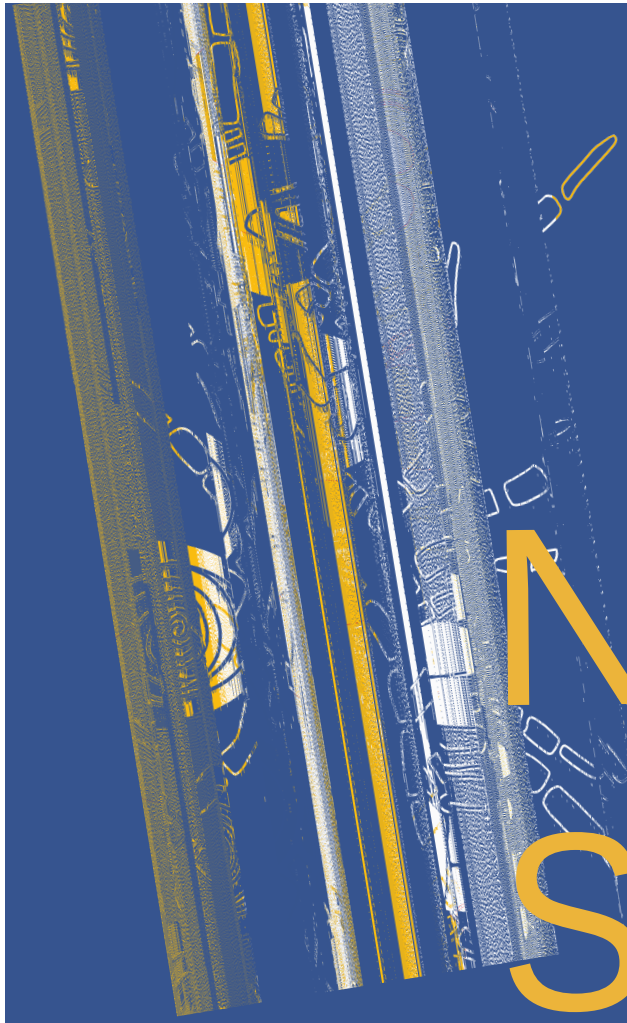

Natural Science

Phosphate Ester Bond Chemistry with Zirconium (IV) Catalysts

Nathaniel Bunnell

The following is an excerpt from a longer piece. For full text, please visit h□ps://scholar.colorado.edu/concern/undergraduate_honors_theses/cf95jc857

Abstract

Earth's infancy was a time of immense chemical complexity. Over millions of years, steady chemical cycles were formed and driven by thermodynamics and organic precursors le□ over from the planet's formation. In aqueous environments, this chemistry may have led to the formation of catalytic RNA species capable of information storage and replication. Presumably, the construction of these oligonucleotides was catalyzed by primordial Earth's abundant mineral content. However, the species that accelerated these types of transformations are unknown. This study explored the role of Zr+4 in the catalytic formation of phosphate ester bonds. Through TLC screening, it was found that most of the test conditions produced no observable phosphorylated products. In the final samples, highly polar spots may have contained phosphate-bearing compounds. These findings provide mixed certainty about zirconium's catalytic capacity for ester formation but suggest that zirconium metal-organic frameworks (MOFs) and alternative metal ions may be viable routes for future investigation.

Lay Summary

Earth began as a planet of rock and magma, hardly recognizable without the biological adornments that characterize it today. For nearly a billion years, consistent comet and asteroid impacts heated the planet and vaporized any reservoirs of water or organic ma□er that covered the surface. As this bombardment subsided, life came to fruition in half the time that the mineral rain had lasted. The question of how this transition occurred is one of the most elusive in the biochemical field. In particular, it is still unknown how all life, whether primordial or modern, came to share polynucleotides as an essential coding system for all their requisite biological functions.

This study explored the role of Zr+4, an abundant mineral on early Earth, in the catalytic formation of phosphate ester bonds, the core linkages in DNA and RNA. Through TLC screening, it was found that most of the test conditions produced no observable phosphorylated products. In the final samples, highly polar spots may have contained phosphate-bearing compounds. These findings provide mixed certainty about zirconium's capacity for ester formation but suggest that zirconium metal-organic frameworks (MOFs) and alternative metal ions that reflect early Earth's composition may be viable routes for future investigation.9535947 5.61766 9.79

MAVEN/IUVS Nadir Observations of Discrete Aurora on Mars: Insights into Regional Local Time Control and Magnetic Reconnection

Ben Johnston

The following is an excerpt from a longer piece. For full text, please visit h□ps://scholar.colorado.edu/concern/undergraduate_honors_theses/cj82k859v

Abstract

Discrete aurora are sporadic ultraviolet emissions on Mars. These emissions, which occur globally and in the upper atmosphere of Mars, are strongly correlated with martian crustal magnetic field. Crustal fields on Mars form from remanent magnetism locked in the crust, and vary in strength across the disk, with the strongest fields located in the southern hemisphere. Previous studies using data taken by the MAVEN spacecra□ has revealed hundreds of detections in limb viewing and a single detection in the nadir observations. Further analysis of all nightside MUV nadir-viewing observations taken by the MAVEN Imaging Ultraviolet Spectrograph (IUVS) instrument has revealed approximately two hundred additional discrete aurora detections. While aurora occur globally and sporadically, events in the strongest crustal magnetic field regions of the martian southern hemisphere show high repeatability. Previous work reported using IUVS limb observations (Schneider et al., 2021) revealed detections occurring before midnight; the emissions identified in the nadir dataset show detections both occurring before midnight and a□er midnight in the strong field region. We find a previously unreported correlation and between local time and geographic location, with two distinct auroral event groups manifesting pre- and post-midnight in separate but adjacent locations in the strong field region. Magnetic field reconnection may explain this regional local time control of discrete aurora on Mars.

Abstract

Biomimicry—design inspired by the functional genius of nature—is becoming increasingly prevalent in fields of material science, architecture, and other sciences. Yet, when it comes to building, biomimicry is

Long-Term Trends in Gas-Particle Partitioning of Reduced Reactive Nitrogen Species, as Analyzed by Annular Denuders and Ion Chromatography

Jared Schlenker

The following is an excerpt from a longer piece. For full text, please visit h□ps://scholar.colorado.edu/concern/undergraduate_honors_theses/9306t067v

Abstract

Reduced reactive nitrogen species, which primarily consist of ammonia and low-mass amines, occur in the gas-phase and the particle-phase of the atmosphere. Despite being present at trace concentrations, these species can have severe e□ects on eutrophication, biodiversity, human pulmonary and cardiac health, and deposition. Long-term sampling of these species is infrequent, and such sampling that has taken place is focused around agricultural sources rather than urban environments. A greater understanding of the gas-particle partitioning of these species elucidates our understanding of the roles they play in the aforementioned environmental e□ects.

I adapted the EPA's procedure for the sampling of ambient air using annular denuders and performed troubleshooting techniques on an ion chromatograph to develop a method to collect and analyze reduced nitrogen species; with this method, phases can be examined separately, thus allowing for a greater understanding of the magnitude of each risk associated with the gas and particle-phases rather than conflating the total concentration together. Method development is a crucial step in initiating long-term sampling, because consistency is the foundation of accuracy. I began preliminary ambient sampling with a focus on ensuring the procedure works and exploring potential trends.

While further sampling over the course of years will be necessary to confirm trends, some trends are beginning to emerge: gas-phase ammonia is present in higher concentrations when the average temperature is greater. The total concentration and the ratio of gas-to-particle concentrations are still being considered, as are these apparent trends. For the future, focus should be directed towards identifying the dominant source of analyte in the second annular denuder, observing e□ects of di□erent filters, refining the gradient method, and considering the maximum collectable concentration on the denuders and filter.

Lay Summary

All living things from plants to animals to humans require nitrogen to perform a variety of essential chemical processes. While ~78% of the atmosphere is made up of nitrogen, the vast majority of this exists in an unreactive, and therefore unusable, form. This is due to a strong triple bond between two nitrogen atoms

in the nitrogen gas molecule (N_2). Reactive nitrogen, on the other hand, is also present in the atmosphere but its lack of a triple bond makes it usable for living things.

In small concentrations, reactive nitrogen can deposit onto ecosystems, providing plants and animals with a vital, and oen limited, nutrient. In larger concentrations, atmospheric reactive nitrogen forms particulate maer; particulate maer is tiny solids or liquids suspended in the air. Of most interest is particulate maer with a diameter of less than 2.5 micrometers ($PM_{2.5}$); for reference the width of a human hair is around 70 micrometers. Particulate maer of this size penetrates deeply into the lungs and causes pulmonary, respiratory, and cardiac diseases. Furthermore, the World Health Organization says that $PM_{2.5}$ is the greatest risk to human health associated with air pollution. Due to the high risk of these species along with projected increases in emissions and limited study in urban environments, there is a lot to be gained from

Impact of experimental forest fragmentation and fire on the funnel-web spider, Atrax sutherlandi.

Wya Metelman-Alvis

The following is an excerpt from a longer piece. For full text, please visit h ps://scholar.colorado.edu/concern/undergraduate_honors_theses/mk61rj17t

Abstract

Habitat fragmentation is one of the leading causes of biodiversity loss and in many regions of the world, climate change now interacts with habitat fragmentation in, as yet, unknown ways. The Wog Wog habitat fragmentation experiment, located in New South Wales, Australia, is one of the longest experiments of its kind, running for over 35 years. The experiment provides an excellent opportunity to examine the e ects of habitat fragmentation on population changes over long time scales. In this project, I am studying the impacts of both habitat fragmentation and the Australian Black Summer Fires of 2019-2020 on the population of the funnel-web spider, Atrax sutherlandi. The fires burned for more than four months, burning more than 45 million acres of land, 30 million of which were forested, including Wog Wog. These bushfires are estimated to have killed over one billion invertebrates. I created models to examine di erences in pre- and post-fire presence and abundance in fragments versus continuous forest using data collected post-fire and for five years before the fires. Here we show that habitat fragmentation and fire do not interact to impact the funnel-web spider. Our results show that funnel-web presence and abundance did not di er before or a er the fires or in habitat fragments compared to continuous forest. A potential explanation for the lack of an impact of fire is that funnel-webs live in burrows in the ground, which may protect them from fire. Also, a previous study from Wog Wog shows that habitat fragmentation did not impact funnel-web abundance in the period of time before the fire, likely because the spiders are generalists and invertebrate food webs remained intact in habitat fragments. Future studies should follow funnel-webs as the burned fragment communities continue to recover.

Self-Assembling Nanodiscs Technology Exploration with Single-Molecule Biophysics Experimentation using Site-Specific A□achment Atomic Force Microscopy

Stephanie Talder

The following is an excerpt from a longer piece. For full text, please visit h□ps://scholar.colorado.edu/concern/undergraduate_honors_theses/xg94hq786

Abstract

The relationship between membrane proteins and functional cells is not yet fully understood, in large part due to the lack of knowledge about the structure and dynamics of membrane proteins. Because of the recent advancement of biotechnology, the visualization of membrane protein dynamics and energetics has progressed significantly, in large part due to nanodisc technology. Nanodiscs allow for the formation of a native environment for membrane proteins, which is essential to learning more about their structure. Atomic force microscopy (AFM) allows for the precise imaging of membrane proteins as well as the utilization of single-molecule force spectroscopy (SMFS). When completing single-molecule experimentation, it is crucial that the covalent a□achment of the probe is completed, because it allows for hundreds of force-extension traces from a single molecule to be completed. Another essential aspect of site-specific a□achment is passivation is necessary for unwanted interactions between the AFM cantilever tip and a single probe molecule. The focus of my senior thesis is to work with the optimization of nanodisc technology formation embedded with the membrane protein bacteriorhodopsin (bR). The bR was inserted into nanodiscs in both wild-type and c-terminal cysteine transformed to allow for site-specific labeling. The formation of nanodiscs with c-terminal cysteine bR was then labeled with DBCO-Maleimide tagging to allow for covalent connections when utilizing AFM SMFS. Altogether, this work shows a methodology for the optimization of nanodisc formation containing c-terminal cysteine bR membrane protein and warrants further investigation utilizing AFM imaging and SMFS with varying conditions of site-specific spectroscopy to target the development of protein-membrane dynamics.

Production of Polyhydroxyalkanoates During Bokashi Composting: A Study on Sustainability

Madelyn Brown

The following is an excerpt from a longer piece. For full text, please visit h□ps://journals.colorado.edu/index.php/honorsjournal/article/view/1745

Abstract

This study examines how the sustainability of the plastic industry can be improved through a concurrent method of polyhydroxyalkanoate production, specifically that of a bokashi compost media. In studying previous research on the plastic manufacturing processes, the researcher found a gap in knowledge in the a□ordability and accessibility of bioplastic production, limiting the expansion of the industry. By studying how Escherichia coli reacts to a feast famine cycle in a bokashi compost habitat, the study addresses the question: to what extent, if any, does the ability to modify phosphorus, nitrogen, carbon, and oxygen levels in compost bins allow for polyhydroxyalkanoates to be produced in order to determine and expand the accessibility of bioplastics? The researcher collected data of the bacterial body mass containing polyhydroxyalkanoate before and a□er a feast famine cycle. These data led to the definitive conclusion that polyhydroxyalkanoates can be produced in a concurrent method of production in a bokashi compost bin.

Fluorescence polarization reveals a possible displacement model of competition in PRC2:RNA:DNA interactions

Regan Fenske

The following is an excerpt from a longer piece. For full text, please visit h□ps://scholar.colorado.edu/concern/undergraduate_honors_theses/5x21tg835

Abstract

PRC2 is a histone methyltransferase that acts on histone subunit H3 at lysine 27 to repress chromatin state and inhibit gene expression. The interactions between PRC2 and RNA have been heavily studied in vivo and in vitro with conflicting results reported on the relationship, but there is less data on interactions between PRC2 and DNA. Fluorescence polarization-based methodology was used with various RNA and DNA species to study the binding kinetics of PRC2 with RNA and DNA. Previous data indicate that PRC2 has a relatively high a□nity for DNA species that are rich in consecutive G and C nucleotides. Double-stranded DNA species with lengths of 50-60 bp were designed for this project. Fluorescence polarization binding experiments were used to identify the general binding a□nity of the DNA and RNA species to PRC2 by calculating the Kd apparent for the binding curve. A□er the apparent binding a□nities were determined, various FP-competition experiments were performed to determine if each DNA species could be competed o□ by an RNA species or itself, and vice versa. These results showed that the DNA species were more e□ective competitors although the RNA species were stronger binders. These results suggest

in how it interacts with PRC2. In order to study how PRC2 interacts with DNA and RNA, fluorescence polarization-based methodology was used with various RNA and DNA species to study their binding kinetics to PRC2 individually. A□er the apparent binding a□nities were determined, various FP-competition experiments were performed to determine if each DNA species could be competed o□ by an RNA species or itself, and vice versa.

The DNA species were more e□ective competitors although the RNA species were stronger binders. These results along with other experiments revealed PRC2 has ionic interactions with DNA that are unique to DNA, which explains how the DNA species could compete o□ RNA. Altogether, the results imply that DNA has additional contacts with PRC2 that limit its displacement by RNA, allowing for RNA to guide PRC2 to its target genetic loci and then for PRC2 to deposit its methyl marks without being sequestered by RNA.