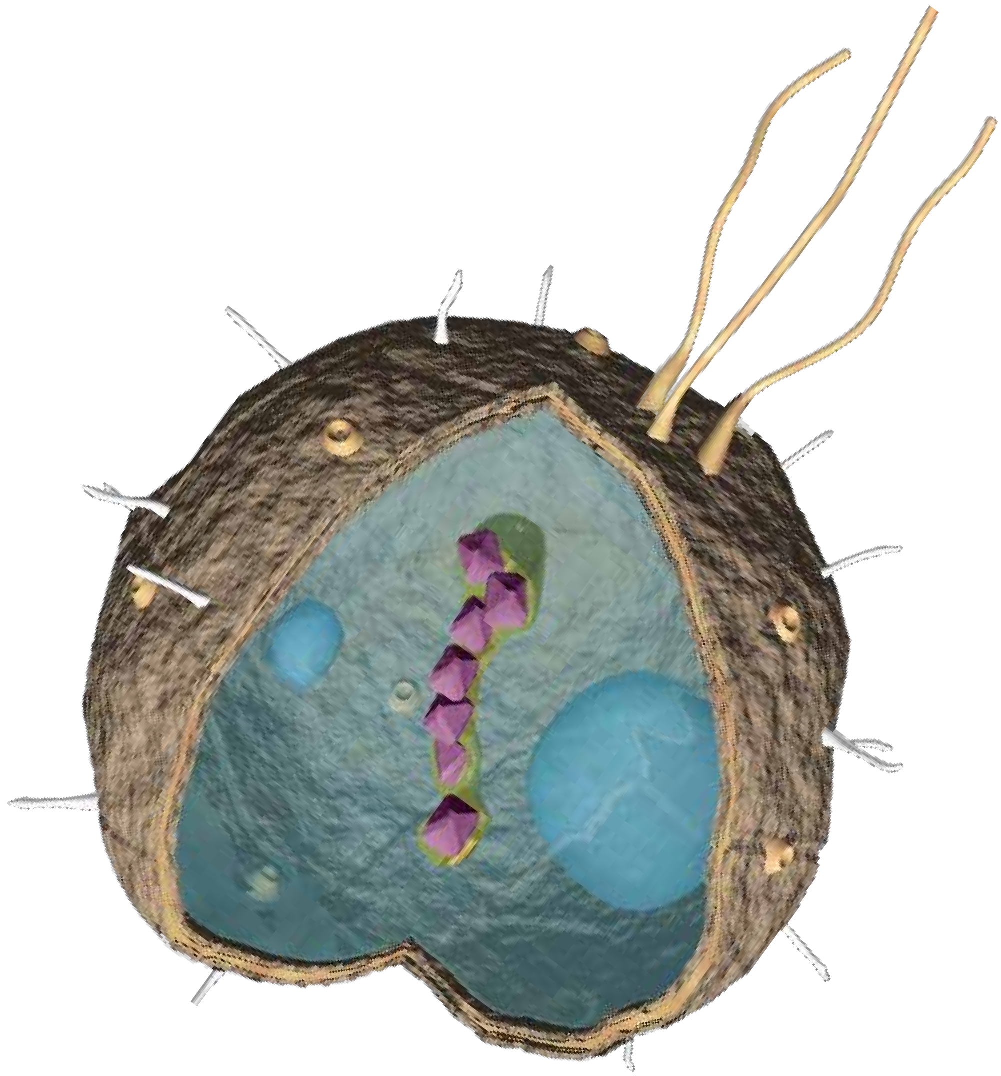
Science News
IN HIGH SCHOOLS | EDUCATOR GUIDE



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Will we know ET when we see it?

SOCIETY FOR
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SN EDUCATOR GUIDE Will we know ET when we see it?

About the Guide

The *Science News* article "Will we know ET when we see it?" explores what life beyond Earth's boundaries might look like and how scientists could identify it.

"Will we know ET when we see it?" can be used across a wide range of curricula, with a focus on **biology** and **astronomy**. The activities, questions and discussions in this educator guide can be used to support the following education standards:

Next Generation Science	Common Core
Earth's Systems: HS-ESS2-2, HS-ESS2-7	ELA Standards: Reading Informational Text (RI): 4
	ELA Standards: Writing (W): 2, 3, 7, 9
	ELA Standards: Speaking and Listening (SL): 1, 3, 4, 6
	ELA Standards: Language (L): 1, 4, 6
	ELA Standards: Reading for Literacy in History/Social Studies (RH): 2, 3, 8
Reinforcement for Middle School: Earth's Systems: MS-ESS3-1	ELA Standards: Reading for Literacy in Science and Technical Subjects (RST): 1, 2
From Molecules to Organisms: Structures and Processes: MS-LS-1-5	ELA Standards: Writing Literacy in History/Social Studies and Science and Technical Subjects (WHST): 1, 2, 4, 7, 9

Prior to reading

Guide student reading by pointing out connections between this article and what students are learning in class. Here find ideas for standard-aligned paths to follow while reading:

- Ask students to create a mind map that includes characteristics that determine whether something is alive. Students might brainstorm their ideas on Post-its so they can easily move and categorize the characteristics. Students can connect the characteristics using linkages that include words and phrases to specify the relationships. Have students add specific examples or, if time allows, find images to support or refute their ideas. *(For example, if a student says "movement" defines life, the student might find an image of a running horse as support but another student might find an image of a radio-operated car to refute the idea.)* As students sort their ideas, encourage them to consider fundamental signs of life, including: order and organization; the use of energy during metabolic processes; some type of reproduction, replication or cell division; growth; genetic information; and reactions to stimuli in the environment.
- Students have previously studied how the Earth has changed throughout its history and are still learning about how changing ecosystems affect organisms. Encourage students to talk about specific physical and chemical factors that have changed on Earth over time *(formation of the atmosphere, acidity of the oceans, degree of volcanic activity)* and how those changes affected what could survive and thrive on the planet. Students might brainstorm organisms that once lived on our planet that could not survive under current conditions, along with organisms alive today that could not have survived under previous conditions. Encourage students to consider conditions on other planets or moons. Could life survive there? Let this conversation spark ideas related to the conditions that make a place habitable.

After reading: Comprehend

You can adapt and print these questions (Blackline Master 1) to check for comprehension and analysis before or after discussion:

1. **What is the main topic of the article?** *(If extraterrestrial life exists, it may not follow the rules for life on Earth.)*
2. **What are some of the existing (if controversial) requirements for life mentioned in the article?** *(Active metabolism, reproduction, Darwinian evolution, cells with ribosomes.)*
3. **Why might researchers have trouble recognizing a living thing on another planet or moon?** *(It may not be made of familiar ingredients, may not function in a similar way or may not grow or reproduce within a timescale that humans can observe.)*
4. **Why is leaving Earth's surface vital to the discovery of extraterrestrial life?** *(Our most powerful telescopes cannot detect microscopic organisms directly. Extraterrestrial life-forms will most likely be microbial. A rover is needed to look for signs of life on or below the surfaces of other planets or moons.)*

After reading: Analyze

1. **Identify one of the assumptions the article makes about alien life. Do you think the assumption is correct? Why or why not?** *(Answers will vary, but some assumptions include: Life definitely exists somewhere beyond Earth, or "Life is a cosmic imperative," as one of the scientists says. Life on another planet or moon would most likely be microbial. Life probably exists on another rocky body like Earth, rather than floating through space or in interstellar dust.)*

2. **What does the author mean by the phrase "a shadow biosphere"? Why is it called that?** *(A shadow biosphere is the hypothetical concept that there's a completely separate world of life on Earth that is based on a different set of biological principles and thus hasn't been recognized.)*

3. **The author suggests that if life is reported on Mars, there will be an argument over whether it is a legitimate finding or not: "It will be a good natured fight because everybody wants to find life, but everybody is aware of the pitfalls of experiments conducted at a 100-million-mile distance by robots," says Steven Benner. What pitfalls might Benner be referring to?** *(Answers may vary, but a key pitfall is the chance of contamination from Earth or from something the spacecraft has picked up along its journey. Other answers include the idea that it is hard to tell whether experiments are working from a great distance and hard to modify those experiments remotely to ask new questions. Also, spacecraft have to travel a long distance and thus have to be lightweight, so the number and type of tests are limited.)*

4. **The article refers to several ways scientists search for life. Use the chart below to identify five techniques scientists use and the information provided by each technique.**

Technique	Type of evidence
Chemical sampling at a planet's surface	*Evidence of chemicals that are changed by a biological process (for example, compounds emitted from photosynthesis or as waste products from digestion or respiration). Also, organic compounds or a skewed distribution of compounds that suggests life is accumulating these compounds in specific locations.*
Paleontology	*Trace, replaced or actual fossils depicting cellular or structured forms.*
Telescope observations of a planet's surface	*Signs of channels carved by water or dried-up lake beds. Signs of tectonic activity.*
Remote sampling by rovers	*Rovers can perform chemical analyses and take pictures to help scientists looking for fossils.*
Telescope observations of the atmosphere	*Signs of compounds in the atmosphere that might be produced by life below.*

Discuss and Assess

After students read the article independently, return as a group to the concepts outlined prior to reading. Invite students to share their answers and observations from the article and lead a class discussion that further underscores your current curriculum. The discussion can serve as an informal assessment. Ideas for further reading discussion or writing prompts include:

- Suppose that a rover collecting samples on Titan reported evidence of azotosomes, stable bubbles that look similar to cell membranes. Would this be considered a discovery of alien life? What types of evidence would students need to evaluate whether it is or isn't a clear sign of life? What next steps would students take to confirm the finding and learn more? Would they plan another mission? Consider whether the mission would be human-led or remote. What tests would they plan for the mission? How long would it take? How would students convince leaders at NASA to approve the plan?

- Encourage students to consider what the discovery of alien life would mean for life on Earth. Would it change their lives if they knew organisms existed on other planets? If so, in what ways? How might this knowledge change how they behave? How might it change the way they think about themselves and humankind, their future and the Earth's future? Consider comparing this potential discovery to historical paradigm shifts in science, such as the realization that the sun does not revolve around the Earth. In what ways would the public response be similar? How would it be different?

- Throughout history, humans have tried to imagine the unknown. Ancient and medieval maps included images of sea monsters, dragons and lions where cartographers had little information. In more modern times, creatures from other worlds have been imagined in print, film and other media. See the article "To an ancient question, no reply" in this same *Science News* issue for examples. But in imagining alien life, we tend to create images based on our own experience and beliefs. As our cultural knowledge changes, so do our representations. Ask students where they would look for life beyond Earth? What physical or chemical attributes would that location have to have? What characteristics would the life have? What might it look like? Students can create a "Wanted" poster incorporating the information or write a classified ad for an interstellar publication.

- The article ends with the message that "life is a cosmic imperative." Ask students to consider why researchers like Robert Hazen are so optimistic that extraterrestrial life exists. After this discussion, introduce students to the Drake Equation, created in the 1960s and still accepted today as a way to think about the number of civilizations in the Milky Way that might communicate with humankind. Here's the equation:

$$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

N The number of civilizations in the Milky Way galaxy with which communication might be possible

R* The average rate of star formation per year in the galaxy

f_p The fraction of stars in the galaxy that have planets

n_e The average number of planets that can potentially support life per star with planets

f_l The fraction of those planets that actually go on to develop life at some point

f_i The fraction of those planets that develop intelligent life

f_c The fraction of intelligent civilizations that develop a technology that releases detectable signs of their existence into space

L The length of time such civilizations release these detectable signals

Discuss the limits of this equation. *(It requires assumptions about what types of planets could support life and what it means to be intelligent. It also requires estimations about the rate of star formation and the number of stars with planets.)* Talk about the values that might be assigned for each variable and ask your students to calculate a rough N based on their existing knowledge and intuition. Is the result surprising? Is it bigger or smaller than students expected, and why? How might the values of the variables change as new information comes in? Would the variables go up or down, and how would those changes affect the value of N? Students might explore independently what happens when numbers for one or more variables change.

Extend

Offer students other ways to explore the content of the article as it relates to your curriculum, such as:

GRADUAL REPLACEMENT

In this activity, Blackline Master 2, students will consider the definition of life from a different perspective. They will read about an octopus that is gradually becoming bionic. At each stage, students will evaluate whether the octopus is still "alive." If students think the octopus is not alive at the end of the exercise, then ask at what point was the octopus no longer alive? Did the octopus die or something else? If students think the octopus is alive, then ask how the octopus differs from a robot or another machine? Encourage students to discuss and debate these questions.

FUZZY DEFINITIONS

"Life" is not the only concept that is challenging to define. Have students use Blackline Master 3 to attempt to define other challenging concepts. Once students have their own definitions, encourage them to share their answers with other students. Discuss why these concepts are difficult. Is it because they are vague? Because we don't have the right language to describe them? Because there is open debate? Have students come up with their own difficult-to-define concepts. There aren't any right or wrong answers in this activity. Instead, the activity is designed to encourage students to think about how an individual's experiences and beliefs shape his or her thinking.

LIFE ON THE EDGE (a card game from NASA)

NASA has designed a great educational guide on astrobiology for middle schoolers. On Page 45, there is a rummy-style game in which students match organisms found on Earth with their environments and potential extraterrestrial environments. You can adapt this activity to fit within high school NGS standards by encouraging students to:

1. Examine one of the card groupings and consider how humans coming to the extraterrestrial environment represented might change that environment, particularly the hydrosphere, cryosphere, atmosphere, biosphere or geosphere. What effects might human presence have and how might those effects impact the survival (positive or negative) of the organism included in the grouping?
2. Use one of the card groupings to develop a claim about life on Earth or potential life at the extraterrestrial location. Include at least two logical arguments with causal links or feedback mechanisms, and consider changes in the biosphere and one or more of the planet's systems. Once the claims have been established, trade the claims and try to support or refute them using logical arguments with reasonable causal links.

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Comprehend

After reading the article “Will we know ET when we see it?,” answer these questions:

1. **What is the main topic of the article?**

2. **What are some of the existing (if controversial) requirements for life mentioned in the article?**

3. **Why might researchers have trouble recognizing a living thing on another planet or moon?**

4. **Why is leaving Earth’s surface vital to the discovery of extraterrestrial life?**

Analyze

1. **Identify one of the assumptions the article makes about alien life. Do you think the assumption is correct? Why or why not?**

2. **What does the author mean by the phrase "a shadow biosphere"? Why is it called that?**

3. **The author suggests that if life is reported on Mars, there will be an argument over whether it is a legitimate finding or not: "It will be a good natured fight because everybody wants to find life, but everybody is aware of the pitfalls of experiments conducted at a 100-million-mile distance by robots," says Steven Benner. What pitfalls might Benner be referring to?**

4. **The article refers to several ways scientists search for life. Use the chart below to identify five techniques scientists use and the information provided by each technique.**

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Gradual replacement

Directions: Decide whether Shelby is alive at each stage of the story and why you think so (or not).

Scenario	Alive or not?	Rationale
Shelby was a normal and curious octopus who lived at the neighborhood aquarium. One day he got a tentacle caught in the aquarium filter, and the tentacle had to be removed. A volunteer on staff replaced it with an artificial tentacle that looked and operated almost like the real thing.		
Soon, Shelby had trouble eating and a large portion of his gut had to be replaced with an elastic tube.		
Shelby was doing fine until some aquarium volunteers bumped into the tank while moving some boxes and a large rock fell on Shelby, pinning him beneath. A vet amputated most of Shelby's tentacles, replacing two with artificial ones so he could move about the tank. Plastic surgery replaced one eye.		
Shelby continued to do OK, but he was plagued by a variety of challenges. His siphon no longer kept pressure, so it was replaced with a mechanical one. His kidney was replaced with a passive filter, and his heart was replaced with a pump. His digestive system was removed due to a spreading infection and so he was fed by the injection of raw vitamins and minerals.		
Shelby was an aquatic miracle. He had artificial limbs, produced no waste and had a mechanical heart and eyes. As his brain cells began to die off and no longer function, a medical student wondered if it might be possible to compress all the machines working on Shelby into a nanochip, which could also control Shelby's movements remotely. The surgery succeeded.		
Shelby's activity was controlled remotely by scientists. The nanochip allowed Shelby full movement without any restrictions, so scientists could direct him to leave the aquarium for hours to explore the nearby tide pools. Since all bodily functions were controlled and carried out by machine, Shelby was no longer susceptible to disease and his lifespan became unlimited.		

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Fuzzy definitions

Directions: Fill in the chart below with your definition of each concept. Two rows have been left blank so you can come up with other concepts that are challenging to define.

Concept	How would you define it?
Planet	
Intelligence	
Nothingness	