

ScienceNews

IN HIGH SCHOOLS | EDUCATOR GUIDE



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SOCIETY FOR
SCIENCE & THE PUBLIC

About the Guide

This guide includes comprehension and analysis questions for the following stories:

Gills gone visionary PAGE 4

The colorful Christmas tree worms grow eyes at the base of their feathery gills — a great example of the varied and often surprising outcomes of evolution.

[Blackline Master 1](#)

Human body not overrun by bacteria PAGE 6

Some estimates have suggested that the human body contains 10 times as many bacterial cell as human cells. But new estimates point to a more even split.

[Blackline Master 2](#)

Mystery hominid settled Sulawesi PAGE 7

Evidence from stone artifacts suggests that ancient relatives of modern humans lived on the island of Sulawesi, in Indonesia, some 200,000 years ago. Researchers are puzzling over who these hominids were and how they got there.

[Blackline Master 3](#)

Red giants map how Milky Way grew PAGE 8

Researchers determined the masses and ages of some 70,000 red giants, a type of star, to better understand the history of our galaxy. Its center is older than its outskirts, as some scientists had suspected.

[Blackline Master 4](#)

This guide also includes discussion prompts for:

GMOs under scrutiny PAGE 22

The public controversy surrounding genetically engineered foods does not always reflect the actual science: Evidence suggests that eating GM foods is no riskier than eating non-GM foods. The environmental consequences are less certain, but in many cases can be mitigated. The strongest critique of GMOs might be that, despite promises, engineered foods have so far done little to fight world hunger or improve global nutrition.

[Blackline Master 5](#)

This guide can be used across a wide range of curricula, with a focus on **biology** and **astronomy**, with connections to **history**, and can be used to support the following education standards:

Next Generation Science	Common Core
Waves and their Applications in Technologies for Information Transfer: HS-PS4-1	ELA Standards: Reading Informational Text (RI): 3, 6
Biological Evolution: HS-LS4-1 , HS-LS4-4	ELA Standards: Writing (W): 2, 9
Earth's Place in the Universe: HSESS1-2 , HSESS1-3	ELA Standards: Speaking and Listening (SL): 4
Earth and Human Activity: HS-ESS3-3	ELA Standards: Language (L): 6
Engineering Design: HS-ETS1-1 , HS-ETS1-3	ELA Standards: Reading for Literacy in Science and Technical Subjects (RST): 2, 6
	ELA Standards: Writing Literacy in Historical/Social Studies and Science and Technical Subjects (WHST): 2, 4, 9

Gills gone visionary

Comprehend

After reading the article "Gills gone visionary," answer these questions:

1. Why is the organism in the story called a "Christmas tree" worm?
2. The eyes of Christmas tree worms are beneath their branching gills. Why is that limiting?

Analyze

3. Why does Michael Bok call the eyes "their own evolutionary tangent"?
4. There are a great variety of eyes across the animal kingdom. What makes the eyes similar? What makes them different?
5. The eyes of Christmas tree worms have followed an evolutionary path different from the eyes of most other worms, yet the eyes still serve the purpose of seeing. Can you think of other examples of independent evolutionary paths producing similar results?

Gills gone visionary

Answer key

Comprehend

1. **Why is the organism in the story called a “Christmas tree” worm?** *The marine worm gets its nickname from its gills, which look like trees because of their feathery and tapering branches. They also come in bright colors, which adds to the holiday appearance.*
2. **The eyes of Christmas tree worms are beneath their branching gills. Why is that limiting?** *In this tucked-under position, the eyes can only see directly in front or behind and do not have a wider view of the surrounding environment. They can’t see predators approaching from the side, for example.*

Analyze

3. **Why does Michael Bok call the eyes “their own evolutionary tangent”?** *The eyes are called an “evolutionary tangent” because they evolved from features that ended up having other functions in other animals. The eyes of Christmas tree worms evolved from different features and headed in a different direction. The eyes use a light-detecting protein of the same big group that many other eyes use (the opsins), but the specific opsin that Christmas tree worms use is hardly ever found outside the brain. Also, the nerves from the Christmas tree worm’s eyes don’t go to the optic lobe of the brain the way eyes typically do. Instead they go to a different, and still largely mysterious, part of the animal’s brain.*
4. **There are a great variety of eyes across the animal kingdom. What makes the eyes similar? What makes them different?** *Answers will vary, but students should explain that eyes, in general, are light sensors. But there are many differences: Eyes can be basic or advanced, simple or compound. They can simply detect light or shadow, or they can create a full and colorful view of a 3-D world, as human eyes do. They can be located in different places, on the front of the head or the side, or in the gills in the case of Christmas tree worms. They can be different shapes and colors and sizes. They can depend on different proteins.*
5. **The eyes of Christmas tree worms have followed an evolutionary path different from the eyes of most other worms, yet the eyes still serve the purpose of seeing. Can you think of other examples of independent evolutionary paths producing similar results?** *Answers will vary, but students should come up with examples of analogous structures or characteristics: the wings of birds, insects and bats, for example, the flippers of dolphins and fins of fish. Bats and dolphins both detect objects through echolocation. Vampire bats and bedbugs both survive on diets of blood. Hummingbirds and many butterflies share long narrow tongues that reach into flowers and extract nectar.*

Human body not overrun by bacteria

Comprehend

After reading the article "Human body not overrun by bacteria," answer these questions:

1. What is the microbiome?
2. What is the "fake fact" questioned by the calculation described in the article?
3. Why, according to the story, might women have a higher bacterial-to-human cell ratio than men?
4. What part of the human microbiome does this study leave out?

Analyze

5. Based on the story and your existing knowledge, why might it be hard to come up with a good estimate for the ratio of bacterial to human cells in the body?
6. If the "standard man" weighing 70 kilograms has 30 trillion human cells, how many do you think you have? Use facts from the story and existing knowledge to justify your answer.
7. Why is it interesting to know the ratio of bacterial to human cells in the body?

Human body not overrun by bacteria

Answer key

Comprehend

1. **What is the microbiome?** *The microbiome is the collection of microorganisms that live in and on the human body.*
2. **What is the “fake fact” questioned by the calculation described in the article?** *Previously scientists had suggested that the ratio of bacterial cells to human cells in the human body is 10 to 1. But this estimate likely made its way into the literature because it is surprising and easy to remember.*
3. **Why, according to the story, might women have a higher bacterial-to-human cell ratio than men?** *Women might have higher bacterial-to-human cell ratio because women have a smaller blood volume than men. Since red blood cells make up a majority of human cells, people with smaller blood volume would have fewer human cells.*
4. **What part of the human microbiome does this study leave out?** *The study considers only bacteria and does not look at viruses, fungi, archaea and other microbes.*

Analyze

5. **Based on the story and your existing knowledge, why might it be hard to come up with a good estimate for the ratio of bacterial to human cells in the body?** *It would be exceedingly difficult to attempt to count all of a person's cells. They can be very small, you can't see them all at the same time and there are a huge number. Because of these facts, researchers rely on estimates. But cells come in different sizes, so estimating by volume is not entirely reliable. Also, the number of cells of both human and bacterial origin will vary depending on the individual and will also vary over time. Bacterial cell counts can vary depending on whether a person has taken antibiotics, used antibacterial soaps, brushed their teeth recently, ate yogurt or even played outside sometime today.*
6. **If the “standard man” weighing 70 kilograms has 30 trillion human cells, how many do you think you have? Use facts from the story and existing knowledge to justify your answer.** *Answers will vary depending on the student, but students should consider their own weight and sex in the calculation they come up with.*
7. **Why is it interesting to know the ratio of bacterial to human cells in the body?** *Knowing that bacteria make up so much of our body helps us think about these organisms in a new way, perhaps with more respect. It also helps us see our bodies as a changing and evolving ecosystem. Also, scientists are coming to appreciate more fully the role that bacteria play in health and disease. Some diseases are thought to be caused by an overgrowth of bacteria, but no one really knows if the number people carry is important. Knowing how many bacteria cells we have and what type will help scientists understand the role of the microbiome in factors like human development, immunity and nutrition.*

Mystery hominid settled Sulawesi

Comprehend

After reading the article "Mystery hominid settled Sulawesi," answer these questions:

1. What did researchers find on the island of Sulawesi?
2. Why is the finding surprising?
3. Who might have made these tools?
4. What ideas do scientists have for how the toolmakers arrived at Sulawesi?

Analyze

5. How do these findings expand our understanding of human evolution and distribution?
6. What new evidence might scientists look for to find out more about human evolution in this region?

Mystery hominid settled Sulawesi

Answer key

Comprehend

1. **What did researchers find on the island of Sulawesi?** *Stone tools.*
2. **Why is the finding surprising?** *The stone tools date to at least 194,000 years ago, long before any toolmakers were thought to have arrived on the island.*
3. **Who might have made these tools?** *Scientists don't know, but they have some hypotheses including Homo floresiensis (also known as hobbits), Denisovans, Homo sapiens or Homo erectus.*
4. **What ideas do scientists have for how the toolmakers arrived at Sulawesi?** *Ancient human relatives might have walked from nearby Java when sea levels were lower, or storms might have carried castaways to the island.*

Analyze

5. **How do these findings expand our understanding of human evolution and distribution?** *The findings expand the known range of ancient human relatives for the time period beginning around 194,000 years ago. Depending on who made these tools, the findings also provide new clues about who was using stone tools, often considered an early marker of intelligence, at this time. The findings add to our understanding of the diversity of hominids present before Homo sapiens evolved, and thus helps us understand how modern humans fit into the bigger picture of hominid evolution. Some students might point out that the finding itself is just one piece in a larger puzzle that will come together over decades, perhaps even centuries.*
6. **What new evidence might scientists look for to find out more about human evolution in this region?** *Scientists would like to find evidence of the ancient human relatives themselves — in the form of bones such as skulls, for example. This evidence might offer some clues to who these hominids were and where they came from. Bones that carry DNA evidence would be especially exciting, though they are unlikely because fossils in tropical areas rarely contain enough preserved DNA for study. Scientists might compare the tools discovered on Sulawesi with tools discovered elsewhere in Asia to try to match the styles and pinpoint the toolmakers. Additional evidence might come in the form of animal bones with gashes or scrapes from hominid tools.*

Red giants map how Milky Way grew

Comprehend

After reading the article "Red giants map how Milky Way grew," answer these questions:

1. What is a red giant?
2. What process allowed scientists to calculate the masses of 70,000 red giants?
3. What new development might help scientists study even more red giants?

Analyze

4. Why do scientists want to know the ages and masses of red giants?
5. Mario Pasquato says the study described was "a galactic archaeology project." In what ways is the study similar to doing archaeology?
6. The ages calculated in the article are accurate to within 40 percent. Is that a good level of accuracy? Why or why not? What factors might have contributed to this uncertainty?

Red giants map how Milky Way grew

Answer key

Comprehend

1. **What is a red giant?** *A bright star that started out like the sun but exhausted all of its hydrogen fuel.*
2. **What process allowed scientists to calculate the masses of 70,000 red giants?** *Using known mass measurements from the Kepler space telescope, scientists taught a computer program to learn how the intensity of light emitted at different wavelengths varies with a red giant's mass. Then the scientists fed the light emitted for red giants measured with the Sloan Digital Sky Survey into the same program to determine their masses.*
3. **What new development might help scientists study even more red giants?** *A new Sloan telescope in Chile will offer scientists a view of the Southern Hemisphere skies.*

Analyze

4. **Why do scientists want to know the ages of red giants?** *Age is very helpful because it tells you when the stars formed. If you learn the ages of many stars, then you can figure out what parts of the galaxy are very old and what parts are younger. From there, you can develop theories about how galaxies evolve and better understand the universe as a whole.*
5. **Mario Pasquato says the study described was "a galactic archaeology project." In what ways is the study similar to doing archaeology?** *Archaeology involves digging up physical clues that provide information about how people lived in the past. In this case, astronomers are using thousands of stars as their artifacts for understanding what the galaxy was like in the past and how it changed over time into what it looks like today.*
6. **The ages calculated in the article are accurate to within 40 percent. Is that a good level of accuracy? Why or why not? What factors might have contributed to this uncertainty?** *Answers will vary. Students might point out that this is a high error range for a scientific study and wouldn't be acceptable in the medical sciences, for example. Others might argue that because this is a first approximation, it is better than having no information and can give scientists a rough starting point to dig deeper into the numbers. The answer matters less than the argument supporting the answer. As for the factors contributing to the uncertainty: The telescope that identified all these stars was conducting a survey. In a survey, scientists care more about finding a lot of stars than studying stars one by one in close detail. That means individual measurements may be a little off, which would skew the age estimate. And even though the mass and age of red giants are related, every star is different, so the conversion isn't perfect.*

GMOs under scrutiny

Comprehend

After reading the article "GMOs under scrutiny," answer these questions:

1. What are the two prevailing narratives concerning genetically modified foods?
2. Why, according to article, are these two broad narratives problematic?
3. Why have scientific bodies concluded that eating GM foods is no riskier than eating non-GM foods?
4. What effect have glyphosate-tolerant GM crops had on farming?

Analyze

5. Why does Matin Qaim keep quiet about his research in casual conversations?
6. What is the "herbicide treadmill"?
7. What hurdles must GMOs overcome to achieve broader public acceptance?

Answer key

Comprehend

1. **What are the two prevailing narratives concerning genetically modified foods?** *People opposed to GMOs often argue that these “Franken” organisms are a new technology with unknowable dangers, while proponents argue that GMOs are harmless and needed to alleviate global hunger and boost nutrition in a changing world.*
2. **Why, according to article, are these two broad narratives problematic?** *GMO is a catchall term that encompasses a lot of different products, with different makers, different production techniques and different risks and benefits.*
3. **Why have scientific bodies concluded that eating GM foods is no riskier than eating non-GM foods?** *GM foods (or products that end up in foods) undergo testing to see how they compare with other foods. They are tested to see if the protein produced by the introduced genetic material is structurally similar to other toxic proteins or known allergens. They are studied for how they will fare in the body. So far, the track record for GM foods is clean.*
4. **What effect have glyphosate-tolerant GM crops had on farming?** *With the introduction of glyphosate-tolerant GM crops, farmers have used more of the herbicide and used it more freely.*

Analyze

5. **Why does Matin Qaim keep quiet about his research in casual conversations?** *The use of GMOs is a very contentious issue that people are very passionate about, sometimes to the point of annoying and harassing phone calls. Qaim avoids talking about his research because most people don't recognize the nuance involved, and bringing it up leads to heated debates.*
6. **What is the “herbicide treadmill”?** *As herbicide-resistant GM plants are introduced, farmers use herbicides more freely, to kill the other weeds growing near these plants. But more herbicide use results in more herbicide resistance among the plants, which means the scientists have to use more herbicide. This cycle continues so farmers have to keep using more and more herbicides, in a race against the weeds. This race against resistance can also occur with non-GM plants.*
7. **What hurdles must GMOs overcome to achieve broader public acceptance?** *Answers will vary, but students should note that scientific evidence is not always enough to convince the public. GMOs will not only have to show that their benefits outweigh their risks, but also overcome a great deal of fear and misinformation.*

Discuss

After students read the article independently, lead a class discussion that further underscores your current curriculum. Ideas for discussion topics include:

1. Humans have been manipulating plants for centuries, from traditional crossbreeding experiments to create tasty and durable fruits and vegetables, to exposing seeds to radiation or chemicals to generate desirable mutants. Is the genetic manipulation seen today different? Why or why not? (*Students might draw on the "How?" column in the "Plant modification throughout history" chart on Page 23 of the story. In more traditional breeding, selection of desirable traits happened indirectly. Usually scientists were working with two closely related species. Often they could not isolate a specific gene. Today, the two organisms don't have to be as closely related. And scientists can turn on or off specific genes more directly, or introduce a specific gene while leaving the others unaffected.*) Encourage students to think about how issues of scale and ease might affect how people perceive a new technological process. Is today's manipulation scarier because it is more direct? Because it is faster? More efficient? Or, does the current controversy over GMOs have more to do with cultural forces? What other factors influence how the wider public perceives a technology? Can students think of other technologies facing a similar controversy? (*One interesting example is the use of drones. Students might also talk about the risks and benefits of screen time. Many might be familiar with controversy surrounding drugs for cognitive enhancement.*)
2. Any choices we make in our personal lives, or as a society, come with potential risks and potential benefits. Ask students whether they consider themselves risk averse or more daring? Ask them to defend their answer, and explore the origins and consequences of that trait. Why do they think they are more or less willing to take risks than their peers? Is it innate, driven by their upbringing, driven by experience or some combination of all these factors? Does their willingness to take risks depend on the situation? Can they think of any specific situation where they had to decide between a risky path with a lot of potential benefits versus a safer path that promised fewer rewards? How did they make the decision? How did it turn out? Ask them to apply this experience to GM foods. They can do additional research and then evaluate the potential risks and benefits of a specific GM product of their choosing — golden rice, for example, or drought-resistant peanuts.
3. Put yourselves in the shoes of a food and drug regulator. What kind of questions would you ask about a new product — genetically modified or not — before you give it approval? What kind of tests would you want to conduct? What experts would you reach out to? What research would you do? Students might also consider what kind of checklist or metrics they might incorporate to track their findings and defend their decisions. Would the approval process be objective, relying solely on a numerical score, or would there be room for subjectivity? If subjective, how would they avoid issues like bias and bribery? What loopholes might exist and how would they close them? What affect might their approach have on innovation in the food and drug industry?