Earth-Life Science Institute

Tokyo Institute of Technology

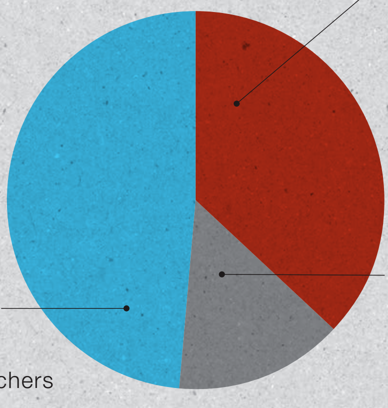
ELSI AT A GLANCE

as of August 1, 2022

COMMUNITY

61 is the total number of people working at ELSI

RESEARCHERS



DIVERSITY

17 out of the total are non-Japanese researchers (49%)

8 are female researchers (23%)

165 papers were published in peer-reviewed journals in 2021

PAPERS

SYMPOSIA

10 international symposia hosted by ELSI

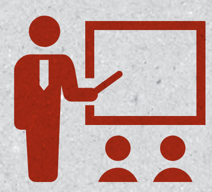
International collaborations with research institutes and universities around the world

NETWORK

ENVIRONMENT

ELSI has an open and flat research environment

ELSI community gathers on Wednesday afternoon for the weekly seminars by researchers and visiting scholars



SEMINARS

OUTREACH

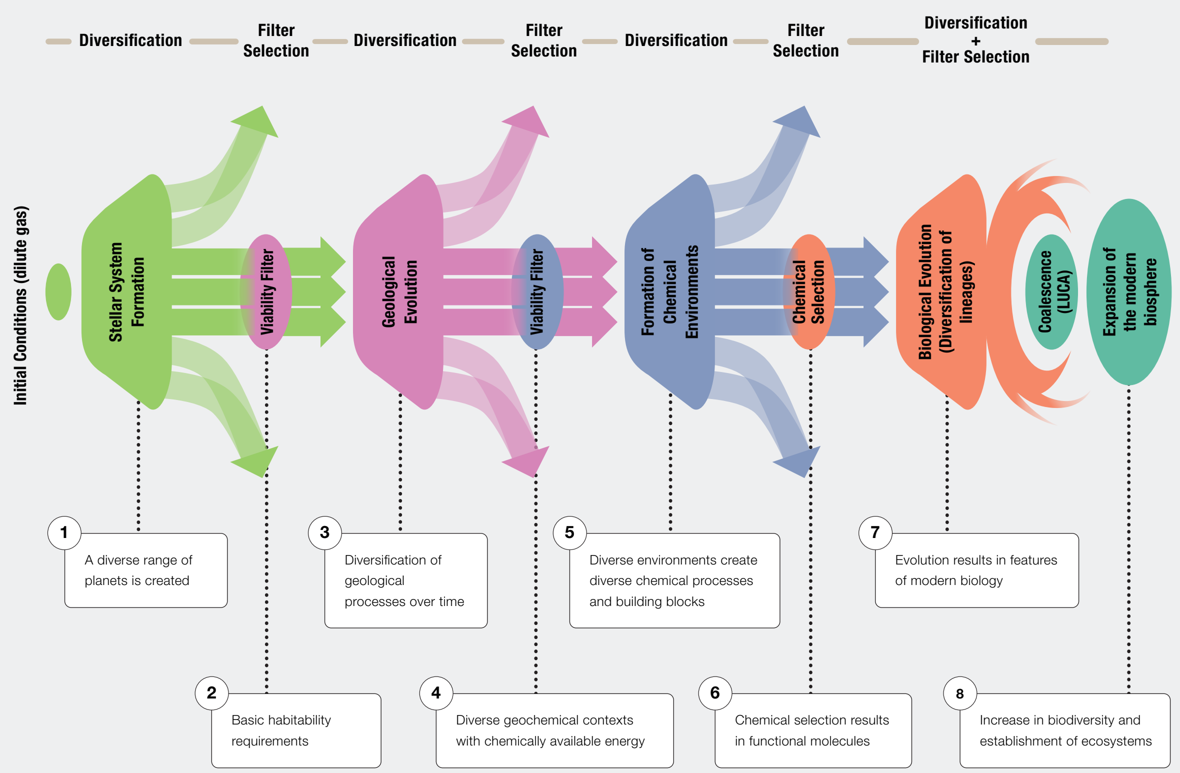
ELSI practice evidence-based-outreach activities throughout the year to assess the societal impact

ABOUT ELSI

The great mystery of how life emerges from non-living matter has been solved at least once, not by humans but rather by naturally occurring processes on the early Earth, more than 3.8 billion years ago. Nature did not succeed in producing life by constructing artificial walls between astrophysical, geological, and chemical phenomena, but rather by drawing upon myriad resources and degrees of freedom that were available to our young planet. The Earth-Life Science Institute (ELSI) is inspired by nature's example, emulating this original successful strategy of open collaboration and diversity, creating a new culture that is better suited to approach one of the great questions of all time.

'Only at ELSI' is a phrase that visiting colleagues use to describe their experience at our home in Tokyo. It beckons a conversation, a collaboration, an idea that could occur only at ELSI. It refers to the unique combination and enormous breadth of our researchers, the spontaneous discussions between astrophysicists, chemists, geophysicists, and biologists that occur daily in our Agora meeting space over tea and coffee, and the uniquely powerful new scientific concepts that are cultivated in an institute of unprecedented breadth and ambition. These impressions are amplified by the context of the institute, its position within Tokyo Institute of Technology (Tokyo Tech), and the dynamic synergy between Japan and the world that naturally emerges in our custom-designed environment that encourages and supports a new brand of science.

ELSI is a research institute that was founded with a large grant from the government of Japan as part of its top-level World Premiere International Research Center Initiative (WPI).



How do planets make life? ELSI's interests extend beyond specific origin scenarios involving particular environments on the early Earth. Our broader aim is to understand the more general strategies employed by nature, such as diversification and selection, that captures how life could arise anywhere in the universe. This is depicted in this diagram, which shows how evolutionary-like processes span astrophysical, planetary, and chemical scales to produce life.

The goals of WPI are to advance cutting-edge science, create new fusion science domains, provide a world-standard international research environment, and to adapt a research administration that is well-suited to accomplish this mission. These four pillars of WPI are woven deeply into the fabric of ELSI; our unwavering and total commitment to all of these aims has been our guiding light for the first ten years. As ELSI became a WPI academy in 2022 and added formal education through a graduate programme in Earth-Life Science, we have adopted the new WPI mission focusing on World-Leading Scientific Excellence and Recognition, Global Research Environment and System Reform, and the Values for the Future. ELSI is one of 17 WPI institutes that have been installed at prominent national universities and institutes across Japan and uniquely devoted to interdisciplinary research and education in the origins of Earth and life.

The WPI new missions: the Values for the Future and the enhancement of the four conventional missions: Science, Fusion, Globalisation, and Reform.

① ICReDD Institute for Chemical Reaction Design and Discovery, Hokkaido University
② AIMR Advanced Institute for Materials Research, Tohoku University
③ QUP International Center for Quantum-field Measurement Systems for Studies of the Universe and Particles, High Energy Accelerator Research Organization
④ IIIS International Institute for Integrative Sleep Medicine, University of Tsukuba
⑤ MANA International Center for Materials Nanoarchitectonics, National Institute for Materials Science
⑥ Kavli IPMU Kavli Institute for the Physics and Mathematics of the Universe, The University of Tokyo
⑦ IRCN International Research Center for Neurointelligence, The University of Tokyo
⑧ Bio2Q Human Biology-Microbiome-Quantum Research Center, Keio University
⑨ NanoLSI Nano Life Science Institute, Kanazawa University
⑩ ITbM Institute of Transformative Bio-Molecules, Nagoya University
⑪ iCeMS Institute for Integrated Cell-Material Sciences, Kyoto University
⑫ ASHBi Institute for the Advanced Study of Human Biology, Kyoto University
⑬ IFReC Immunology Frontier Research Center, Osaka University
⑭ PRIMe Premium Research Institute for Human Metaverse Medicine, Osaka University
⑮ $SKCM^2$ International Institute for Sustainability with Knotted Chiral Meta Matter, Hiroshima University
⑯ I^2CNER International Institute for Carbon-Neutral Energy Research, Kyushu University

Earth-Life Science Institute (ELSI)
Tokyo Institute of Technology
Director: Yasuhito Sekine

World Premier International Research Center Initiative (WPI) consists of 17 research institutes around Japan.

ELSI Science

ELSI is an institution founded on the understanding that the origin of the Earth and the origins of life are aspects of the same scientific question: “How do planets make life?”. The stages and layers in which our planet formed are reflected in ELSI’s major research domains. The formation of planets begins with the birth of their stars, which shapes the first basis for their diversity. Planets constantly shift and evolve structurally and chemically, forming atmospheres and occasionally oceans and magnetic fields; with time, each planet develops along a unique geological history. Near-surface geochemistry on Earth, and perhaps elsewhere, generated the first molecules and energy flows resulting in life. Geological and biological chemistry have always been intertwined, resulting in joint geo-bio evolution throughout history. A common underlying dynamic of diversification and selection, which generates complexity in planets and in biospheres, allows us to understand the planetary foundation of life on Earth and to explore the possibilities for complexity on extrasolar planets.

ELSI scientists engage in research that spans billions of years to micro-seconds, galaxies to subatomic forces, deep ocean volcanoes to alpine hot springs, the centre of the Earth to moons of Neptune. We do this research all in one single building, where it is possible for a microbiologist to consult with a planetary scientist or a chemist with an expert on neural networks. Connecting such broad and challenging topics requires our researchers to engage with each other in ways that go beyond what is usually possible in a typical department setting: other than our scientific goals, connection, cross-teaching, and listening is a major goal of our researchers and students. The common purpose of understanding “how do planets make life?” motivates interactions within the research environment in which ELSI scientists explore novel ideas and techniques. In a relatively short time, contributions from ELSI research have inspired researchers around the world to view planets and how to think about life and its origins in new and innovative ways.

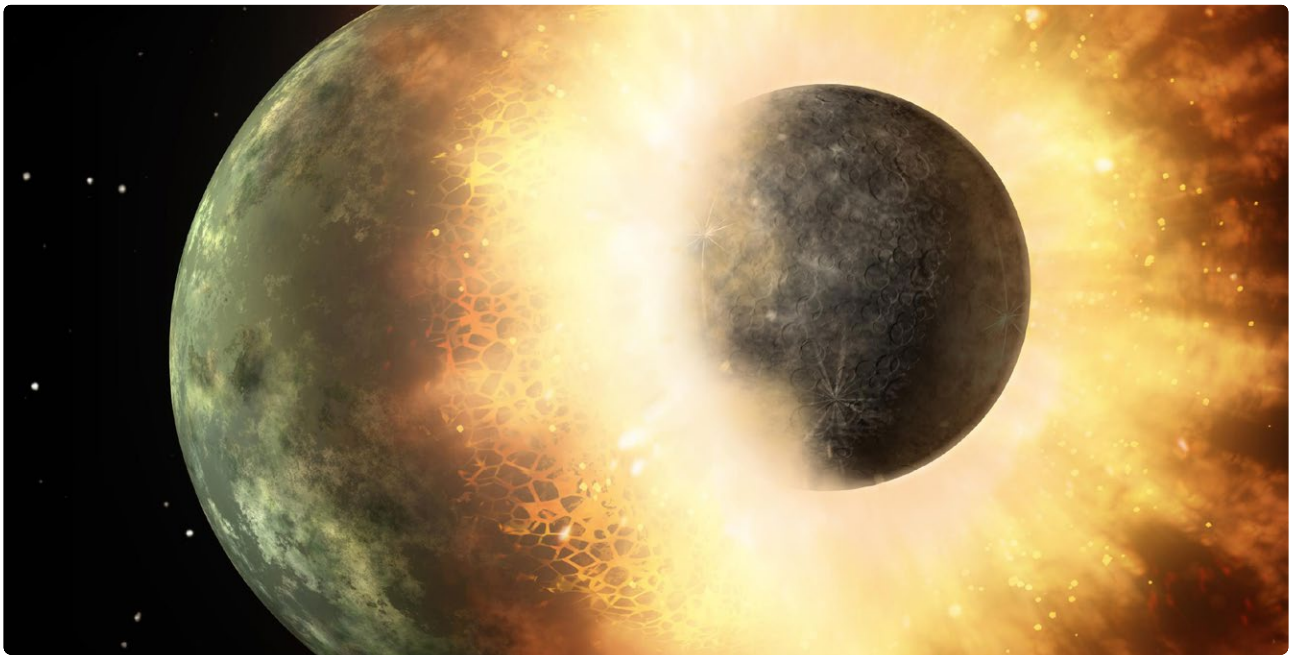
In its initial phase, ELSI supported a large cohort of research scientists who are now positioned in laboratories across the globe, where they continue to build their own programmes based on the foundation of cross-discipline scientific exploration. ELSI now supports a growing interdisciplinary and international graduate course programme. ELSI courses are team-taught and cover broad topics such as planets or life in integrated ways that are not usually possible in a typical department setting. At ELSI, students experience the breadth of Earth-life sciences, setting the stage for them to lead the next generation in catalysing breakthroughs which expand our knowledge of planetary chemistry in relation to the origin and evolution of life in the universe beyond our present horizons.

Stellar System Formation

Origin of Planets

We reconstruct key stages in Earth's formation, answering questions of where and how our planet formed, what determined its composition, how its internal state matured over time, how crucial chemical elements responsible for the atmosphere and oceans were delivered and retained, and how surface conditions responsible for life depended on these earlier stages. We have developed the first integrated models of accretion and transport in stellar discs across scales from gas and dust, through crucial intermediates known as 'pebbles', to the migrating orbits of early planets, and effects of giant impacts. By combining computer models with cosmochemical measurements, we can account for the diversity seen in planetary systems, and constrain the possible sources for light elements (C, O, Si, H, S, N) on early Earth. Our planet represents a delicate and probably rare balance between dry and completely ocean-covered worlds. We have begun a special programme on water worlds as the most common kind of planets thought likely to harbour life, with three representatives even in our own solar system.

We test models of planet formation against observations from Earth and other bodies in our Solar System and beyond.



Questions

- How do planets form from gas and dust, and how fast do they form?
- What explains the great diversity of planets and of entire planetary systems?
- How do special events like the Moon-forming impact shape a planet's future evolution?
- How do early formation conditions affect a planet's potential to create a biosphere?

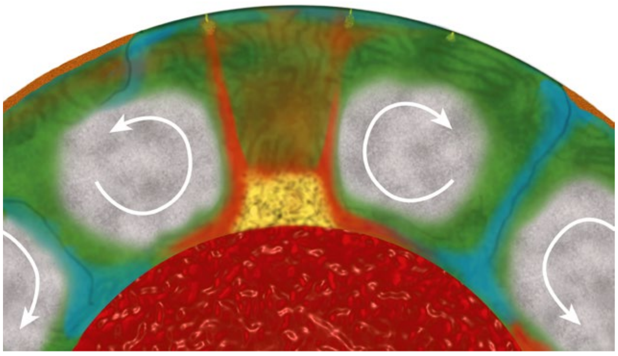
Tools & Techniques

We integrate the most current theories and models of gas and many-particle dynamics with evidence from meteor and comet isotope data and crater chronology to create an integrated understanding of the early stages of solar system formation. Our domestic and international collaborations with space mission and telescope projects anchor models of planetary diversity in extrasolar-planet data and enable ELSI to participate in mission planning.

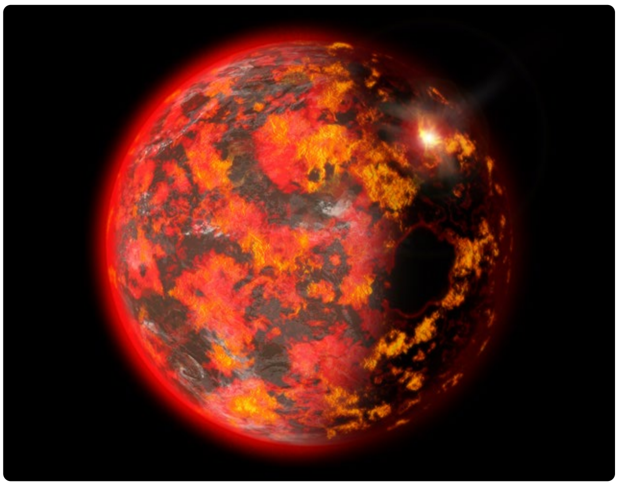
accretion - magma ocean - giant impact - moon formation - exoplanets **KEYWORDS**

Planet Evolution

ELSI explores Earth and other bodies in our solar system from the inside out to reveal the connections among planetary processes. As planet accretion tapers off, one of the first stages in planet evolution is core-mantle differentiation, which may have proceeded on Earth through magma ocean phases. We have discovered that as Earth's core separated from its rocky mantle, it could have incorporated much more silicon and oxygen than thought, along with significant hydrogen. Crucially, the early precipitation of silicon oxides as the core cooled created a vigorous buoyant stirring force, increasing the likelihood of forming an early magnetic field. This in turn protected Earth's atmosphere from loss by the solar wind. We have found that the cooling rate of early planetary surfaces is highly sensitive to solar irradiance. It differed by more than a factor of ten between near neighbours Venus and Earth, driving Venus into a stagnant lid greenhouse state and Earth into climate resiliency. As Earth settled into a layered structure of core, mantle, and crust, its earliest mineral differentiation may have locked in deep large-scale heterogeneities that continue to organise tectonic dynamics and magmatism even today. By modelling the partition and circulation of volatile elements, we explore the differences among rocky planets in their potential to sustain the complex chemistries needed for life to emerge and evolve.



The Bridgmanite Enriched Ancient Mantle Structures (BEAMS) model proposes that the early Earth's highly viscous mantle sets the stage for sustaining plate tectonics.



An illustration of early Earth, which may have had a toxic atmosphere like Venus's today.

We explore Earth and other bodies in our solar system from the inside out to reveal the connections among planetary processes.

Questions

- Which planets form and retain atmospheres, oceans, and magnetic fields?
- How are heat, volatiles (i.e., water, nitrogen, etc.), and elemental abundance distributed among gaseous atmospheres, surface crusts, rocky mantles, and metallic cores?
- How has Earth's atmosphere changed over time?
- What processes are active on other bodies in our Solar System?
- What fraction of planets could harbour life?

Tools & Techniques

We weave together experimental, theoretical, and observational approaches to identify critical points in the planetary system that determine how a planet could potentially evolve. Seismic imaging is combined with high-temperature/pressure mineral physics and computational modelling to resolve and interpret deep-Earth structure and dynamics. ELSI scientists have written the world's most advanced computer codes to simulate giant impacts. Laboratory experiments provide analogue studies for conditions on ocean worlds in our solar system.

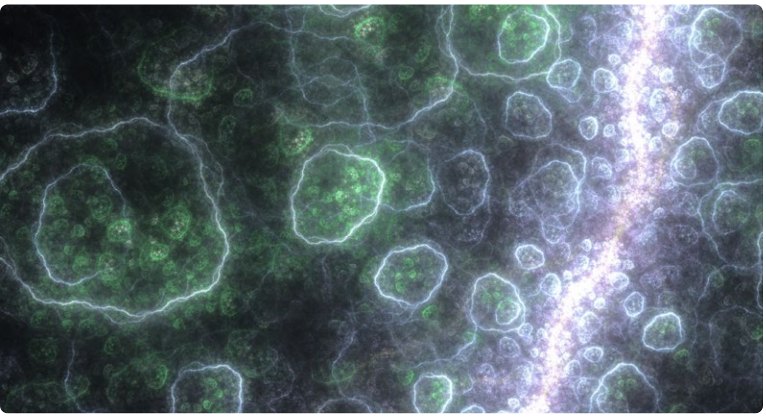
KEYWORDS	*mineral physics - geochemistry - planet dynamics - core formation – geodynamo - atmosphere generation*

The Chemical Origins of Life

We seek to understand the origins of life as the emergence of a new Earth system, accounting for the interactions between the key ingredients for early chemical evolution: oceans, atmosphere and solid Earth. The most universal factor influencing complexity in carbon chemistry on a planet is the disequilibrium among reservoirs of electron donors and acceptors. In addressing this question, we have discovered that a single late giant impact could have produced a secondary hydrogen-rich atmosphere at the start of the Hadean aeon that lasted for up to 200 million years. Moreover, the complex stable isotope signatures of sulfur indicate that Earth maintained a higher ratio of CO to CO_2 than previously suspected well into the Archean. These two findings would significantly affect the synthesis and ensuing transformations of organic compounds leading to the origin of life.

Diverse planetary surface conditions may have been essential for the emergence of life. We have studied the roles of the seafloor and land masses as nutrient sources; and the Sun, atmosphere, rock/water interface, and radioactive subsurface as sources of energy. We have also investigated the timing of water delivery, and composition of the earliest oceans and crust. These parameters clarify how special Earth may be in its capacity to spark life. Our research has shown how numerous energy sources can produce reactive C and N compounds, including electrochemical gradients at hydrothermal vents, secondary electrons from ionising γ-radiation, and atmospheric UV radiation. Our models indicate that species such as nitrate, ammonia, and CO were available in the early oceans, and we have found reaction pathways that produce precursors to biological compounds such as nucleobases, as well as activators that can drive polymerisation. Our understanding of how vital diverse environments are for life on Earth extends to our consideration of other bodies in the Solar System and other stars, enriching the complex concept of habitability.

Computational combinatorial methods allow us to ask which aspects of terrestrial life reflect the inherent limits of chemistry, and which of these may be universal. We have shown that the biological set of amino acids cover a much wider range of properties essential to protein function than random sets of possible amino acids. Selection has made the biological set unique in that they are perched at the brink of chemical possibility.



Questions

- What is life?
- What molecules were available on the prebiotic Earth, and for how long?
- How do chemicals in the environment assemble into living systems?
- What was the early Earth environment like and how did it contribute to chemical evolution?
- Are there many chemically different kinds of life or only one?

Tools & Techniques

Our approach to these questions combines theory, computation, chemical synthesis and analysis, and synthetic biology techniques. We have in-house facilities to mimic a variety of primitive planetary environments, including high radiation environments, high temperature/pressure environments and evaporative environments, as well as state-of-the-art facilities for conducting sensitive chemical analysis.

We study how organic compounds can form and react in primitive planetary environments to understand how life originates.

KEYWORDS *Origins of Life - hydrothermal environments - wet-dry cycling - endogenous synthesis - RNA World - synthetic biology*

Biosphere-Geosphere Interaction and Evolution

Biological Evolution
(Diversification of lineages)

ELSI scientists study the major transitions that shaped the evolving biosphere: its architecture and modes of evolution and its dependence on planetary conditions over time. We also examine how biological evolution has in turn moulded Earth's geological history. We integrate synthetic and evolutionary biology to understand elements of structure and function in early organisms. We have demonstrated functional proteins translated using simpler genetic codes. ELSI has achieved increasingly complex functions in synthetic cell membranes, and coordination of molecular systems within and across them. Our researchers reconstruct genomes and bioenergetic systems of ancient bacteria, showing their coevolution with planetary chemistry and life's capacity to maintain ever larger and more reliable molecular systems. We have reconstructed isotopic and mineral signatures linking the rock record to major biological transitions, both for sulfur metabolism and for oxygenic photosynthesis: the biological innovation that has had the most impact on Earth's surface environments.

Terrestrial genomes persist with varying degrees of interaction to other genomes: the extremes being “free living” cells and viruses which required a cell host. Across this diversity a key question about the complexity and ecology of life is to understand how genome-genome interaction observed today may be a result of the genomic milieu of at the stage of the progenote. At ELSI, we have expanded global knowledge of the diversity of thermophilic Archaeal viruses by nearly 100%, and ELSI now hosts one of the largest collections of Archaeal viruses of any institution in the world. Studying hot springs which are analogous to some conditions in Earth history, we have expanded our understanding of the tree of life and physiology, predicting thermodynamically possible yet undiscovered metabolisms.

We research the molecular pre-cursors to the first cells, their interaction with proto-compartments, and the diversity and activity of microbes and viruses in environments which may be similar to those of early Earth.

Questions

- What were the earliest life forms like, and can we reconstruct them in the lab?
- How did planetary evolution affect biological evolution?
- What are the functional capabilities and evolutionary histories of short peptides and RNAs?
- What properties of ancient life can be deduced from chemical signatures in ancient rocks?
- How do life forms like viruses and cells work together to carry and shape life’s genetic history?
- What is the history of biological evolution, and what types of life have yet to be discovered on Earth?
- To what extent, and from what molecular diversity can a cell be synthesised?

Tools & Techniques

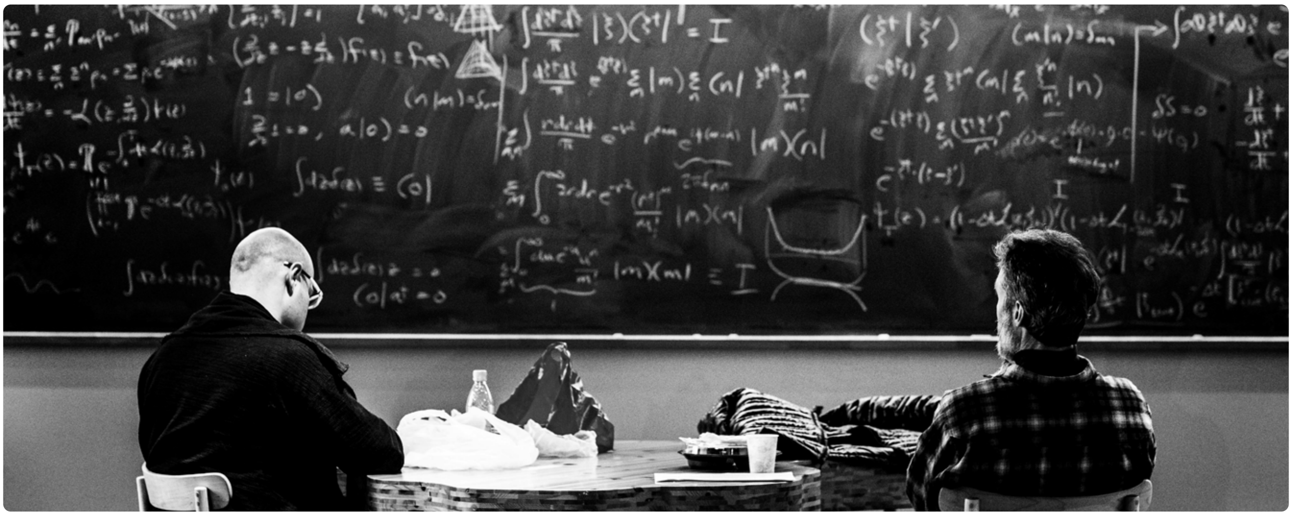
We combine bioinformatics, experimental evolution, isotope geochemistry, and synthetic biology to study the evolutionary history of genes and organisms, and to integrate them with models of planetary evolution. We use sequence comparison and synthetic methods to reconstruct ancestral proteins and pathways, and combine these with protein and RNA activity assays to understand founding polymeric molecular elements of life. We relate it all to signatures of life in the rock record and the geochemical environment expected ~4 billion years ago. We employ artificial cells to study key cellular functions. Laboratory evolution, and microbial genetics are used to extract and characterise new genomes and lifecycles.

KEYWORDS *isotope ratio mass spectrometry - metagenomics - enzymology - ancestral state reconstruction - RNA chemistry - artificial cells – virology*

Complex Life

Our studies of the history of Earth and its life reveal a unifying paradigm of alternating stages of diversification and selection, which serves as a springboard to understand the habitability of planets around other stars and what principles may make life on them similar to or different from our own. At the core of understanding life's complexity is the question of whether hallmarks of life such as heredity and adaptability could have existed earlier in prebiotic chemical systems, and under what conditions these can emerge either within or growing out of planetary chemistry. We have formalised these questions in terms that can be applied to systems that do not yet have individual-based organisation or replication. Our researchers have shown that some of these systems can support heredity and limited forms of adaptation. Heredity becomes most powerful when it can employ large libraries of possible chemicals created combinatorially. Linking theory to experiments, we have demonstrated how the diversity in such libraries can be produced from prebiotically plausible alphabets through simple reactions. We investigate methods to select among the resulting chemical polymers and control the folds that make them functional – in particular the crucial interactions of RNA with peptides – using high-throughput studies on libraries of linked RNA and peptides.

We tackle theories behind life's complexity through theoretical, computational and experimental approaches.



Questions

- How do chemical systems exhibit adaptation to environmental pressures?
- Which features in a given chemical system can undergo selection and which cannot?
- How can chemical specificity arise from non-specific complex chemical mixtures?
- Through what mechanisms can heritability and evolution arise from chemical systems?
- What determines whether evolution occurs through an open-ended succession of major transitions?

Tools & Techniques

We integrate computational, theoretical, and experimental approaches to develop the overarching concepts of diversity generation and selection. Computational approaches include abstract 'minimal modelling' and machine learning. Theoretical concepts are drawn from information theory, coarse-graining, statistical physics, and phase transitions. Experimental approaches include generation of random oligomer libraries, mRNA-display, and cell-free protein synthesis.

open-ended evolution - machine learning - in vitro evolution - lineage selection - phase transition - minimal model

KEYWORDS



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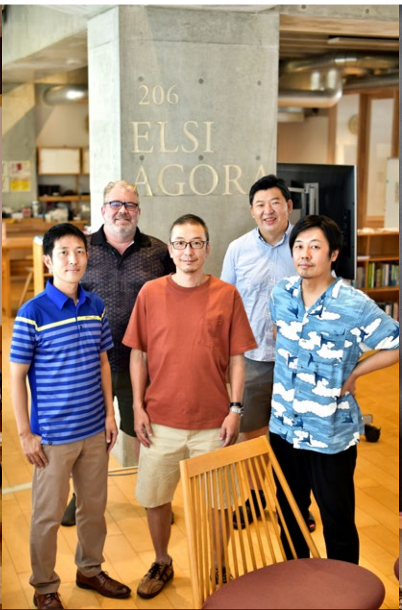
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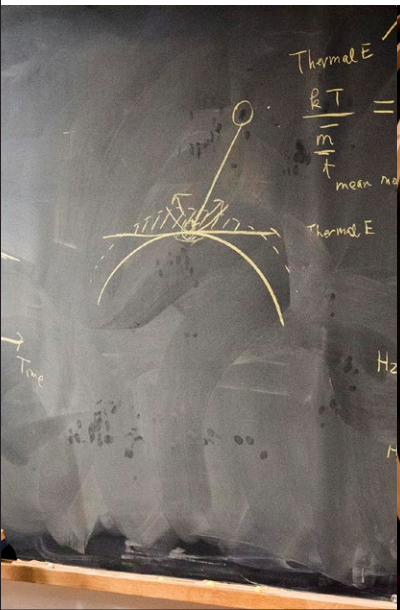
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EDUCATION

Introduction to the Graduate Programme in Earth-Life Science

In April 2022, ELSI established a new graduate programme in Earth-Life Science. This is one of the few integrated five-year Masters-PhD programmes provided fully in English in Japan. Students will receive both a Master's degree and a PhD degree upon completion (upon completion of both a Master's and PhD dissertation and defence in the second year and fifth years, respectively). ELSI has a target to accept up to 10 students per year (~5 Japanese, 5 international[1]) with financial support available (*vide infra*). Students will be affiliated with and formally supervised an ELSI Principal Investigator[2](PI) from one of the following departments:

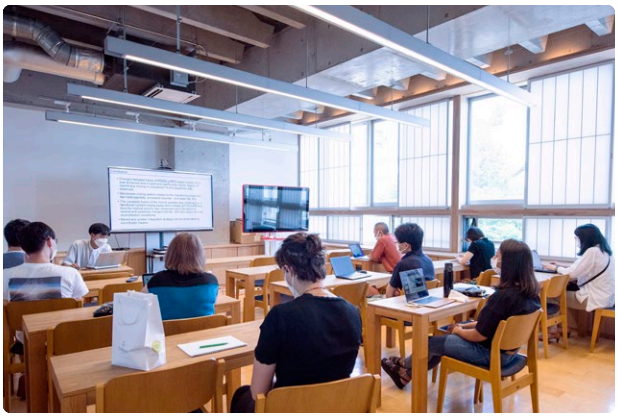
-Department of Earth and Planetary Sciences (EPS)
-Department of Life Science and Technology (LST)
-Department of Chemical Science and Engineering (CSE)

1. International students are defined as those eligible to live in Japan on a student visa.
2. Students may also be co-supervised by an ELSI Associate Principal Investigator (API).

Application Process

There are two application cycles per year for international students, for entrance in April or September; for Japanese students, there is a single application cycle per year, for entrance in April. To apply, students must first contact a prospective ELSI PI[3], and the international students must obtain a "Letter of Consent". Then, students will apply through the Tokyo Tech online application (international students apply through the International Graduate Program [IGP] C-track, while Japanese students apply through the A-track)[4]. Each student will apply to one of the departments listed above, and after an internal selection process (which differs by the department; ELSI does not participate in this process), students will have an interview with the ELSI PIs, which includes a research proposal presentation, after which decisions will be conferred[5].

3. APIs are not eligible to issue Letters of Consent but can still co-supervise students (with a PI).
4. Due to possible technical errors with the online application/payment system and strict application requirements that may differ from other countries, international students are encouraged to apply early to avoid unforeseen issues close to the application deadline.
5. For more details, please check https://www.titech.ac.jp/english/admissions.



Programme Contents

The graduate programme is conducted fully in English and consists of a combination of coursework and research, with an optional outreach aspect. Courses will be completed in the first 1–2 years and include a range of choices, including planetary science, biology, chemistry, and global science communication. Students will also participate in a research tutorial, which will help students to design their research plan for the rest of the programme period. Additionally, students have the option to participate in an outreach aspect in collaboration with the ELSI Public Relations (PR) Office. Finally, as PhD programmes are research-focused, the latter years of the programme will be focused on research. Earth-life science is an interdisciplinary field and at least one collaborative project between the student, their main supervisor, and another ELSI researcher (such as a co-supervisor, an API, a researcher, etc.) is encouraged. While first-author publication is not strictly a requirement of the programme, students may be subject to Tokyo Tech departmental publishing requirements, which may differ by the department; such publications may also be a requirement for external fellowships (*vide infra*).

Financial Support

Students in the Earth-Life Science programme will receive financial support in the form of a monthly salary in Japanese yen (around 170,000 JPY). This salary (as taxable income through work as a laboratory research assistant) is guaranteed for five years as long as the student also attempts to apply for other competitive external fellowships or scholarships. If a student receives an external fellowship or scholarship with a stipend, they will no longer directly receive salary through a research assistantship[6]. As is common in Japanese universities, both an entrance fee and tuition are charged for the programme, which the student must pay directly[7].

6. If an external fellowship or scholarship provides a stipend less than that of the research assistantship, then a student's financial support may be supplemented by a research assistantship salary which brings their aggregate monthly stipend/salary to the 170,000 JPY range. In certain cases, it is possible to aggregate fellowship support to be combined with ELSI support, and the stipend/salary will be greater than the 170,000 JPY range.
7. Neither ELSI nor its labs are allowed to pay the enrollment fee or tuition directly; students must pay them by themselves, and financial support can be provided only as a research assistant's salary (unless the student receives an external fellowship). However, tuition from the second and subsequent semesters for international students may be waived upon application and approval by Tokyo Tech (not by ELSI); Japanese students can apply for a waiver for the enrollment fee and for tuition for the first semester as well as all subsequent semesters.

Contact

For inquiries, please contact edu-info@elsi.jp

ELSI ACTIVITIES

Fusion

Interdisciplinary research at ELSI

Nature did not produce life more than 3.8 billion years ago by artificially dividing astrophysical, geological, and biological phenomena, and neither should we. The immense advances in the evolution of life, such as photosynthesis or multi-cellularity, required uniting unique combinations of life (proximity), facilitating cross-fertilisation (communication), and enabling the development of concerted and robust systems-level behaviours (culture) in response to the same kinds of external influences. At ELSI, we enable fusion between disciplines in much the same way as life achieved its major revolutions.

Globalisation

Geographical and gender diversity

Nothing distinguishes ELSI's achievements more than its strong international research environment and staff, which are catalysts for breakthrough science and administrative reform. ELSI has grown a vast international network and recruited top scientists from around the world at both junior and senior levels. As of August 2022, the total number of ELSI researchers is 35: 13 PIs 5 APIs and 17 other researchers. 17 are non-Japanese researchers (49%) and 8 are female researchers (23%).

International and domestic collaborations

ELSI maintains international and domestic collaborations with Ehime University, the Institute for Advanced Study, Harvard University, the University of Tokyo, and Columbia University in New York, JAXA, NASA, and more. The network keeps expanding as 'ELSI Research Exchange Programme' allows to bring in experts to ELSI for short visits and ELSI members visit other institutions and universities for research collaborations.

ELSI symposia

Annually, ELSI holds an international symposium on the origins of life research and its related fields. Every year, more than 100 researchers from more than 10 countries participate in presentations and debates. The symposia thrive on an active dialogue through breakout sessions, discussions and panels.

2013	March	The First ELSI International Symposium
2014	March	Origin & Evolution of the Earth-Life System
2015	January	Life in the Universe
2016	January	Early Earth, Venus & Mars
2017	January	Expanding Views on the Emergence of the Biosphere
2018	January	Building Bridges from Earth to Life
2019	January	Comparative Emergence
2020	February	Extending Views of Catalysis
2021	January	Science in Society
2022	January	ELSI Past & Future
2023	March	The Living Universe

Reform

Director’s Office

ELSI directors meet weekly to discuss important and urgent matters. These regular meetings help to coordinate the needs of the institutions and strategise the research scope. The Director’s Office consists of the institution director, deputy directors, admin director, and communications director, all supported by the secretary.

Top-down management system

The directors make important management decisions at the weekly Director’s Office meeting, which supporting coordinators and chiefs also attend. This centralised system allows for quick decision-making and effective management of the institute. Major decisions are reported at the monthly ELSI ALL Meeting – in which all staff (including administrators and technicians) and students participate – and feedback is collected from its researchers and staff. Important topics are often discussed at the faculty meetings – attended by PIs and APIs – before the Directors make decisions.

Efforts to foster young researchers

ELSI provides start-up funds to young researchers so that they can begin their research while acquiring external funds. The institute requires young researchers to apply for at least one external grant annually. This requirement is a form of professional training to cultivate the skills necessary to acquire competitive funds: managing grant application calendars, planning one’s budgetary needs, and building proposal-writing skills.

Annual evaluation and incentive award

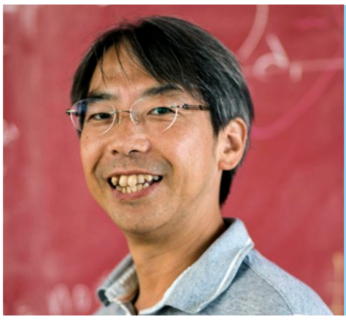
Every year, individual researchers prepare annual evaluation sheets in January. Early-career researchers send theirs to senior PIs for review, and the results are scrutinised and summarised by the Director’s Office, which selects candidates for the incentive award winners of the year. The awardees are announced at the subsequent ELSI ALL Meeting. Younger researchers evaluated senior researchers once, but this was impractical. Therefore, in 2018 the institute asked its International Advisory Board to conduct an external review of senior PIs. The Board employed three reviewers for each PI and made quantitative evaluations of *** (superior), ** (median), and * (lowest). The 14 PIs reviewed obtained average 38.5 stars in total: 2.75 stars per PI.

RESEARCHERS

PRINCIPAL INVESTIGATORS

My dream is to find life beyond Earth in the Solar System. ELSI is the best place where I can tackle this together with wonderful colleagues. What is your dream?

Yasuhito Sekine
Astrobiology



I've been working on deep Earth structure, dynamics, and evolution at ELSI. It is an amazing place for researchers from different fields to work together and expand their perspectives.

Kei Hirose
High-pressure geoscience

Life results from an open planet-scale collaboration that we must emulate in the way that we do science in order to truly understand its origins and limits.

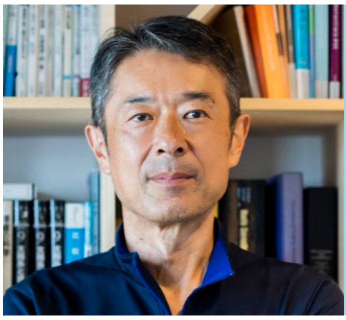
John Hernlund
Geophysical modelling

You are alive because your parents were, and their parents, in an unbroken lineage of four billion years; join ELSI to get to know more about your pedigree!

Piet Hut
Astrophysics

We want to find the rules underline the current biological systems, and use them to recreate life.

Tomoaki Matsuura
Biotechnology

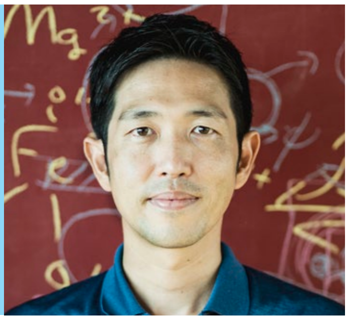


ELSI has an environment that allows me to follow my own interest in exo-planets and exo-life, step by step, forwards.

Shigeru Ida
Planet formation

I am making polymers that perhaps once existed on this planet and/or elsewhere. I believe ELSI is the place to realise the paradigm shift from molecules to life.

Kosuke Fujishima
Astrobiology and synthetic biology

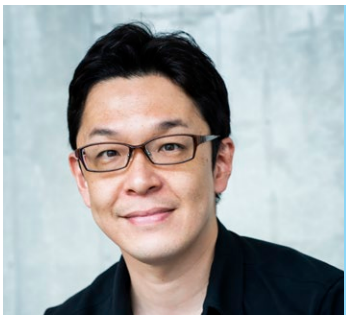


ELSI is probably the most intellectually exciting place I've been. It's a great place to get 'off the map' of current understandings and to become familiar with the unknown.

Shawn McGlynn
Microbial biogeochemistry

ELSI has created a good atmosphere to do high-impact research, explore from unique angles, and to publish in a timely manner.

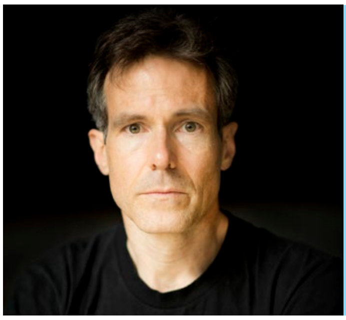
Hidenori Genda
Planet formation



I'm fascinated by the elegance and beauty in Nature's energy-conversion processes. At ELSI, I research how deep-sea electric currents may have provided the spark for the origins of life.

Ryuhei Nakamura
Electrochemistry

ASSOCIATE PRINCIPAL INVESTIGATORS

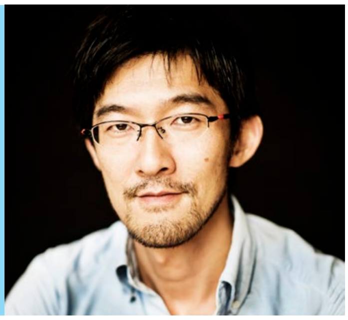


We used to view Life and the geological Earth system in very different terms. Lately we are finding more and more areas where they cross into one another.

Eric Smith
Complex systems

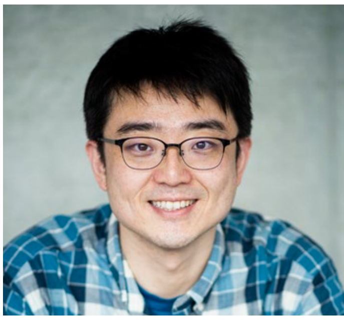
We have developed a new geochemical technique and analysed ancient rock samples to study a biosphere of another planet 'Early Earth'.

Yuichiro Ueno
Biogeochemistry



ELSI is a place to explore what's possible and what's impossible.

Mary A. Voytek
Astrobiology



ELSI stands at the interface of interdisciplinary research on planets, Earth, and life. Let's use these tools to understand how prebiotic chemistry built the first compartments on Earth!

Tony Z. Jia
Prebiotic chemistry and astrobiology

How do planets form and co-evolve with life? This is the question which drives my researches at ELSI. Come and join us to tackle this mystery and find new ones!

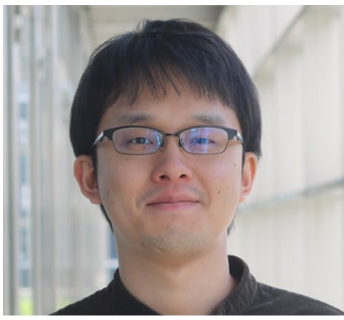
Hiroyuki Kurokawa
Planetary science

Join ELSI and let's uncover the history of life on Earth together!

Liam Longo
Protein evolution

ELSI is a great place to study fundamental questions about life and where it came from. How did life emerge, and why did it happen?

Nathaniel Virgo
Artificial life



ELSI is an international and cross-disciplinary place to do cutting-edge researches related to the origin of the Earth and Life following your own interest.

Naohiro Terasaka
Synthetic biology

OUTREACH

Evidence-based Outreach

ELSI's Public Relations (PR) Office coordinates multilingual outreach efforts in English and Japanese for students and the public. The outreach is conducted under the framework of 'Science with and for Society (SwafS)' to have a multi-level engagement between the publics and the researchers as one societal community. The activities are focused on introducing and engaging with ELSI's interdisciplinary research in Origins of life and Earth.

The PR Office highlights ELSI's latest research efforts through annual outreach efforts such as ELSI Annual Public Lecture, Joint Public Lecture with Kavli IPMU and IRCN, and Tokyo Tech Festival (Koudaisai). ELSI School Visit Programme invites school students to visit ELSI for direct engagement with researchers and graduate students. These visits often include lab tours and experiments by giving hands-on experience. ELSI researchers and graduate students frequently visit schools to conduct lectures and other activities. These internal and external outreach efforts are focused on research, scientific careers, and ELSI graduate programme.

Together with the ELSI Editorial Board, the PR Office publish Press Releases and Research Highlights to bring the latest results to the media, publics, and the scientific community. The number of articles per year has been increasing steadily and is often covered in local and international media outlets.

Departing from traditional methods, the office thrives on discovering fresh, creative approaches that combine science and art highlighting the human side of research. As a result, the PR Office established the 'Science-Art Residency Programme', in which an artist is selected to work with a group of ELSI researchers on a particular theme annually. The outcome of these collaborations is displayed on the third floor of ELSI building.

In conveying ELSI's most recent revelations to the public, the PR Office enjoys playing a part in sparking the interest, excitement, and curiosity of the wider community.

SCIENCE COMMUNICATION

Effectively Communicating Science

ELSI recognises the importance of making science understandable, and engagement with the publics helps develop the scientific capital. The science communication efforts at ELSI started in 2018 with the aim of providing skills to achieve the objectives such as science simply must be open, understandable, and accessible to the masses, rather than hiding behind the doors of offices and university auditoriums. Science needs to be communicated with everyone in an understandable and accessible language.

ELSI has set up formal education in science communication through a course provided within the Earth-Life Science graduate programme. The course is provided in English with the latest trends, tools, and skills that are relevant to science graduate students. The participating students also get hands-on experience during the course by running a project by putting their learning into practice.

ELSI also hosts science communication workshops, symposia, and conferences collaboratively. The Japan SciCom Forum (JSF) is one of the key efforts ELSI supports to bring the science communication community of Japan together annually to network and share best practices by experts.

ELSI hosts several science communication workshops and symposia for researchers and graduate students annually to provide skills that are necessary to communicate their research effectively. ELSI also launched 'Falling Walls Engage Hub Japan' in 2022 to develop science engagement activities in Japan and to network with global expertise.

INSIDE ELSI

Buildings and Facilities

By acquiring a supplementary budget from MEXT, the long-awaited research building was built for ELSI in 2015 at Ookayma Campus (Ishikawadai Area, Bldg. No.7; total floor area of 4,970m^2). The building was designed under the concept of 'harmony between Japanese and western styles', paying attention to a good balance between research and communication spaces.

The entrance on the 1st floor features a lecture hall called 'Mishima Hall' that can hold over one hundred people. The 2nd and 3rd floors include compact and functional research rooms for ELSI researchers and extended-stay visiting researchers. Moreover, the ELSI building hosts students' offices, the PR Office, the Secretaries' Office, Administration Office, and a Visitors' room for researchers from partner institutions to work at ELSI.

The open-ceiling communication room on the 2nd floor, called the 'Agora', can be used by many researchers for interdisciplinary communication. The 3rd floor features art pieces done by the ELSI Science-Art Residents over the years.

The basement of the ELSI building contains an electron microscope, a high-pressure experiment lab, a geochemistry lab, a life science lab, and a chemistry lab.

Message from the President

Kazuya Masu
President, Tokyo Institute of Technology

The Earth-Life Science Institute (ELSI) was launched in 2012 with generous support from the World Premier International Research Center Initiative (WPI), MEXT. In just a few years, ELSI has grown into a fully formed and mature institution. We at Tokyo Tech are proud of the accomplishments of ELSI, which include a highly successful recruiting strategy, the establishment of a global collaborative network of world-leading scholars, and a genuinely international environment that welcomes researchers from all over the world. ELSI is intended to be a role model for the university as a whole and forms a key part of my vision for Tokyo Tech to become a top global university.

Diversity is one of the key factors in making new discoveries, tackling new fields of study, and surmounting challenges in research. ELSI is leading Tokyo Tech with its diversity in members that address a wide range of research topics.

ELSI is now established as a permanent independent institute and operates directly under the Tokyo Tech president. ELSI's scientific leadership has been rewarded with both a large amount and a variety of foreign and domestic funding. ELSI's future is bright and it will continue to grow and enhance its vigorous research activities long after the initial WPI grant period.

Seeing how far ELSI has come in these years, I am excited by our shared future. Let's continue to rise together.

Message from the Director

Yasuhito Sekine
Director, Earth-Life Science Institute, Tokyo Tech

In the first ten years, ELSI provided the view of the sequence of diversifications and selection mechanisms that gave rise to the current Earth-life system. While keeping existing approaches at ELSI to understand key transitions toward the emergence of our Earth-life system, we will explore new approaches to understanding and predicting the possibilities of alternative planet-life systems which may exist anywhere in the Universe. We will work in close cooperation with space exploration missions by extending the research scope from the Origins and Evolution of the Earth and life to include searching for evidence of extra-terrestrial life.

As a World Premier International Research Center (WPI Center) based at Tokyo Institute of Technology, our mission is to facilitate breakthroughs at the frontier of science by attracting and interacting with the best minds from around the world, to promote interdisciplinary research in origins of Earth and life, and to play a leading role in implementing and promoting administrative innovation and organisational excellence among universities in Japan. ELSI has cultivated a multidisciplinary international community of researchers, integrating disciplines to study the origins of life within the context of the origin of the Earth and other planets. ELSI hosts dozens of short-and long-term visitors to develop innovative ideas. With the implementation of Earth-Life Science graduate programme at ELSI, we are paving the path for future researchers. We are committed to science education and sharing our research with the general public. All are welcome to visit ELSI and join our quest to understand the origins of Earth and the life it supports.

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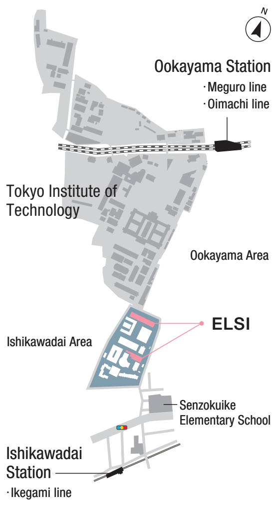
EARTH-LIFE SCIENCE INSTITUTE
TOKYO INSTITUTE OF TECHNOLOGY



ELSI Logo: Designed by art director Ms. Naoko Fukuoka, ELSI's logo is versatile in its symbolism: the globes to the right simultaneously represent a moon-forming giant impact, cell division, and planetary orbits. The lines branching out within the larger sphere create a phylogenetic tree that stands for the origin and evolution of life and, returning to the metaphor of planets, also symbolises the origin and evolution of the Earth itself. In this manner, the logo embodies multiple fields of research at ELSI. Behind the letters of ELSI, semi-transparent infinity symbols are depicted. They signify both the infinite potential of ELSI's future research and the infinite knowledge awaiting discovery there.

Tokyo Tech

wpi

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