Produced by the NASA Astrobiology Program to commemorate 50 years of Exobiology and Astrobiology at NASA.

www.nasa.gov
This is the story of life in the Universe—or at least the story as we know it so far. As scientists, we strive to understand the environment in which we live and how life relates to this environment. As astrobiologists, we study an environment that includes not just the Earth, but the entire Universe in which we live.

The year 2010 marked 50 years of Exobiology and Astrobiology research at the National Aeronautics and Space Administration (NASA). To celebrate, the Astrobiology Program commissioned this graphic history. It tells the story of some of the most important people and events that have shaped the science of Exobiology and Astrobiology. At now over 60 years old, this field is still relatively young. However, as you will see, the questions that astrobiologists are trying to answer are as old as humankind.
The year 2010 marked the 50th anniversary of NASA’s Exobiology Program, established in 1960 and expanded into a broader Astrobiology Program in the 1990s. To commemorate the past half century of research, we are telling the story of how this field developed and how the search for life elsewhere became a key component of NASA’s science strategy for exploring space. This issue is the ninth in what we intend to be a series of graphic history books. Though not comprehensive, the series has been conceived to highlight key moments and key people in the field as it explains how Astrobiology came to be.

-Linda Billings, Editor
Astrobiologists study life on Earth and the potential for life in the Universe.

* See Issue 1

The research reaches through the Solar System to potentially habitable places like Mars and Enceladus, then beyond to exoplanets around different stars.

** See Issues 1-8

Astrobiologists ask big questions about life...

** See Issues 1-8

...and people from many backgrounds work to reveal the answers.

Issue 9: But how do I become an astrobiologist?
The first part of being an astrobiologist is to be curious about the world around you.

Why do we find life almost everywhere on our planet?

What makes an environment habitable?

Why is water so important?

Where did life originate on Earth? And when?

Astrobiology is a science, and science is all about asking questions and making observations.

Think of science as steps in a process...

...what we call The Scientific Process
First, there’s the question.

Is there life in this dry, dead looking place?

Astrobiologists have found life in similar, extremely dry places.

My conclusion, the hypothesis is correct. There is life here!

Based on previous studies, I think microbes could live under the ground.

Onto the next Question.

In the first sample... nothing.

But deeper underground 85% of the samples have microbes!

Based on previous studies, I think microbes could live under the ground.

We’ll add fluorescent dye that sticks to the DNA of microbes, and then take a look.

Time to experiment and gather data!

Based on previous studies, I think microbes could live under the ground.

Time to experiment and gather data!

We’ll add fluorescent dye that sticks to the DNA of microbes, and then take a look.
The results have raised more questions.

What types of microbes are they?
Back to the Scientific Process!!

Why don’t they live near the surface?

What do they eat?

Where do they get water from?

Could similar organisms have evolved on worlds like Mars?

I have questions about space... And how life evolved... And life on other planets... So how do we become astrobiologists?

Anthony Chan (NASA Ames)
Daniella Scalise (NASA Ames)
Melissa Kirven-Brooks (NASA Ames)
Astrobiology means the study of stars to life... so it encompasses everything from astronomical phenomena to living organisms.

Microbiologists study microscopic organisms like bacteria, archaea, and viruses.

Ecologists study how different organisms in an environment live together.

Biology is the study of life, and it occurs at all scales, from molecules to planets.

In terms of school subjects, of course Biology is important.

Biology is the study of life, and it occurs at all scales, from molecules to planets.

Heather Graham (NASA Goddard)
Biochemists study the chemistry of living organisms.

Molecular biologists study the molecules of life; how they're made, modified, and how cells use them to function and interact.

Geneticists work with molecules like DNA. They study genes and genetic variation in life.

Cell biologists study the structure and function of living cells.

Biochemists study the chemistry of living organisms.

Evolutionary biologists study how life evolves over time in connection with the environment.

Biology is controlled by its environment, but biology can also modify the environment on planetary scales.

Biology and planet Earth are linked. These and other areas of biology are important in understanding that connection.
Chemical reactions can lead to molecules that are more complex... and increasing complexity through chemistry is what eventually led to life.

Another important topic is **Chemistry**, the study of chemicals and how they react.

Prebiotic chemistry is the study of chemical reactions involved in the origins of life.*

Chemical reactions that only happen in life are a special class of reaction known as 'biochemistry.'

We may be able to use complexity to distinguish life from non-life.**

Many branches of chemistry, from cosmochemistry to geochemistry, play an important role in astrobiology research.

We may be able to use complexity to distinguish life from non-life.**

*See Issue 7
**See Issue 8
Organic chemistry involves carbon and hydrogen molecules...

...and is fundamental to life, providing energy, structure, metabolism, and cell machinery.

No life here... but there's lots of organics. (1)

Chemical reactions happen in space, on Earth, and on other planets and bodies... basically everywhere. On our planet, reactions happen between rocks, fluids, gases, and in life.
In short, we look at rocks. They're amazing records of our planet and all the things that have happened here over billions of years. Rocks can preserve evidence of past life, and can even tell us what our ancient planet was like.

That brings us to another big subject, **Geology**.

Geologists study the physical structure of Earth and other worlds.

This includes studying what worlds are made of, their history and evolution through time, and the powerful processes that act on them.

Geology shapes the surface of a planet, creating environments for prebiotic chemistry and life.

Geology shapes the surface of a planet, creating environments for prebiotic chemistry and life.
And if life is present, geology and related disciplines can help us understand how the biosphere and the planet itself co-evolve.

Geology has an effect on whether or not life can survive on a planet. But biology can also change a planet. Biology and Geology become interconnected.

Understanding how a planet works, and all the crazy things that happen as a planet forms and evolves, is necessary for us to determine whether or not a planet is habitable.

Space missions help us study the geology of other planets, like Mars.

Mars Science Laboratory (MSL)*

InSight Lander*

*See Issue 2

Mary Droser (University of California, Riverside)
Astronomy provides a foundation for astrobiology, helping us determine where life might exist amongst the stars.

Could every star have planets in orbit?

Astrobiologists use observational data to look for signs of life beyond the Solar System, or biosignatures (See Issue 7).

Some astronomers also look for technosignatures, like radio signals from other planets.

Technosignatures are a subset of biosignatures* defined as evidence of advanced life.

*See Issue 8
I've identified thousands of exoplanets, many that might be habitable!

Examing spectra can tell us about the composition of a planet's atmosphere.

Astrobiologists look for biosignatures like biological gases in the atmosphere or life-driven changes to the surface.

Look at this planet forming from the dust!

Many branches of astronomy play a role in astrobiology research.

Astrochemistry focuses on the abundance and reactions of molecules in the Universe.

Astrophysics focuses on the physics of the Universe's components, such as planets.
Those are four big disciplines, but to complete the story of life’s potential, there are so many more.

Are you saying everyone is an astrobiologist?

Earth and Atmospheric Sciences
Physics
Mathematics and Statistics
Heliophysics

I guess everyone can be an astrobiologist!

Many people study two or more of these disciplines over their career.
Biology isn’t the only discipline in astrobiology...
...and not all biology at NASA is astrobiology.

For instance, medicine and human biology are important to our astronauts.

And if you’re interested in what happens when life from Earth goes to space...
that’s Space Biology (7).

Biology isn’t the only discipline in astrobiology...

Astrobiology and Space biology sometimes share experimental subjects and techniques, but ask different questions.

Biology also has a role in many programs at NASA. Each program does unique work, but there are connections. (8)

If we contaminate samples with life from Earth, that would ruin experiments designed to search for non-Earth life.

One way to find life on another planet is to bring it with us...

The problem is, that would make it much harder to see what was there before we arrived.

Planetary Protection, for instance, is extremely important in astrobiology missions. (8)
Once you’ve started on your journey in astrobiology, there are lots of resources and activities to be aware of!

Funding awards help support student travel and field research.

After your PhD, the NASA Postdoctoral Program supports postdocs to work with funded scientists, including astrobiologists.

Events like AbGradCon help college students and early career scientists meet each other, share their science and career advice, and build collaborations.

Luiz Felipe Benitez (Rutgers University)
Debashish Bhattacharya (Rutgers University)

There is a wealth of information available from the NASA Astrobiology Program. (12-16)

https://astrobiology.nasa.gov/careers-employment/

NASA also has many other, broader opportunities for teachers, scientists, and learners of all kinds. (17)
A degree in something you are passionate about is essential. And then find your specific focus in graduate school. This is a general path to astrobiology, but everyone’s path in life is unique.

Students of all ages can join the NASA Research Coordination Networks (RCNs) to learn more about astrobiology. A degree in something you are passionate about is essential. And then find your specific focus in graduate school.

Start by feeding your curiosity. Read reliable sources, from books and articles to blogs from scientists. Watch NASA videos like Ask an Astrobiologist (18).

Workshops and conferences will help you meet others, share ideas, and build collaborations. Check the Astrobiology website for opportunities, but also talk to scientists who do cool research!

This is a general path to astrobiology, but everyone’s path in life is unique.
Beyond the natural sciences, humanities and social sciences also play an important role.

As part of the National Aeronautics and Space Act, NASA has a responsibility to serve the public and to make sure NASA science benefits society. (20)

For NASA, sharing our story is a vital part of our mission.

We need to communicate about everything we learn, to both the science community and the public.

We study how to accurately and effectively communicate major findings...

...for instance, the discovery of life in the Universe.

Science, and astrobiology in particular, is a journey of discovery.

Rarely is there an instantaneous leap, it’s more like small steps toward a goal.

Communicating the excitement and the importance of this progress can be challenging, but is so important.

And, of course, NASA also needs people who can visualize science by creating infographics and illustrations to help tell the story!
Disciplines like sociology, art, history, and philosophy help us understand those important connections.

Understanding the origin, distribution, and future of life in the Universe challenges anthropocentric ideas about the Universe.

It’s important to know how astrobiology research relates to and affects society.

“Look again at that dot. That’s here. That’s home. That’s us.”

“On it everyone you love, everyone you know... every human being who ever was... the history of our species lived there on a mote of dust suspended in a sunbeam.”

We also study the culture of science to help the scientific community grow into a better place for everyone to learn and work.

Arsev Aydınoğlu (Orta Doğu Teknik Üniversitesi)

“Look again at that dot. That’s here. That’s home. That’s us.”

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Astrobiology isn’t just about doing science... ...how we do our work and how we work with each other matters. 

We are growing in how we understand our responsibility to where we work and the people who care for and connect with that land.

Shawnell McFarlane (NASA Ames), Skokomish and Squaxin Island tribes

Svetlana Shkolyar (University of Maryland/NASA Goddard)

The NASA Astrobiology team also recognizes that while not all learners have equal access to STEAM*, all learners matter equally.

NASA partners with Indigenous communities in the US and internationally to co-create unique educational materials and programs... ...bringing together Traditional Indigenous Knowledges with astrobiology science.

Meagan Thompson (NASA HQ), member of the Red Lake Band of Chippewa

We have worked with incarcerated learners to share the story of astrobiology in the context of themes relevant to their environment, such as relationality, innovation, adaptability, resilience, and creativity in extreme conditions. (23)

We are revitalizing Indigenous knowledges AND teaching STEAM in culturally-based contexts.

We work to connect them with opportunities and broader educational initiatives at NASA.

Caitlin Bordeaux (NASA Ames), member of the Sicangu Lakota

Early Career Scientists and communicators are crucial to the future.


* Visit NASA Astrobiology for resources and more (12)

Caitlin Bordeaux (NASA Ames), member of the Sicangu Lakota

NASA Science Activation (SciAct)

Early Career Scientists

Svetlana Shkolyar (University of Maryland/NASA Goddard)
To assist the science community and advance astrobiology research, the NASA Astrobiology Program supports conferences...

Welcome to the Astrobiology Science Conference!

Bradley Burcar (NASA HQ)

...many other activities.

What would be the best biosignature to look for on an icy ocean world?

What new tech do we need in order to find and identify that signature?

NASA Biosignatures Ideas Lab

Dawn Cardace (University of Rhode Island)

Welcome to the Astrobiology Science Conference!

Workshops and meetings...

What are the best ways to communicate major findings to other scientists and the rest of the world?

NASA’s Research Coordination Networks also have many seminars, workshops, and other opportunities for students and early career astrobiologists.

Astrobiology Debates, the Astrobiology Learning Progressions (25), this book... over decades we have supported many unique outreach activities.

We are committed to reaching out beyond the science community, to teachers, students, and anyone interested in science.

The NASA Astrobiology Debates

Talking Astrobiology with NASA
The NASA Astrobiology Program funds proposals selected from a number of NASA Solicitations. NASA provides funds to support scientists all over the United States. This funding comes from the American people.

Many NASA employees manage the research programs that scientists apply to for funding.

Your proposal was amazing! We're so excited to help support this important work.

The NASA Astrobiology Program funds proposals selected from a number of NASA Solicitations.

NASA releases funding calls each year in the Research Opportunities in Space and Earth Science (ROSES). This includes programs for graduate students and early career scientists.

This is how everyone can apply for NASA funding, whether they are based at NASA Centers around the United States, or at universities and research institutions.

Funding Opportunities and Announcements

NASA also has guides and workshops to help understand the process.

https://science.nasa.gov/researchers/sara/grant-solicitations/

Michael New (NASA HQ)

Max Bernstein (NASA HQ)

Christina Richey (NASA JPL)
For astrobiologists outside the USA, it is important to explore the opportunities in your home agencies, institutions, and universities. Many countries have strong space agencies, but also look at research taking place at universities.

So much of science is about communication. Talk to scientists who do work you are interested in, and ask them about what path they took to become part of the global astrobiology science community.

Betül Kaçar (University of Wisconsin–Madison)
Zachary Adam (UW-Madison)

You don’t have to work at NASA to be an astrobiologist.

Many scientists at universities and research institutes apply to NASA for astrobiology funding.

In fact, most astrobiologists do not work at space agencies.

There are also many Astrobiology Societies throughout the world. Search for what is being done in your country or region.
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