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To accompany the peer-reviewed introductory article by N. Chandra Wickramasinghe, Sc.D.:

“Life from Space: An Emerging Paradigm” (May 2001)

www.actionbioscience.org/newfrontiers/wickramasinghe/article.html

and the peer-reviewed paper by N.C. Wickramasinghe, Sc.D. and Fred Hoyle, Ph.D.:

“Evolution of Life: A Cosmic Perspective” (May 2001)

www.actionbioscience.org/newfrontiers/wickramasinghe/wick_hoyle.html

with **counterpoint commentary** by Max Bernstein, Ph.D. (May 2001):

www.actionbioscience.org/newfrontiers/wickramasinghe/review.html

Panspermia: Did Life Arrive from Space? (Oct. 2002)

Lesson by **R. Brian Watts**, Ph.D., Professor, Dept. of Biology & Chemistry, CEGEP De La Gaspésie et Des Îles, Gaspé, QC, CAN

Educator's section: <i>p. 1-3</i>
Student handout 1: <i>p. 4</i>
Student handout 2: <i>p. 5-6</i>

Grades & Levels:

- **Handout 1:** high school (general)
- **Handout 2:** high school (AP/advanced) - undergraduate (year 1-2)

Time Recommendations:

- **Handout 1:** 2-3 days
- **Handout 2:** 2 class periods and up to a week for assignments

NSES (USA) Content Standards, 9-12:

- 3.3. Physical Science: chemical reactions
- 4.3. Life Science: biological evolution
- 5.3. Earth & Space Science: origin and evolution of the earth system

Note: View the NSES content standards on this site to choose other curricular applications for additional activities at: <http://www.actionbioscience.org/educators/correlationcharts.html>

Learning Objectives: Students will ...

- outline the Panspermia/Cosmic Ancestry hypothesis as proposed by Wickramasinghe & Hoyle
- summarize the evidence in support of this hypothesis and the main criticisms of it
- explain what would be needed for the hypothesis to be accepted by scientists
- compare this hypothesis to others on the origins of life on Earth
- examine how scientists propose hypotheses

Key Words Include: alien, anaerobic bacteria, astrobiology, astronomy, chemicals, comets, cosmic, exobiology, extremophiles, interstellar, meteorite, microbial, microorganisms, NASA, panspermia, paradigm, paradigm shift, primordial pond/primeval soup, striations, terrestrial/extraterrestrial

Preparation

Article Discussion:

- It is recommended that this lesson be conducted after students have studied the more widely accepted hypotheses about origins of life on Earth, such as the primordial soup model.
- For high school (general): have students read the introductory article by Wickramasinghe.
- For high school (AP/advanced) - undergraduate (year 1-2): have students read both the introductory article and the Wickramasinghe/Hoyle paper, along with the commentary by Bernstein.
- Answer the applicable questions listed in the “Article Discussion” section on pages 2 and 3.

Student Handouts: Students should begin Internet research with the links that follow the introductory article. These links are found in the “learn more” section and in *useful links* in the “educator resources” section at the end of the article. A literature reference list is also provided in Handout 2.

Author’s Disclaimer: *The author of this lesson neither supports nor rejects the Panspermia/Cosmic Ancestry of life hypothesis proposed by Drs. Wickramasinghe and Hoyle. He has prepared this lesson so students may learn more about the value of hypotheses and scientific peer review as a crucial part of the scientific process.*

For Educators: Article Discussion

The following questions are based on the article “**Life from Space: An Emerging Paradigm**” by N. Chandra Wickramasinghe at www.actionbioscience.org/newfrontiers/wickramasinghe/article.html

1. According to Wickramasinghe, why does the scientific community resist the “theory” that life did not originate on Earth, but arrived here from space. (Give two reasons.)
2. Why did Wickramasinghe and Hoyle believe it improbable that life had arisen on the primitive Earth? (Give three reasons.)
3. What discovery “enriched the hypothesis” for Wickramasinghe?
4. Summarize the crucial five points of the Wickramasinghe and Hoyle hypothesis that emerged by the 1980s.
5. What does Wickramasinghe think could happen if life continues to arrive on Earth from space?
6. What announcement from NASA scientists in 1996 seemed to support Wickramasinghe’s hypothesis?
7. List two research efforts now (or soon to be) underway to investigate or to search for evidence of life in space.
8. List three profound implications that the discovery of life existing outside the solar system would have for the future of the human race.
9. How does the Panspermia/Cosmic Ancestry model compare to other hypotheses you’ve studied about origins of life on Earth?
10. Do you think scientists will ever actually determine the origin of life on Earth? Why or why not?
11. Should scientists even attempt to answer such questions as “How did life come to exist on Earth?” Why or why not?
12. What is Astrobiology? In what ways does this field present new challenges to science?

Article Discussion (cont'd)

The following questions are based on the paper “**Evolution of Life: A Cosmic Perspective**” by N. Chandra Wickramasinghe and Fred Hoyle at www.actionbioscience.org/newfrontiers/wickramasinghe/wick_hoyle.html and the accompanying commentary “**Counterpoint Commentary on the Original Paper -- Evolution Of Life: A Cosmic Perspective by N. Chandra Wickramasinghe and Fred Hoyle**” by Max Bernstein at www.actionbioscience.org/newfrontiers/wickramasinghe/review.html

1. What is *panspermia*? Why is panspermia not really a new idea? Give two examples from the history of science that illustrate or hint that panspermia may be a possible explanation for the origin of life.
2. Build a case based on Wickramasinghe and Hoyle’s explanation for the possibility that life arrived on Earth as microorganisms from space.
3. Why do Wickramasinghe and Hoyle believe that cosmic dust provides evidence for their hypothesis?
4. What was their crucial insight? What other evidence do they see as supporting this insight?
5. What astronomical bodies do Wickramasinghe and Hoyle believe are the source of the “biological particles in interstellar space”? Why? How could these particular astronomical bodies act as both interstellar bacterial incubators and delivery systems of these microbes to newly-formed planets similar to early Earth?
6. Explain why meteorite ALH84001 was initially thought to contain evidence of microbial life from Mars. What would the implications be to the Panspermia/Cosmic Ancestry hypothesis? Are there other cases of meteorites in which evidence occurs for extraterrestrial life? Outline one such case.
7. Is planetary panspermia within the solar system plausible? What do Wickramasinghe and Hoyle believe to be “a stronger process” in transferring life within the solar system?
8. What is the argument that Wickramasinghe and Hoyle use, involving probabilities, to discredit what they call the “warm little pond paradigm”? What do they mean by the “warm little pond paradigm”?
9. What property of the universe is crucial to their hypothesis on the interstellar origin of life and cosmic panspermia? What sort of evidence would be required to confirm this? (Suggest two sorts of evidence.)
10. Why does Bernstein say that Wickramasinghe and Hoyle cannot dismiss the origin of life from non-living matter at some time, somewhere in the universe? Do they?
11. Why does Bernstein believe that Wickramasinghe and Hoyle have not convincingly shown that the extreme hardiness of bacteria is “unworldly”? Explain briefly with one example.
12. Why does Bernstein conclude that other explanations than interstellar bacterial degradation for the origin of widespread organic molecules in space provide a better explanation than that of Wickramasinghe and Hoyle? (He cites three reasons.)
13. What fundamental feature of early Earth’s molecular world does Bernstein suggest would make Wickramasinghe and Hoyle’s probability calculations regarding enzymes irrelevant? Why?
14. Why does Bernstein conclude that the Wickramasinghe and Hoyle hypothesis is equivalent to creationism? What does he mean? Is he criticizing the *scientific* validity of Wickramasinghe and Hoyle’s idea? How? Does this necessarily mean that Wickramasinghe and Hoyle’s idea is wrong?

Extension Questions:

1. What would be required for a wider scientific acceptance of Cosmic Ancestry? (Suggest three factors.)
2. What role does the proposal and publication of scientific ideas, such as the “Cosmic Ancestry of life”, that do not conform to more widely-accepted hypotheses play in science?
3. Is the fact that www.actionbioscience.org provides both viewpoints on this issue on its website an example of good scientific procedure? Why or why not?

Panspermia: Did Life Arrive from Space?

Student Handout 1

Is It Scientific?

You are called upon to explain at a scientific meeting why your research interests include panspermia. Make notes for your presentation, covering these points in your explanation:

- What is the “scientific method”? Make a checklist of the steps in the scientific method.
- What is a hypothesis? Write its definition and compare it to a theory.
- What role does the proposal and publication of scientific ideas, such as the “Cosmic Ancestry of life,” that do not conform to widely-accepted hypotheses play in science?

Careers in Space

Write a job description for a space exploration agency seeking:

- an astrobiologist
- an exobiologist

Explain also the goals of the company and its exploration mission.

Illustrated Glossary of Space Biology

Create an illustrated glossary that explains the following terms and their relevance to space exploration:

- Biomarkers
- Biofilms
- Microfossils
- Biogenic elements
- Extremophiles

Add any other terms that may be of interest.

Mars Meteorites

Scientists have discovered a good number of meteorites on Earth that came from Mars. Impress your audience at a rock fair with your knowledge of Mars rocks. Prepare a visual presentation that describes:

- the physical characteristics of the Martian rocks
- the composition of these rocks
- any microfossils or other biogenic material found in the rocks

Origins Survey

With a partner, prepare a questionnaire to find out which origins hypothesis other students favor. Research various hypotheses and provide a brief explanation of each. In your list of hypotheses, include Panspermia/Cosmic Ancestry and hypotheses related to primordial pond/primeval soup. Conduct the questionnaire during or after class. If anyone asks, explain that there are many hypothesis on the subject but no theory as yet, so several options are possible (some more than others) as long as they adhere to the scientific method of inquiry. Present your findings to the whole class.

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Student Handout 2

1. What If? Scenarios

Work in teams of 2 to 4 individuals and consider scenario A or B. After reading it, list the issues involved. Discuss the issues and, after discussion, suggest a resolution or solution.

Scenario A: *It is 2061 and you are a crew member on the United Nations Explorer space ship on the way to rendezvous with Halley's Comet as it returns to the inner solar system. As your ship approaches the comet nucleus near Mars' orbit, you launch a probe which lands on the surface of the comet. While there, it drills into the icy core of this "dirty snowball" retrieving a sample which is returned to the ship two days later. You and your crewmates then begin the eight-month voyage back to Earth's orbit. During the trip home, scientists working in the ship's lab discover microscopic structures in the samples which look something like bacteria.*

The lab spokesperson:

Propose how you would determine

1. that these are actually living bacteria, and
2. they are not from Earth, but are truly "extraterrestrial" or even "interstellar"

The lead scientist:

Prepare an illustrated presentation to convince a panel of Earth-bound experts of the findings and conclusions.

The mission's scientific writer:

Prepare an article on the discovery explaining just how it was determined that these were actually living extraterrestrial bacteria. Put this in the form required for publication in a relevant scientific journal of your choosing. You will need to check the journal's format requirements.

Scenario B: *Your team receives an invitation from the editor of a prestigious science journal to peer review an article submitted for publication. The article reports the discovery of extra-terrestrial microbial life on Mars after a team of scientists at NASA has tested samples of Martian soil returned by the first team of astronauts sent to Mars to collect samples in the year 2035.*

Write a report or critical commentary to explain your answers to the following questions:

- What criteria would you use to evaluate the article for publication?
- How would you expect the authors of the article to test the Martian soil samples for life?
- What supporting data and evidence would you require in the article?

2. Debate *Whether or not life is of cosmic origin*

Two teams of two students each should prepare arguments for and against the Panspermia/Cosmic Ancestry of life hypothesis. You may prepare slides, posters, or other visual aids. Present the debate in class at a time determined by your professor.

3. Interview *What a scientist thinks about the Panspermia/Cosmic Ancestry hypothesis*

Arrange to interview a scientist or someone with some knowledge of the topic, who supports or disputes the Panspermia/Cosmic Ancestry of life hypothesis. Prepare a videotape, audiotape, or "news" article based on the interview.

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Student Handout 2 (*cont'd*)

4. Survey/Opinion Poll *What do people think is the likely explanation for the origin of life on Earth?*

With a partner, prepare a questionnaire to find out which origins hypothesis other students or the general public favor. Research various hypotheses and provide a brief explanation of each. In your list of hypotheses, include Panspermia/Cosmic Ancestry and hypotheses related to primordial pond/primeval soup. If anyone asks, explain that there are many hypotheses on the subject but no theory as yet, so several options are possible (some more than others) as long as they adhere to the scientific method of inquiry. Report your findings.

5. Internet/Library Research *Is the Panspermia/Cosmic Ancestry hypothesis “good science”?*

Prepare a presentation based on Internet and/or library research to determine why or why not the Panspermia/Cosmic Ancestry of life hypothesis may or may not be considered “good science.” If the research or analysis shows that it lacks scientific credibility, then indicate what would be required for it to gain that status. If it should be considered “good science,” explain what makes it credible.

Research sources are provided in the “learn more” section and in *useful links* in the “educator resources” section at the end of www.actionbioscience.org/newfrontiers/wickramasinghe/article.html. Also, see the article and paper references provided online by the authors. The following list of books and articles is by no means complete but can also assist you in finding background information or research ideas.

- Aczel, Amir D., 1998. *Probability 1: Why There Must Be Intelligent Life in the Universe*, Harcourt Brace & Company, New York, NY, USA, 230 pp. [ISBN: 0-15-100376-9]
Aczel strongly supports the speculative hypothesis of alien intelligence and provides, in Chapter 5, a summary of the Panspermia hypothesis, including an analysis Carl Sagan’s version of it.
- Davies, Paul, 1999. *The Fifth Miracle: The Search For The Origin And Meaning Of Life*, Simon & Schuster, New York, NY, USA, 304 pp. [ISBN: 0-684-83799-4]
The physicist illustrates that life may have had its origins deep within the crust of the Earth and not in “some warm little pond.” But his chapter 8 deals with the possibility of origin of life on Mars.
- Fortey, Richard, 1997. *Life: A Natural History of the First Four Billion Years of Life on Earth*, Alfred A. Knopf, New York, NY, USA, 357 pp. [ISBN: 0-965-034097]
A thorough account of the history of life on this planet as mainstream biological science now understands it.
- Irion, Robert, 2001. “Did Life on Earth Come from Mars?” *Discover Magazine* 22(8):64-69. (August 2001 issue). [ISSN : 0274-7529] See also the *Discover* web site.
The article recounts development and evidence for panspermia of life on Earth from Mars. Interesting illustrations are presented which summarize the main ideas of the article.
- Irion, Robert, 2002. “Like Alaska, Like Europa,” *Discover Magazine* 23(5):34-41. (May 2002 issue). [ISSN : 0274-7529] See also the *Discover* web site.
An examination of hardy bacteria found in Alaska sea ice and the implications this may have to the possibility of life existing on Europa and to our understanding of the origins of life in the solar system.
- Kaufman, Stuart, 1995. *At Home In The Universe: The Search for the Laws of Self-Organization and Complexity*, Oxford University Press, Oxford & New York, NY, 322 pp. [ISBN: 0-19-509599-5]
The author proposes that natural selection operates along with a tendency of matter to self-organize in arrangements of increasing complexity. Chapter 2 discusses the origins of life, including Wickramasinghe & Hoyle’s calculations of the low probability of assembling functional enzymatic proteins by a random process.