anniversary celebration (<https://eps.jhu.edu/events/>). Prospective students should contact individual faculty members with whom they are interested in working. Students with interests that cross disciplinary boundaries or who use techniques found in different groups are strongly encouraged to apply as we believe that the most exciting questions to pursue in science today involve interdisciplinary research.

All Ph.D. students are expected to have a background of general biology, physics, chemistry and calculus. Deficiencies can be made up in the first semesters at Johns Hopkins. Students take a core program of statistics, Earth history, stable isotope geochemistry, and ecology. In conjunction with the Department of Environmental Health and Engineering, Earth and Planetary Sciences offers course work opportunities in aquatic chemistry, microbial ecology, geospatial analysis, and analytical environmental chemistry.

PLANETARY SCIENCES

In the last decade, the department has hired four new faculty members in the Planetary Sciences who study bodies ranging from Mercury to Pluto to exoplanets. Key questions include: What role do planetary atmospheres play in the habitability of planets and the origin and/or evolution of life? (Hörst) What can we learn from the sedimentary record on Mars about what processes have shaped the evolution of that planet? (Lewis) How do planetary dynamos work? (Stanley) How can we use the wealth of spectra coming to us from new sensors to learn about planetary atmospheres? (Sing) A common thread across all of this work is the question of habitability - what sort of things need to happen in order for a planet to be able to support life, and for us to detect it? These questions are addressed using a combination of observation (ground-based telescopes and robotic spacecraft), laboratory experimentation, theoretical modeling, and Earth-analog field studies. The program requires an interdisciplinary focus, drawing from a wide variety of fields including astronomy, geosciences, physics and chemistry. Research often includes data from active planetary exploration missions. EPS faculty include members of the Cassini mission to the Saturn system, New Horizons mission to the Pluto system, and Mars Science Laboratory Rover teams, along with a number of proposed future missions to Venus, and Titan, and other worlds.

Students are encouraged to take courses in astrophysics, chemistry, physics, applied mathematics, computer science, and engineering to gain the comprehensive background necessary for interdisciplinary research. The best undergraduate preparation is a broad background in physics, applied mathematics, chemistry, or earth science. Advanced

undergraduate courses in these fields (including differential equations, linear algebra, classical mechanics, electricity and magnetism, thermodynamics, organic, and physical chemistry) are strongly recommended. The EPS Planetary Science research program has close ties with the Space Department of the JHU Applied Physics Laboratory (APL), and students may be co-advised by APL researchers. Students in the department additionally benefit from the local availability of outside institutions including the Space Telescope Science Institute (co-located on the JHU campus), NASA Goddard Space Flight Center, the Carnegie Institution for Science, and the Smithsonian Institution.

DEEP EARTH GEOSCIENCES

This area focuses on understanding chemical and physical processes deep within the Earth and other planetary bodies. Key questions include: How do materials behave at very high temperatures and pressures, and what are the implications of this behavior for the whole planet system? (Wicks, Sverjensky) By what processes and at what rates do petrologic and tectonic systems evolve, and what are the feedbacks with the biosphere? (Viète). How is the Earth's geodynamo changing with time - and why? (Stanley) The interdisciplinary techniques used to study these questions include X-ray scattering and laser studies of planet-building minerals at extreme conditions (Wicks), geological field work and observation, and spatially-resolved geochemical and geochronological analysis of crystalline rocks (Viète), as well as theoretical and laboratory studies of mineral-fluid interactions (Sverjensky).

Aqueous geochemical studies centered in the Sverjensky group focus on the role of water in the evolution of Earth through deep time, particularly the linkages between water in the deep Earth and the near-surface environment. It involves quantitative geochemical modeling of the chemistry of water-rock interactions from Earth's surface into the upper mantle. Students participate in research involving the interpretation of experimental studies of water-rock interactions in terms of fundamental properties of aqueous inorganic and organic species over extreme ranges of pressure and temperature. Developing a thermodynamic characterization of the behavior of fluids at elevated pressures and temperatures enables exciting research into topics such as the origins of diamonds, the development and evolution of the continents and the potential roles of abiogenic hydrocarbons in Earth's deep carbon cycle. Collaborations with experimental laboratories enable a wide range of training in combined theoretical and experimental studies of the role of fluids in the history of Earth and other planets.

Students applying in this area will come from a wide variety of backgrounds, including class and research experience in chemistry, mechanical engineering, material science and condensed matter physics. Recommended classes, depending on the research track, include crystallography, mineralogy, petrology, and field geology, thermodynamics, quantum mechanics, continuum mechanics, and mineral physics.

Research within the fields of petrology and tectonics centered in the Viète group focuses on questions of length scales, time scales and drivers. It seeks to understand the tectonic processes that operate at plate margins, the nature and utility of the rock record, and interactions between the solid Earth and biosphere. Current foci include crustal heating and the tectonic significance of metamorphic rocks, scales of tectonic organization and episodicity, and petrologic records of seismicity. Student projects begin in the field, first involving mapping, measurement, observation and sampling. With field context established, geological questions are further interrogated through micro-scale structural, geochemical and geochronological analysis of sampled

materials. Simple analytical and numerical modeling of processes of deformation and heat and material transfer are used to reproduce observed features and constrain processes recorded in landscapes and rocks.

Students applying in this area should enjoy field work and the outdoors and will preferably have some background and interest in chemistry, physics and/or mathematics. Recommended classes, depending on research track, may include field geology, petrology and petrography, structural geology, sedimentology, transport phenomena, thermodynamics, and rock mechanics.

GEOSCIENCE IN THE SURFACE ENVIRONMENT

This area focuses on what the geological record can tell us about the evolution of life on Earth and its interaction with climate. A particular focus of this group is the use of isotope geochemistry to examine the carbon, nitrogen, oxygen and sulfur cycles, and to link changes in the rock record to the actual organisms present at the time. Key questions include: What was the physical and chemical context in which the earliest complex life formed? (Smith) How do environmental conditions and/or biological communities influence geochemical signatures found in the rock record? (Gomes)

Students working in this area will learn a range of skills, including: the field geology methods necessary to put samples in context, how to make isotopic measurements necessary to characterize the large-scale chemical environment, and how to use this information in conjunction with quantitative and modeling tools to investigate the coevolution of life and the Earth surface. Additionally, the Smith group has expertise in the paleontology of Ediacaran organisms and the Gomes group uses the tools of microbial ecology. Using multi-disciplinary tools, researchers in this area seek to use insight about the coevolution of life and the Earth surface to provide context to understand modern climate change and investigate the tools that can be used to search for life on other planets.

OCEANS, ATMOSPHERES AND CLIMATE

The Oceans, Atmospheres and Climate area focuses on understanding planetary-scale and regional dynamics with implications for planetary climates, including anthropogenic climate change. The philosophy underlying the department's program is a rigorous and thorough process-based understanding of the climate system, with a grounding in fluid dynamics, energy exchange, and relevant chemical and biological interactions. Researchers in the department address these processes with theory, laboratory and numerical experiments, and study both remotely sensed and *in situ* field observations. Johns Hopkins is a member of the University Corporation for Atmospheric Research.

The best preparation for graduate study in this program is an undergraduate degree in physics, applied mathematics, mechanical engineering, or another parent science such as chemistry, oceanography, meteorology, or geology/geophysics. Prior course work in fluid dynamics, while highly desirable, is not mandatory to pursue graduate study in this area. It is strongly recommended to have a broad background in the parent sciences, specialization in one of them, and at least three years of undergraduate mathematics. Research experience is also desirable.

Research in physical oceanography (involving Profs. Haine, Gnanadesikan and Waugh) focuses on the processes that maintain the global ocean circulation and the ocean's role in climate and global biogeochemical cycling. In particular, attention is on the role of waves, eddies, and small-scale mixing in controlling the ocean's part in Earth's heat and freshwater balances. We also study advection, stirring, and mixing processes in the interior ocean and their roles in dispersing

atmospheric trace gases and nutrients. The research program also includes computational oceanography, with links to other Hopkins departments and centers.

Research in atmospheric dynamics, (involving Prof. Waugh) focuses on large-scale dynamics, the transport of trace constituents, and understanding the composition of the global atmosphere (e.g., distributions of stratospheric ozone and tropospheric water vapor). Current interests include stratospheric vortex dynamics, troposphere-stratosphere couplings, transport and mixing processes, and global modeling of chemical constituents.

Research in hydroclimate, including atmospheric processes that drive precipitation and terrestrial hydrology, is a focus of Prof. Zaitchik's group. This research employs satellite image analysis, numerical modeling, and field observation to build a process-based understanding of the ways in which climate shapes landscape and vice versa. Current interests include drivers of rainfall variability in the tropics, coupled natural-human systems, seasonal forecast, and the application of hydroclimate analysis to studies of water resources, agriculture, and human health.

Research on climate and radiation is found across all of the research groups in this area and includes study of the global climate system and its response to radiative forcing due to changes in greenhouse gases and solar luminosity, the feedback effects of water vapor and clouds, and the radiative and hydrological effects of aerosols. These studies involve global and regional scale modeling, and the analysis and interpretation of satellite observations.

Additionally Prof. Gnanadesikan's group conducts research in biogeochemical cycling, focussing on applying and developing three-dimensional computational models that can be combined with observations and remotely sensed data to characterize cycling of key elements (including carbon, nitrogen, and oxygen) in the earth system. Opportunities exist to link this work to the observational and theoretical geochemistry work done in the department as well as to simulate key periods and transitions in Earth History.

ECOLOGY: ORGANISMS, ECOSYSTEMS AND ENVIRONMENTAL CHANGE

This area of research involves understanding how organisms interact with each other and with the physical world, and how humans affect ecological processes and ecosystems. Questions include: How does past and present land use change affect species distribution, community assembly and biogeochemical cycles (Avolio, Szlavecz)? How does biodiversity, especially invasive species, affect the rates of soil biogeochemical cycling and the production of greenhouse gases (Szlavecz)? How do urban environments shape the ecology and evolution of plants and soil organisms within these systems (Avolio, Szlavecz)? What are the linkages between plant community composition and ecosystem function and/or services in grasslands and cities (Avolio)? How resistant or resilient are grasslands to global change drivers and what is their capacity to adapt to new environmental conditions (Avolio)? Students are invited to participate in ongoing collaborations at two Long Term Ecological Research Sites (Baltimore Ecosystem Study and Konza Prairie Biological Station), the Smithsonian Environmental Research Center, the Beltsville Agricultural Research Center, or to design an original research project under the advisement of our faculty.

Graduate Programs

Requirements for Admission

The department expects applicants for advanced degrees to have completed undergraduate training in the basic sciences and mathematics. Normally this includes mathematics through at least integral calculus and coursework, plus at least one year of coursework in physics, chemistry, and/or biology (with the exact combination depending on specialization). Further undergraduate study in one or more of these subjects or in mathematics is highly desirable for all programs in the Earth sciences; additional mathematics is essential for geophysics, atmospheric sciences, and dynamical oceanography. Extensive undergraduate work in Earth sciences is not a requirement for admission. If students lack formal training in this area or have deficiencies in the other related sciences, they may be admitted but will have to allow additional time in the graduate program to make up for deficiencies in their preparation. Students who have not attended undergraduate universities where the language of instruction is English will either be required to provide evidence of their reading, writing and speaking ability in English at level sufficient to conduct high-level scholarship. This may either take the form of a standardized test, evidence of work experience in a comparable environment, or an interview with the proposed advisor.

Requirements for Advanced Degrees

Candidates for the Ph.D. must meet the requirements specified by their advisory committee. This begins with at least one year of coursework or supervised research, followed by passing both a comprehensive examination before a departmental committee and an oral examination administered by the Graduate Board of the University. Finally, students must submit an acceptable dissertation involving significant original research, as determined by two faculty readers, and present this research to the department. A minimum of two consecutive terms registered as a full-time student (engaged in some combination of classwork and research) is required.

The department rarely accepts candidates for the M.A. degree alone, but Ph.D. students can, with the consent of their advisors, complete a program that will qualify them for the M.A. degree at some point after their first year. Candidates for this degree must pass a comprehensive examination before a departmental committee, and must satisfy the residency requirement specified above for the Ph.D. degree. A student's advisor may require an essay demonstrating research capability.

For further information about graduate study in the Earth and planetary sciences contact the Chair, Department of Earth and Planetary Sciences.

Financial Aid

Applications for admission to graduate study and financial aid (including all supporting documents and, if necessary, evidence of proficiency in English) should be submitted to the department before January 1.