National Aeronautics and Space Administration

Issue #9

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.

www.nasa.gov

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

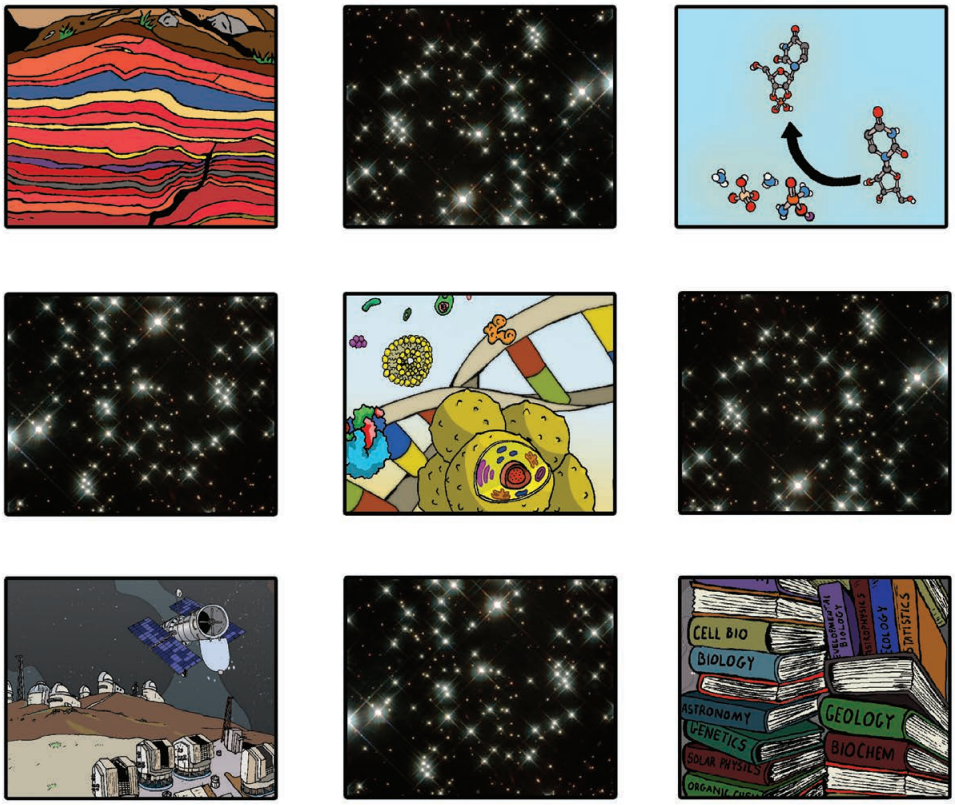
Aaron L. Gronstal

Editor

Linda Billings
Mary Voytek

2024, NASA Astrobiology Program
First Edition

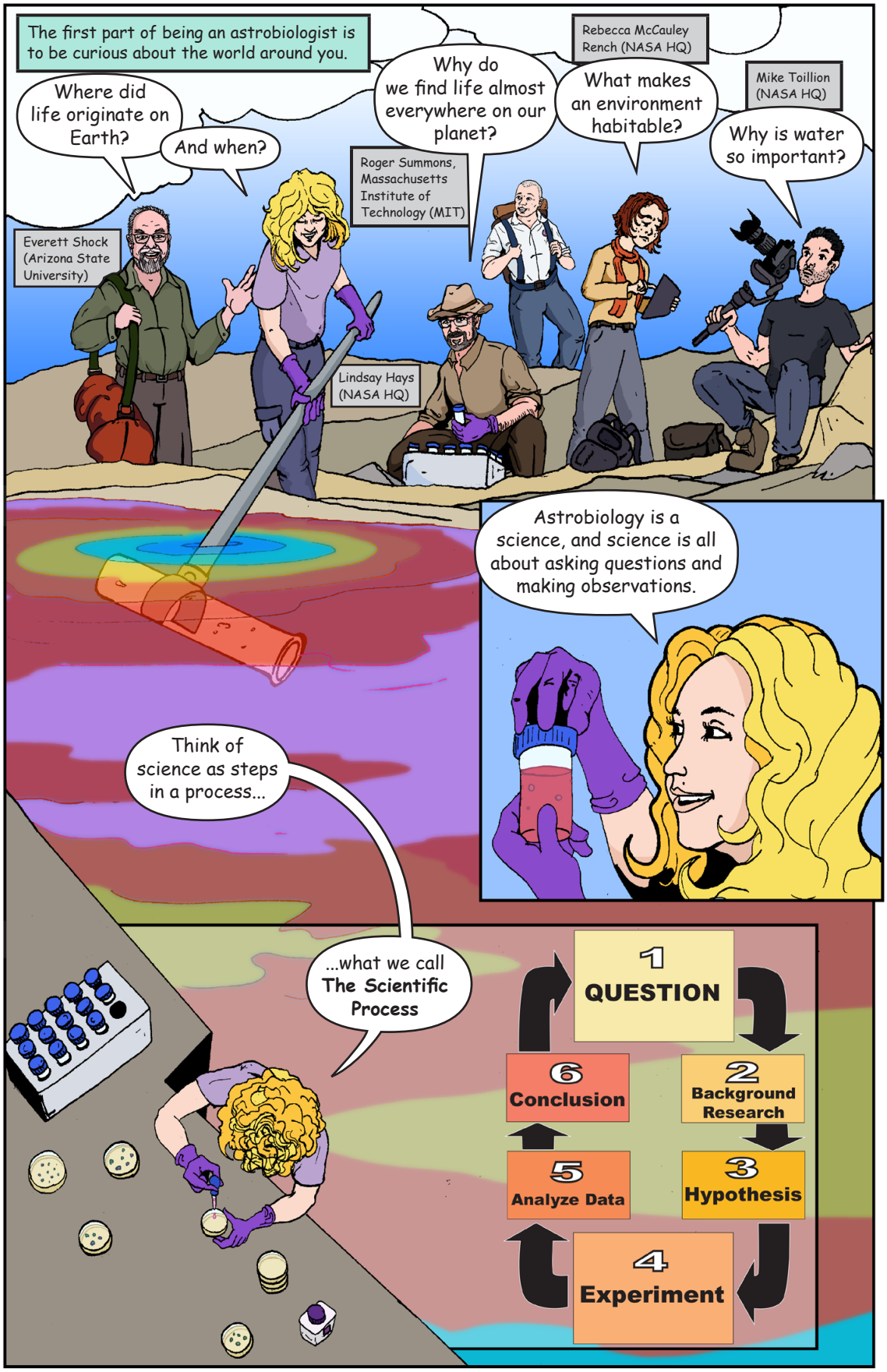
Issue #9—Becoming an Astrobiologist

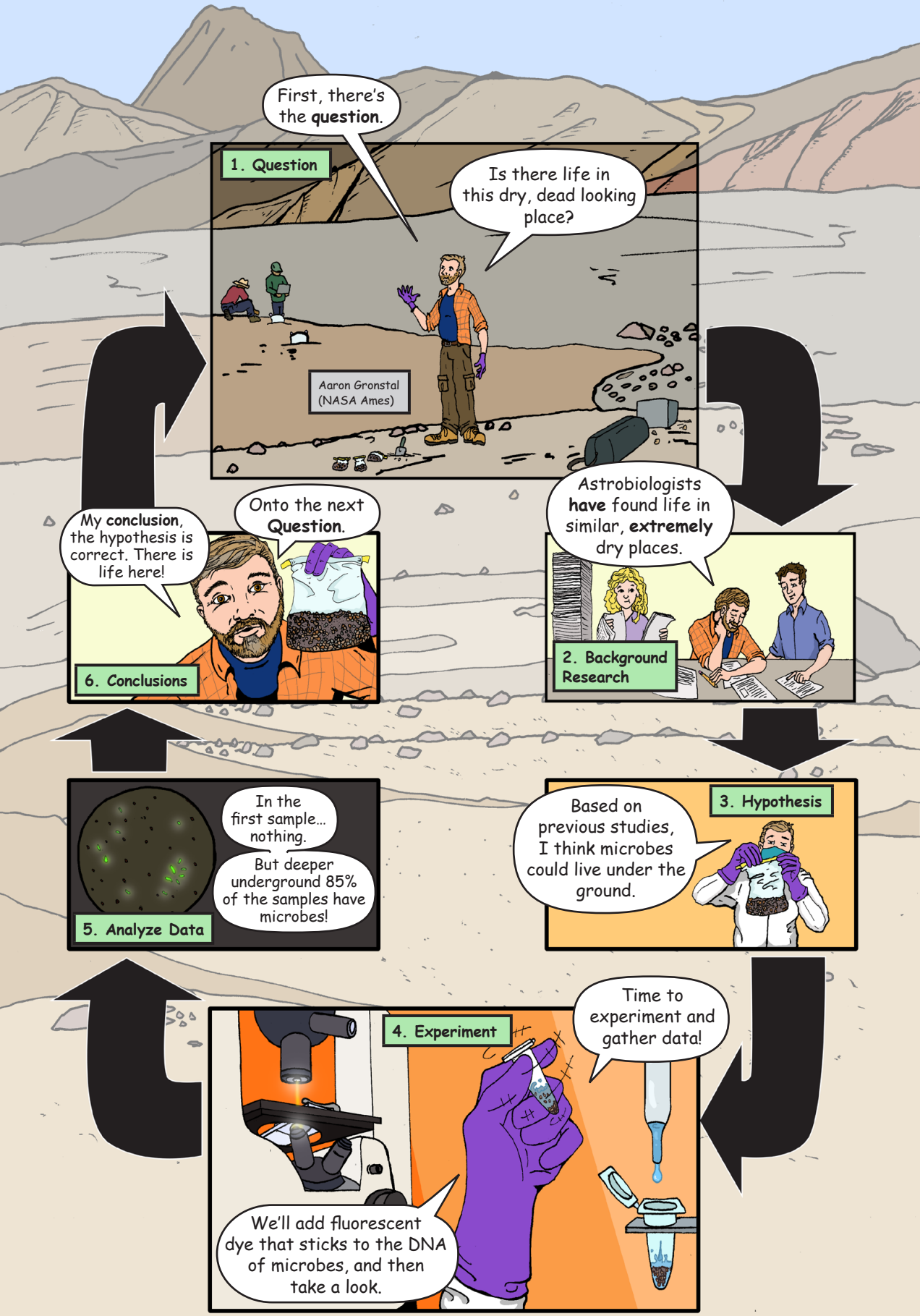


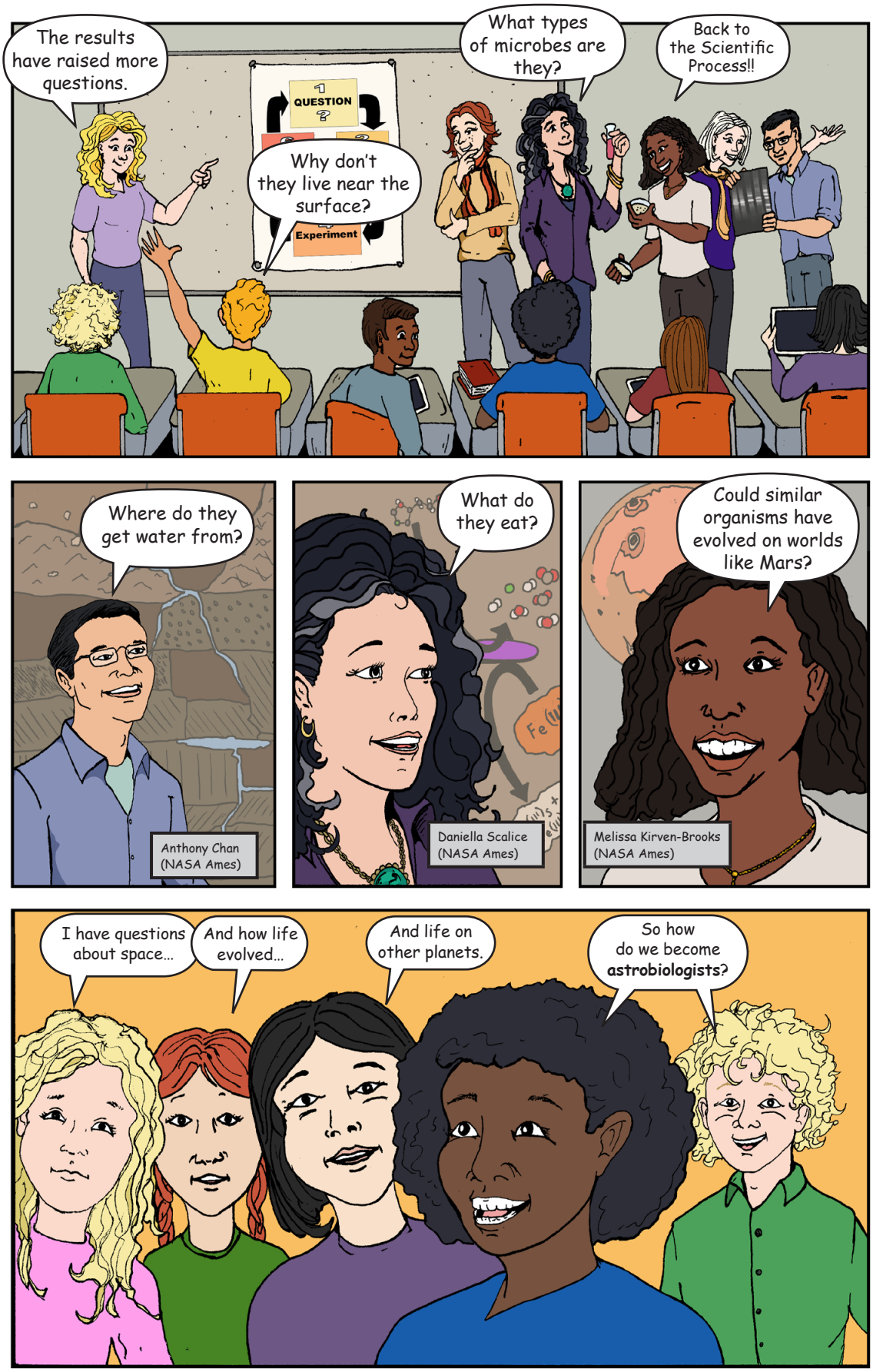
The year 2010 marked the 50th anniversary of NASA's Exobiology Program, established in 1960 and expanded into a broader Astrobiology Program in the 1990s. To commemorate the past half century of research, we are telling the story of how this field developed and how the search for life elsewhere became 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

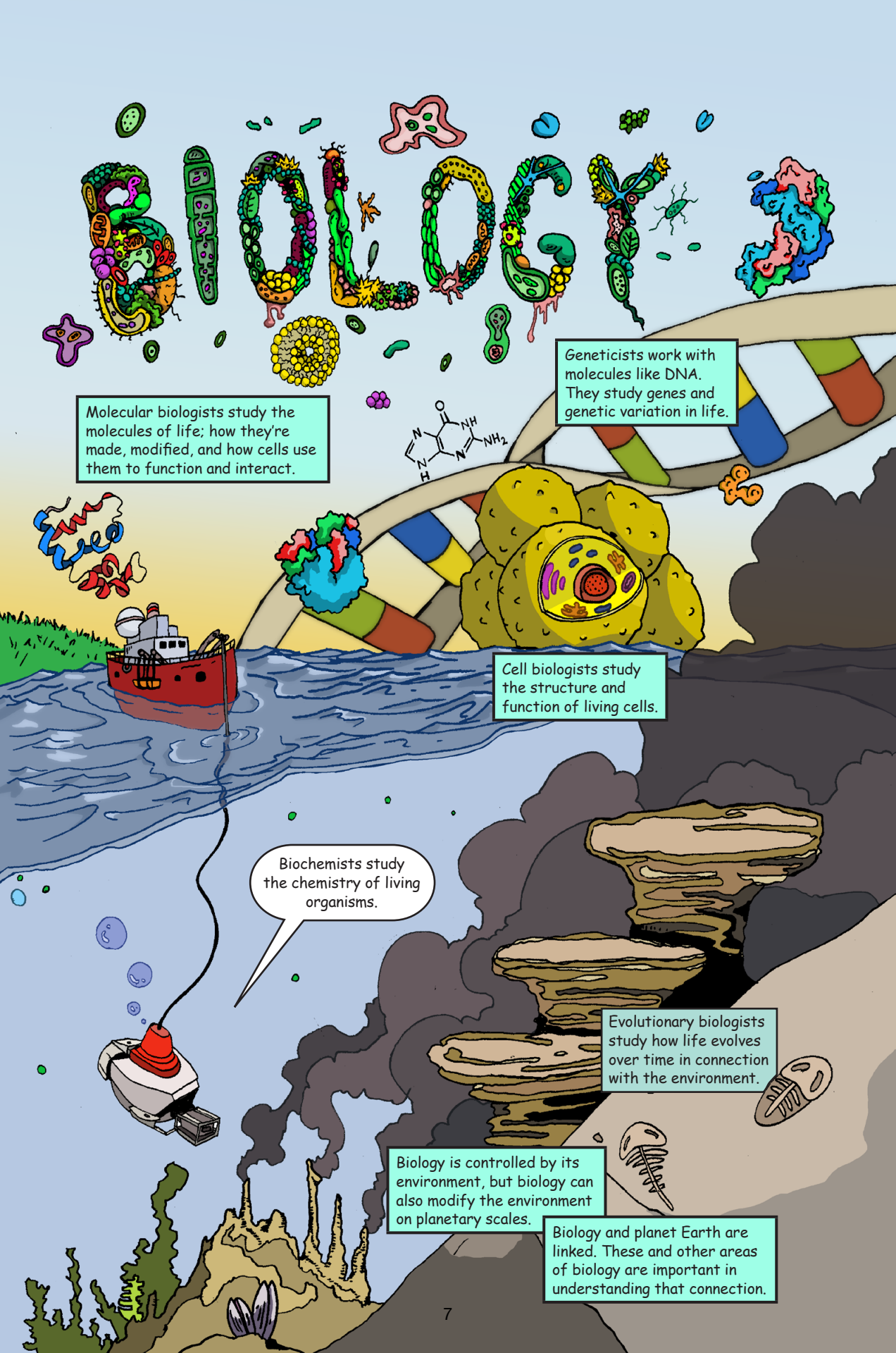
Astrobiology has been a part of NASA since the agency's beginning*.
* See Issue 1
Astrobiologists study life on Earth and the potential for life in the Universe.
Bacteria
Archaea
Eukarya
The research reaches through the Solar System to potentially habitable places like Mars and Enceladus, then beyond 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?

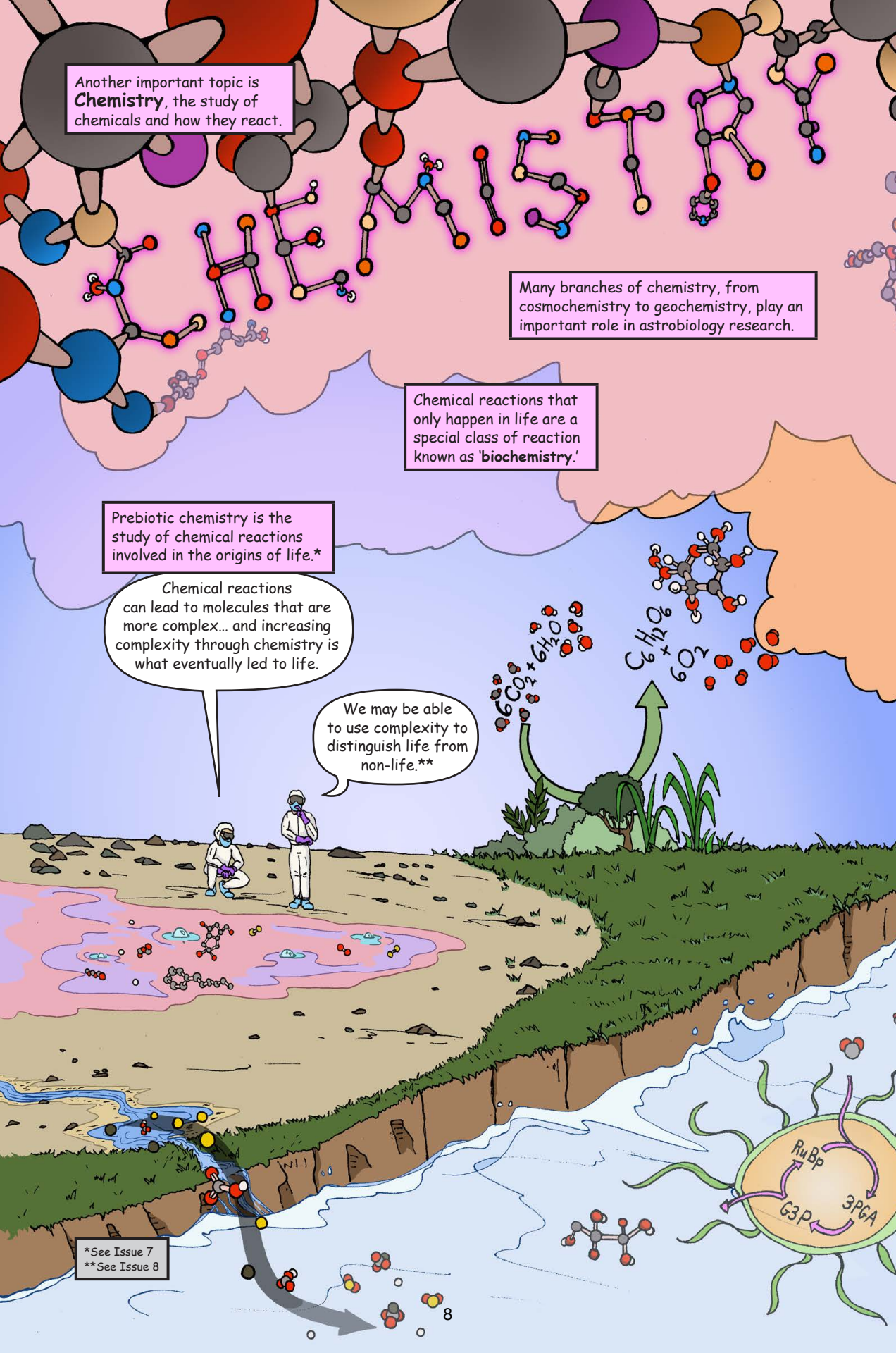

The first part of being an astrobiologist is to be curious about the world around you.
Where did life originate on Earth?
And when?
Everett Shock (Arizona State University)
Why do we find life almost everywhere on our planet?
Roger Summons, Massachusetts Institute of Technology (MIT)
Lindsay Hays (NASA HQ)
Rebecca McCauley Rench (NASA HQ)
What makes an environment habitable?
Mike Toillion (NASA HQ)
Why is water so important?
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
1 QUESTION
2 Background Research
3 Hypothesis
4 Experiment
5 Analyze Data
6 Conclusion

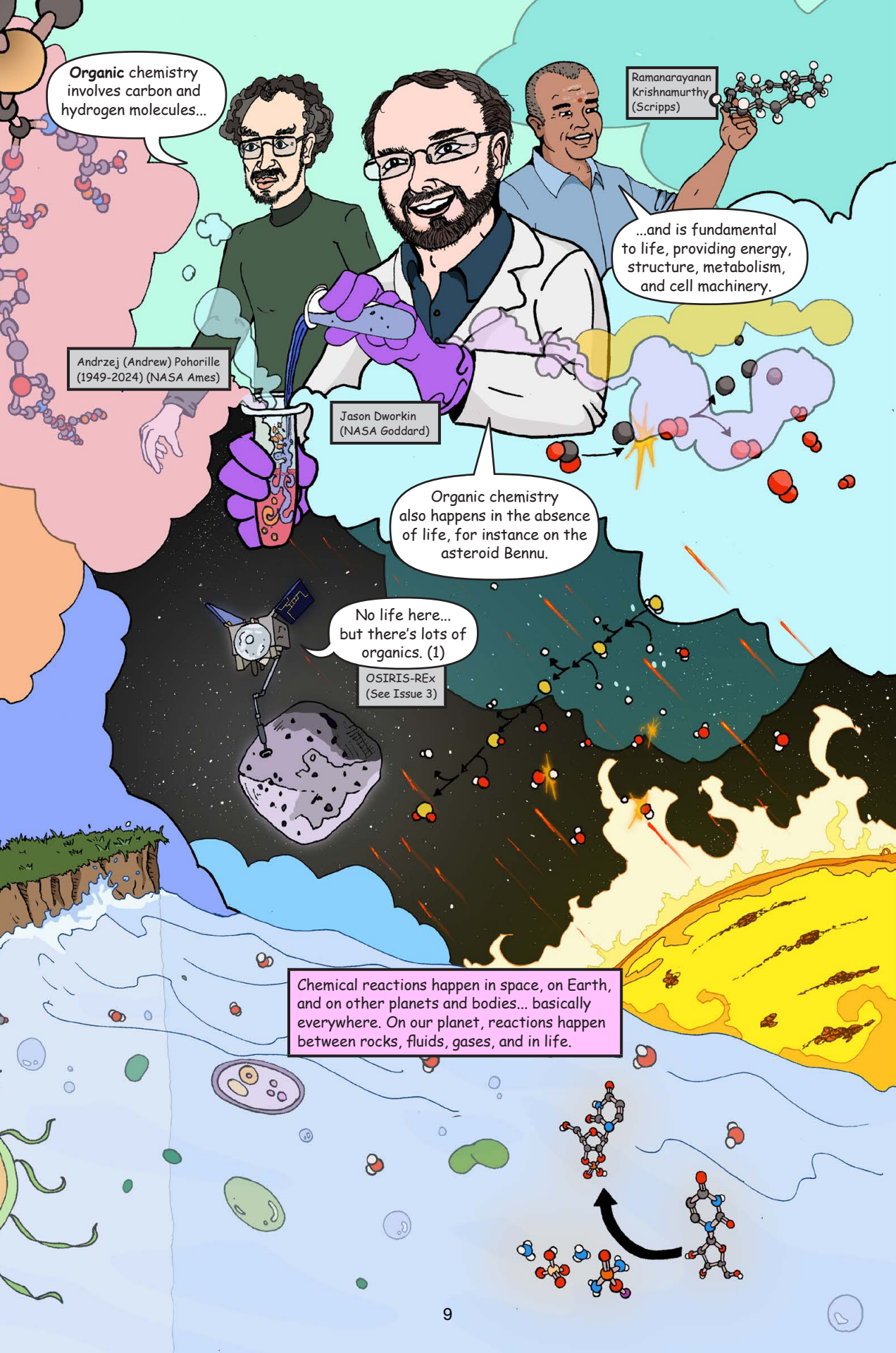

First, there's the **question**.
1. Question
Is there life in this dry, dead looking place?
Aaron Gronstal (NASA Ames)
Astrobiologists **have** found life in similar, **extremely** dry places.
2. Background Research
Based on previous studies, I think microbes could live under the ground.
3. Hypothesis
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.
In the first sample... nothing.
But deeper underground 85% of the samples have microbes!
5. Analyze Data
My **conclusion**, the hypothesis is correct. There is life here!
Onto the next **Question**.
6. Conclusions

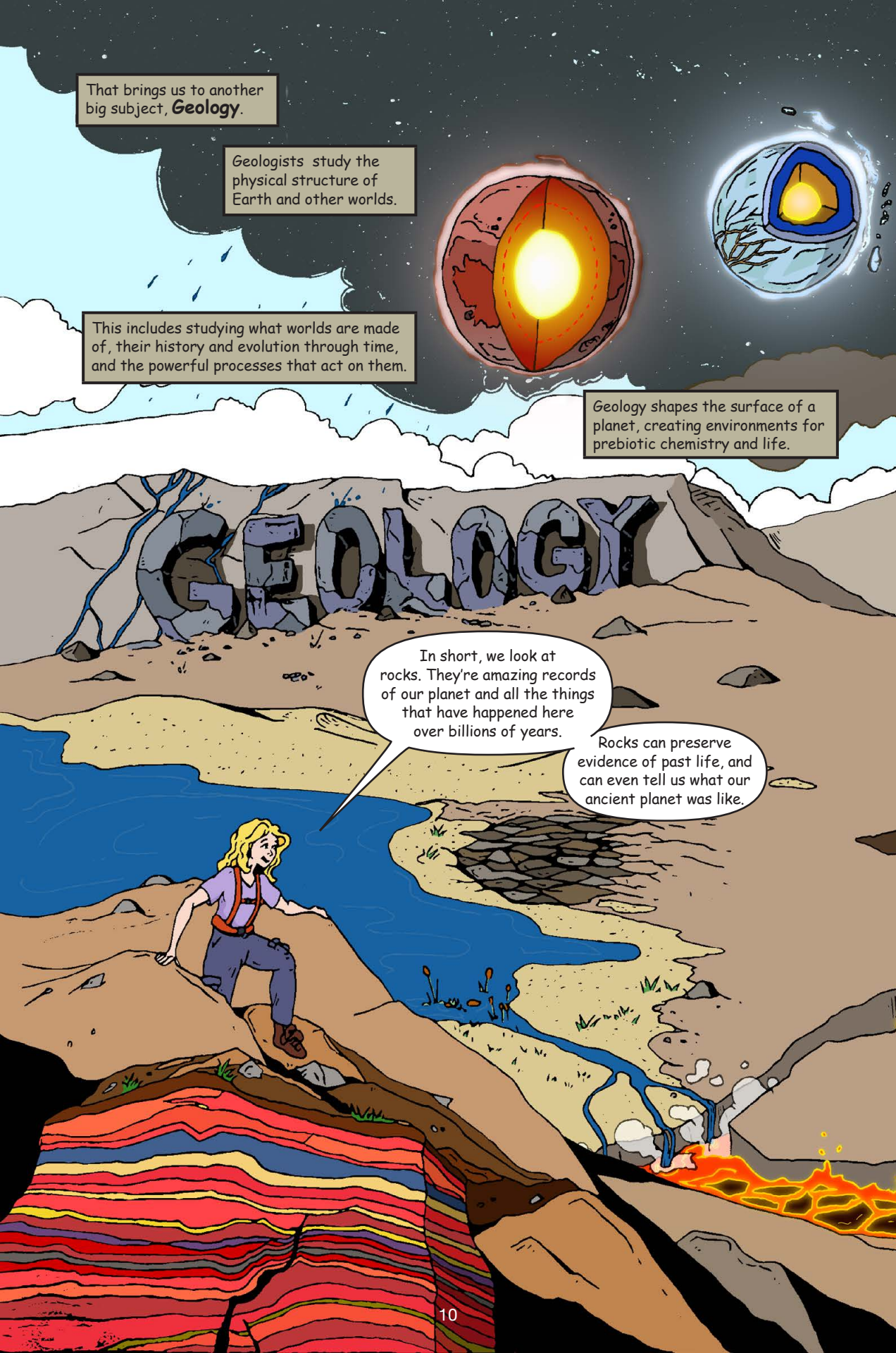

The results have raised more questions.
1 QUESTION ?
Why don't they live near the surface?
Experiment
What types of microbes are they?
Back to the Scientific Process!!
Where do they get water from?
Anthony Chan (NASA Ames)
What do they eat?
Daniella Scalice (NASA Ames)
Could similar organisms have evolved on worlds like Mars?
Melissa Kirven-Brooks (NASA Ames)
I have questions about space...
And how life evolved...
And life on other planets.
So how do we become **astrobiologists**?

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)

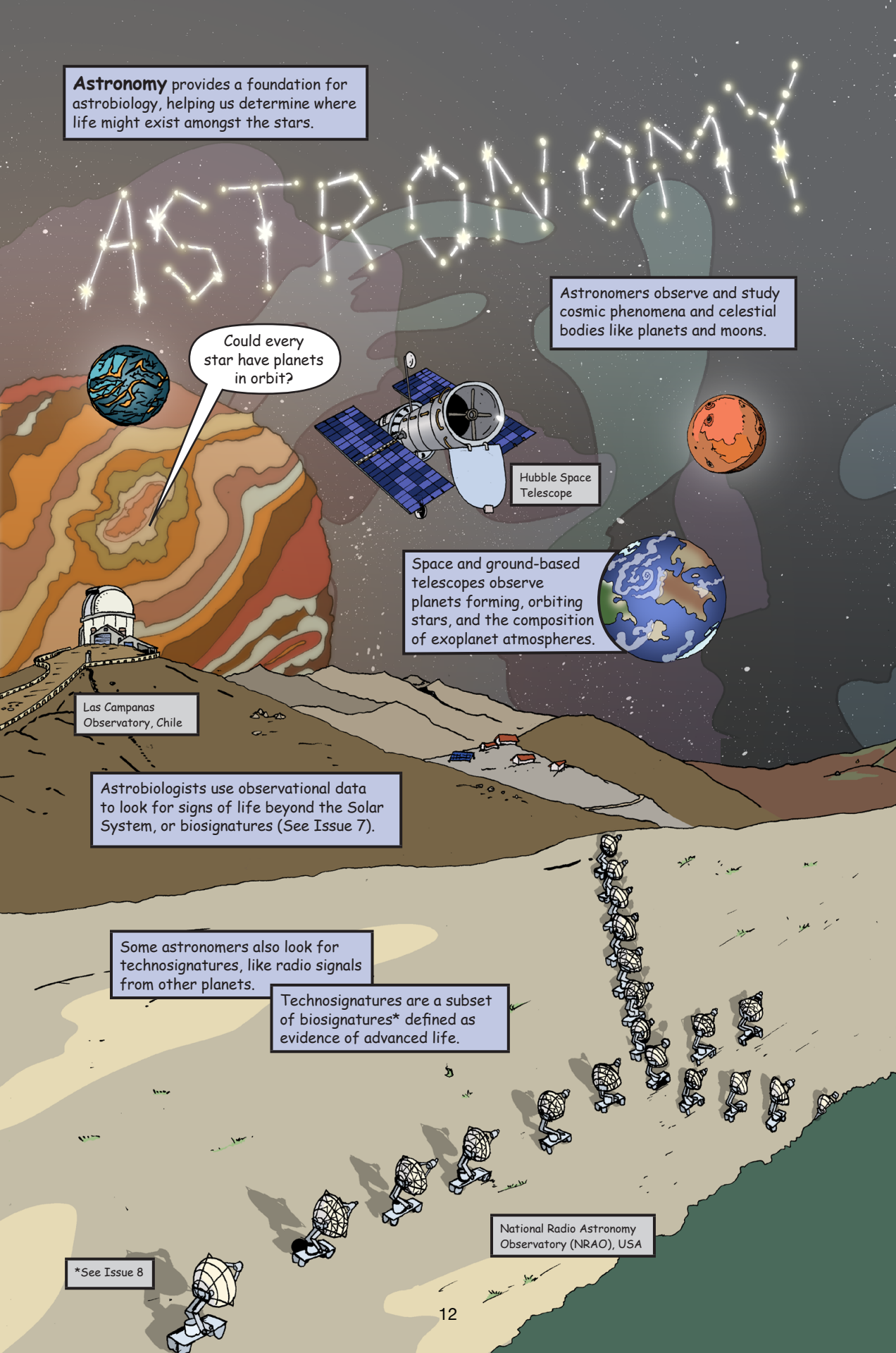

BIOLOGY
Molecular biologists study the molecules of life; how they're made, modified, and how cells use them to function and interact.
Geneticists work with molecules like DNA. They study genes and genetic variation in life.
Cell biologists study the structure and function of living cells.
Biochemists 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.

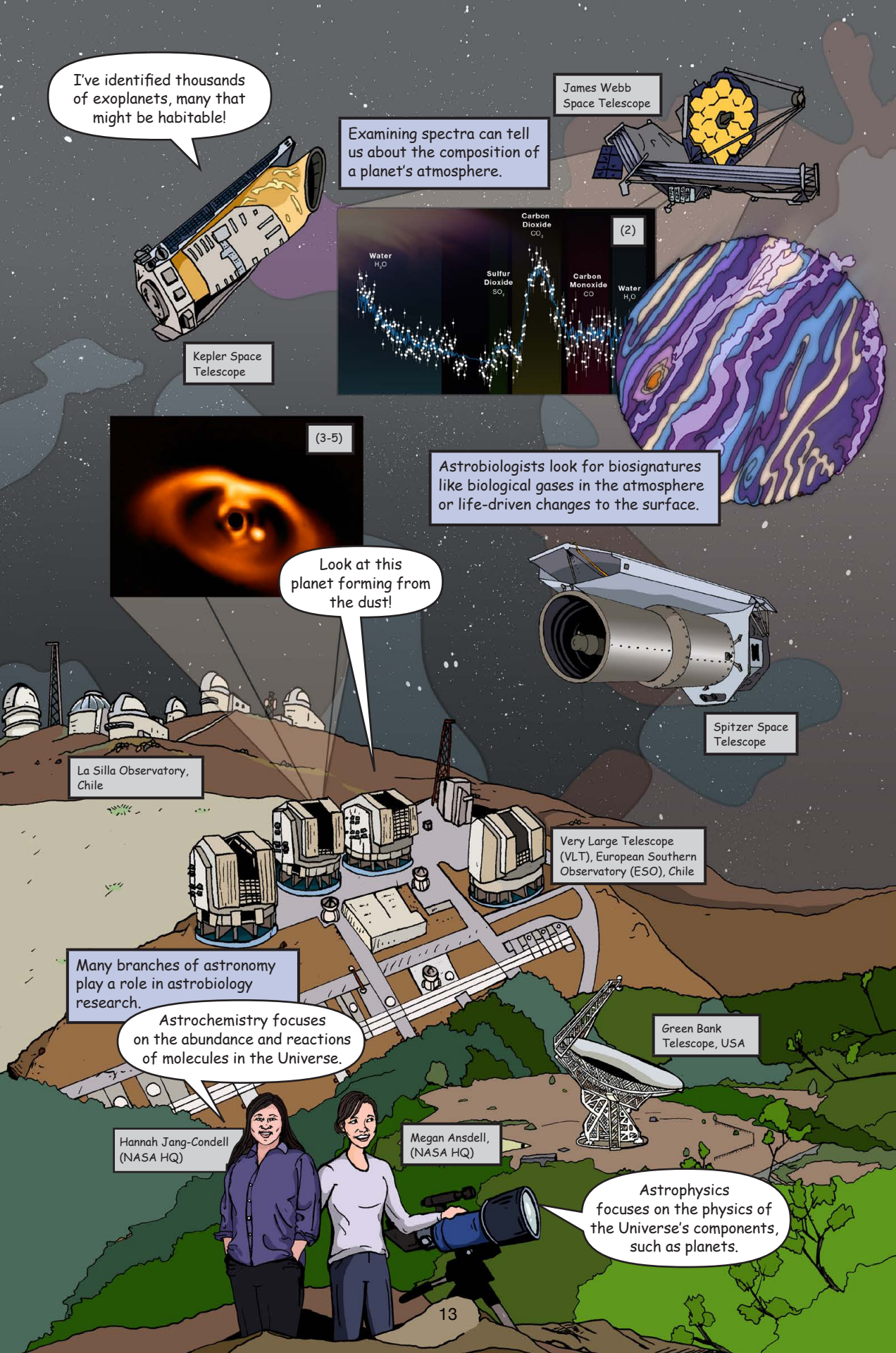

CHEMISTRY
Another important topic is **Chemistry**, the study of chemicals and how they react.
Many branches of chemistry, from cosmochemistry to geochemistry, play an important role in astrobiology research.
Chemical reactions that only happen in life are a special class of reaction known as '**biochemistry**.'
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.**
$6CO_2 + 6H_2O$
$C_6H_{12}O_6 + 6O_2$
RuBp
3PGA
G3P
*See Issue 7
**See Issue 8


Organic chemistry involves carbon and hydrogen molecules...
Andrzej (Andrew) Pohorille (1949-2024) (NASA Ames)
Jason Dworkin (NASA Goddard)
Ramanarayanan Krishnamurthy (Scripps)
...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.

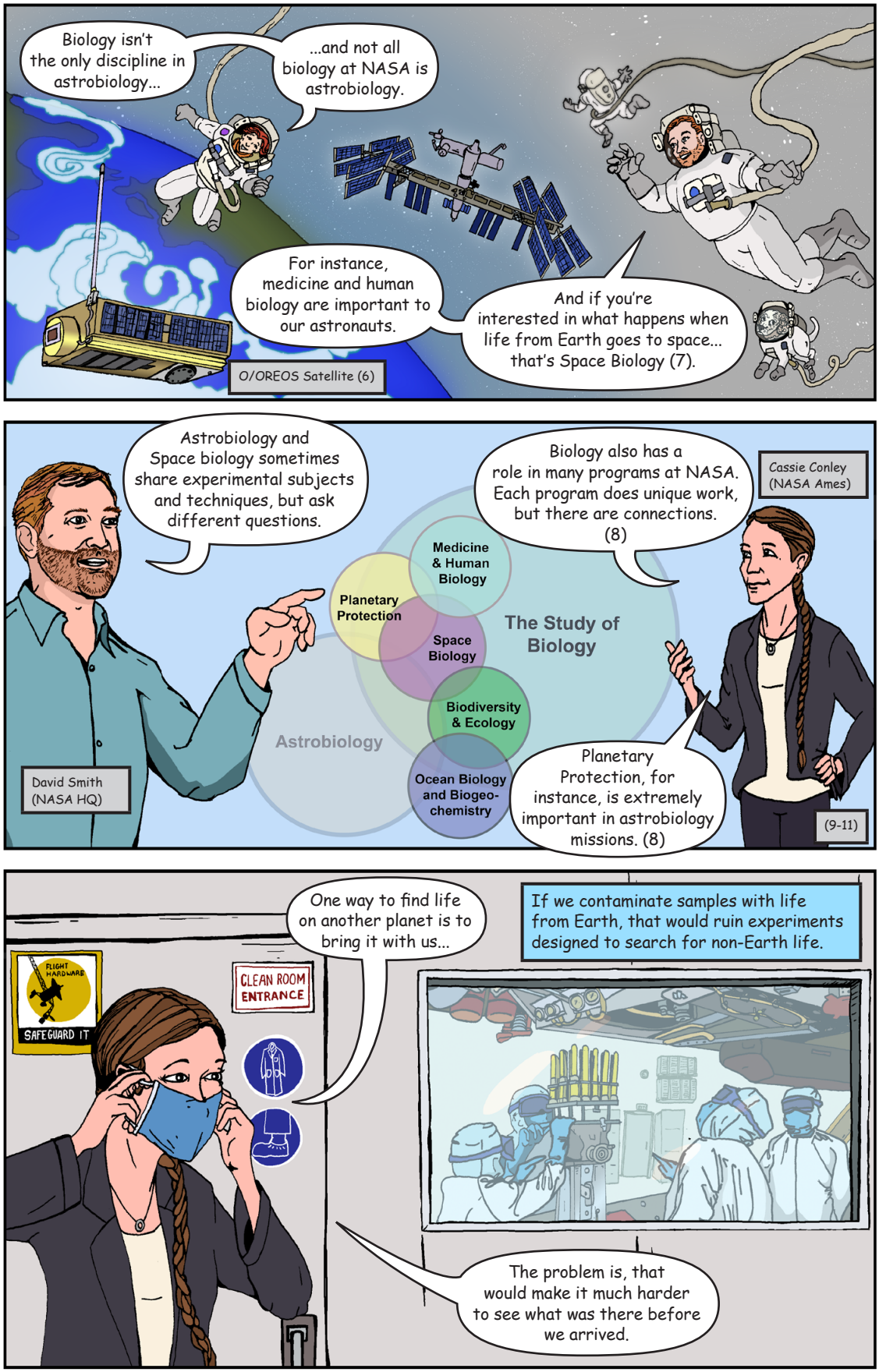

That brings us to another big subject, **Geology**.
Geologists study the physical structure of Earth and other worlds.
This includes studying what worlds are made of, their history and evolution through time, and the powerful processes that act on them.
Geology shapes the surface of a planet, creating 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.

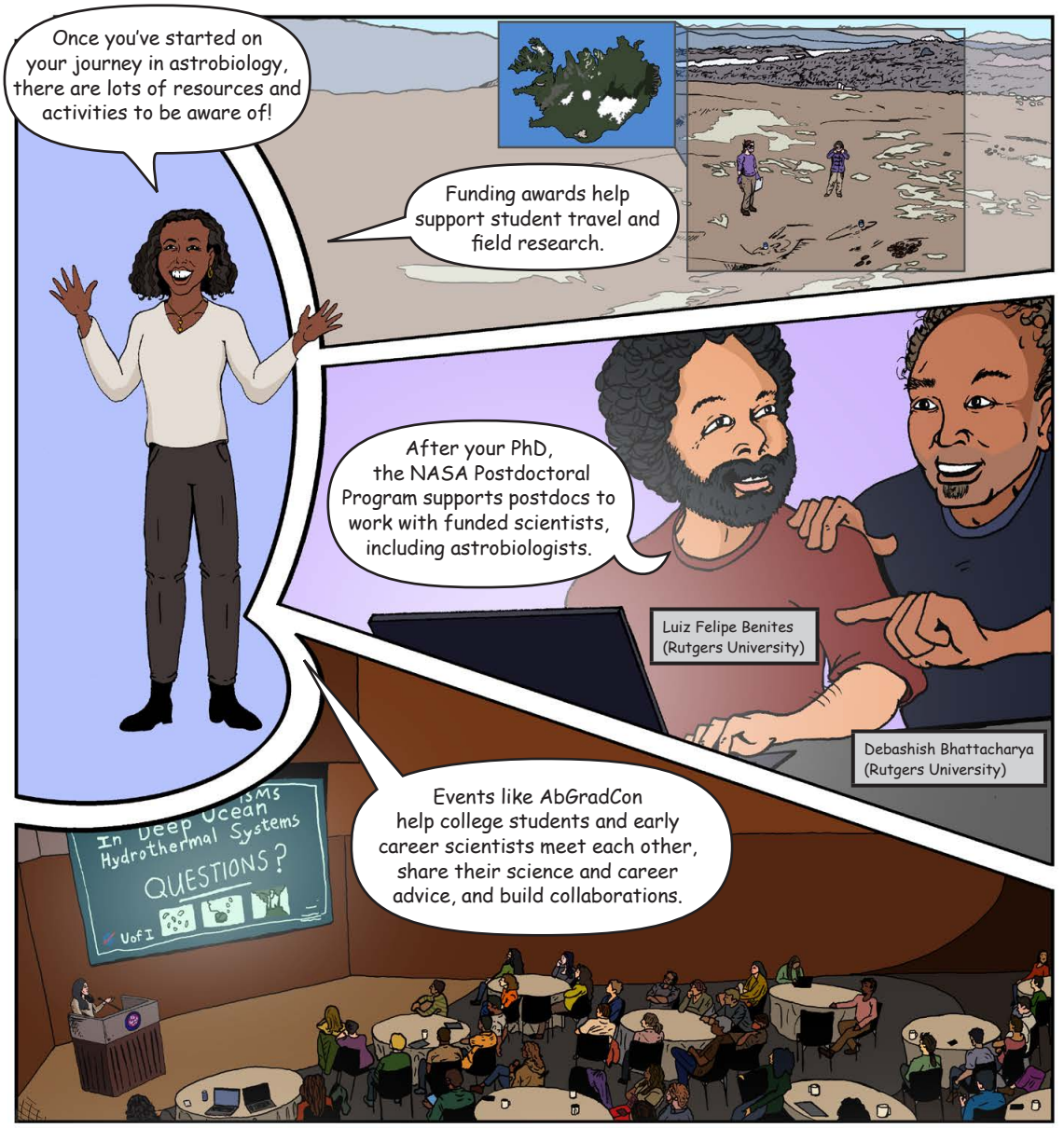
Understanding how a planet works, and all the crazy things that happen as a planet forms and evolves, is necessary for us to determine whether or not a planet is habitable.
Mars Science Laboratory (MSL)*
Space missions help us study the geology of other planets, like Mars.
InSight Lander*
And if life 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

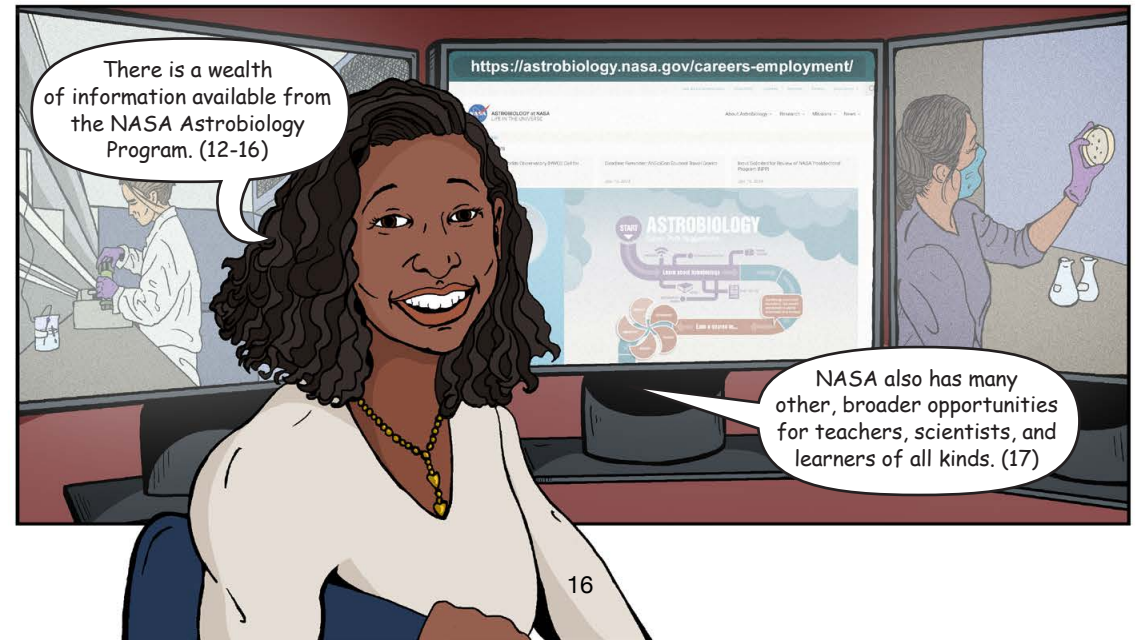

Astronomy provides a foundation for astrobiology, helping us determine where life might exist amongst the stars.
ASTRONOMY
Astronomers observe and study cosmic phenomena and celestial bodies like planets and moons.
Could every star have planets in orbit?
Hubble Space Telescope
Space and ground-based telescopes observe planets forming, orbiting stars, and the composition of exoplanet atmospheres.
Las Campanas 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

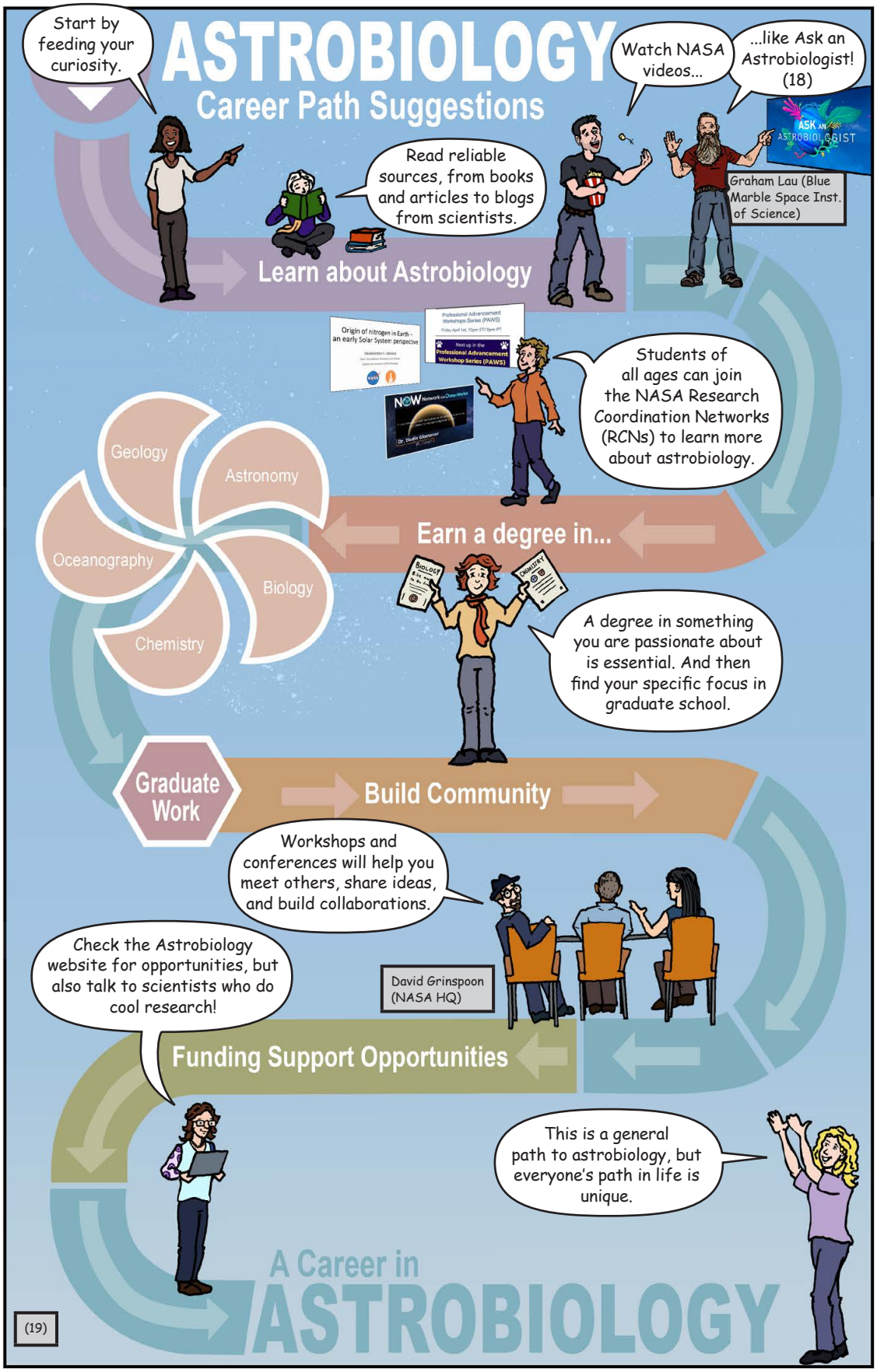

I've identified thousands of exoplanets, many that might be habitable!
Kepler Space Telescope
Examining spectra can tell us about the composition of a planet's atmosphere.
James Webb Space Telescope
(2)
Water H_2O
Sulfur Dioxide SO_2
Carbon Dioxide CO_2
Carbon Monoxide CO
Water H_2O
(3-5)
Astrobiologists 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.

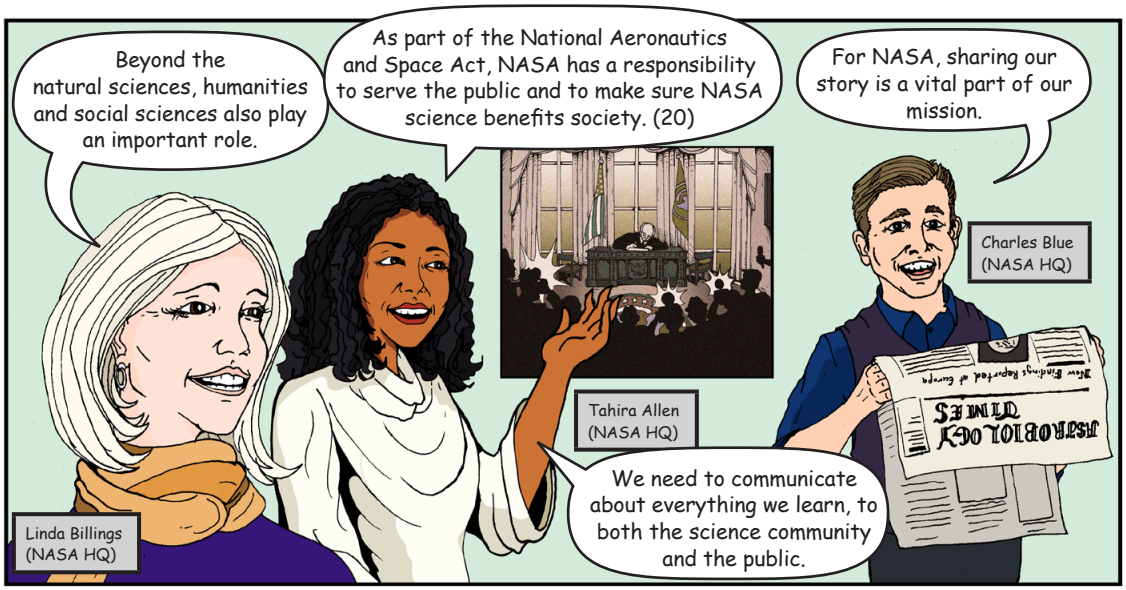
Those are four big disciplines, but to complete the story of life's potential, there are so many more.
Are you saying everyone is an astrobiologist?
BIOLOGY
GEO-CHEMISTRY
Heliophysics
Earth and Atmospheric Sciences
Physics
BOINK!
Mathematics and Statistics
Engineering and Technology
Polar Science
Computer Science
(6)
Planetary Science
Many people study two or more of these disciplines over their career.
Oceanography
I guess everyone can be an astrobiologist!
Geoff Wheat (NASA HQ)


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).
O/OREOS Satellite (6)
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)
Cassie Conley (NASA Ames)
Medicine & Human Biology
Planetary Protection
Space Biology
The Study of Biology
Biodiversity & Ecology
Astrobiology
Ocean Biology and Biogeo-chemistry
David Smith (NASA HQ)
Planetary Protection, for instance, is extremely important in astrobiology missions. (8)
(9-11)
One way to find life on another planet is to bring it with us...
If we contaminate samples with life from Earth, that would ruin experiments designed to search for non-Earth life.
FLIGHT HARDWARE
SAFEGUARD IT
CLEAN ROOM ENTRANCE
The problem is, that would make it much harder to see what was there before we arrived.


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.
In Deep Ocean Hydrothermal Systems
QUESTIONS?
U of I

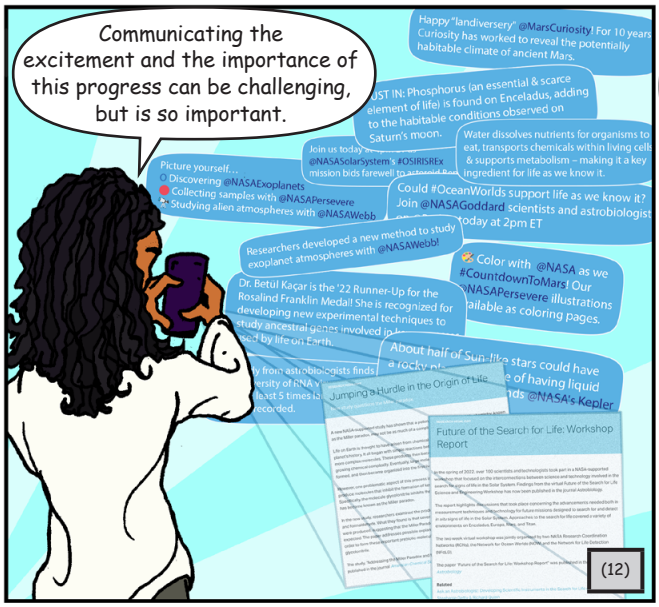

There is a wealth of information available from the NASA Astrobiology Program. (12-16)
https://astrobiology.nasa.gov/careers-employment/
ASTROBIOLOGY
NASA also has many other, broader opportunities for teachers, scientists, and learners of all kinds. (17)


ASTROBIOLOGY
Career Path Suggestions
Start by feeding your curiosity.
Watch NASA videos...
...like Ask an Astrobiologist! (18)
ASK AN ASTROBIOLOGIST
Graham Lau (Blue Marble Space Inst. of Science)
Read reliable sources, from books and articles to blogs from scientists.
Learn about Astrobiology
Origin of nitrogen in Earth – an early Solar System perspective
Professional Advancement Workshops Series (PAWS)
Next up in the Professional Advancement Workshop Series (PAWS)
NOW Network on Ocean Worlds
Dr. Sheila Ghazarian
Students of all ages can join the NASA Research Coordination Networks (RCNs) to learn more about astrobiology.
Geology
Astronomy
Oceanography
Biology
Chemistry
Earn a degree in...
BIOLOGY
CHEMISTRY
A degree in something you are passionate about is essential. And then find your specific focus in graduate school.
Graduate Work
Build Community
Workshops and conferences will help you meet others, share ideas, and build collaborations.
David Grinspoon (NASA HQ)
Check the Astrobiology website for opportunities, but also talk to scientists who do cool research!
Funding Support Opportunities
This is a general path to astrobiology, but everyone's path in life is unique.
A Career in
ASTROBIOLOGY
(19)

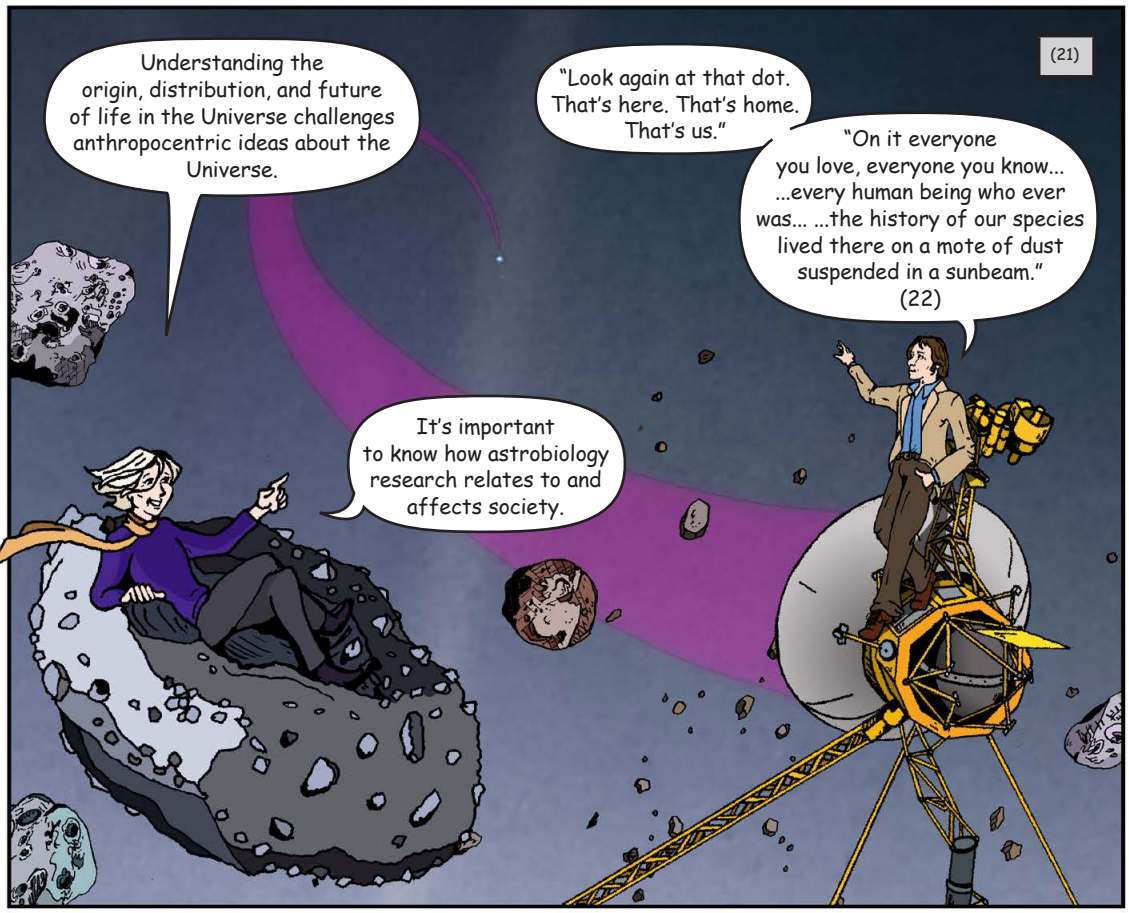

Beyond the natural sciences, humanities and social sciences also play an important role.
As part of the National Aeronautics and Space Act, NASA has a responsibility to serve the public and to make sure NASA science benefits society. (20)
For NASA, sharing our story is a vital part of our mission.
Charles Blue (NASA HQ)
Tahira Allen (NASA HQ)
We need to communicate about everything we learn, to both the science community and the public.
Linda Billings (NASA HQ)

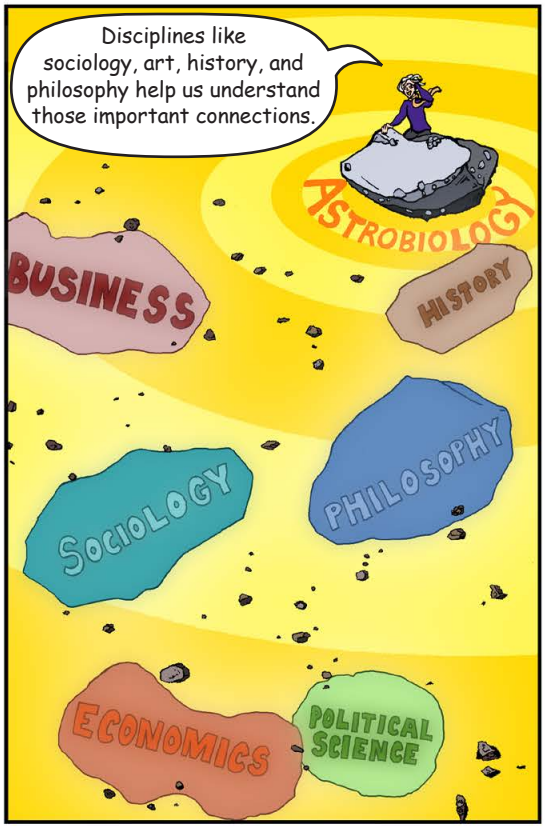
We study how to accurately and effectively communicate major findings...
...for instance, the discovery of life in the Universe.
HISTORY OFFICE
WORLD EVENTS
DECORATION
HISTORY OF SPACE
STATISTICS
POLITICAL SCIENCE
HISTORY OF LOGIC
HISTORY OF SCIENCE
PHILOSOPHY
WORLD HISTORY
ECONOMICS
HISTORY ASTROBIOLOGY
ANTHROPOLOGY

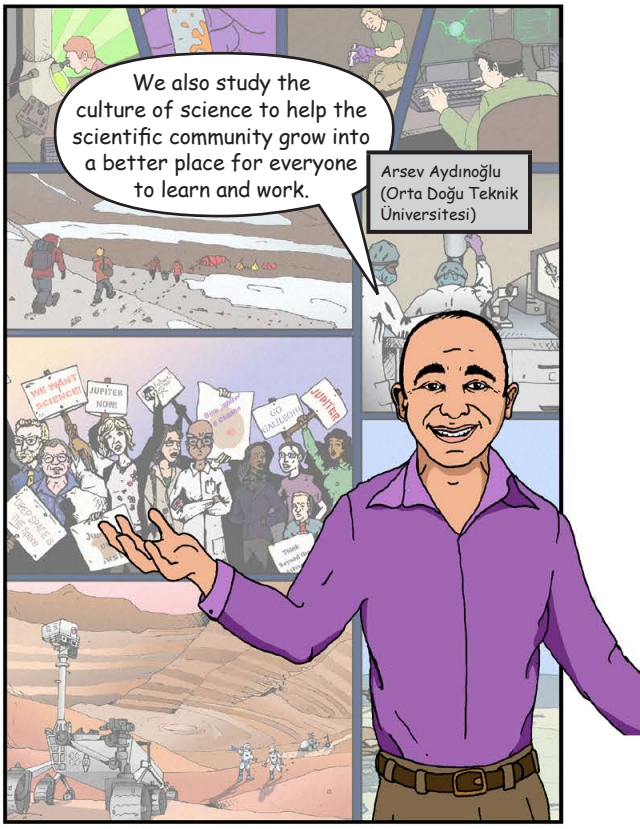
Science, and astrobiology in particular, is a journey of discovery.
Rarely is there an instantaneous leap, it's more like small steps toward a goal.
See Issue 8

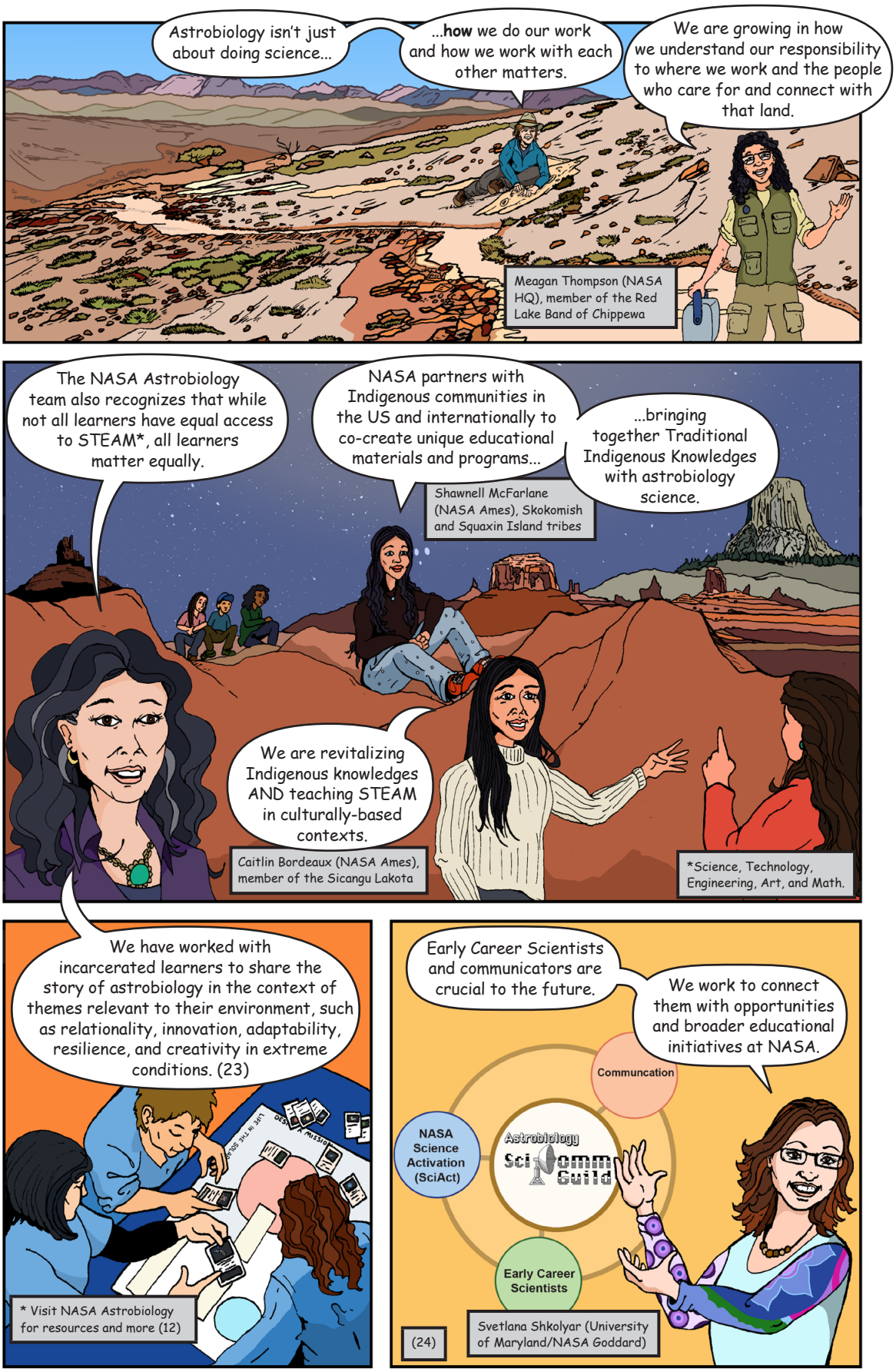

Communicating the excitement and the importance of this progress can be challenging, but is so important.
Happy "landiversery" @MarsCuriosity! For 10 years Curiosity has worked to reveal the potentially habitable climate of ancient Mars.
JUST IN: Phosphorus (an essential & scarce element of life) is found on Enceladus, adding to the habitable conditions observed on Saturn's moon.
Water dissolves nutrients for organisms to eat, transports chemicals within living cells & supports metabolism – making it a key ingredient for life as we know it.
Picture yourself...
Discovering @NASAExoplanets
Collecting samples with @NASAPersevere
Studying alien atmospheres with @NASAWebb
Could #OceanWorlds support life as we know it? Join @NASAGoddard scientists and astrobiologists today at 2pm ET
Researchers developed a new method to study exoplanet atmospheres with @NASAWebb!
Color with @NASA as we #CountdownToMars! Our @NASAPersevere illustrations available as coloring pages.
Dr. Betül Kaçar is the '22 Runner-Up for the Rosalind Franklin Medal! She is recognized for developing new experimental techniques to study ancestral genes involved in
About half of Sun-like stars could have a rocky
of having liquid
Jumping a Hurdle in the Origin of Life
Future of the Search for Life: Workshop Report
(12)

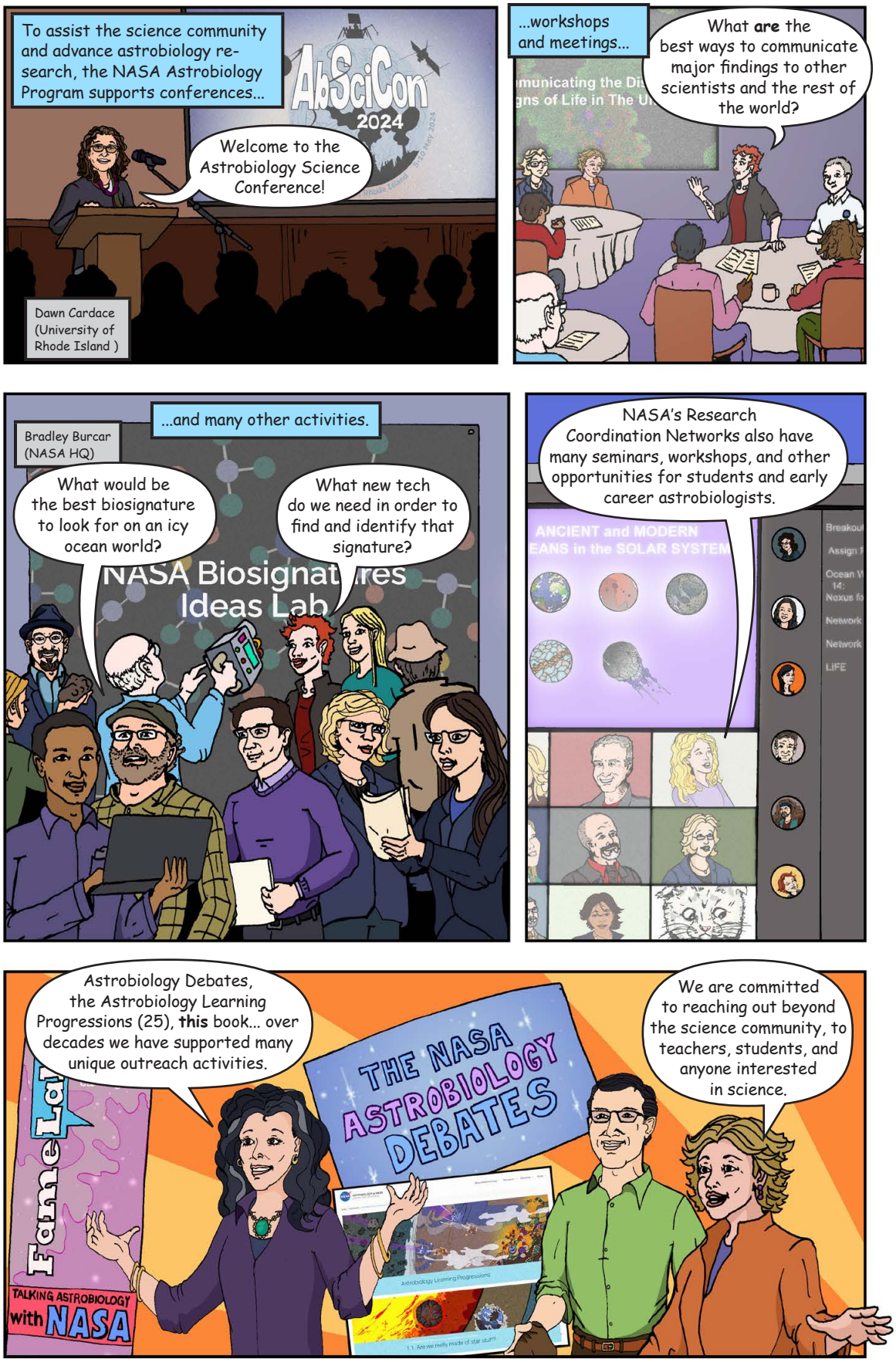
And, of course, NASA also needs people who can visualize science by creating infographics and illustrations to help tell the story!
ASTROBIOLOGY
Career Path Suggestions
Jenny Mottar (NASA HQ)

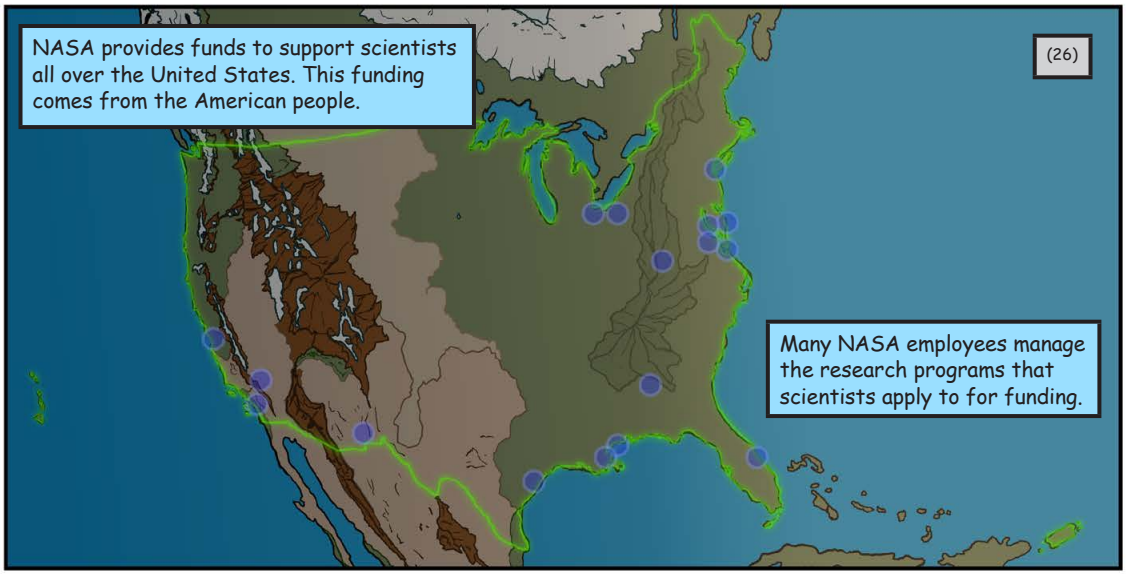

(21)
Understanding the origin, distribution, and future of life in the Universe challenges anthropocentric ideas about the Universe.
"Look again at that dot. That's here. That's home. That's us."
"On it everyone you love, everyone you know... ...every human being who ever was... ...the history of our 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.

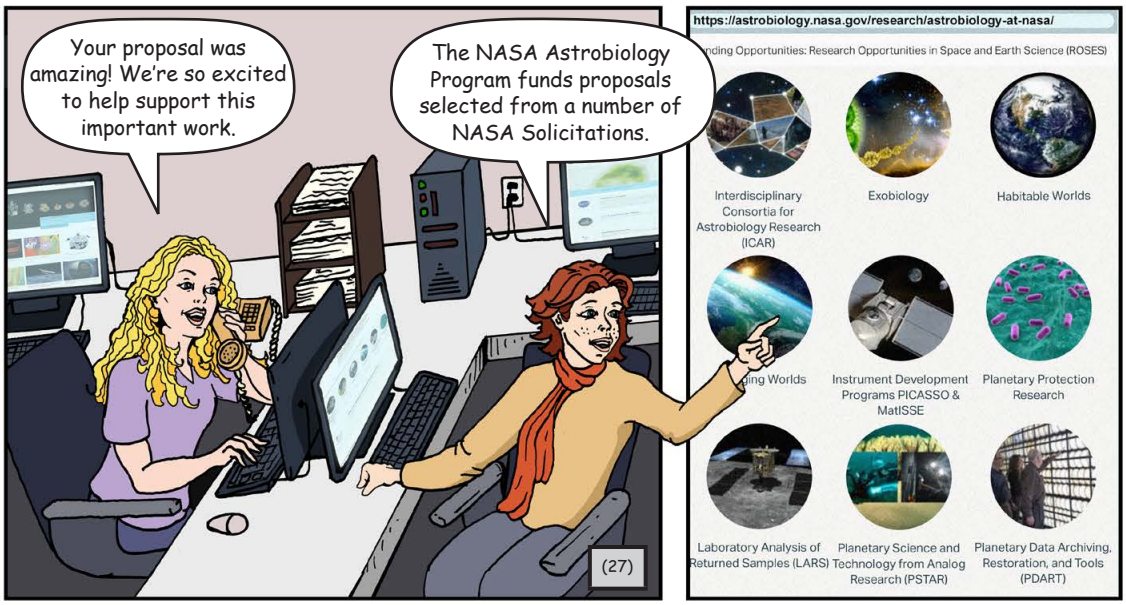

Disciplines like sociology, art, history, and philosophy help us understand those important connections.
ASTROBIOLOGY
BUSINESS
HISTORY
SOCIOLOGY
PHILOSOPHY
ECONOMICS
POLITICAL SCIENCE

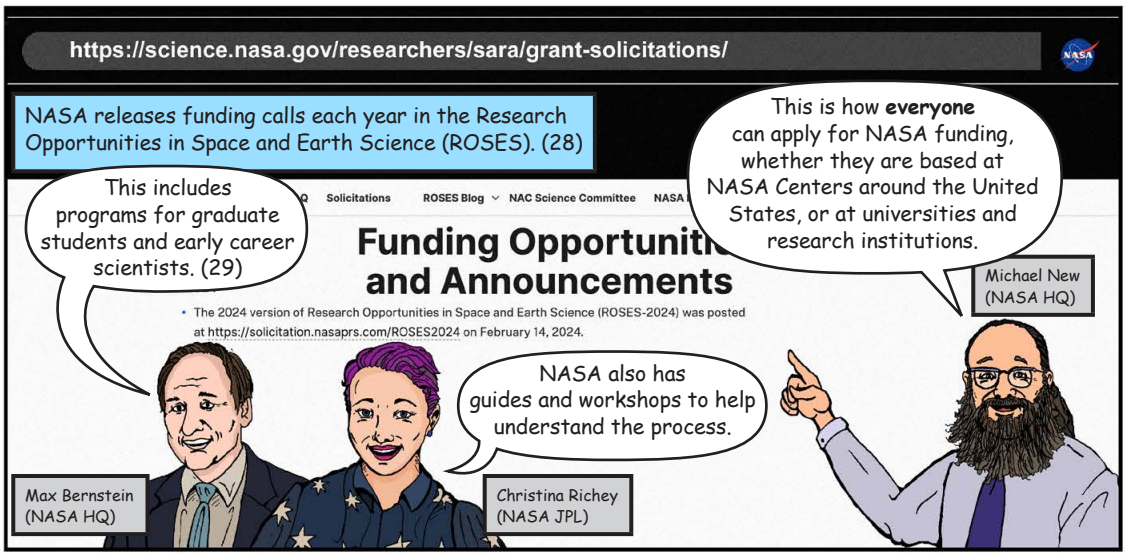

We also study the culture of science to help the scientific community grow into a better place for everyone to learn and work.
Arsev Aydınoğlu (Orta Doğu Teknik Üniversitesi)
WE WANT SCIENCE!
JUPITER NOW!
GO GALILEO!
JUPITER

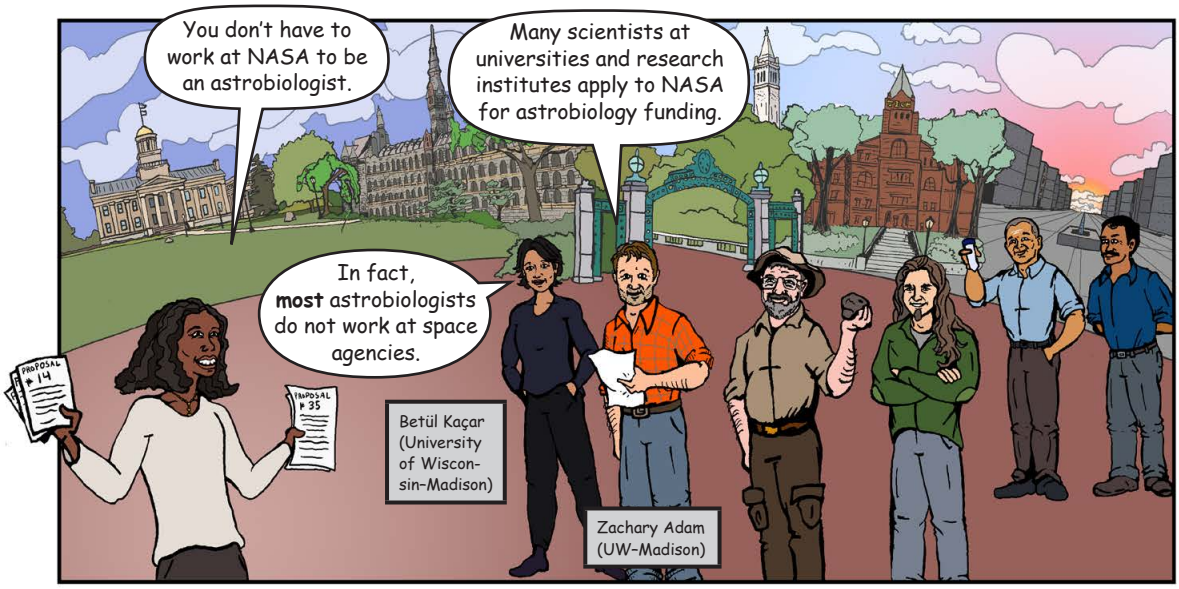

Astrobiology isn't just about doing science...
...how we do our work and how we work with each other matters.
We are growing in how we understand our responsibility to where we work and the people who care for and connect with that land.
Meagan Thompson (NASA HQ), member of the Red Lake Band of Chippewa
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.
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.
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)
* Visit NASA Astrobiology for resources and more (12)
Early Career Scientists and communicators are crucial to the future.
We work to connect them with opportunities and broader educational initiatives at NASA.
Communcation
NASA Science Activation (SciAct)
Astrobiology
SciComm Guild
Early Career Scientists
(24)
Svetlana Shkolyar (University of Maryland/NASA Goddard)

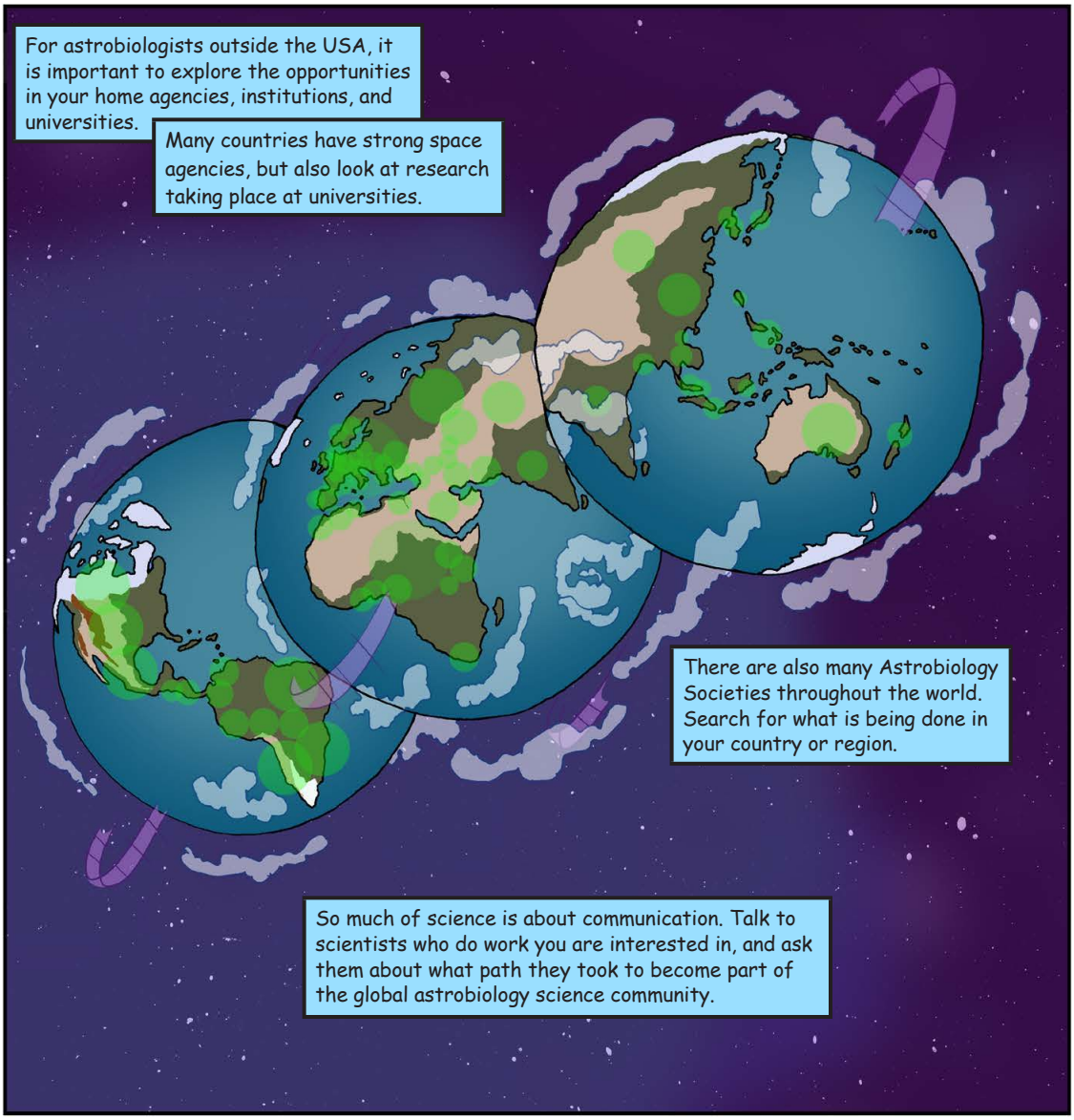

To assist the science community and advance astrobiology research, the NASA Astrobiology Program supports conferences...
AbSciCon 2024
Welcome to the Astrobiology Science Conference!
Dawn Cardace (University of Rhode Island)
...workshops and meetings...
What are the best ways to communicate major findings to other scientists and the rest of the world?
...and many other activities.
Bradley Burcar (NASA HQ)
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
Astrobiology Debates, the Astrobiology Learning Progressions (25), this book... over decades we have supported many unique outreach activities.
THE NASA ASTROBIOLOGY DEBATES
We are committed to reaching out beyond the science community, to teachers, students, and anyone interested in science.
Fame Lab
TALKING ASTROBIOLOGY with NASA


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/
nding Opportunities: Research Opportunities in Space and Earth Science (ROSES)
Interdisciplinary Consortia for Astrobiology Research (ICAR)
Exobiology
Habitable Worlds
ging Worlds
Instrument Development Programs PICASSO & MatISSE
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 includes programs for graduate students and early career scientists. (29)
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.
Solicitations
ROSES Blog
NAC Science Committee
Funding Opportuniti
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.
Michael New (NASA HQ)
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.
PROPOSAL # 14
PROPOSAL # 35
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

Further Resources and References cited in this issue:

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   https://sma.nasa.gov/sma-disciplines/planetary-protection
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   https://www.nasa.gov/reference/space-operations-mission-directorate/
10. NASA Biological Diversity and Ecological Conservation:
    https://cce.nasa.gov/biodiversity/
11. NASA Ocean Biology and Biogeochemistry:
    https://cce.nasa.gov/ocean_biology_biogeochemistry/index.html
12. NASA Astrobiology: https://astrobiology.nasa.gov/
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    astrobiology.nasa.gov/funding/ecexplorationfund/
14. NASA Astrobiology Postdoctoral Program: astrobiology.
    nasa.gov/nasa-astrobiology-postdoctoral-program/
15. NASA Astrobiology Early Career Collaboration Award:
    astrobiology.nasa.gov/education/ecc/

16. NASA Astrobiology Career Information:

astrobiology.nasa.gov/careers-employment/

17. Information on broader opportunities at NASA:

- NASA Learner Opportunities:

  science.nasa.gov/learn/learner-opportunities/

- NASA Postdoctoral Program:

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- NASA Learning Resources:

  science.nasa.gov/learn/resources

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