National Aeronautics and Space Administration

ASTROBIOLOGY

The Story of our Search for Life in the Universe

Issue #1

Produced in 2010 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 marks 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 only 50 years old, this field is 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

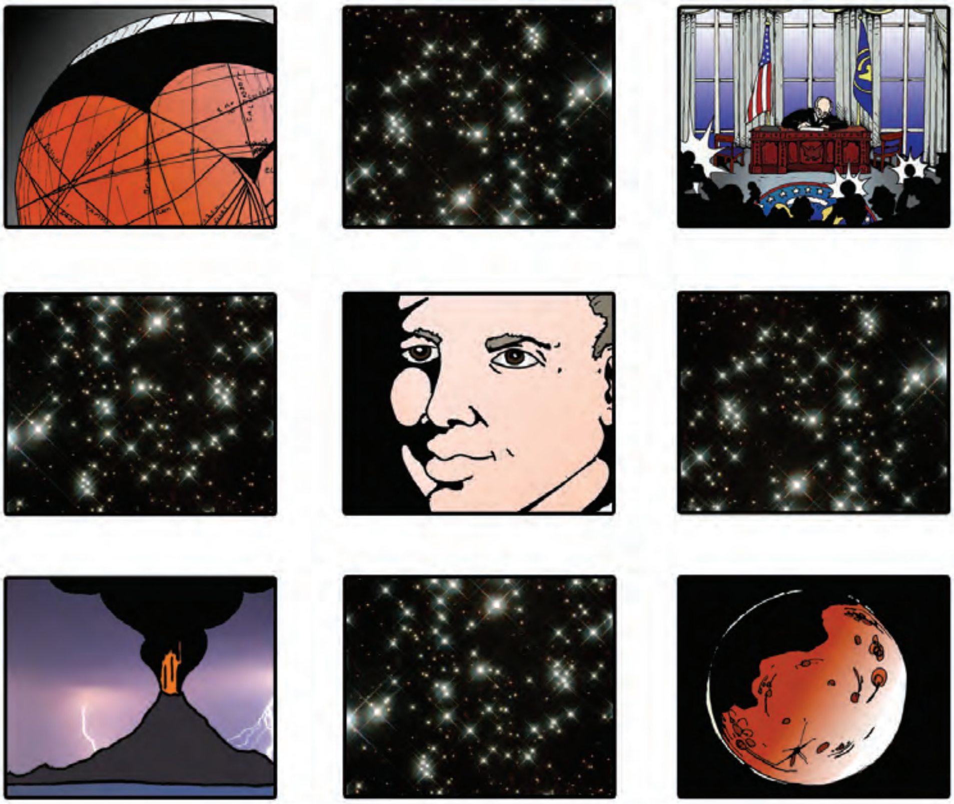
Editor

Linda Billings

Layout

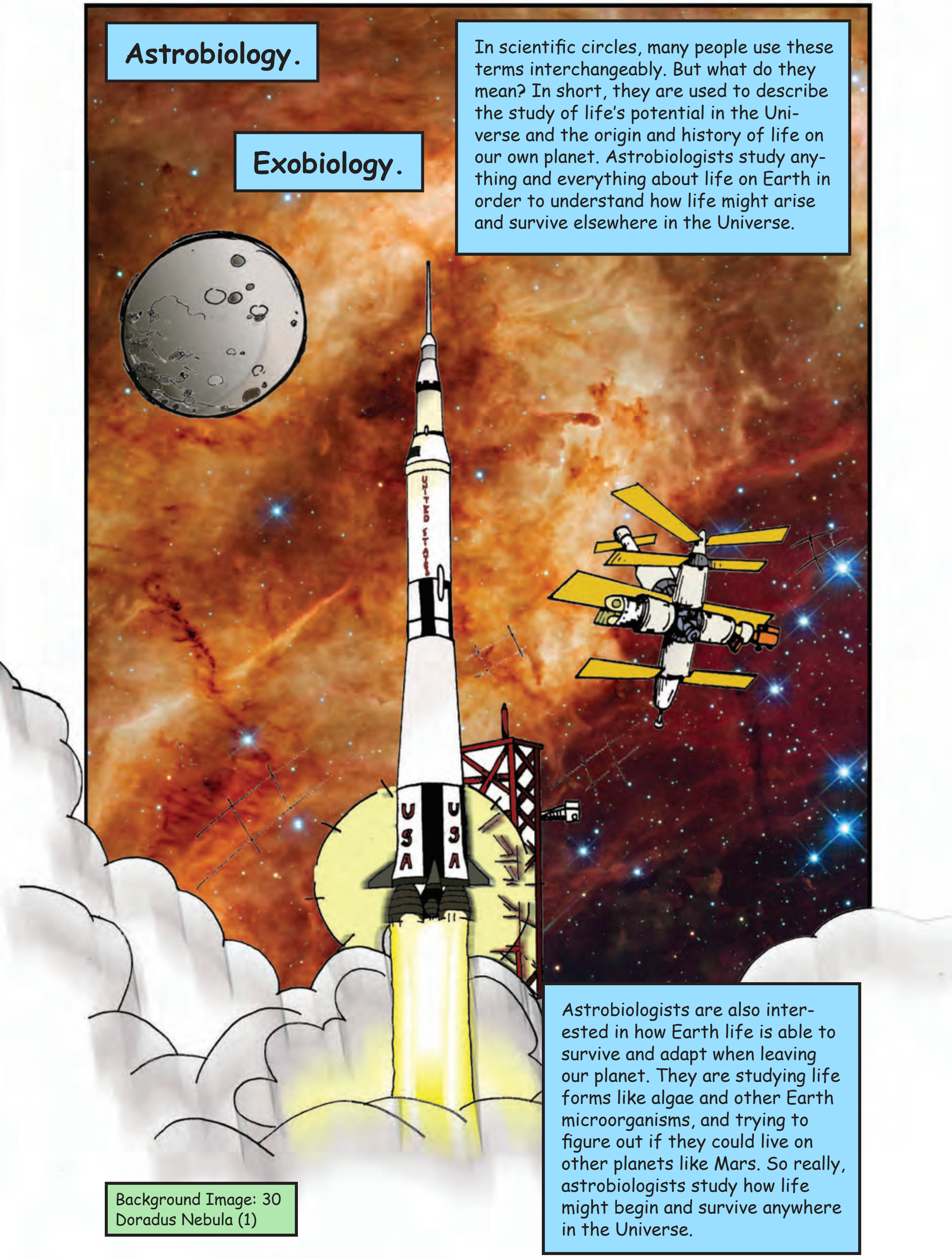
Jenny Mottar

Issue #1—The Origin of a Science

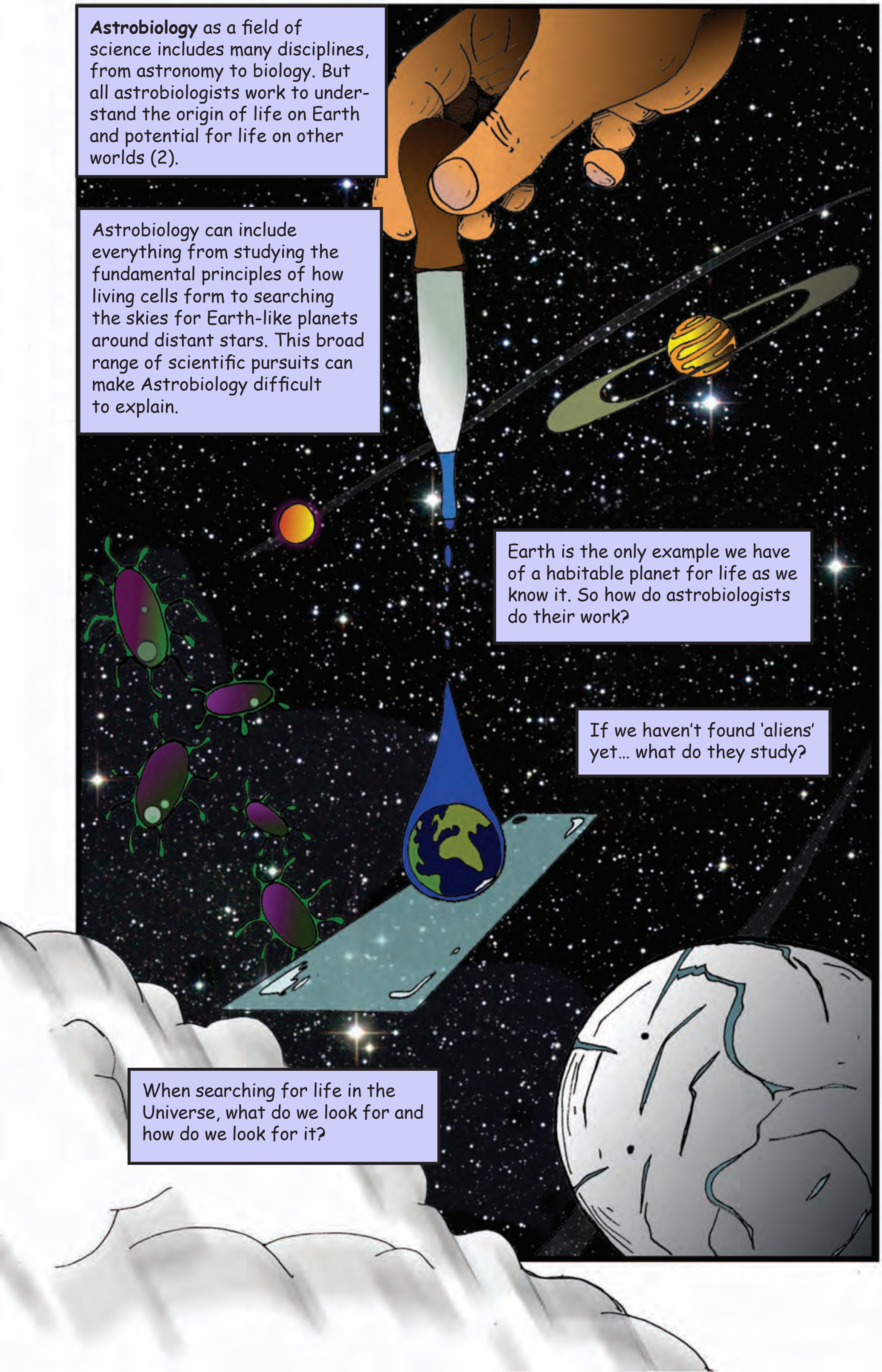


This year marks the 50th anniversary of NASA's Exobiology Program, established in 1960 and expanded into a broader Astrobiology Program in the 1990s. To commemorate the past half century of research, we are telling the story of how this field developed and how the search for life elsewhere became a key component of NASA's science strategy for exploring space. This issue is the first 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.

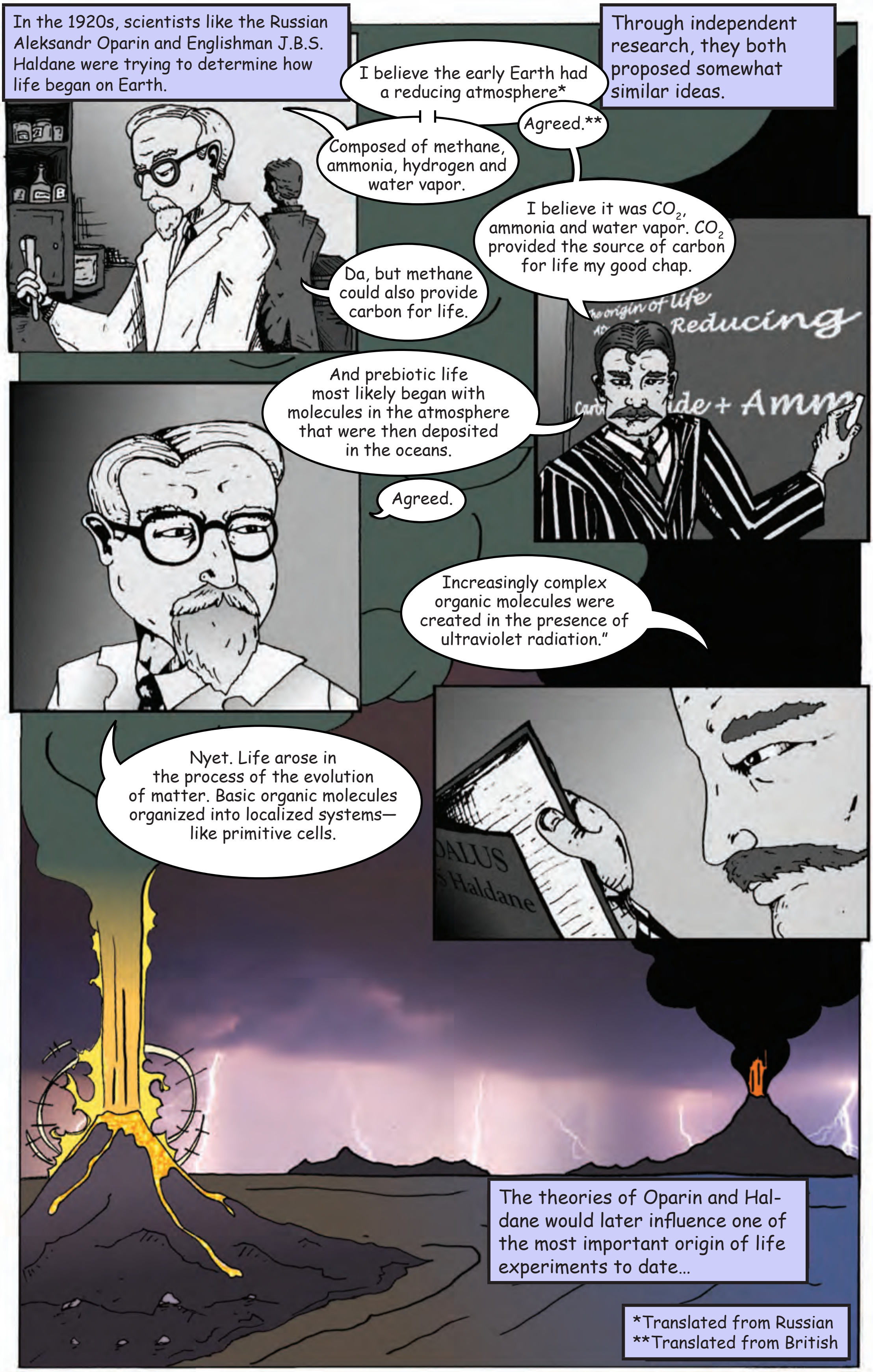
-Linda Billings, Editor

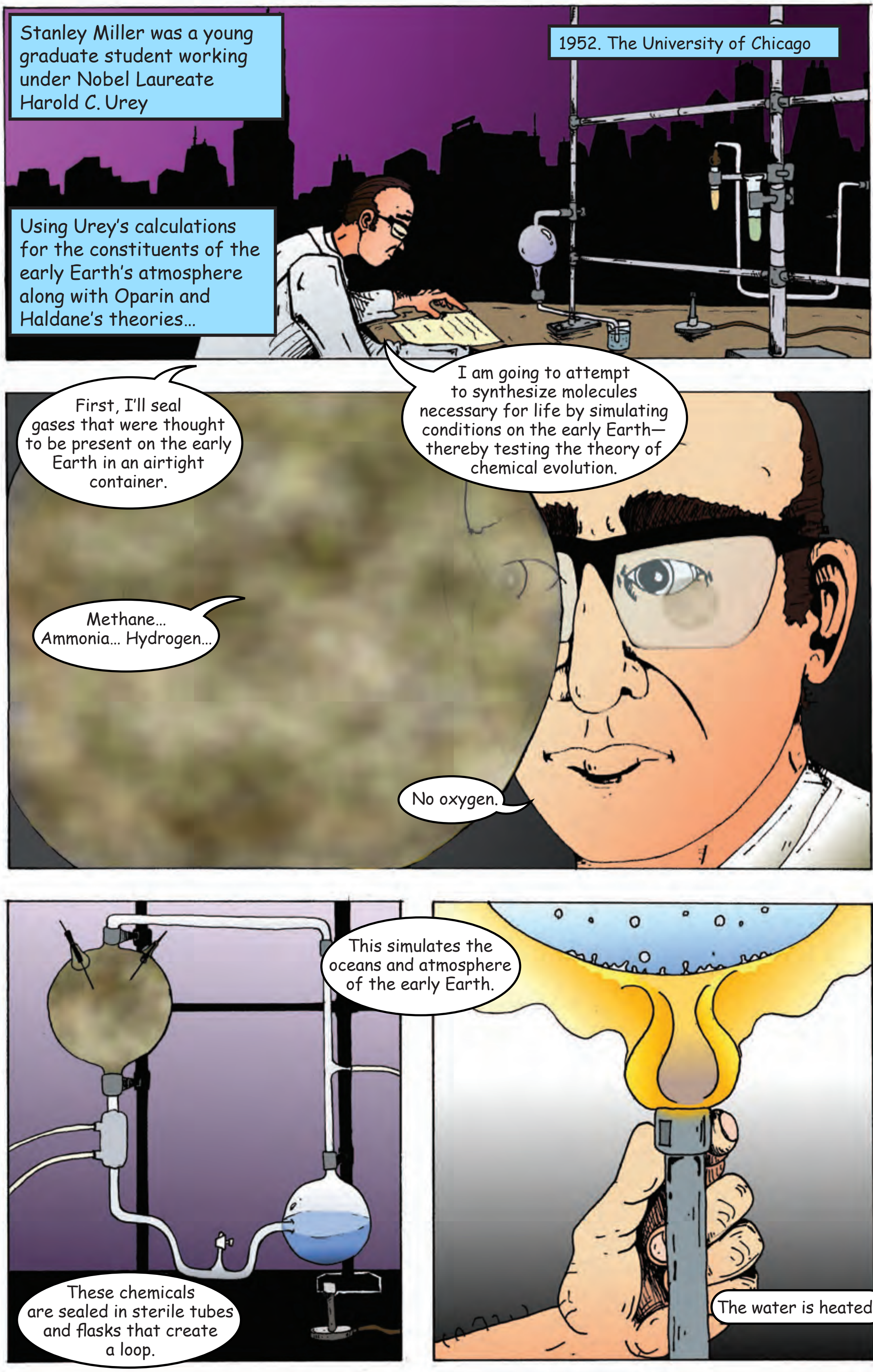


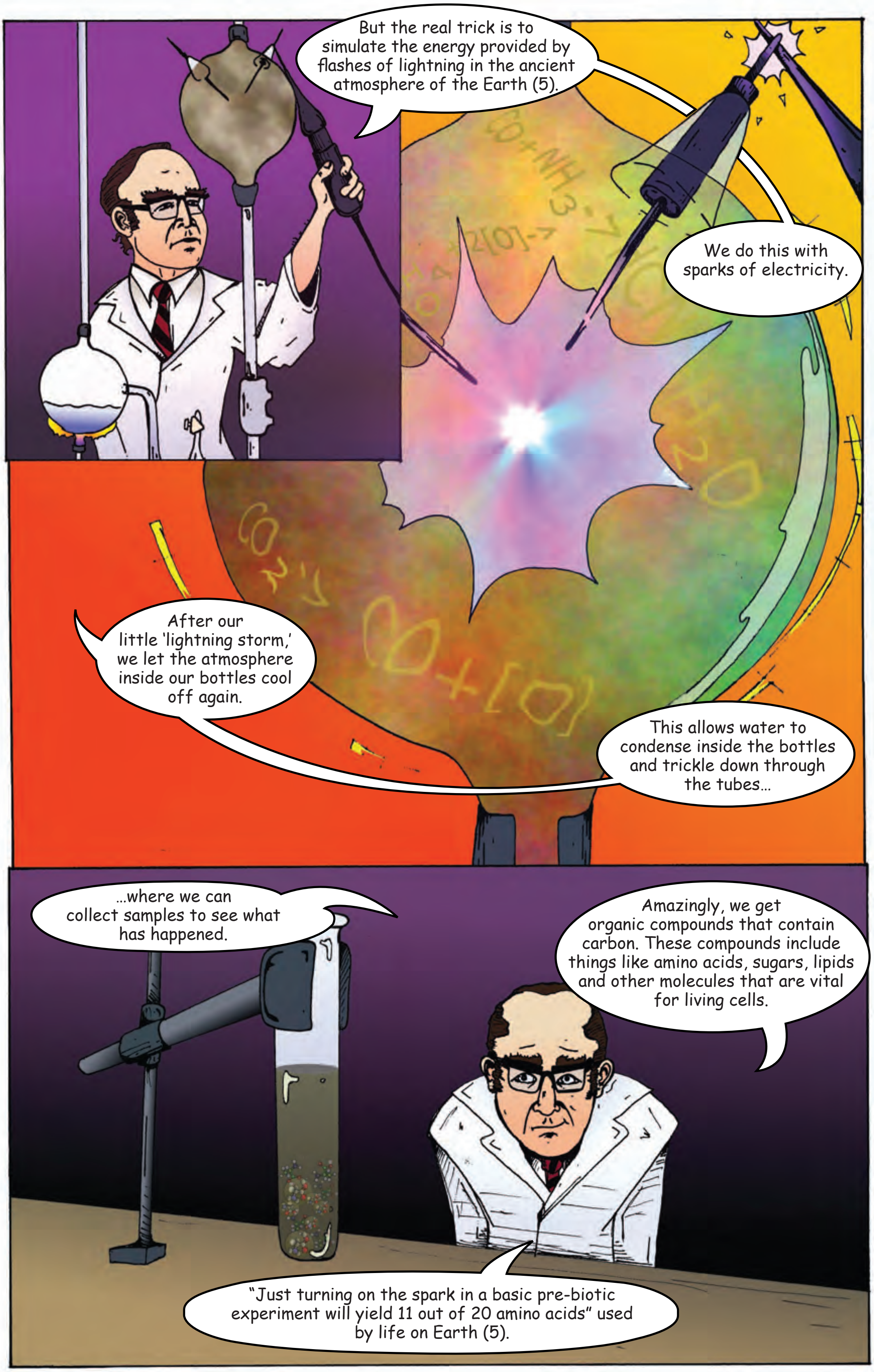
Background Image: 30 Doradus Nebula (1)


Astrobiology as a field of science includes many disciplines, from astronomy to biology. But all astrobiologists work to understand the origin of life on Earth and potential for life on other worlds (2).
Astrobiology can include everything from studying the fundamental principles of how living cells form to searching the skies for Earth-like planets around distant stars. This broad range of scientific pursuits can make Astrobiology difficult to explain.
Earth is the only example we have of a habitable planet for life as we know it. So how do astrobiologists do their work?
If we haven't found 'aliens' yet… what do they study?
When searching for life in the Universe, what do we look for and how do we look for it?

Humans have long been fascinated with the potential for life in the Universe—even before people knew what the Universe was. Ancient cultures had a variety of explanations for what the stars and planets were, but nearly all of them believed in the possibility of life forms much different from those they saw on Earth.
Twenty-three centuries ago, the Greek philosopher Epicurus wrote about the existence of other worlds in a letter to Herodotus (300 BCE).
"There are an infinite number of worlds, some like this world, others unlike it."
"With regard to living things, it cannot be proven that the seeds from which animals, plants and other things originate are not possible on any particular world-system."
Epicurus 341 BCE–270 BCE
There are many different translations and interpretations of Epicurus' words, but it is clear that he did not believe the Earth was the only inhabited world in existence.
Astronomers have played an important role in helping us understand that Earth is not the only world in the Universe. The discovery of other planets and moons helped to spark ideas that the Earth might not be the only world with life.
Christiaan Huygens (1629-1695) discovered Saturn's moon, Titan.
Galileo Galilei is one of the most famous astronomers in history. He perfected the early telescope and made some truly profound observations of the Solar System. In 1610, he observed:
"I have seen Jupiter accompanied by three fixed stars, totally invisible by their smallness… The planets are seen very rotund, like little full moons (3)."
Giovanni Cassini (1625-1712) was the first to observe four of Saturn's moons, including Iapetus.
"The bodies of the planets are solid like that of our Earth." "These new Earths may be stocked with plants and animals (4)."
Galileo 1564-1642
In fact, Galileo had discovered Jupiter's largest moons. He later identified Io, Europa, Callisto and Ganymede. This is why we refer to them as 'Galilean' satellites today.

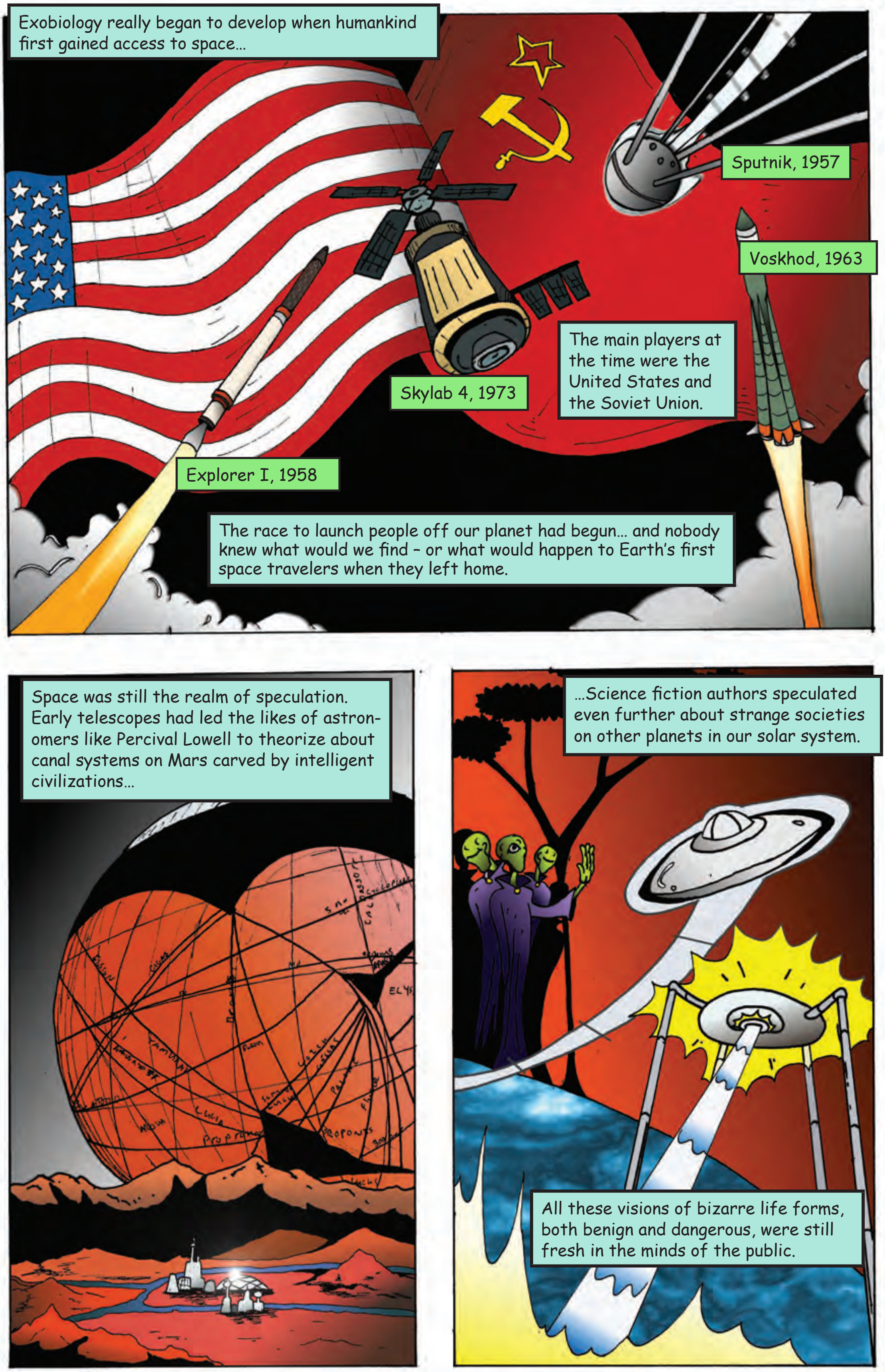

In the 1920s, scientists like the Russian Aleksandr Oparin and Englishman J.B.S. Haldane were trying to determine how life began on Earth.
Through independent research, they both proposed somewhat similar ideas.
I believe the early Earth had a reducing atmosphere*
Composed of methane, ammonia, hydrogen and water vapor.
Agreed.**
I believe it was CO_2, ammonia and water vapor. CO_2 provided the source of carbon for life my good chap.
Da, but methane could also provide carbon for life.
Reducing
And prebiotic life most likely began with molecules in the atmosphere that were then deposited in the oceans.
Agreed.
Increasingly complex organic molecules were created in the presence of ultraviolet radiation."
Nyet. Life arose in the process of the evolution of matter. Basic organic molecules organized into localized systems—like primitive cells.
Haldane
The theories of Oparin and Hal-dane would later influence one of the most important origin of life experiments to date...
*Translated from Russian
**Translated from British

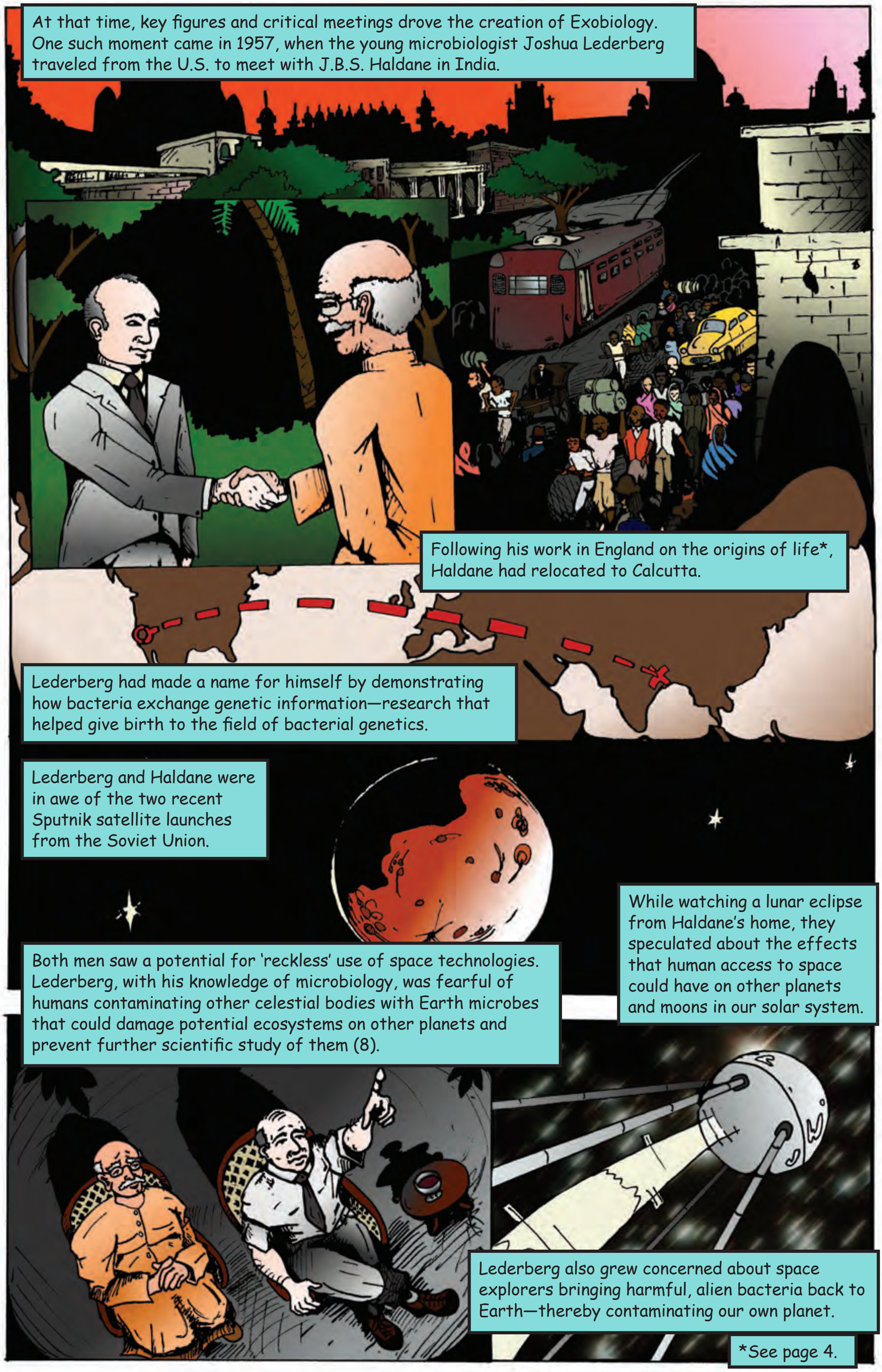

Stanley Miller was a young graduate student working under Nobel Laureate Harold C. Urey
1952. The University of Chicago
Using Urey's calculations for the constituents of the early Earth's atmosphere along with Oparin and Haldane's theories...
I am going to attempt to synthesize molecules necessary for life by simulating conditions on the early Earth—thereby testing the theory of chemical evolution.
First, I'll seal gases that were thought to be present on the early Earth in an airtight container.
Methane... Ammonia... Hydrogen...
No oxygen.
This simulates the oceans and atmosphere of the early Earth.
These chemicals are sealed in sterile tubes and flasks that create a loop.
The water is heated...



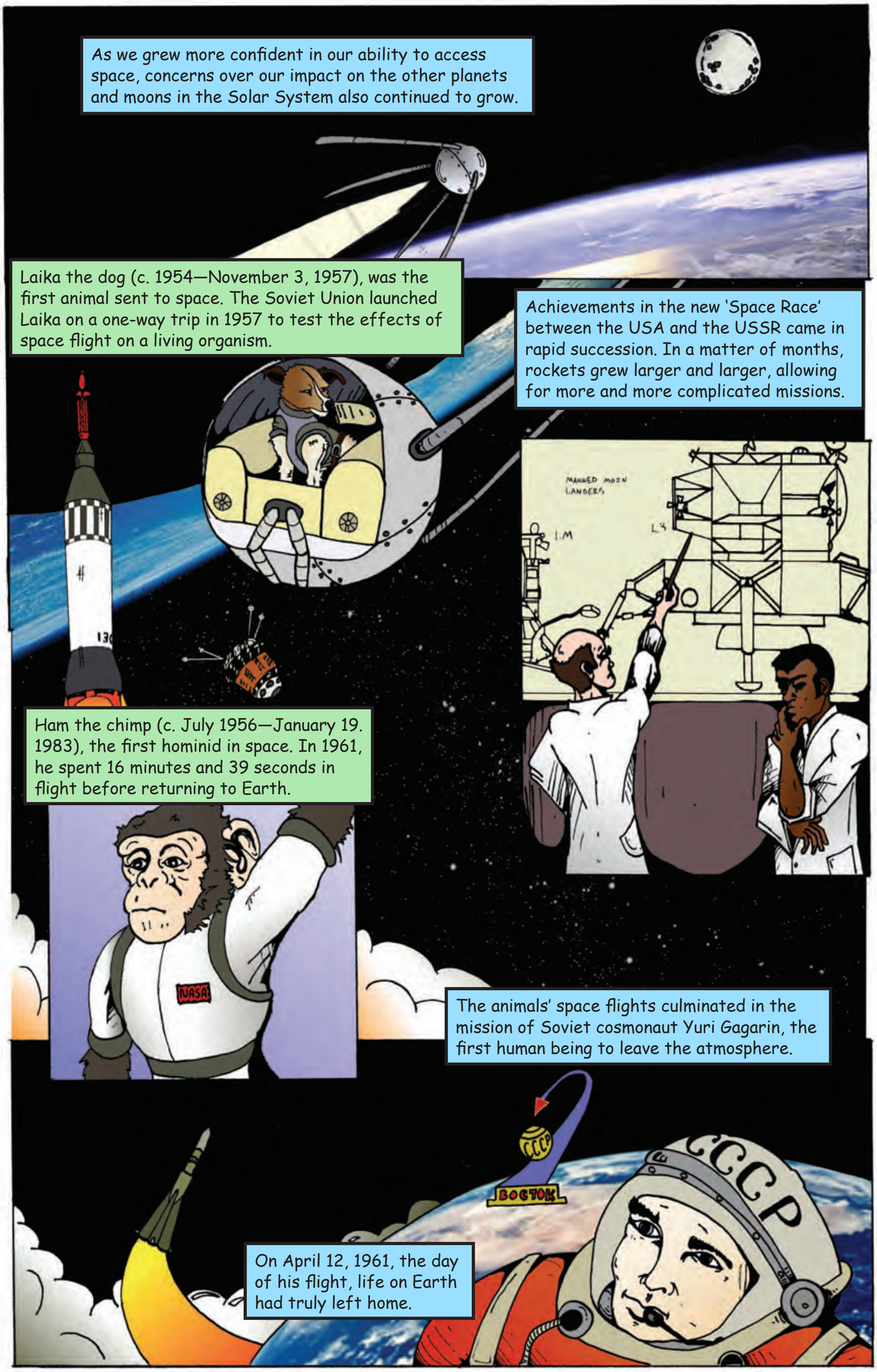
But the real trick is to simulate the energy provided by flashes of lightning in the ancient atmosphere of the Earth (5).
We do this with sparks of electricity.
After our little 'lightning storm,' we let the atmosphere inside our bottles cool off again.
This allows water to condense inside the bottles and trickle down through the tubes...
...where we can collect samples to see what has happened.
Amazingly, we get organic compounds that contain carbon. These compounds include things like amino acids, sugars, lipids and other molecules that are vital for living cells.
"Just turning on the spark in a basic pre-biotic experiment will yield 11 out of 20 amino acids" used by life on Earth (5).

Other key steps in the 20th century were major advances in the fields of biology and chemistry that would later provide astrobiologists with the tools they needed to examine life at the molecular level.
DNA is a big helix in several chains. Phosphates on the outside... phosphate-phosphate inter-helical bonds disrupted by water (6).
British scientist Rosalind Franklin was a key figure in biology. Her work with x-ray diffraction would provide clues to the structure of one of life's most important molecules—DNA.
Franklin's data was the foundation for the work of James D. Watson and Francis Crick, who put forward their theory of the DNA helix in 1953.
We have found the secret of LIFE!!!
The Eagle Pub Cambridge
Watson and Crick provided the world with a visual understanding of how nucleotide base pairs fit together to ultimately provide the fundamental blueprint for life as we know it. Their paper hit the stands in 1953, following their now infamous announcement at the Eagle Pub in Cambridge, England. Only three weeks later, Stanley Miller and Harold Urey published their equally famous paper on the chemical building blocks of life.
In 1962, Watson and Crick, along with molecular biologist Maurice Wilkins, were awarded the Nobel Prize for this invaluable contribution to molecular biology.
Sadly, Rosalind Franklin passed away in 1958 without receiving the proper credit for her contribution.
"You look at science (or at least talk of it) as some sort of demoralising invention of man, something apart from real life, and which must be cautiously guarded and kept separate from everyday existence. But science and everyday life cannot and should not be separated. Science, for me, gives a partial explanation for life. In so far as it goes, it is based on fact, experience and experiment (7)."

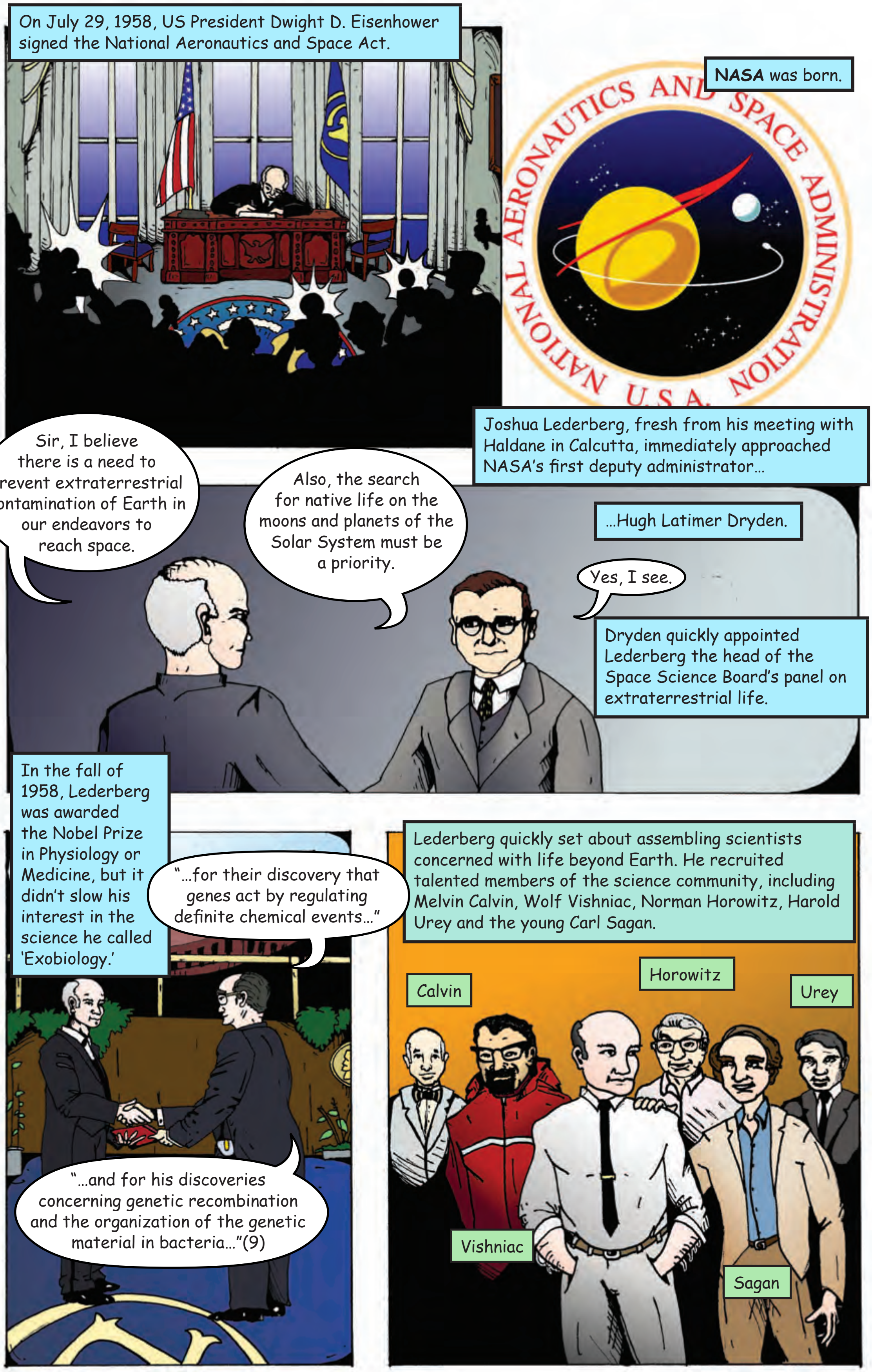

Exobiology really began to develop when humankind first gained access to space...
Sputnik, 1957
Voskhod, 1963
The main players at the time were the United States and the Soviet Union.
Skylab 4, 1973
Explorer I, 1958
The race to launch people off our planet had begun... and nobody knew what would we find – or what would happen to Earth's first space travelers when they left home.
Space was still the realm of speculation. Early telescopes had led the likes of astronomers like Percival Lowell to theorize about canal systems on Mars carved by intelligent civilizations...
...Science fiction authors speculated even further about strange societies on other planets in our solar system.
All these visions of bizarre life forms, both benign and dangerous, were still fresh in the minds of the public.



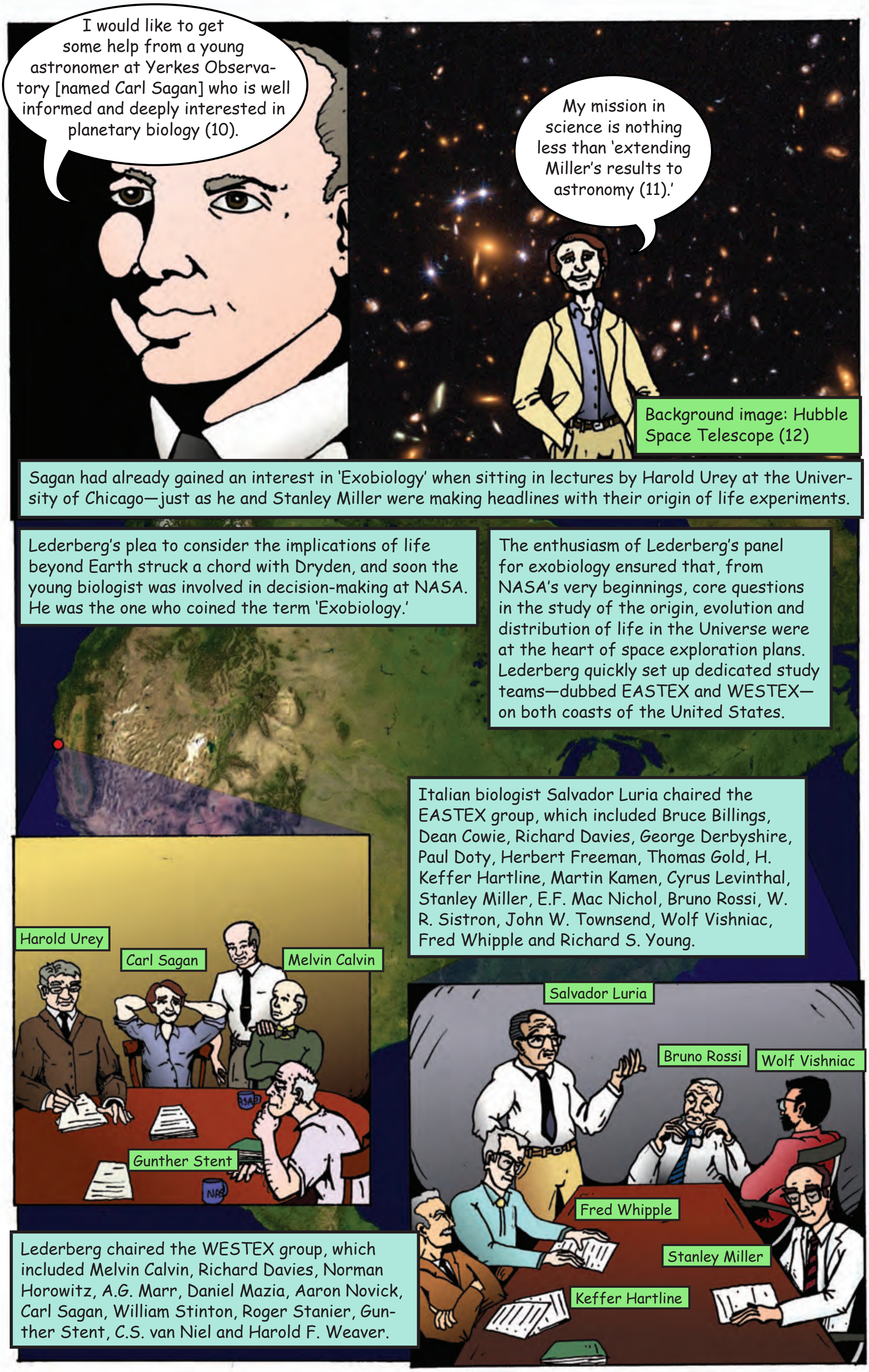
At that time, key figures and critical meetings drove the creation of Exobiology. One such moment came in 1957, when the young microbiologist Joshua Lederberg traveled from the U.S. to meet with J.B.S. Haldane in India.
Following his work in England on the origins of life*, Haldane had relocated to Calcutta.
Lederberg had made a name for himself by demonstrating how bacteria exchange genetic information—research that helped give birth to the field of bacterial genetics.
Lederberg and Haldane were in awe of the two recent Sputnik satellite launches from the Soviet Union.
While watching a lunar eclipse from Haldane's home, they speculated about the effects that human access to space could have on other planets and moons in our solar system.
Both men saw a potential for 'reckless' use of space technologies. Lederberg, with his knowledge of microbiology, was fearful of humans contaminating other celestial bodies with Earth microbes that could damage potential ecosystems on other planets and prevent further scientific study of them (8).
Lederberg also grew concerned about space explorers bringing harmful, alien bacteria back to Earth—thereby contaminating our own planet.
*See page 4.



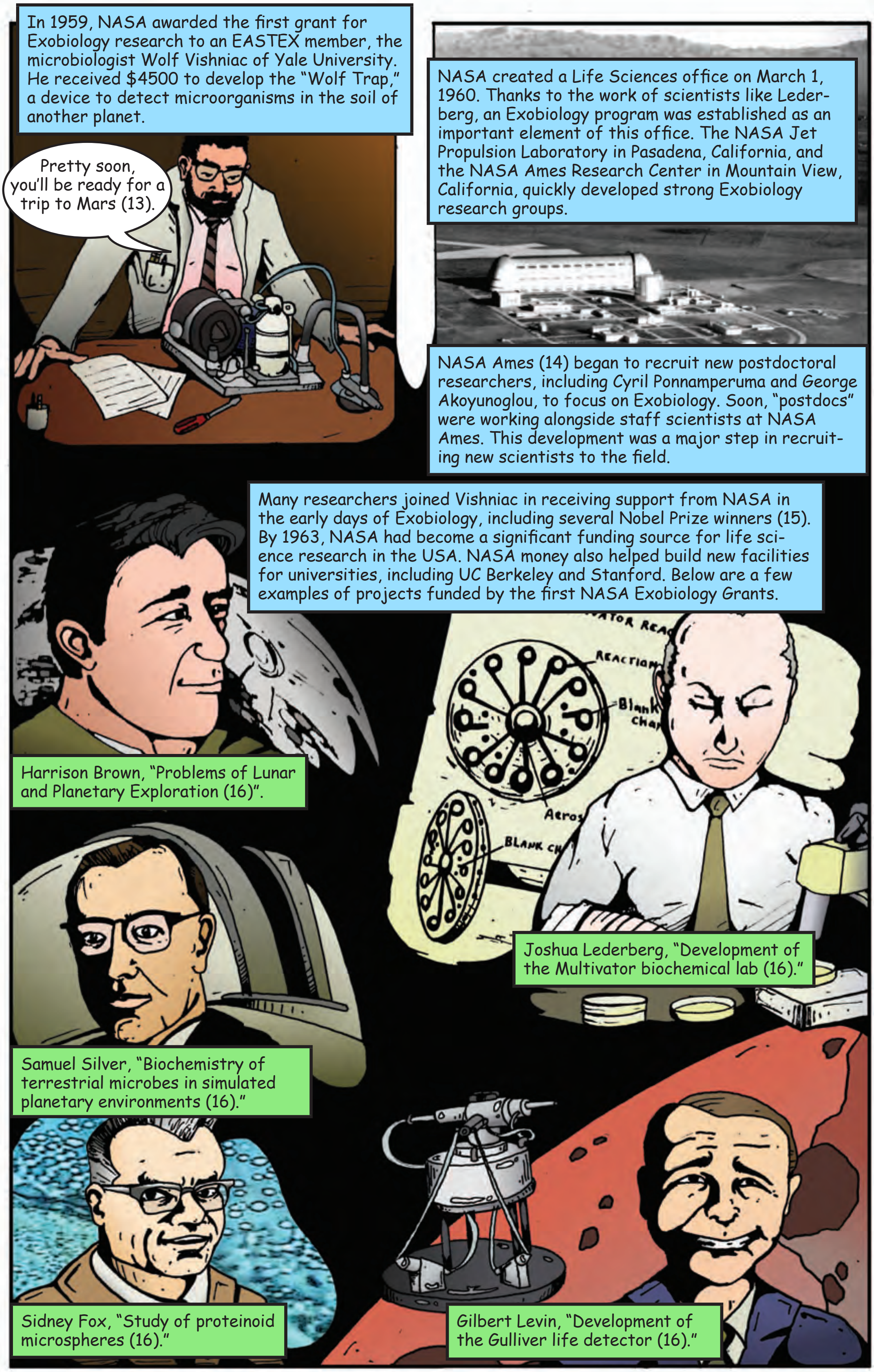
As we grew more confident in our ability to access space, concerns over our impact on the other planets and moons in the Solar System also continued to grow.
Laika the dog (c. 1954—November 3, 1957), was the first animal sent to space. The Soviet Union launched Laika on a one-way trip in 1957 to test the effects of space flight on a living organism.
Achievements in the new 'Space Race' between the USA and the USSR came in rapid succession. In a matter of months, rockets grew larger and larger, allowing for more and more complicated missions.
MANNED MOON LANDERS
Ham the chimp (c. July 1956—January 19. 1983), the first hominid in space. In 1961, he spent 16 minutes and 39 seconds in flight before returning to Earth.
NASA
The animals' space flights culminated in the mission of Soviet cosmonaut Yuri Gagarin, the first human being to leave the atmosphere.
CCCP
BOCTOK
CCCP
On April 12, 1961, the day of his flight, life on Earth had truly left home.



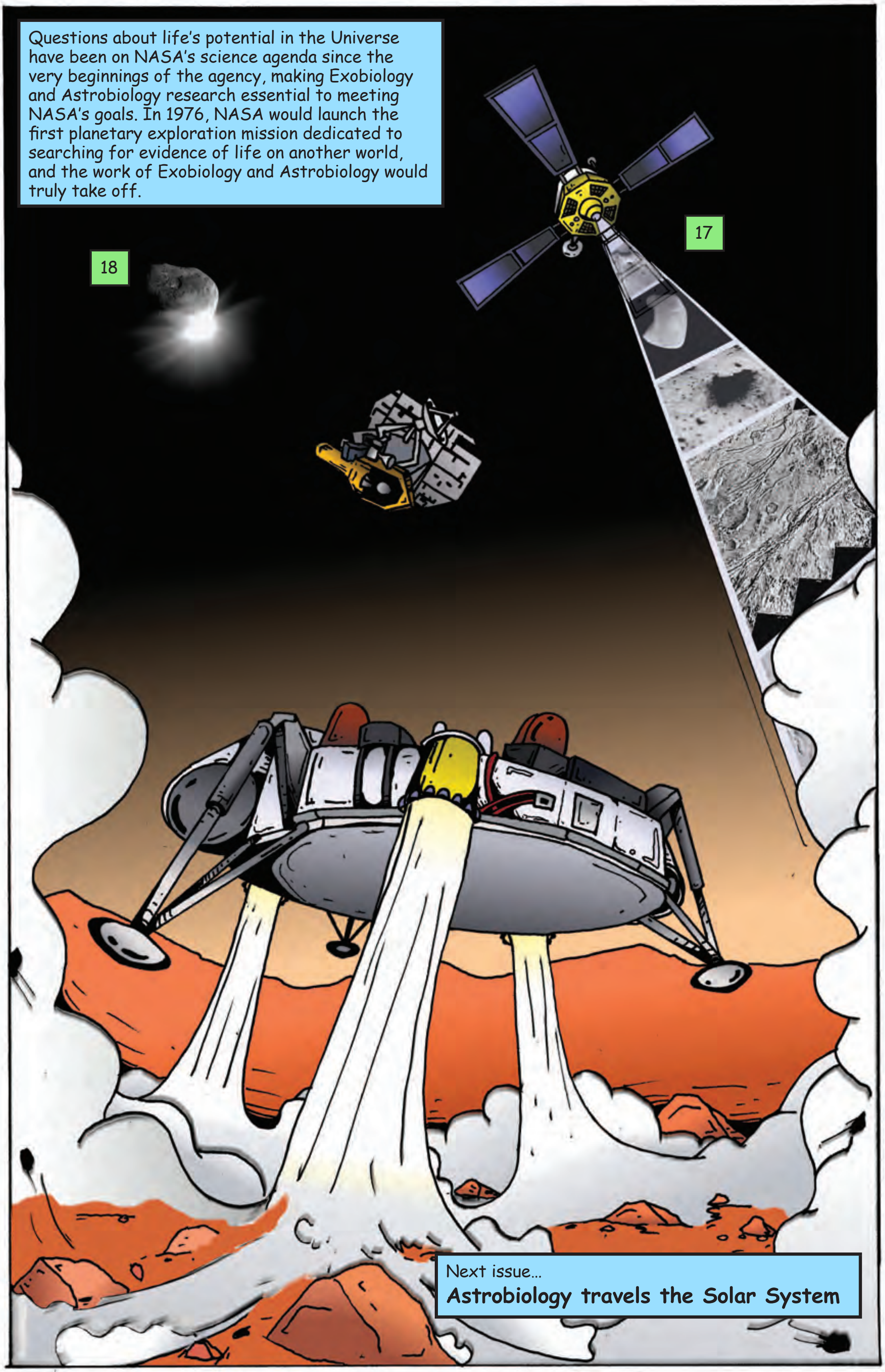
On July 29, 1958, US President Dwight D. Eisenhower signed the National Aeronautics and Space Act.
NASA was born.
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION U.S.A.
Joshua Lederberg, fresh from his meeting with Haldane in Calcutta, immediately approached NASA's first deputy administrator...
...Hugh Latimer Dryden.
Sir, I believe there is a need to prevent extraterrestrial contamination of Earth in our endeavors to reach space.
Also, the search for native life on the moons and planets of the Solar System must be a priority.
Yes, I see.
Dryden quickly appointed Lederberg the head of the Space Science Board's panel on extraterrestrial life.
In the fall of 1958, Lederberg was awarded the Nobel Prize in Physiology or Medicine, but it didn't slow his interest in the science he called 'Exobiology.'
"...for their discovery that genes act by regulating definite chemical events..."
"...and for his discoveries concerning genetic recombination and the organization of the genetic material in bacteria..."(9)
Lederberg quickly set about assembling scientists concerned with life beyond Earth. He recruited talented members of the science community, including Melvin Calvin, Wolf Vishniac, Norman Horowitz, Harold Urey and the young Carl Sagan.
Calvin
Horowitz
Urey
Vishniac
Sagan



I would like to get some help from a young astronomer at Yerkes Observatory [named Carl Sagan] who is well informed and deeply interested in planetary biology (10).
My mission in science is nothing less than 'extending Miller's results to astronomy (11).'
Background image: Hubble Space Telescope (12)
Sagan had already gained an interest in 'Exobiology' when sitting in lectures by Harold Urey at the University of Chicago—just as he and Stanley Miller were making headlines with their origin of life experiments.
Lederberg's plea to consider the implications of life beyond Earth struck a chord with Dryden, and soon the young biologist was involved in decision-making at NASA. He was the one who coined the term 'Exobiology.'
The enthusiasm of Lederberg's panel for exobiology ensured that, from NASA's very beginnings, core questions in the study of the origin, evolution and distribution of life in the Universe were at the heart of space exploration plans. Lederberg quickly set up dedicated study teams—dubbed EASTEX and WESTEX—on both coasts of the United States.
Italian biologist Salvador Luria chaired the EASTEX group, which included Bruce Billings, Dean Cowie, Richard Davies, George Derbyshire, Paul Doty, Herbert Freeman, Thomas Gold, H. Keffer Hartline, Martin Kamen, Cyrus Levinthal, Stanley Miller, E.F. Mac Nichol, Bruno Rossi, W. R. Sistron, John W. Townsend, Wolf Vishniac, Fred Whipple and Richard S. Young.
Harold Urey
Carl Sagan
Melvin Calvin
Gunther Stent
Salvador Luria
Bruno Rossi
Wolf Vishniac
Fred Whipple
Stanley Miller
Keffer Hartline
Lederberg chaired the WESTEX group, which included Melvin Calvin, Richard Davies, Norman Horowitz, A.G. Marr, Daniel Mazia, Aaron Novick, Carl Sagan, William Stinton, Roger Stanier, Gunther Stent, C.S. van Niel and Harold F. Weaver.



In 1959, NASA awarded the first grant for Exobiology research to an EASTEX member, the microbiologist Wolf Vishniac of Yale University. He received $4500 to develop the "Wolf Trap," a device to detect microorganisms in the soil of another planet.
Pretty soon, you'll be ready for a trip to Mars (13).
NASA created a Life Sciences office on March 1, 1960. Thanks to the work of scientists like Lederberg, an Exobiology program was established as an important element of this office. The NASA Jet Propulsion Laboratory in Pasadena, California, and the NASA Ames Research Center in Mountain View, California, quickly developed strong Exobiology research groups.
NASA Ames (14) began to recruit new postdoctoral researchers, including Cyril Ponnamperuma and George Akoyunoglou, to focus on Exobiology. Soon, "postdocs" were working alongside staff scientists at NASA Ames. This development was a major step in recruiting new scientists to the field.
Many researchers joined Vishniac in receiving support from NASA in the early days of Exobiology, including several Nobel Prize winners (15). By 1963, NASA had become a significant funding source for life science research in the USA. NASA money also helped build new facilities for universities, including UC Berkeley and Stanford. Below are a few examples of projects funded by the first NASA Exobiology Grants.
Harrison Brown, "Problems of Lunar and Planetary Exploration (16)".
Joshua Lederberg, "Development of the Multivator biochemical lab (16)."
Samuel Silver, "Biochemistry of terrestrial microbes in simulated planetary environments (16)."
Sidney Fox, "Study of proteinoid microspheres (16)."
Gilbert Levin, "Development of the Gulliver life detector (16)."


Questions about life's potential in the Universe have been on NASA's science agenda since the very beginnings of the agency, making Exobiology and Astrobiology research essential to meeting NASA's goals. In 1976, NASA would launch the first planetary exploration mission dedicated to searching for evidence of life on another world, and the work of Exobiology and Astrobiology would truly take off.
18
17
Next issue...
Astrobiology travels the Solar System

Astrobiology

A History of Exobiology and Astrobiology at NASA

Further Resources and References cited in this issue:

1. The background image on Page 1 is of the 30 Doradus Nebula of the Large Magellanic Cloud. This is one of the most active star-forming regions discovered thus far in our region of the galaxy. This image combines ultraviolet, visible, and red light captured by the Hubble Space Telescope's Wide Field Camera 3. Credit: *NASA, ESA, and F. Paresce (INAF-IASF, Bologna, Italy), R. O'Connell (University of Virginia, Charlottesville), and the Wide Field Camera 3 Science Oversight Committee photo.* Image available online at: http://www.astrobio.net/index.php?option=com_galleryimg&task=imageofday&imageId=216&pageNo=24
2. See the Astrobiology Roadmap at: http://Astrobiology.nasa.gov/roadmap
3. Drake, S. (1978) Galileo at Work: His Scientific Biography, University of Chicago Press
4. Huygens, C. (1968) Cosmostheoros: Book 1
5. "EXOBIOLOGY: An interview with Stanley L. Miller". Accessexcellence.org
6. Lecture Notes of Franklin, "Colloquium Nov. 1951." The report is typewritten, dated 7 Feb. 1952, in A Sayre, Rosalind Franklin and DNA (1975), 128.
7. Letter to Ellis Franklin, possibly summer 1940 whilst Rosalind Franklin was an undergraduate at Cambridge. Cited in Brenda Maddox (2002) The Dark Lady of DNA, HarperCollins Publishers, 380p.
8. Morange, M. (2007) What history tells us: X. Fifty years ago: the beginnings of Exobiology. *J. Biosci.* 32(6), September 2007, 1083–1087
9. www.nobelprize.org
10. http://www.njhn.org/Humanist_Candle_in_the_Dark.html
11. Sagan to Lederberg, 1959, Lederberg Papers, National Library of Medicine. Available at: http://profiles.nlm.nih.gov/BB/Views/Exhibit/narrative/exobio.html
12. Image from the Hubble Space Telescope entitled, "A Five Quasar Gravitational Lens". Credit: *K. Sharon (Tel Aviv U.) and E. Ofek (Caltech), ESA, NASA*. Available from www.hubblesite.org and www.nasaimages.org
13. Wolf Vishniac's instrument, the Wolf Trap, would later become one of four instruments selected to fly on NASA's Viking Mars lander mission.
14. This aerial photograph of what is now the NASA/Ames Research Center was captured by the Navy NAS on May 1, 1936. The distinctive large dirigible hanger can still be seen today when driving past NASA Ames in Mountain View, CA, on California Highway 101. From the Ames Research Center Image Library Collection, Image A93-0073-8
15. Nobel Prize winning scientists involved in early Astrobiology projects with support from NASA included the likes of Lederberg, Calvin, Urey, H.J. Muller, Fritz Lipmann, George Wald, M. Keffer Hartline and Manfred Eigen (Dick and Strick 2005, p. 30)
16. Dick, S.J. and Strick, J.E. (2005) The Living Universe: NASA and the development of Astrobiology. Rutgers University Press, New Brunswick, New Jersey, and London
17. Images captured by the Viking Orbiters: (1) Image of the Mars surface from Viking 1 (1976) (2) Mars' moon Deimos as captured by Viking 2 (1977) (3) The infamous 'face' on Mars captured by Viking 1 (1976) (4) Channels and Craters on Mars. Captured by Viking 2 (1976)
18. The comet Tempel 1 as viewed by the NASA Deep Impact mission (2005).

NP-2010-09-681-HQ