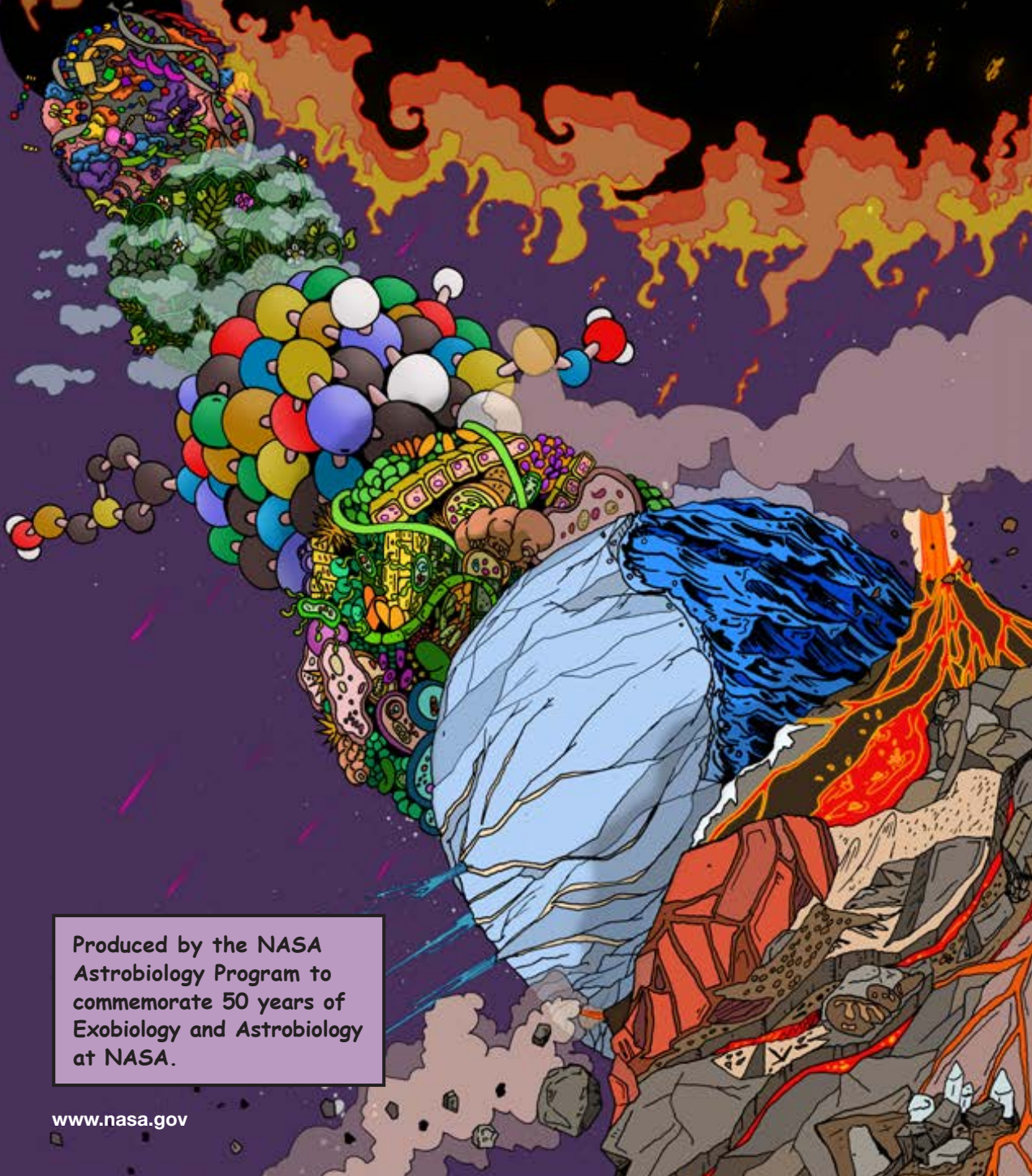




# ASTROBIOLOGY

The Story of our Search for Life in the Universe



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

# Astrobiology

## A History of Exobiology and Astrobiology at NASA

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.

### Concept & Story

Mary Voytek  
Linda Billings  
Aaron L. Gronstal

### Artwork

Aaron L. Gronstal

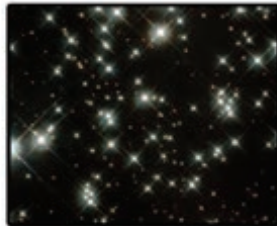
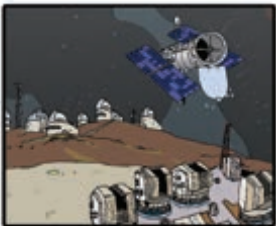
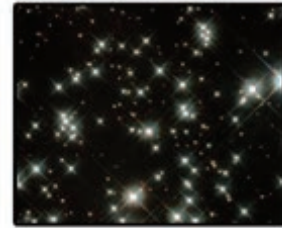
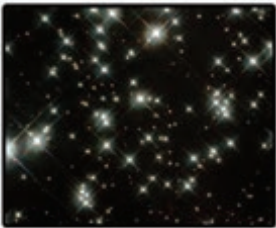
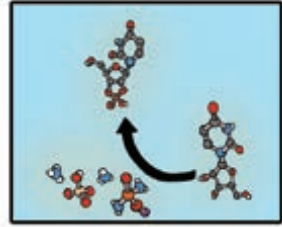
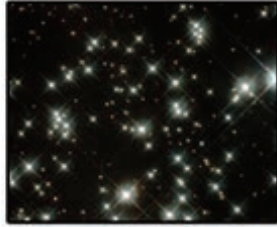
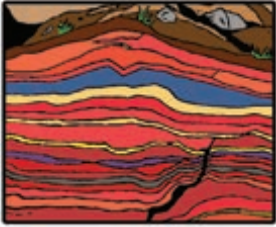
### Script

Aaron L. Gronstal

### Editor

Linda Billings  
Mary Voytek

# Issue #9—Becoming an Astrobiologist



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

Astrobiology has been a part of NASA since the agency's beginning\*.



\* See Issue 1

Astrobiologists study life on Earth and the potential for life in the Universe.



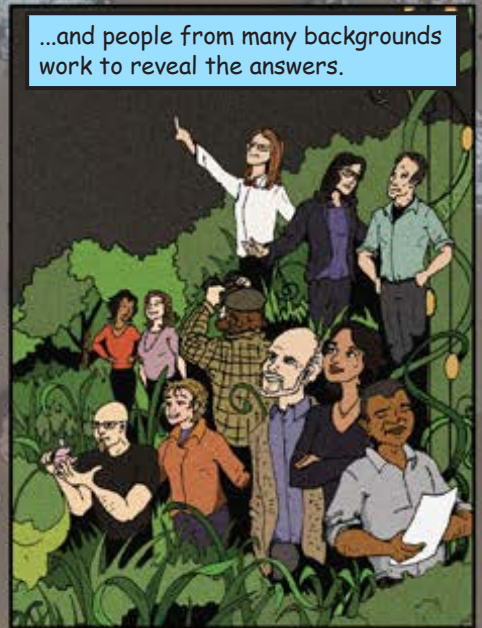
The research reaches through the Solar System to potentially habitable places like Mars and Enceladus, then beyond to exoplanets around different stars.\*\*



\*\* See Issues 1-8

Astrobiologists ask big questions about life...

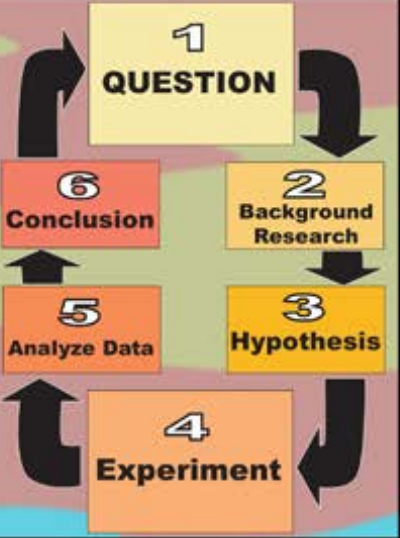
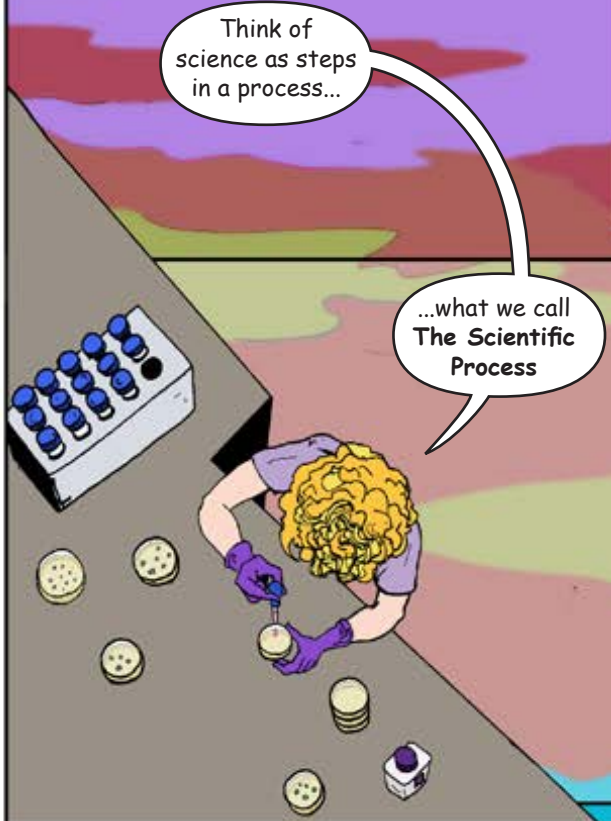
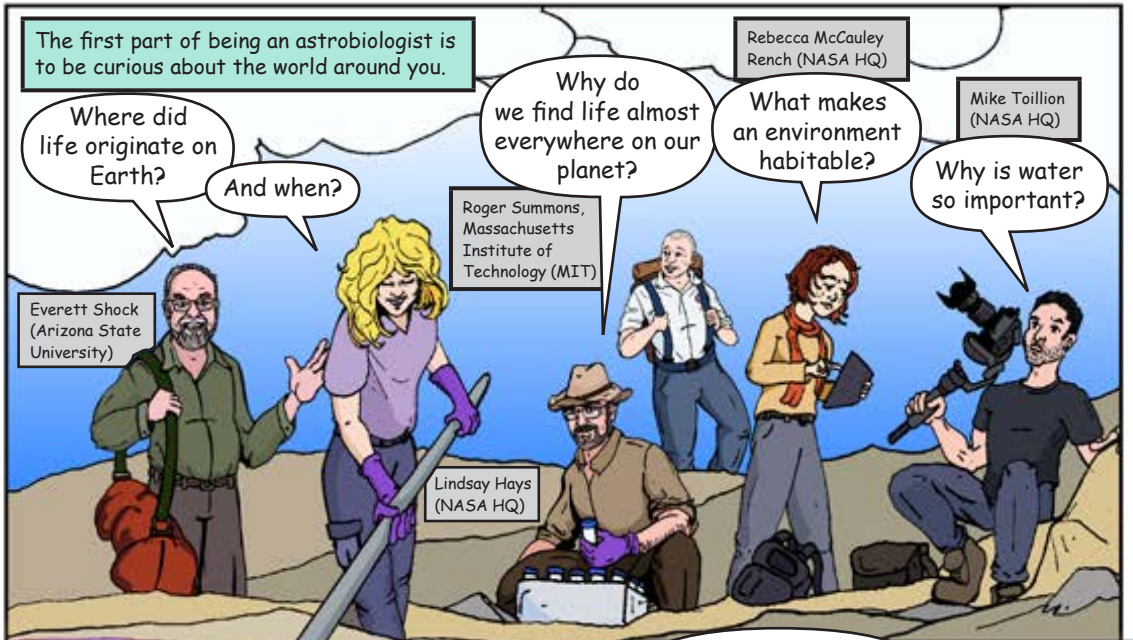
...and people from many backgrounds work to reveal the answers.



**Issue 9:**

But how do I become an astrobiologist?





First, there's the question.

1. Question

Is there life in this dry, dead looking place?

Aaron Gronstal  
(NASA Ames)

Onto the next Question.

Astrobiologists have found life in similar, extremely dry places.

2. Background Research

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

6. Conclusions

In the first sample... nothing.  
But deeper underground 85% of the samples have microbes!

5. Analyze Data

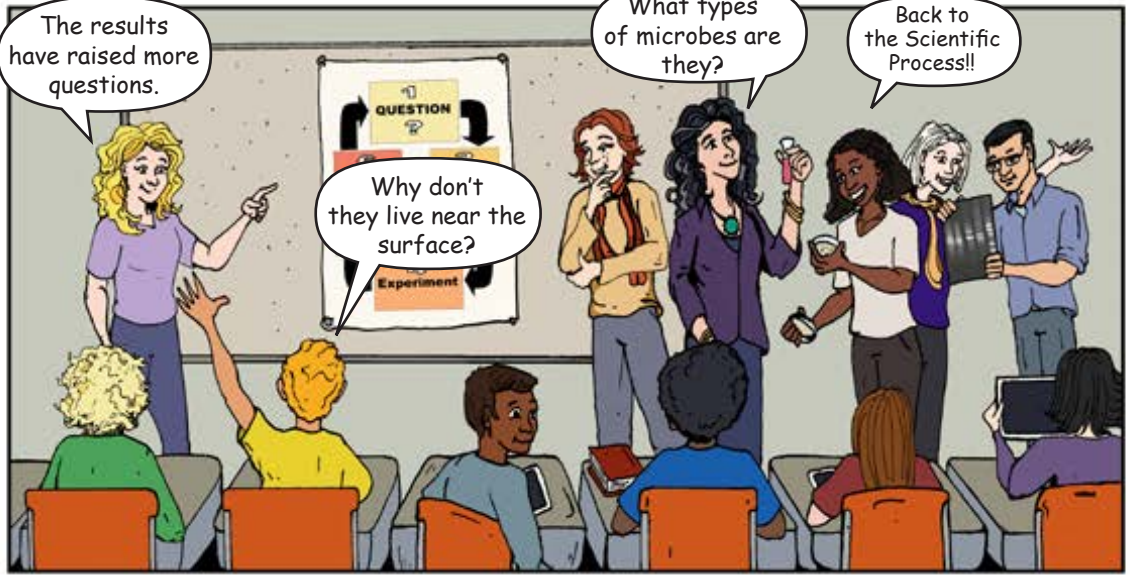
Based on previous studies, I think microbes could live under the ground.

3. Hypothesis

Time to experiment and gather data!

4. Experiment

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



Astrobiology means the study of stars to life... so it encompasses everything from astronomical phenomena to living organisms.

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.

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

Ecologists study how different organisms in an environment live together.

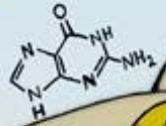
Heather Graham  
(NASA Goddard)



# BIOLOGY

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.

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

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

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

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

Chemical reactions can lead to molecules that are more complex... and increasing complexity through chemistry is what eventually led to life.

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...

Ramanarayanan Krishnamurthy (Scripps)

Andrzej (Andrew) Pohorille (1949-2024) (NASA Ames)

Jason Dworkin (NASA Goddard)

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

Organic chemistry also happens in the absence of life, for instance on the asteroid Bennu.

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

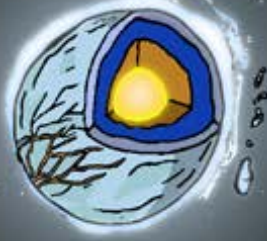
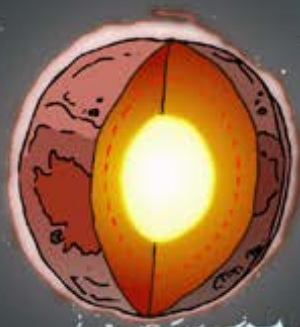
OSIRIS-REx (See Issue 3)

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.

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.

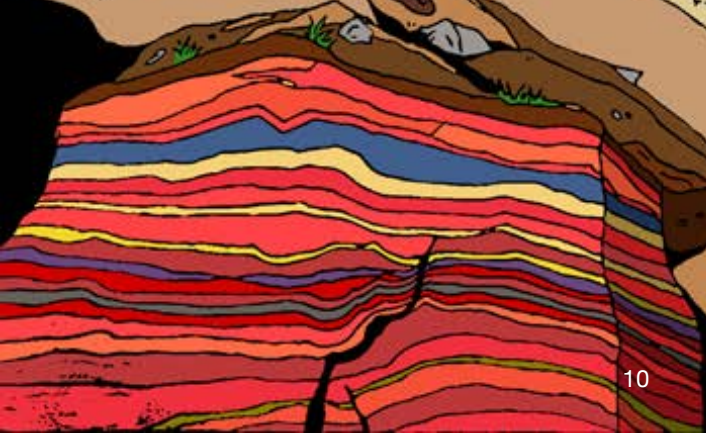


Geology shapes the surface of a planet, creating environments for prebiotic chemistry and life.

# GEOLOGY

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.





Mars Science Laboratory (MSL)\*

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

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.

InSight Lander\*

And if life is present, geology and related disciplines can help us understand how the biosphere and the planet itself co-evolve.

Mary Droser (University of California, Riverside)

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.

\*See Issue 2

**Astronomy** provides a foundation for astrobiology, helping us determine where life might exist amongst the stars.



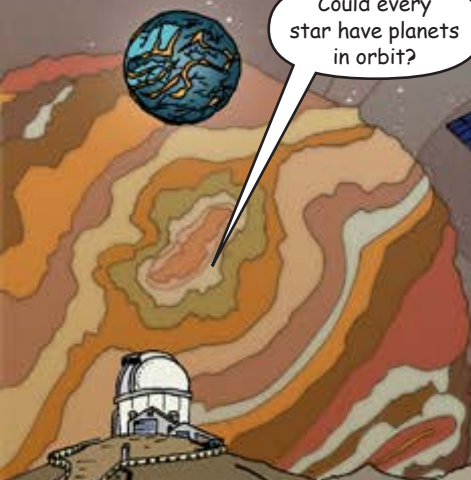
Could every star have planets in orbit?

Astronomers observe and study cosmic phenomena and celestial bodies like planets and moons.



Hubble Space Telescope

Space and ground-based telescopes observe planets forming, orbiting stars, and the composition of exoplanet atmospheres.



Las Comanas Observatory, Chile

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.



National Radio Astronomy Observatory (NRAO), USA

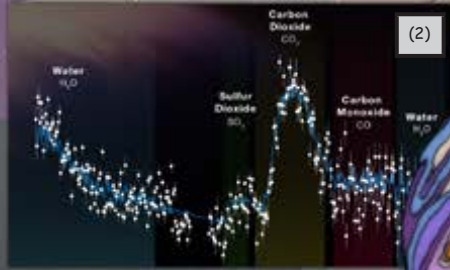
\*See Issue 8

I've identified thousands of exoplanets, many that might be habitable!

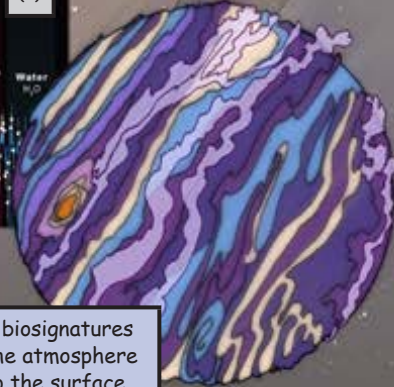


Kepler Space Telescope

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



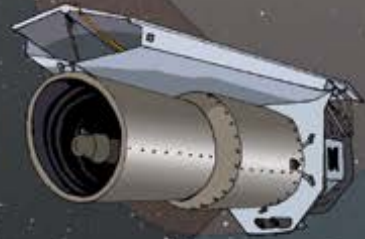
James Webb Space Telescope



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!



Spitzer Space Telescope

La Silla Observatory, Chile



Very Large Telescope (VLT), European Southern Observatory (ESO), Chile



Many branches of astronomy play a role in astrobiology research.

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

Green Bank Telescope, USA

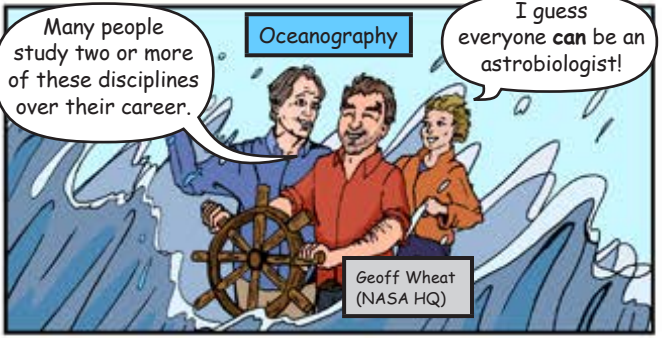
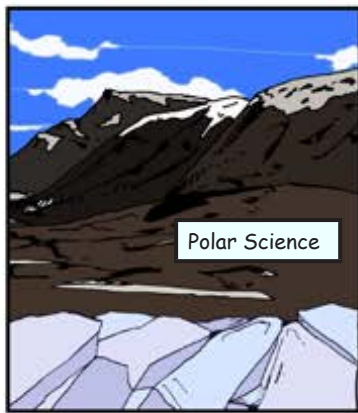
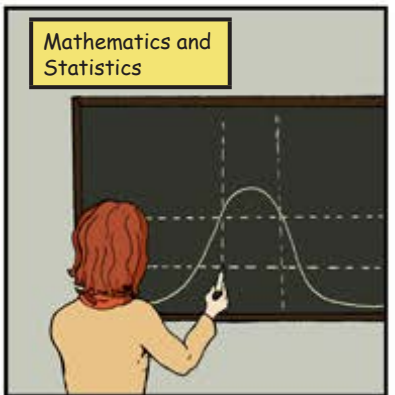
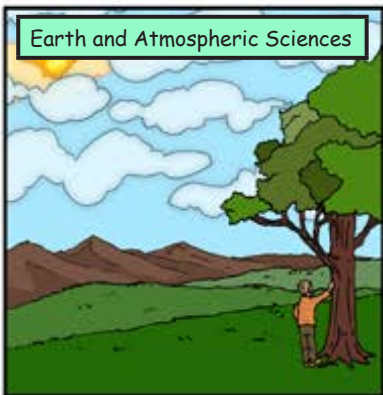
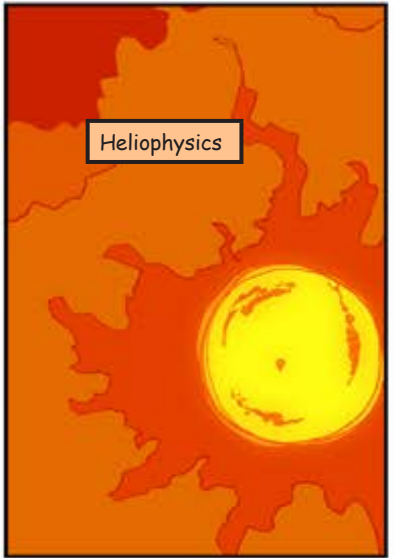


Hannah Jang-Condell (NASA HQ)

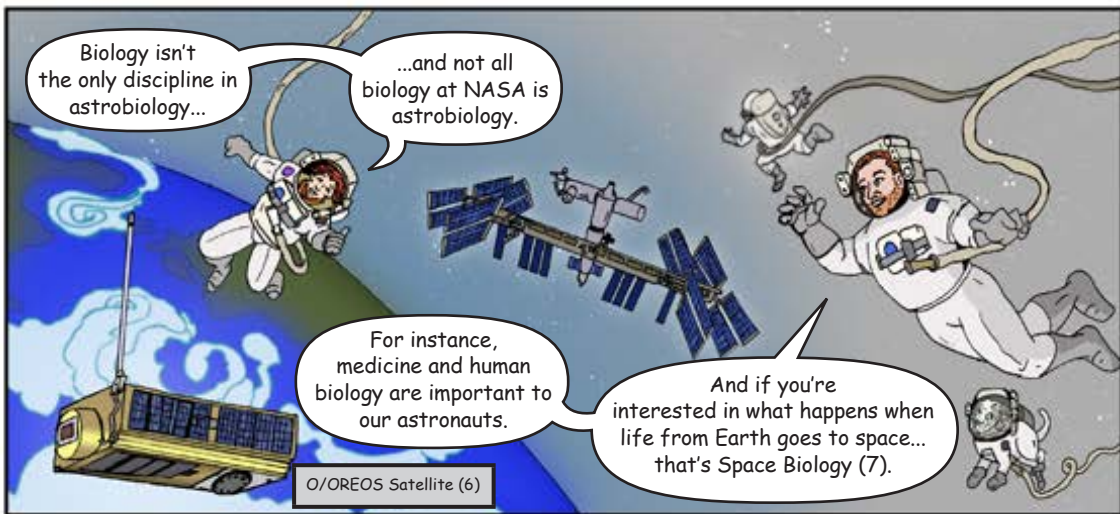
Megan Ansdell, (NASA HQ)



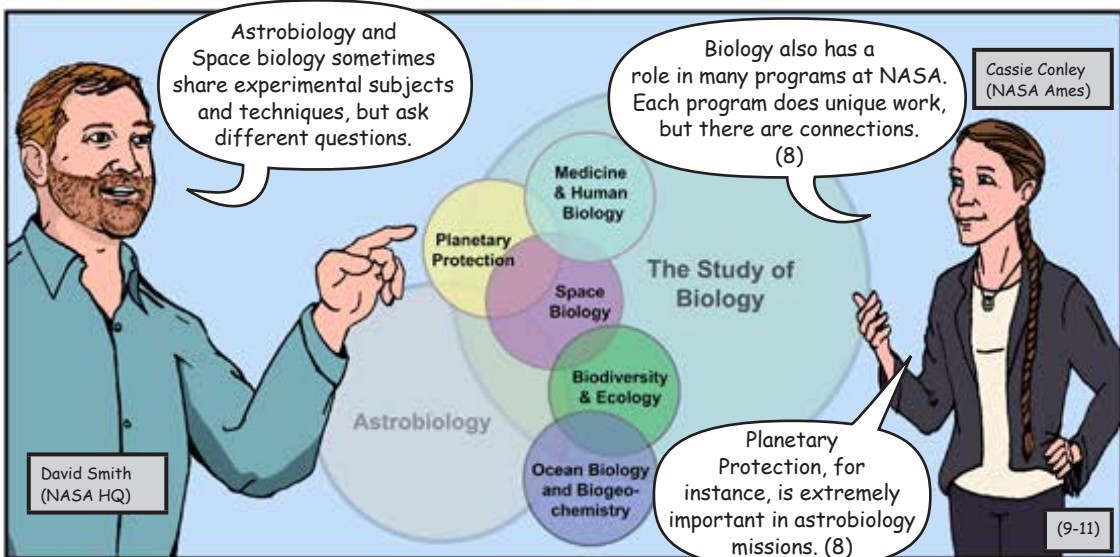
Astrophysics focuses on the physics of the Universe's components, such as planets.







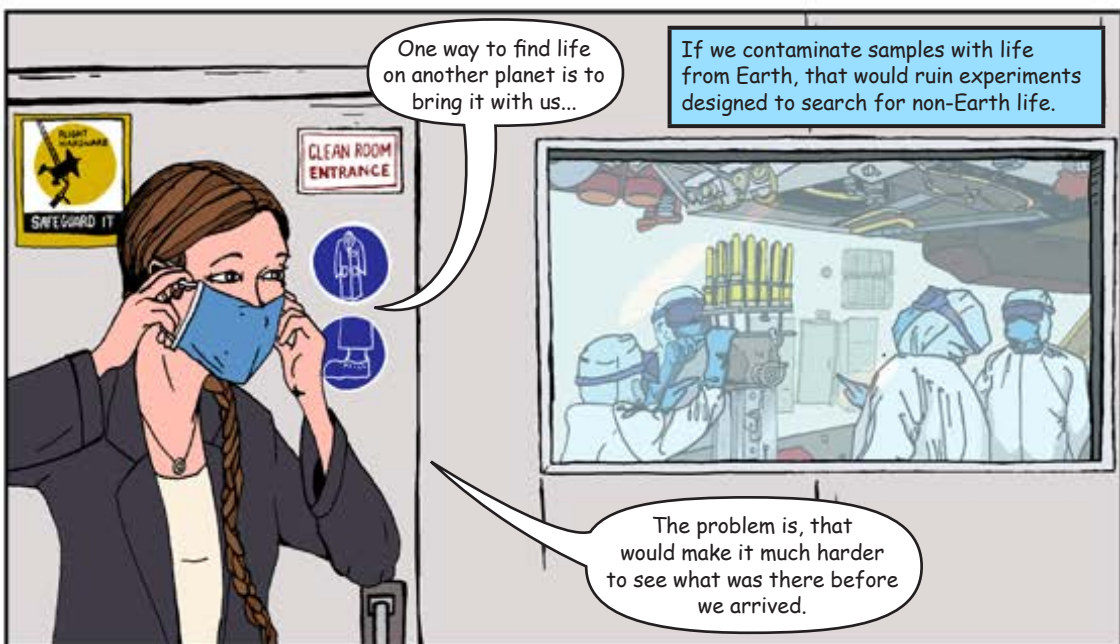
O/OREOS Satellite (6)



David Smith (NASA HQ)

Cassie Conley (NASA Ames)

(9-11)



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

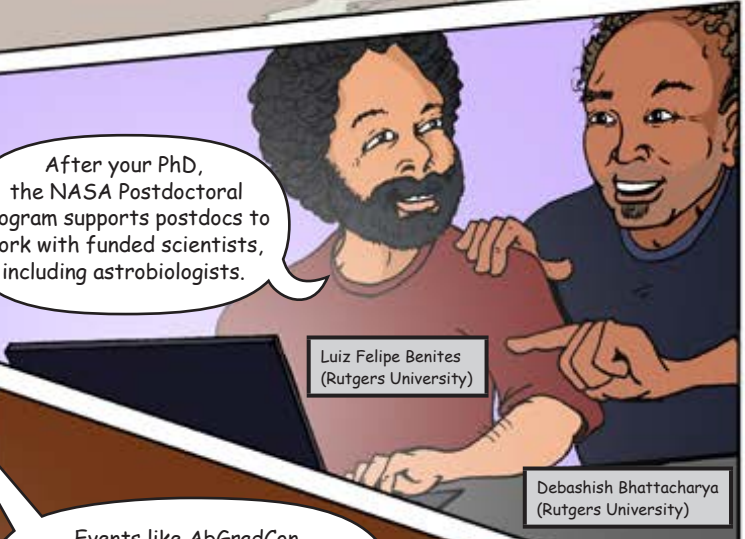
Once you've started on your journey in astrobiology, there are lots of resources and activities to be aware of!



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.



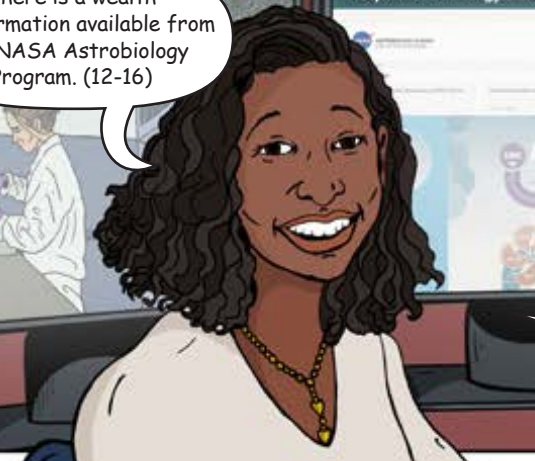
Luiz Felipe Benites (Rutgers University)

Debashish Bhattacharya (Rutgers University)

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



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



NASA also has many other, broader opportunities for teachers, scientists, and learners of all kinds. (17)

# ASTROBIOLOGY

## Career Path Suggestions

Start by feeding your curiosity.

**Learn about Astrobiology**

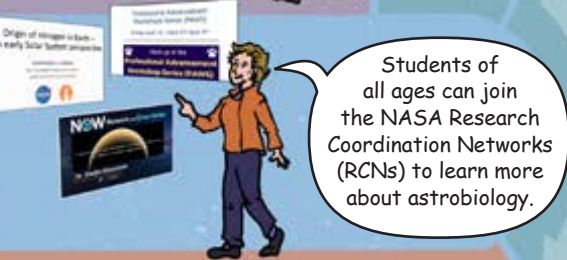
Read reliable sources, from books and articles to blogs from scientists.

Watch NASA videos like Ask an Astrobiologist (18).



**Earn a degree in...**

Students of all ages can join the NASA Research Coordination Networks (RCNs) to learn more about astrobiology.



**Graduate Work** → **Build Community**

A degree in something you are passionate about is essential. And then find your specific focus in graduate school.



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!

David Grinspoon (NASA HQ)



**Funding Support Opportunities**

This is a general path to astrobiology, but everyone's path in life is unique.

A Career in **ASTROBIOLOGY**





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

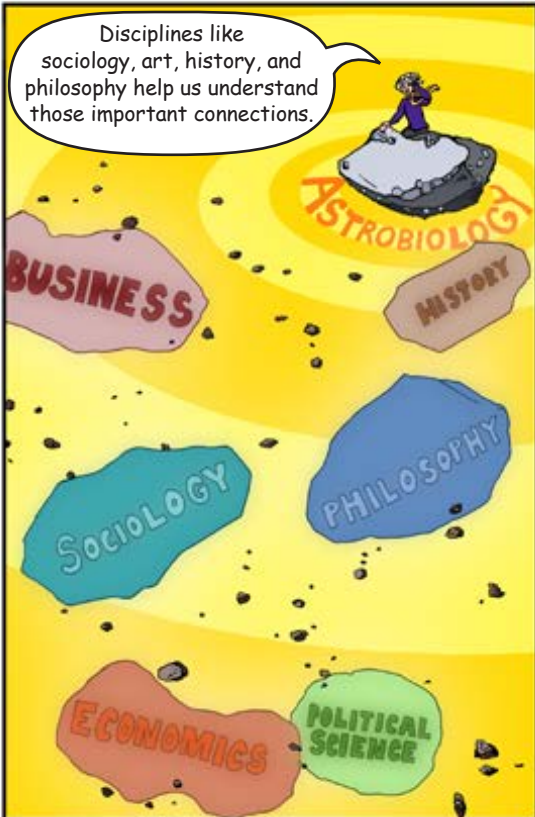
"Look again at that dot. That's here. That's home. That's us."

"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."  
(22)

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

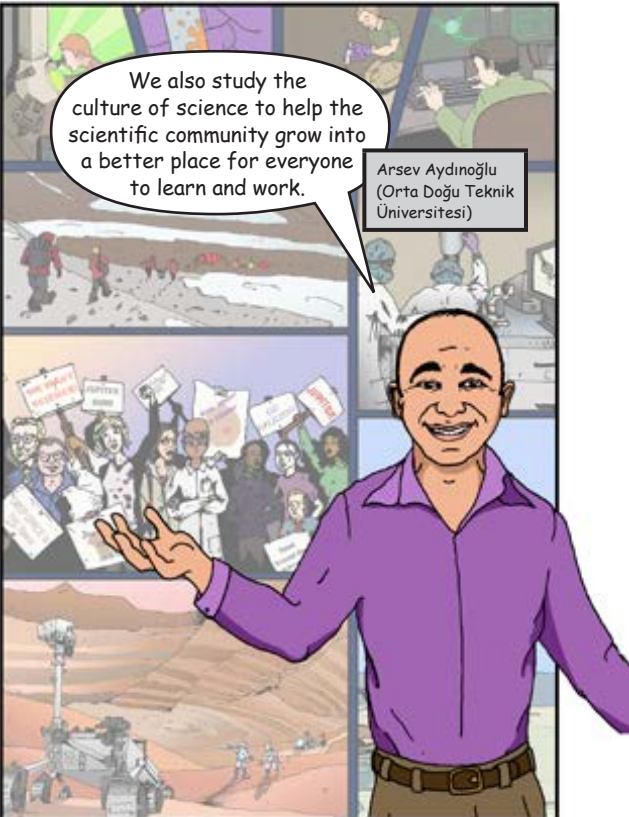


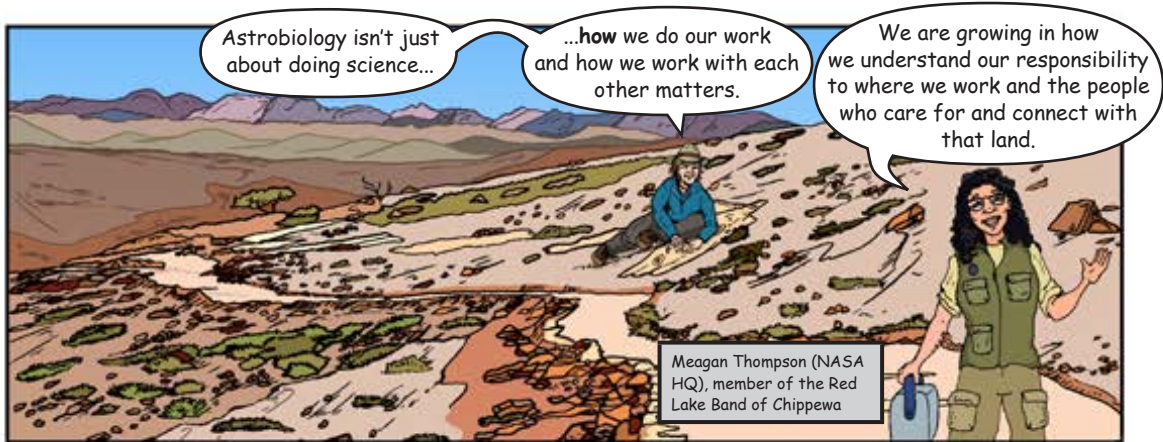
Disciplines like sociology, art, history, and philosophy help us understand those important connections.



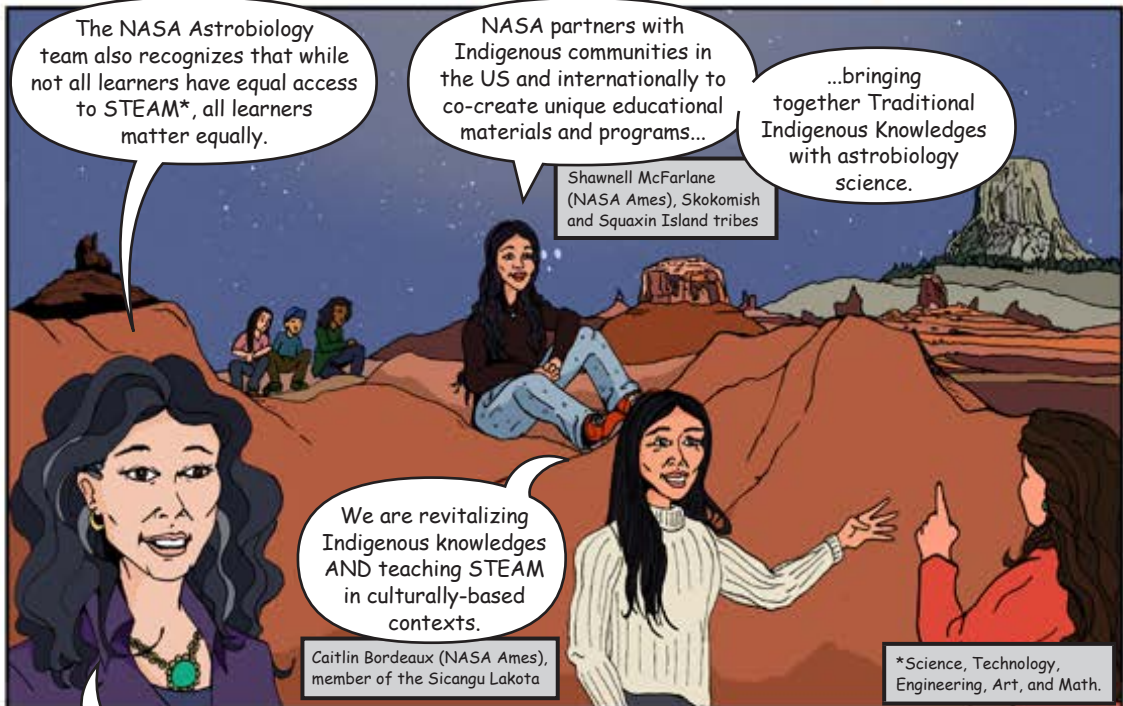
We also study the culture of science to help the scientific community grow into a better place for everyone to learn and work.

Arsev Aydınoğlu  
(Orta Doğu Teknik Üniversitesi)





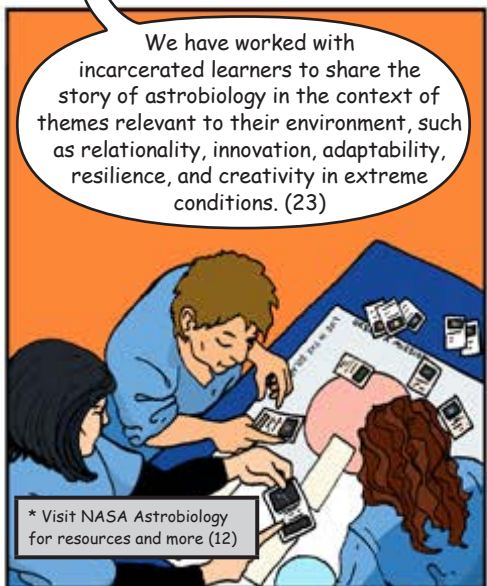
Meagan Thompson (NASA HQ), member of the Red Lake Band of Chippewa



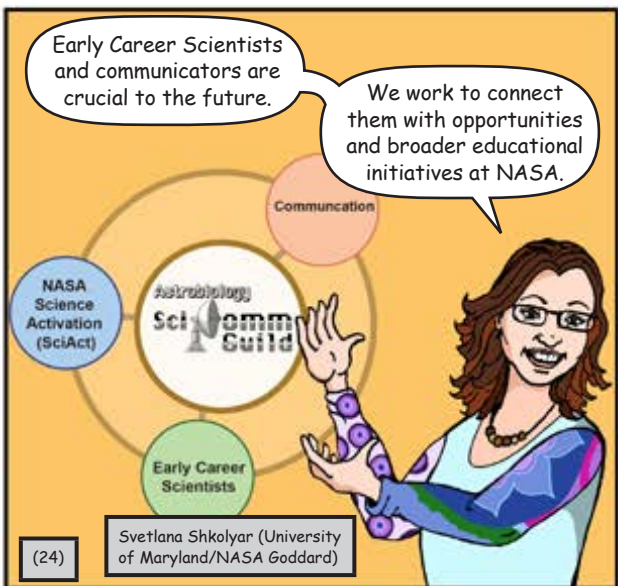
Shawnell McFarlane (NASA Ames), Skokomish and Squaxin Island tribes

We are revitalizing Indigenous knowledges AND teaching STEAM in culturally-based contexts.  
Caitlin Bordeaux (NASA Ames), member of the Sicangu Lakota

\*Science, Technology, Engineering, Art, and Math.



\* Visit NASA Astrobiology for resources and more (12)



(24) Svetlana Shkolyar (University of Maryland/NASA Goddard)

To assist the science community and advance astrobiology research, the NASA Astrobiology Program supports conferences....

AbSciCon 2024

Welcome to the Astrobiology Science Conference!

Dawn Cardace  
(University of Rhode Island)

...workshops and meetings...

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

Bradley Burcar  
(NASA HQ)

...and 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

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

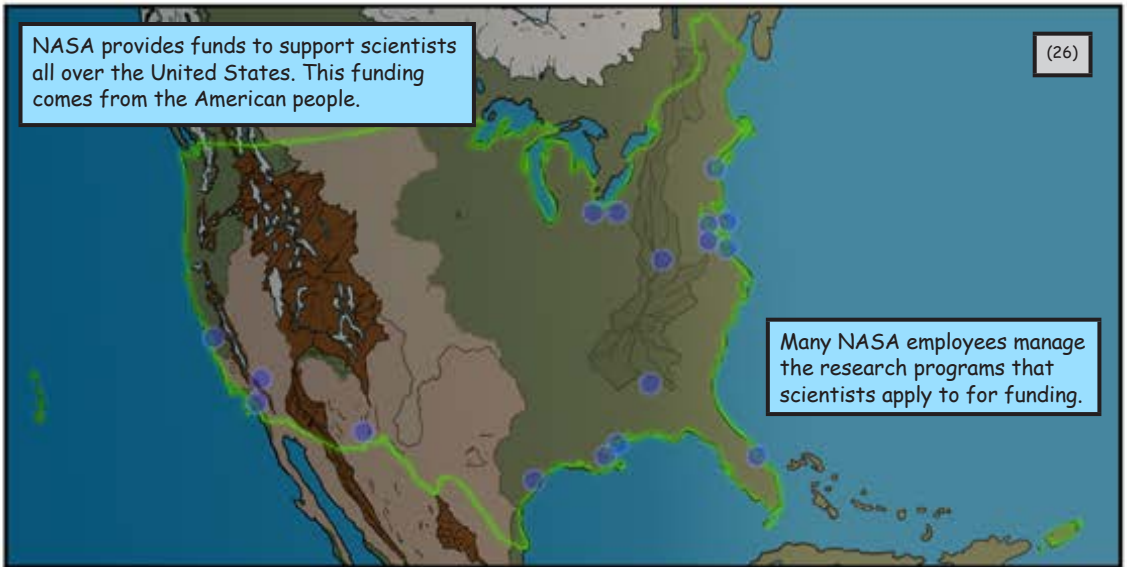
ANCIENT and MODERN GEMS in the SOLAR SYSTEM

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

THE NASA ASTROBIOLOGY DEBATES

TALKING ASTROBIOLOGY with NASA

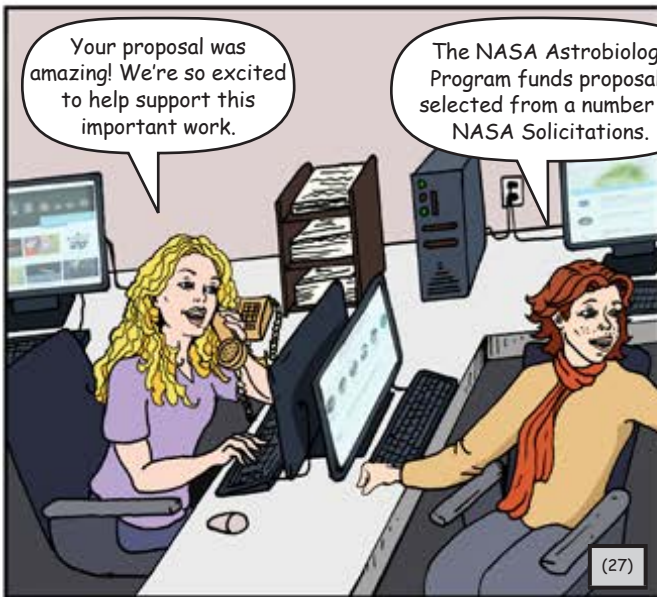
We are committed to reaching out beyond the science community, to teachers, students, and anyone interested in science.



NASA provides funds to support scientists all over the United States. This funding comes from the American people.

(26)

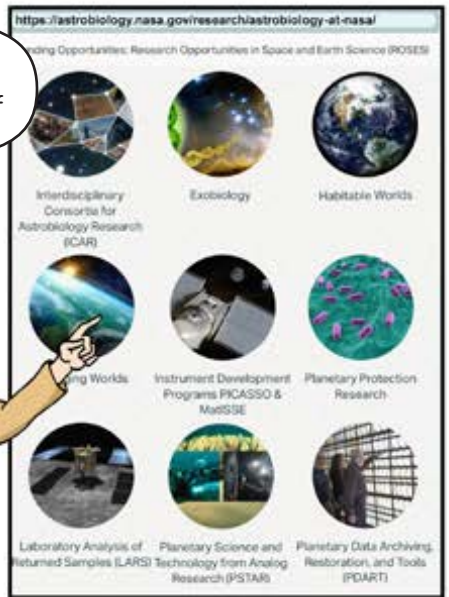
Many NASA employees manage the research programs that scientists apply to for funding.



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.

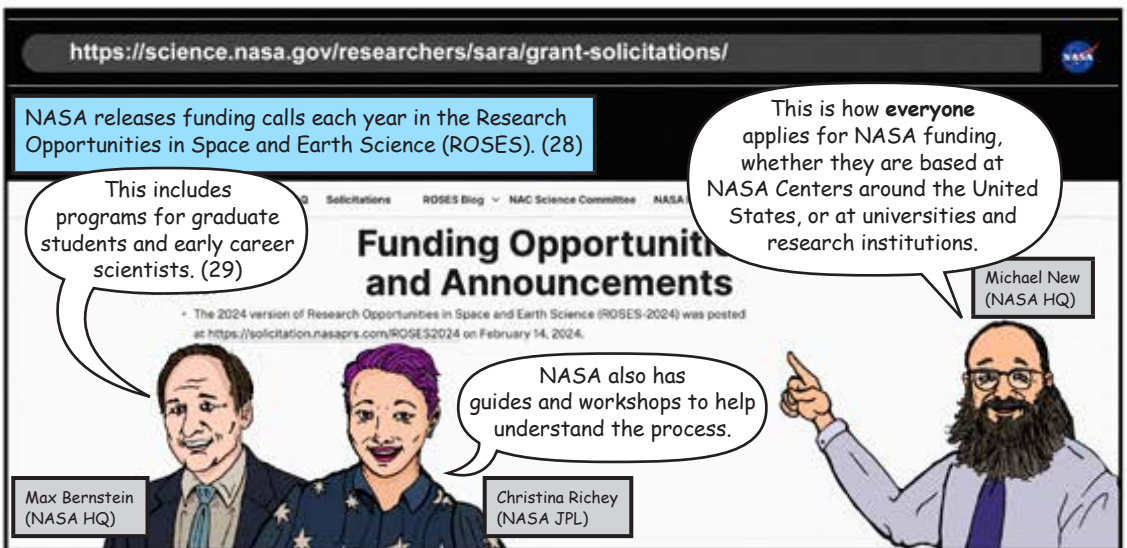
(27)



<https://astrobiology.nasa.gov/research/astrobiology-at-nasa/>

Funding Opportunities: Research Opportunities in Space and Earth Science (ROSES)

- Interdisciplinary Consortia for Astrobiology Research (ICAR)
- Exobiology
- Habitable Worlds
- Living Worlds
- Instrument Development Programs PICASSO & MARSIS
- Planetary Protection Research
- Laboratory Analysis of Returned Samples (LARS)
- Planetary Science and Technology from Analog Research (PSTAR)
- Planetary Data Archiving, Restoration, and Tools (PDART)



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



NASA releases funding calls each year in the Research Opportunities in Space and Earth Science (ROSES). (28)

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

Michael New (NASA HQ)

This includes programs for graduate students and early career scientists. (29)

## Funding Opportunities and Announcements

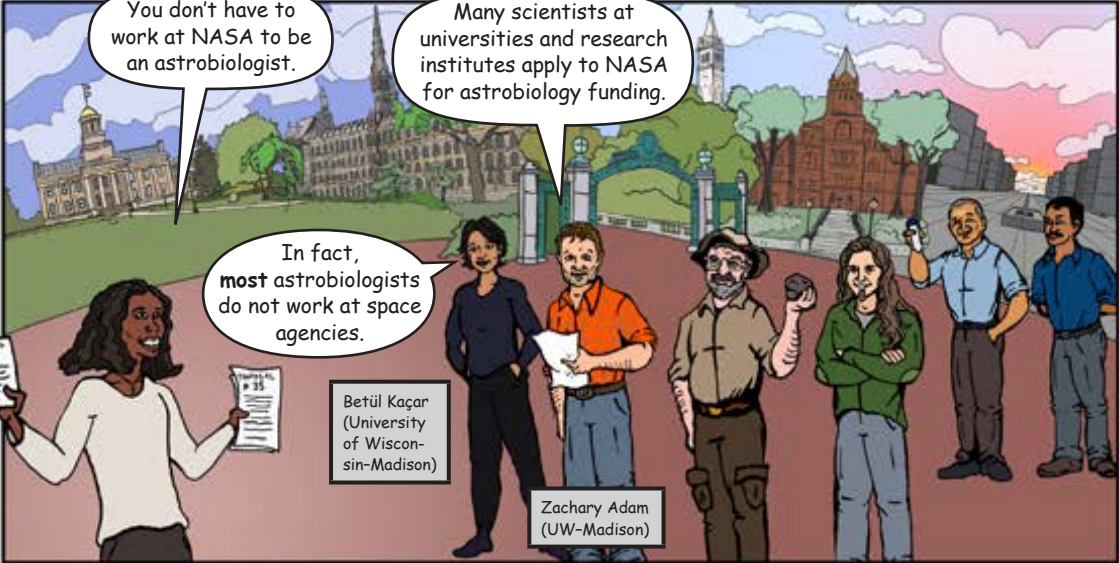
The 2024 version of Research Opportunities in Space and Earth Science (ROSES-2024) was posted at <https://solicitation.nasaprs.com/ROSES2024> on February 14, 2024.

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

Max Bernstein (NASA HQ)

Christina Richey (NASA JPL)





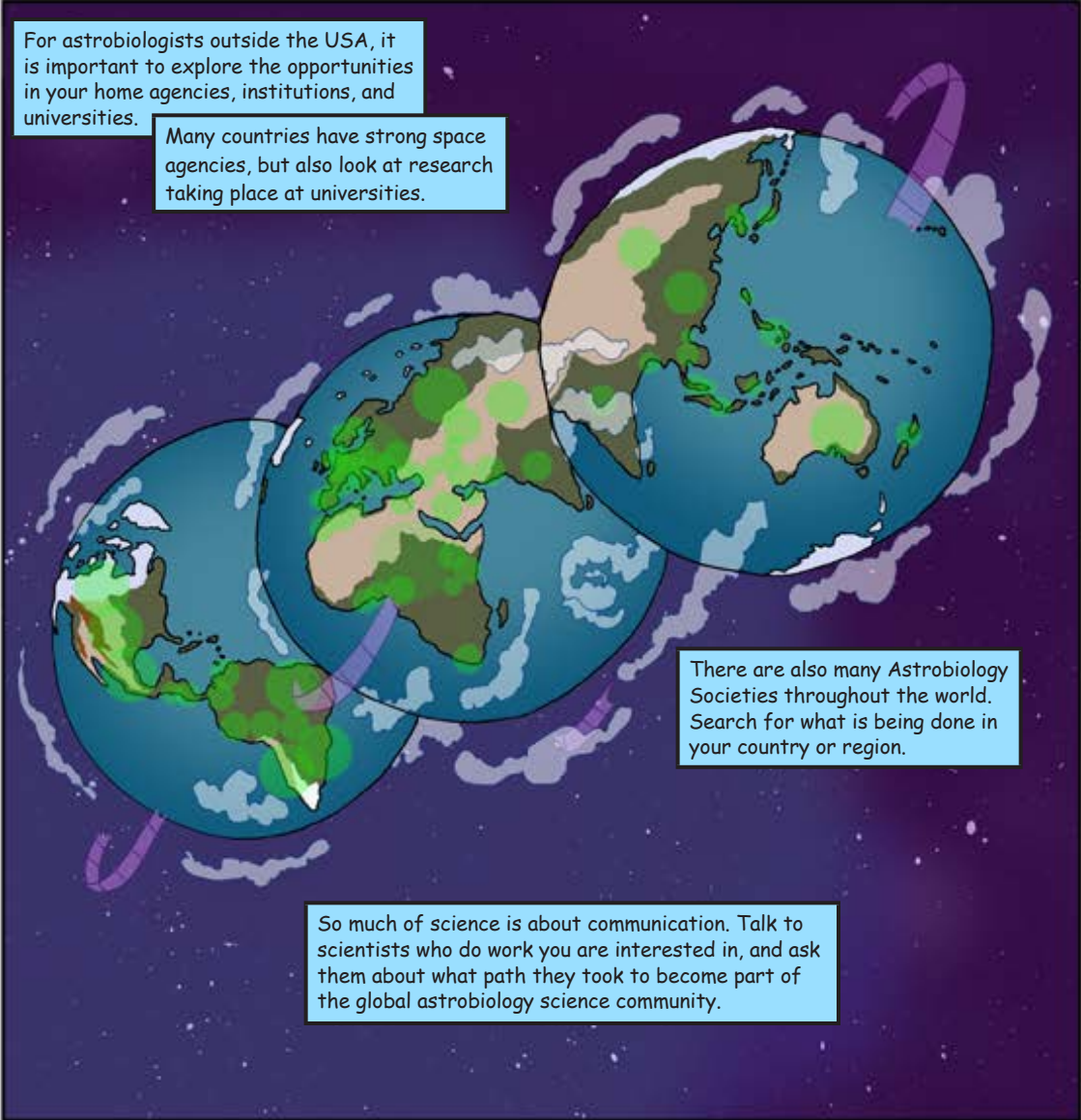
You don't have to work at NASA to be an astrobiologist.

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

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

Betül Kaçar  
(University of Wisconsin-Madison)

Zachary Adam  
(UW-Madison)



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.

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

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.

# Astrobiology

## A History of Exobiology and Astrobiology at NASA

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[science.nasa.gov/nasa-postdoc-program/](https://science.nasa.gov/nasa-postdoc-program/)
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[science.nasa.gov/learn/resources](https://science.nasa.gov/learn/resources)
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