Planetary Habitability Committee Report

Committee Members: Tamar Barkay, Paul Falkowski, Juliane Gross (Co-Chair), Saurabh Jha, Charles Keeton, Greg Herzog, John Reinfelder, Sonia Tikoo-Schantz, Costa Ventriani, and Nathan Yee (Co-Chair)

Research

Rutgers University has the potential to become a leader in the field Planetary Habitability. Currently, our main strength is the diversity of faculty members in the Rutgers community who are interested in planetary sciences and astrobiology. Our broad expertise and diverse perspectives are ideal for fostering novel and innovative collaborations. Existing EOAS faculty members in planetary sciences/habitability include Juliane Gross (EPS), Nathan Yee (DES/EPS), Sonia Tikoo (EPS), Robert Kopp (EPS), John Reinfelder (DES), Costa Ventriani (DMCS), Lee Kerkhof (DMCS), Claude Herzberg (EPS) and Paul Falkowski (EPS/DMCS/RB). Outside of EOAS, faculty in planetary sciences/habitability span multiple departments such as Chemistry (e.g. Greg Herzog) Physics & Astronomy (e.g. Saurabh Jha and Charles Keeton), RBHS (e.g. Vikas Nanda) and Biochemistry & Microbiology (e.g. Yana Bromberg and Tamar Barkay).

The most significant need in the core area of Planetary Habitability is a new faculty hire to lead planetary research and teaching at Rutgers University. Although there are many faculty members in the Rutgers community who are interested Planetary Habitability, we lack a cohesive vision. A larger goal needs to be established. A new hire will be critical for creating an exciting vision of Planetary Habitability. This larger vision will naturally pave the way to more (and better) grants and new collaborations. Preferably, the new hire is associated with (or leading) a major NASA mission. One suggestion is for EOAS to sponsor seminars, invite top people to give talks, ask them if they want to have a job here, and then create that position. This seminar series will also get the excited faculty together to talk and share ideas. Speakers will see how excited our faculty is and can see the potential for work/collaborations/opportunities for them. Our collegial and outstanding faculty is a major recruitment tool.

The committee identified five prominent gaps within EOAS in Planetary Habitability:

Exoplanet research, Exo-solar system research, Protoplanetary Disk processes (exo and our solar system): This topic includes, but is not limited to: Exo-solar systems, planetary evolution, solar system evolution, chondritic studies, origin of refractory inclusions, presolar grains, primitive organics, interplanetary dust particles. Using ultrahigh-resolution ion- and electron-microscopy and microprobe techniques, including focused-ion-beam scanning-electron microscopy, electron-probe micro-analyses, and transmission electron microscopy, to determine the composition and structure of these materials at scales ranging from millimeters down to the atomic. Knowledge of these details of planetary materials provides incomparable insights into the origin of our solar system and ancient stars.

Experimental planetary petrology: Low and high pressure experiments; low and high temperature experiments; fluid-rock interaction at low and high T, P; magma-fluid interactions; hydrothermal systems.

Planetary Spectroscopy/remote sensing: to study planetary bodies by using a variety of observational tools at wavelengths ranging from visible to radio to study the composition, size, shape, surface, temperature, and atmospheric structures that comprises these planetary bodies.

Planetary Atmospheres: modeling the evolution of planetary atmospheres within our own solar system (gas giants) as well as exoplanets.

Planetary Geomorphology/Planetary Surface Processes: to better understand the evolution of the Earth and other planetary bodies. This includes but is not limited to: planetary aeolian processes, planetary fluvial processes, field work, planetary remote sensing, and numerical modeling.

If EOAS received an unrestricted gift of $5 million, these funds should be used for a cluster hire in Planetary Habitability. Hiring three people in the field would be transformative for Rutgers. This cluster hire should include large start up packages for senior level hires. Funds should be used to build new analytical facilities for the new hires (e.g., spectroscopy lab, experimental facilities, FIB-TEM). One of the goals is to hire someone already associated with a NASA mission.

Currently, there are several prominent NASA Planetary Habitability Missions and Exoplanetary Research Programs:

- Mars: Insight, Mars 2020 Rover, MSL, MER, Mars Express, MAVEN
- Future "New Frontier Missions" [which have not been selected yet, but the request for proposals have been announced: Venus In Situ Explorer, Saturn Probe, Trojan Tour and Rendezvous; Lunar Sample Return; Comet Sample Return; Ocean Worlds (Titan and/or Enceladus)]
- Current "New Frontier Missions": Juno, New Horizons, OSIRIS-Rex
- Europa Klipper mission plus lander (search for biosignatures)
- Psyche (Iron World: a mission to an asteroid that is entirely made of iron, most likely a left over planetary core)
- James Webb Space Telescope
- TESS (Transiting Exoplanet Survey Satellite)
- WFIRST (Wide-Field Infrared Survey Telescope)
- NAI (NASA Astrobiology Institute)

If Rutgers is to become a leader in the field Planetary Habitability, then hiring a top researcher in the next five years should be a high priority for the university. Because the new hire would likely have a joint appointment between departments, developing strong relationships with existing EOAS departments and forming a multi-department search committee are important first steps.

Teaching

Rutgers University offers a wide range of courses related to Planetary Habitability.

Course Title (U=Undergraduate / G=Graduate)	Course Description	Instructor
Structure and Formation of the Earth (U / G)	Topics of current research on the internal structure of the Earth. Mantle structure, phase changes, seismic discontinuities, trace element/isotopic properties, mineral physics, core formation, meteorites, moons, asteroids.	C. Herzberg
History of Earth Systems (U / G)	This course integrates atmospheric, oceanographic, geological and biological concepts with a historical perspective to introduce the student to the major processes that have shaped Earth's environment. The course will examine climatic processes on geological time scales, the evolution of organisms, the cycling of elements, and the feedbacks between these processes.	P. Falkowski
Building and Maintaining a Habitable Planet (U)	Understanding human-cause environmental changes in the context of Earth's 4.6 billion year history. Geological and human timescales; planetary habitability; planetary, biological, and civilizational flows of energy and entropy; feedbacks between life, the carbon cycle, and climate; the evolution of complex life; human alterations of the Earth system; intelligent life in the universe.	R. Kopp
Introduction to Geochemistry (U)	Low and high temperature geochemistry, element distribution, geochemical structure of the Earth, Laboratory exercises include sample materials, preparation techniques, mass spectrometry, data collection, reduction and interpretation.	M. Feigenson
Introduction to Oceanography (U)	The course is designed to introduce students to the oceans through methods, rationale, discoveries and relevance to our lives with emphasis on the seafloor. Students will learn the basic principles behind the exploration methods, and examine what these methods are revealing about the ocean. Students will experience the discoveries that are changing the way we think about our planet and beyond.	S. Severmann
Planet Mars (Mars, the Next Frontier) (U)	Planet Mars is the next frontier. Cross-disciplinary evidence for the formation and evolution of the planet over 4.56 billion years and the Martian climate system will be explored. Interpretation of Mars' surface from current and future space missions will be used to search for likely landing sites on the planet.	J. Gross

Geology of the Moons and Planets (U)	Origin, composition, and evolution of the solar system, meteorites, comets, asteroids, Moon, Mercury, Venus, Mars, Jupiter, Io, Europa, Ganymede, Callisto, Saturn and its satellites, Uranus, and Neptune.	S. Tikoo
Water Chemistry (U)	Concepts of thermodynamics, acid/base chemistry, carbonate chemistry, aqueous/surface complexation, colloid chemistry, kinetics, redox processes, isotope hydrochemistry, and biogeochemistry will be covered in the lectures. Students will learn how to calculate gibbs free energy, equilibrium constants, pH, dissolved ion concentrations, rate constants, redox potentials, and isotope fractionation factors.	N. Yee
Invisible Galaxies: How Microbial Life Shapes Our Planet and Inspires Frontier Science (U)	This Byrne Seminar explores microbial life in an earth systems context. Students will discuss a range of diverse topics, which span their role as critical first responders to climate change, how they are central in our search for extraterrestrial life, and how they inspire the interface between art and science.	K. Bidle
Killer Asteroids, Comets, and Impact Craters (U)	In this Byrne Seminar key concepts of of geology and planetary science are introduced and used to understand the processes and effects that impacts have on planets, including Earth. This seminar includes a trip to the American Museum of NAtural History in NY.	J. Gross J. Wright
Astrobiology: Is There Life on Other Planets? (U)	This Byrne Seminar explores the kinds of life forms that exist on Earth, whether life on other planets would share similar characteristics, such as DNA and RNA, and what the role of impacts, comets, Solar wind, magnetic fields in the evolution of life.	G. Montelione
Life on Mars (U)	This Byrne Seminar examines the new data returned by the Curosity rover and critically analyzes previous evidence for life on Mars. Methods for life detection and evaluate the claims of bacterial fossils in the martian meteorite ALH84001 are discussed in detail.	N. Yee
Astronomy and Cosmology 109 & 110 (U)	A predominantly descriptive introduction to current ideas concerning the nature and origin of the earth, the solar system, the galaxy, and the universe; neutron stars and black holes; the "big-bang"; the possibility of life outside the earth.	S. Jha
Physical Oceanography (U)	This course explores the principles of ocean physics: mass, momentum, heat, and freshwater conservation and atmospheric exchange; influence of Earth's rotation; the ocean's role in climate; tides, waves, and currents; and the effects of ocean circulation on its biology and chemistry.	J. Miller D. Haidvogel

The Greenhouse Effect (U)	The course investigates the physical and chemical bases of the "greenhouse effect" and its global impact on biology, climate, economy, and politics. Reducing the emission of "greenhouse" gases; nuclear energy, and other alternative energy sources are discussed.	P. Chandra
Bioinformatics (U/G)	This course is designed to introduce experimental biologists to bioinformatics concepts, principles, and techniques. Students have access to the same computational resources used by bioinformatics labs on campus. By the end of this course, students are expected to possess a sufficient bioinformatics skill set for productive collaboration within a multi-disciplined research team.	Y. Bromberg
Major Events In Earth History (U/G)	This course explores the history of the solid Earth, oceans, atmosphere, and life over the past 4.5 billion years as narrated by major events in the geological record.	C. Herzberg
Planet Earth (U)	This course covers basics in physical geology and historical geology. The course is designed for Earth Science majors, minors, and non-science majors. The course covers a variety of topics as bases for advanced courses in Earth Sciences or as a terminal level for non-science majors. The learning goal for the course is for students to understand basics about Earth building materials (mineral and rocks), how the Earth has operated in the past, and how it operates today.	M Glamoclija
Rocks and Minerals (U)	A detailed introduction to rocks and minerals – the essential materials of the solid earth. Classification and systematic study of the chemical and physical properties of the common rock-forming mineral groups; textural and mineral compositional studies of common igneous and metamorphic rocks. In this course students acquire skills of petrographic microscopy, basic skills in XRD techniques with the data interpretation.	M Glamoclija

A new Planetary Habitability minor program for undergraduates can be readily developed at Rutgers University. This minor can be jointly offered by the Department of Physics and Astronomy and the Department of Earth and Planetary Sciences. The three existing courses would form the core of this program: “Astronomy and Cosmology 109 & 110” (2 companion courses), which are offered by the Department of Physics and Astronomy, and “History of Earth Systems”, which is offered through the the Department of Earth and Planetary Sciences. “Astronomy and Cosmology 109” covers the historical foundations of astronomy, and modern knowledge of our solar system and planets around other stars, and how they might have originated. The emphasis of the course is on how astronomers know what they claim to know, and how confident they are of their claims. The companion course, “Astronomy and Cosmology 110”, covers the structure and evolution of stars, the properties of galaxies, and the past, present, and future of the Universe. “History of Earth Systems” examines climatic processes on geological time scales, the evolution of organisms, the cycling of elements, and the feedbacks between these processes. These three core courses will be complemented by existing undergraduate courses, e.g. Planet Mars; Moons and Planets; Petrology; Mineralogy (see table above).

Hiring new faculty is absolutely required to establish a Master's or Ph.D. program in Planetary Habitability at Rutgers University. New faculty hires would lead new teaching initiatives and offer courses in planetary sciences and habitability covering topics such as the exoplanets, Early Earth; planetary atmosphere evolution; extremophiles and microbial life. If associated with NASA missions, new faculty members could potentially bring graduate students to visit a space center (e.g. Goddard) to see how big NASA science is being done, how telescopes are being build, etc.

Outreach and Policy Engagement

Currently, Rutgers is undertaking very little public outreach activities related to Planetary Habitability. Potential new outreach initiatives include developing a Planetary Habitability Activity for Rutgers Day; exhibitions at the Rutgers Geology Museum; develop activities for the Rutgers Science Explorer Bus; Teacher training workshops; Develop a Public Lecture Series to get the general public interested and informed; develop a university wide lecture series to bridge the gap between departments and schools; Open House.