Abstracts of talks
in the international workshop "Exploring Quantum, Elements, and Life Interactions"

Special Seminar: May 2nd, 10:00 am – 11:00 am

Prebiotic to Present:

The Chemical Biology and Physical Organic Chemistry of Sulfur Species"

Prof. Mike Pluth (University of Oregon)

Sulfur plays diverse roles in prebiotic and contemporary chemistry. Prior to the oxygen-rich environment that we live in today, many organisms used sulfur as a key energy source. Based on this evolutionary history, many of the cellular remnants of this sulfur-based energy economy are still present in modern day organisms. This presentation will cover a broad array of the physical organic chemistry of reactive sulfur species that contribute to the importance of this element for terrestrial life. Specific examples will include the roles of reactive sulfur species in prebiotic chemistry as well as more contemporary roles of reactive sulfur species in chemical biology and human health.

International Workshop: May 9th, 2022

9:05 am – 9:30 am

Planetary Metabolism: Science of a Living Planet

Prof. John Hernlund (Tokyo Institute of Technology)

Natural science is presently at a historical juncture that follows in the footsteps of major paradigm shifts such as the Copernican revolution and the theory of evolution: The distinction between life and non-life is vanishing. Prior revolutions challenged the notion that Earth was the center of the universe, that humankind was special and seperate from the animal kingdom, while the present revolution is challenging the distinction of life itself. In the present era of planetary exploration it is increasingly impractical to maintain arbitrary distinctions between life and non-life, and future discoveries are likely to further erode the idea that any meaningful separation can be made between biology and geology. The reason is very simple: life only exists in an open system, and in an open system there are no boundaries. Life as we know it is part of a symphonic collaboration of natural processes spanning all spatial and temporal scales of a planet, sharing the same matter and energy sources, evolving together as a meta-system through deep time, and bound together by the same origin and fate. In this talk I will discuss how many traits usually attributed to life as distinct characteristics are in fact not unique to "life" but are manifested by numerous physical and chemical processes. I will argue that the best way to understand a living planet is to focus on the vast network and hierarchy of process interactions, with implications for habitability and life detection outside the Earth system.

International Workshop: May 9th, 2022

9:30 am - 9:55 am

Deep time connections between the atmosphere, biosphere and Earth's interior

Prof. Craig O'Neill (Origins Research Institute, Research Centre for Astronomy and Earth Sciences)

The evolution of Earth's surface environment is intimately tied to the deep interior and thermal state. Today, the coupling is mediated by plate tectonics, driven by heat loss from the deep interior. Convergent plate boundaries drive mountain-building – and erosion of this topography provides nutrient flux into the oceans, and removes CO2 from the atmosphere via the CO2-silicate weathering cycle. Together with subduction of carbonates back into the interior, this acts as a thermostat for surface temperatures.

Deep interior processes may have also affected the evolution of surface oxygen. Despite evidence of photosynthetic cyanobacteria 3.5 Ga ago, atmospheric oxygen did not rise to appreciable levels until 2.4 Ga – an event known as the Great Oxidation Event (GOE). Earth's interior may have acted as a redox buffer on the surface, with reducing (low fO2) volcanic gases such as CH4 consuming produced oxygen.

Geological evidence suggests the redox state of volcanic gases may have changed leading up the GOE. Mantle samples across the interval show an increase in fO2 leading up to the GOE, suggesting the GOE was a tipping point, where the redox state of volcanic gases dropped enough to allow the accumulation of molecular atmospheric oxygen. The mantle shift was probably driven by the mixing of a deep primordial high fO2 layer formed during the magma ocean. We have modelled the mixing time of such a layer, and show it is consistent with the timing of the GOE, and the magnitude in upper mantle redox shift required to reach an atmospheric tipping point. The evolution of the deep Earth is capable of driving surface changes over billion-year timescales, and the interactions between these systems are critical for understanding long-term habitability of planets.

International Workshop: May 9th, 2022

10:05 am - 10:30 am

Ocean dynamics and their impact on the marine ecosystem

Prof. Kelvin Richards (University of Hawaii at Manoa)

The fluid flow in the ocean is well described by Newtonian physics and the Navier Stokes equations. The range of scales, however, is large: from the viscous scale of order 1 millimeter to global, and from seconds to millennia and beyond. Approximations to the equations and the parameterization of unresolved processes are needed. Improvements in observations and numerical models over the last few decades has allowed smaller scale processes to be resolved, revealing the rich nature of the ocean circulation, and the importance of those smaller scales. The marine ecosystem is equally rich in terms of species diversity, functionality and interactions, all taking place in a turbulent ocean. I will give examples of the fluid flow at various scales, how the flow impacts ecosystem dynamics, and ending with some open questions.

International Workshop: May 9th, 2022

10:30 am - 10:55 am

Earth system modeling for gaining comprehensive understanding of global change

Prof. Michio Kawamiya (Japan Agency for Marine-Earth Science and Technology)

Global change is not only limited to climate change. Changes in land use, nitrogen load on land and consequent coastal eutrophication, ocean acidification and deoxygenation, among others, are now the issues on the planetary scale. Earth system models (ESMs) have been a synonym for climate models with carbon cycle but, equipped with many component models developed in the dedicated fields, are transforming into a powerful tool to deal with those complex problems. ESMs can, for example, quantify the impacts on carbon cycle, caused by land use change through biofuel production to meet with a socio-economic scenario consistent with a given mitigation target; this should then be considered to revisit the scenario. Various aspects of recent ESM development, such as coupling with models for human activities, will be reviewed in the presentation as a food for thought regarding ESM's role in quantifying the planetary boundaries.

International Workshop: May 9th, 2022

10:55 am - 11:20 am

Carbonyl sulfide interface evolving energy metabolism and environmental stress response in organisms

Prof. Takaaki Akaike (Tohoku University)

Recently, we found that sulfur respiration is highly conserved and evolved in microbiota and organisms including humans, addressing the overall picture of a fundamental energy metabolism. Our studies conducted so far identified the sulfur respiration as mediated by reactive sulfur species like persulfides or supersulfides expressed by all organisms including archaea, prokaryotes and eukaryotes, and even mammals in mitochondria. These findings are further innovated by another important discovery of carbonyl sulfide (COS) derivatives formed physiologically in all organisms including human, which should become a milestone and therefore envisage us a fully contemporary view of a remarkable interface of diverse biota and environments on the earth and even in interstellar spaces. This lecture will also deal with the redox and antioxidant responses of organisms and their microbiome surrounding to protect from various environmental stresses, which thus warrants our extremely interdisciplinary and productive research program that we are now proposing.