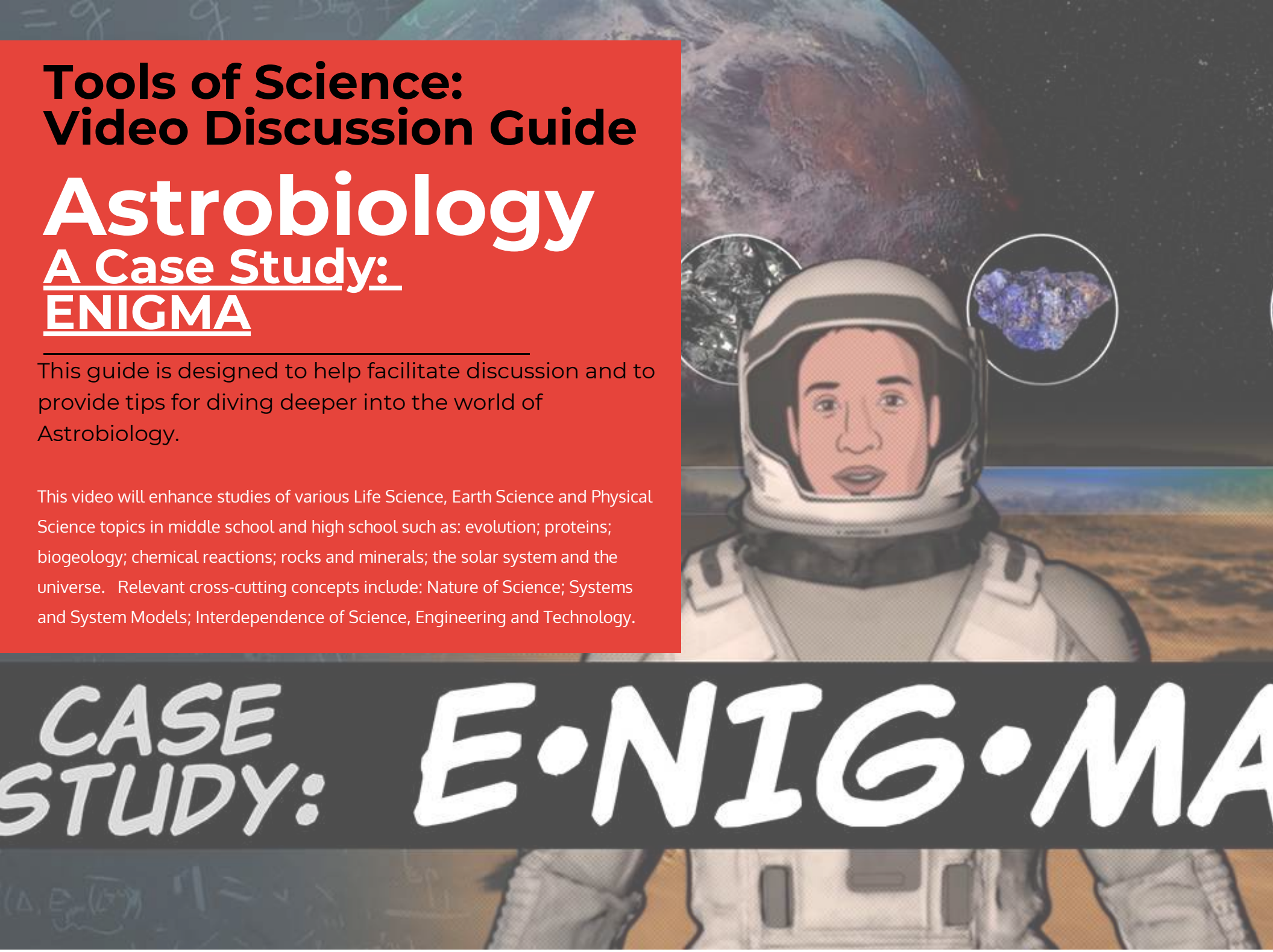
Tools of Science: Video Discussion Guide

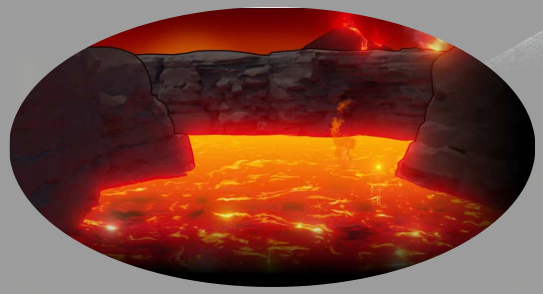
Astrobiology

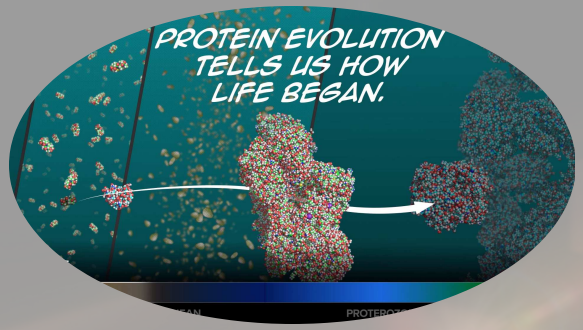
A Case Study: ENIGMA

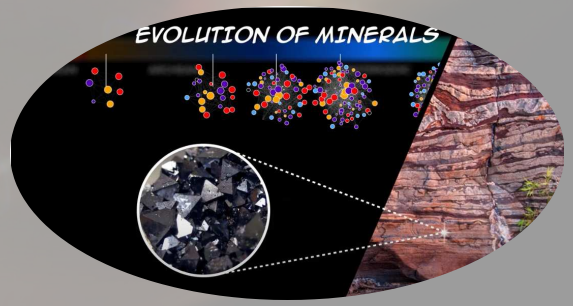
This guide is designed to help facilitate discussion and to provide tips for diving deeper into the world of Astrobiology.

This video will enhance studies of various Life Science, Earth Science and Physical Science topics in middle school and high school such as: evolution; proteins; biogeology; chemical reactions; rocks and minerals; the solar system and the universe. Relevant cross-cutting concepts include: Nature of Science; Systems and System Models; Interdependence of Science, Engineering and Technology.









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How do I use this guide?

Learn about the exciting astrobiology research being conducted by the ENIGMA team, and see how an interdisciplinary team is using the tools of Testable Questions, Collaboration and Modeling to answer big questions about life's origins on Earth and in the universe.

This video will enhance studies of various Life Science, Earth Science and Physical Science topics in middle school and high school such as: evolution; proteins; biogeology; chemical reactions; rocks and minerals; the solar system and the universe. Relevant cross-cutting concepts include: Nature of Science; Systems and System Models; Interdependence of Science, Engineering and Technology.

This guide is designed to help facilitate discussion and to provide tips for diving deeper into the content. The video content is divided into four main segments: project introduction, proteins, rocks and the big picture. Time stamps are provided along with suggested discussion questions; these questions are mostly open-ended and focus on science process or reflection, rather than content.

Check out the other Tools of Science videos on our YouTube channel (relevant TOS videos are also linked in the discussion guide). To learn more about the ENIGMA team's research, please visit the project web site.

Introduction to ENIGMA:

In this section, meet the project team and their motivating questions.

The ENIGMA team's idea is that if we can find out how life started on Earth, we can figure out how life may have started on other planets and search for it. They are looking back in time (looking back in Earth's history) at the earliest proteins and rocks to find the answers. This interdisciplinary team is using three different approaches to the problem to generate a conclusion.

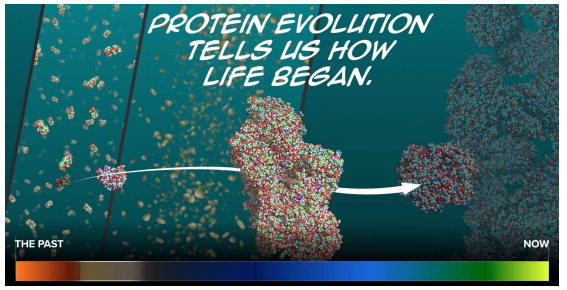
Watch ENIGMA

Time	Topic	Discussion Questions	Related Resources
0.16	Project Leader Dr. Paul Falkowski asks the "two big questions" - Are we alone? Where did we come from?	Do you think scientists can answer these questions? What are your thoughts as to whether or not life exists elsewhere in the universe?	View the TOS Video - Testable Questions and discuss the ENIGMA project big questions - are they testable? Watch TOS Video
0:30	ENIGMA Project Team Graphic: Scientists from different specialties are collaborating.	Are you surprised by the size of the team? What are the pros and cons of such a large team?	View the TOS Collaboration Video and discuss how the ENIGMA project team demonstrates this essential tool. Watch TOS video
1:25	Finding out how the ingredients for life turned into life on our planet can help us look for life on other planets.	What do you think of this strategy for finding life on other planets? Do you think that life on other planets is similar to life on Earth? What other planets do you think life could start on? What conditions do you think would have to be present?	Research the planetary objects depicted in the video and why life may exist there: Mars (planet), Trappist 1E; Keppler 1229B (exoplanets), and Europa; Enceladus (moons).
1:30	Team wants to understand how Earth chemistry turns into Earth biochemistry.	How do you know something is living? How is it different from things that are non-living?	Try a class activity about living vs. nonliving (many excellent lessons can be found online). Try this Activity
1:48	The three ENIGMA subteams are described in the context of two important facts: Earth is made of rocks, Life is made of proteins.	How do you think this interdisciplinary team structure might improve the scientific results?	View the TOS Collaboration Video and discuss how the ENIGMA project team demonstrates this essential tool. Watch TOS video

Proteins:

Begins at 2:05: In this section, meet the two Protein teams and learn how they are using different approaches to solve the same problem – figuring out the earliest proteins.

Every form of life on this planet, now and in the past, is made of proteins - but the proteins in bacteria, plants and animals are very different. In the past, there must have been smaller, simpler proteins that then evolved into larger, more complex proteins that make up modern life. Figuring out these early proteins can help us figure out how life began on Earth. The teams will both use computer modeling to figure out these early proteins and see if their results match. Then, they will work with the Rocks team to check their computer results against the Earth's geologic record.



Time	Topic	Discussion Questions	Related Resources
2:10	Proteins are the machines that run life; you are made of proteins.	Why do you think the ENIGMA team calls proteins "machines that run life"?	Look up the names of these proteins mentioned in the video: What breaks down food? What transports oxygen? What contracts muscles? What provides structure? Can you find other proteins and their functions in the human body? Upper-level students can research the source of energy in proteins (metals.)
2:50	These first simple universal proteins can be thought of as the "Legos® of life".	What makes Legos® a good model to use when describing proteins?	See how Legos® can be used to model other scientific concepts with a lesson from MIT's Edgerton Center. Link to Activity
3:45 – 4:30	Modern proteins are like completed Lego® sets but we can't see all the pieces. The two protein teams are using different strategies to figure out what the first proteins looked like – by trying to build the first protein (the "first Lego") or by trying to break down modern proteins (whole "Lego sets").	Which team would you like to be on and why? How do you think approaching this problem from two different angles will impact the validity of their findings?	Another type of scientific model is a mathematical model. View the TOS Modeling video and discuss the various types of scientific models. Watch TOS Video

Rocks:

Begins at 4:50: In this section, meet the Rocks team and learn how their work connects with the Protein teams.

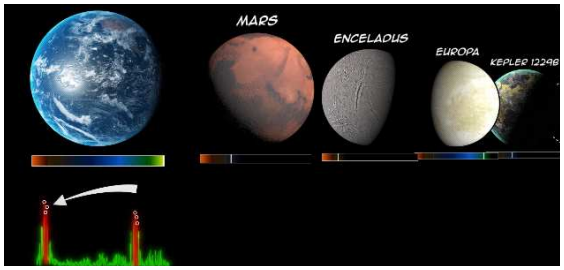
The Rocks team has developed a way to map the evolution of minerals over time. All minerals record the conditions under which they form. Certain minerals only exist because living organisms created the conditions necessary for them to form. The Rocks team will use this interrelation between rocks and life to create a timeline that connects the history of rocks with the history of life and proteins.

Time	Topic	Discussion Questions	Related Resources
5:06	Minerals capture information; they record the conditions in which they formed and that may include biological information.	If minerals and rocks are recorders of information – do you have any ideas of what information they might capture - and how they might capture it?	Research these examples and what they record; can you find others? Amber (insects; trapped bubbles of ancient air); Magnetite (magnetic field direction); and coal (plant fossils).
5:28	The chemical interaction between earth materials and life has caused many of the minerals you see today to form. Life influences the types of rocks and minerals that can form on our planet - and you won't see these minerals on planets that don't have life. Life has fundamentally changed the kinds of rocks and minerals on our planet.	What are some ways you can think of that life has changed the environment around it over time? (e.g., photosynthesis added oxygen to the atmosphere). What are some ways in which your biological processes change the environment around you each day?	Research these minerals and find out how life created conditions for them to form: Hematite, Magnetite, Azurite, Calcite. View the PBS NOVA program Life's Rocky Start featuring ENIGMA team member Robert Hazen. Upper level students can research mineral evolution. Watch PBS Video Research mineral evolution

The Bigger Picture:

Begins at 6:36: In this section, find out how the results of the ENIGMA team's research will help scientists explore the universe for evidence of life on other planets and moons.

For most of Earth's history, life was microscopic and chances are high that life on other planets may also be microscopic. While we can't easily detect microscopic life, we can detect minerals on other planets. If we understand which minerals need life in order to form, then we will know the "mineral signature" of life and we can look for these same minerals on other planets.



Time	Topic	Discussion Questions	Related Resources
6:50	We can see minerals from space. If we know how life changed rocks on the planet, then we can look for these mineral signatures of life on other planets.	What do you think about this strategy? What are some ways we might be able to find "hotspots" where life might be without physically travelling to other moons/planets? How do you think we can "see" minerals from space? What technology and tools are needed?	Research different remote sensing techniques and how they might be useful. Using spacecraft: Saturn's moon Enceladus and using telescopes, satellites: Using Light to Study Planets Research Enceladus Research Light to Study Plants
7:18	Sending the Perseverance Rover to land in Jezero Crater on Mars.	What are some reasons you can think of why scientists picked this place on Mars to explore?	Research Jezero Crater, its history, and why scientists think it could have sustained life (also discussed here.) View the TOS Sampling video. Research Jezero Crater Watch TOS Video
7:52	We now have tools and technology to answer the question of whether there was life somewhere besides Earth.	"We've changed from science fiction to hard core real science" – team member Nathan Yee. What is science fiction compared with science? How do you tell the difference?	View this recording of ENIGMA scientists talking with students about their research and exploring Mars. Watch Scientist Video

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Evolution of Nanomachines In Geospheres and Microbial Ancestors
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