Environmental Science Institute
THE UNIVERSITY OF TEXAS AT AUSTIN

1 University Station C9000
Austin, TX 78712
(512) 471-5847
www.esi.utexas.edu

Engineering Life: Organic Connections between Science Fiction and Real Biomedical Research

Lesson plan for grades 9-11
Length of lesson: 1-2 Class Periods, depending on activities undertaken
Authored by: Geoff Hensgen (Overall Lesson Plan) York School District One (Worksheet)

SOURCES AND RESOURCES:

- Hot Science Cool Talks Lecture: "Diagnosing Ourselves: Take Two Assays and Don't Call Me in the Morning" by Dr. Andrew Ellington, April 4, 2013: http://www.esi.utexas.edu/k-12-a-the-community/hot-science-cool-talks/diagnosing-ourselves-biotechnology-in-your-back-pocket
- Exercise comparing Organic vs. Inorganic molecules: York School District One: (http://www.york.k12.sc.us/)
  Source worksheet:
  http://www.york.k12.sc.us/files/u79/3_2_Inorganic_Vs_Organic_A_Worksheet.pdf

POTENTIAL CONCEPTS TEKS ADDRESSED THROUGH THIS LESSON:

Biology Grades 9, 10, or 11
§112.34. (c) (9) (A) (D)

PERFORMANCE OBJECTIVES:

Students will be able to:

- Articulate meaningful differences between the sources of organic and inorganic compounds
- Describe and distinguish between common features of molecules that make up organic compounds
- Describe the four main classes of biochemical molecules
- Describe real-world examples of how biomedical research is undertaken to engineer and detect biochemical molecules

MATERIALS (per group of four):

- Engineering Life PowerPoint Slides (LOCATED AT THE END OF THIS FILE)
- York School District One Organic vs. Inorganic Worksheet (LOCATED AT THE END OF THIS FILE)
- Prentice Hall Molecular Model Set for General and Organic Chemistry ($80) – one per student group: http://www.pearsonhighered.com/educator/product/Prentice-Hall-Molecular-Model-Set-for-General-and-Organic-Chemistry/9780139554445.page

CONCEPTS:

Organic matter is composed of compounds that have *come from (or make up) living things* such as animals and plants. *They include carbon atoms*, and can be molecules that make up gases, liquids, or solids.

Environmental Science Institute
THE UNIVERSITY OF TEXAS AT AUSTIN

1 University Station C9000
Austin, TX 78712
(512) 471-5847
www.esi.utexas.edu

Inorganic matter is made of compounds that *lack carbon and hydrogen atoms*. They are often viewed as being synthesized by geological systems (not biological systems).

Molecules are made up of two or more atoms held together by bonds. Molecules that make up organic compounds are typically more complex than ones that make up inorganic compounds. That is, they often have more atoms from different elements, and they can have more complex structures.

Biochemical Molecules are associated with chemical processes within, and relating to, living organisms. There are four classes of biochemical molecules: carbohydrates, lipids, proteins, and nucleic acids.

Carbohydrates are commonly referred to as a "sugar". They perform numerous roles in living organisms and serve for the storage of energy and as structural components in the bodies of many living things.

Lipids constitute a group of naturally occurring molecules such as fats, waxes, and fat-soluble vitamins

Proteins perform a vast array of functions within living organisms, including speeding metabolic reactions, replicating DNA, responding to stimuli, and transporting molecules from one location to another

Nucleic acids are the molecules that make up DNA, an extremely important substance that all cellular organisms use to store their genetic information.

Some organic molecules can have the same chemical formula, but differ in shape. Differences in molecular structure can fundamentally alter the function of a particular molecule in organic chemistry – this is essential to understanding organic chemistry, and why we have the diversity of molecules supporting living things!

BACKGROUND:

This lesson has two goals: 1) provide students a working knowledge of the difference between organic and inorganic matter, and 2) apply that knowledge to build an understanding of the main classes of biochemical molecules. These goals are pursued while providing students an appreciation for key advancements in scientists' ability to engineer and detect different biochemical molecules as seen in real life, and juxtaposed against science fiction.

Dr. Andy Ellington's 2013 Hot Science – Cool Talks lecture (see Sources and Resources) provided a real-life example of how scientists are performing remarkable engineering feats at the level of biochemical molecules. Among many things, Ellington's research lab works on creating biochemical molecules that perform specific functions, and detecting biochemical molecules. Popular science fiction movies such as Prometheus depict a future where humans discover that life on Earth was created by an ancient race of aliens who engineered humans. It is important, however, to point out to students that humans themselves are engineering molecules and technology that support living things in real life. Dr. Ellington's research provides many examples of this (see his Hot Science – Cool Talks lecture, linked in Sources and Resources). To develop a

1 University Station C9000
Austin, TX 78712
(512) 471-5847
www.esi.utexas.edu

working knowledge and appreciation of biomedical research, it is essential that students understand what biochemical molecules are, and be able to describe the differences between organic and inorganic compounds. This lesson enables high school teachers to provide their students a timely introduction to these concepts, and ties their application to both a popular science fiction movie, and real-life research in the Ellington Lab at the University of Texas.

PREPARATION:
Teachers should familiarize themselves with this lesson's Engineering Life PowerPoint slide deck, and the York School District worksheet for Organic and Inorganic Molecules (see Sources and Resources). Depending on the level of complexity desired for the lesson plan, teachers should also obtain one the Prentice Hall Molecular Model Set for each group of students that a teacher designates for the lab activity. The number of student groups depends on class size; we recommend groups consisting of 2-3 students. Teachers should have a projector screen and computer with a live internet connection ready in order to utilize the PowerPoint slide deck, as well as play the Prometheus Science Fiction Movie Trailer linked in the PowerPoint slide deck.

ENGAGE: (15 minutes)
The 2012 science fiction movie *Prometheus* is a popular and critically acclaimed prequel to the legendary science fiction classic *Alien* (1979), both of which were directed by Ridley Scott. Prometheus has stunning imagery and scenes that are likely to be remembered by high school students, or inspire them to see the film if they have not already done so. This lesson plan engages students by having student's watch the trailer, and provide an interesting quote from a specific movie scene to launch an active exploration of organic and inorganic molecules.

Teachers should first play the official *Prometheus* movie trailer on the class projector screen from a computer to capture students' attention. The trailer can be accessed via the hyperlink in the first slide of the Engineering Life PowerPoint slide deck (see Sources and Resources section), where the title of the lesson can also be presented to the class. Following the conclusion of the trailer, the teacher should immediately advance to the second slide, and explain to the class that a notable scene from the movie unfolds when an explorer witnesses black ooze emanating from mysterious vases housed within an alien facility on a distant planet. The explorer proclaims the substance to be "organic!"

As the slide shows, people who came into direct contact with the black ooze did not fare well!

Teacher Asks: How did the explorer know that the black ooze coming from the vase was organic?

Note to teachers: It is very important for teachers to allow an open discussion by students here. It is expected that most students do not know what the term "organic" means. Teachers should allow (or guide) student discussions to arrive at that question – it is an essential part of this lesson, and prerequisite for their ability to

1 University Station C9000
Austin, TX 78712
(512) 471-5847
www.esi.utexas.edu

understand the difference between organic and inorganic chemistry is, what biochemical molecules are, and the importance of biomedical research.

Teacher Asks (if students have not already done so):

- What does it mean when something is "organic"?
- What does it mean when something is "inorganic"?

Second Note to Teachers: It is equally important for teachers to understand that in real life, there is no established answer to the question of how the explorer arrived at the conclusion that the black ooze was organic! Although the substance looks like tar or oil (both of which are organic in origin), it would be unsafe and possibly inaccurate to assume that the black ooze was organic just by inspecting it visually or touching it.

The above point is essential to convey to the class; it is the springboard for the activity in the Explore section.

To identify a substance as either "organic" or "inorganic" we must know what these terms mean and be able to identify key characteristics within a substance's chemical formula or structure.

EXPLORE: (20 minutes)
The teacher should carefully present the next 8 slides, which give a progressive overview of:

1. What organic and inorganic molecules are
2. Their key distinguishing characteristics
3. An overview of what biochemical molecules are
4. The four major classes of biochemical molecules

Third Note to Teachers: *During the slide presentation, the teacher is encouraged to involve the class as much as possible.* Specifically, the teacher is encouraged to note the blue arrow in molecule diagrams that denotes the carbon atom (or lack thereof), which is an essential distinguishing characteristic of organic and inorganic molecules. Slide 11 reinforces this concept in the form of a classroom question.

At this point, the teacher should query students and check to see that they've absorbed three points:

1) Organic matter makes up (or comes from) living things, whereas inorganic matter does not
2) Organic compounds include carbon atoms, inorganic compounds do not
3) Inorganic compounds are generally produced by geological systems, and not biological ones

If students reflect this knowledge, they are ready to complete the Organic vs. Inorganic Worksheet, authored by York School District One (see Sources and Resources section).

1 University Station C9000
Austin, TX 78712
(512) 471-5847
www.esi.utexas.edu

EXPLAIN: (20 minutes)
The teacher should instruct students to carefully complete the worksheet, and answer the following questions in their own words on notebook paper, to be handed in to the teacher (NOTE: The answers are provided on the source worksheet PDF, which should ***not*** be handed out to students). The teacher should encourage students to pay particular attention to the chemical formulas, and not be intimidated by them; they hold the key to the exercise.

Questions:
1. What element all organic compounds have in common?

2. What is the most common use for most of the lightweight organic compounds?

3. Can you infer from their formulas which seem more complex, inorganic or organic compounds? Give some examples to defend your answer.

4. How does the composition of organic foods compare to the composition of organic fuels? Explain.

The teacher should ask students to hand in the answers to the worksheet (both the table and questions) to earn credit for the class assignment.

ELABORATE: (20 Minutes)
The teacher should hint to the class that the premise of the movie *Prometheus* is that a race of ancient aliens engineered life on earth (and specifically humans) from the molecular level (DNA). Slide 12 supports this point, and serves as a way to bring the class around to an interesting point: *Humans themselves are already engineering biochemical molecules! Concepts and ideas in Prometheus are already happening in some form out in the real world.*

A prime example of this is Dr. Andy Ellington's lab at The University of Texas. His lab engineers molecules supporting biomedical applications, and systems to detect the presence of certain biochemicals such as molecules from drug-resistant tuberculosis. PowerPoint slides 13-16 support the teacher's presentation of this information, and include a hyperlink to Dr. Ellington's lab webpage.

At this point the teacher should ask the class to break up into groups of 2-3 students. Each student group will be constructing models of select biochemical molecules from the Organic vs. Inorganic Worksheet. The purpose if this exercise is to show students that *molecules which share a common set of elements can form drastically different substances* because:

1 University Station C9000
Austin, TX 78712
(512) 471-5847
www.esi.utexas.edu

1) The molecules have different numbers of these atoms, or
2) The molecules differ in the way common atoms create the structure of the molecule (they are structurally different

Below is a table containing select molecules for students to diagram (depending on the number of student groups in the class; each group should diagram one molecule), and a hyperlink to a webpage that students can use to create a model of the molecule using the Prentice Hall Molecular Model Sets (see Sources and Resources). The teacher should print out diagrams of these molecules (in color if necessary) before the class begins so that students can efficiently complete this task, and then share answers to the questions in the Evaluate section with the whole class.

Glucose	$C_6H_{12}O_6$	http://library.thinkquest.org/11226/main/s03.htm
Cellulose (wood)	$(C_6H_{10}O_5)n$	http://216.223.146.109/models/gphmodel/orbit-cellulose-model.html
Canola oil	$C_{18}H_{30}O_2$	http://www.goshen.edu/chemistry/files/2010/10/veggy-oil-molecule.jpg
Sucrose	$C_{12}H_{22}O_{11}$	http://simple.m.wikipedia.org/wiki/File:Sucrose_molecule_3d_model.png
Isopropyl alcohol	C_3H_7OH	http://www.experts123.com/q/how-many-hydrogen-atoms-are-in-5-molecules-of-isopropyl-alcohol.html
Fructose (in fruit)	$C_6H_{12}O_6$	http://lunar.thegamez.net/lactose/fructose-intolerance-food-list/fructose-foods-fructose-molecule-size-fructose-intolerance-612x444.jpg
Glycerin	$C_3H_8O_3$	http://www.123rf.com/photo_12416088_glycerol-glycerin-molecule.html
Ethyl alcohol	C_2H_5OH	http://www.erowid.org/chemicals/alcohol/alcohol_chemistry.shtml
Lactose (in milk)	$C_{12}H_{22}O_{11}$	http://en.wikipedia.org/wiki/File:Alpha-lactose-from-xtal-3D-balls.png
Olive Oil	$C_{18}H_{34}O_2$	http://www.cardiactherapy.org/Members/chewingthefat.html
Baking Soda	$NaHCO_3$	http://allaboutbakingsoda.blogspot.com/2010/05/structure-of-baking-soda.html
Starch	$(C_6H_{10}O_5)n$	http://216.223.146.109/models/gphmodel/orbit-starch-model.html

EVALUATE: (15-20 minutes)
Teachers should determine if students have constructed the organic molecules they were assigned properly, and effectively describe the differences in a) structure and b) composition that are responsible for the vast variety of forms and functions these molecules serve in living things.

1) Teachers should ask one student from each group to *compare and contrast the number of Carbon, Hydrogen, and Oxygen atoms in their assigned molecule with molecules that were assigned to other student groups.* The student should note whether molecules with similar numbers of each atom also make up similar substances (such as oils, alcohols, or sugars such as sucrose, glucose, and lactose).

1 University Station C9000
Austin, TX 78712
(512) 471-5847
www.esi.utexas.edu

2) Next, teachers should ask a second student in the groups to *compare and contrast the overall structure of the molecule they were assigned with others in the class*. The student should note whether molecules that are structurally similar also make up similar substances such as those in step 1 above.
3) **FINAL ACTIVITY:** Time permitting, student groups could receive extra credit (or be required to) correctly categorize and label each organic molecule in the Organic vs. Inorganic Worksheet they completed earlier in the lesson as one if the four classes of biochemical molecules (Carbohydrates, Lipids, Proteins, Nucleic Acids)

Inorganic Vs. Organic
A Worksheet

Standard: PS-3
Indicator: PS-3.2

Infer the practical applications of organic and inorganic substances on the basis of their chemical and physical properties.

Procedure:

Fill in the following table of organic and inorganic compounds and answer the questions that follow.

Substance	Formula	Organic or Inorganic	Use
Octane	$C_8 H_{18}$		
Starch	$(C_6 H_{10} O_5)n$		
Steel	Fe		
Butane	$C_4 H_{10}$		
Baking Soda	$NaHCO_3$		
Olive Oil	$C_{18} H_{34} O_2$		
Methane	$C H_4$		
Vaseline	$C_{20} H_{42}$		
Neon	Ne		
Sodium	Na		
Lactose (milk)	$C_{12} H_{22} O_{11}$		
Ethyl alcohol	$C_2 H_5 OH$		
Steroid	$C_{27} H_{46}$		
Hydrogen peroxide	H_2O_2		
Propane	$C_3 H_8$		
Glycerin	$C_3H_8O_3$		
Fructose (fruit)	$C_6H_{12}O_6$		
Aluminum	Al		
Ammonia	NH_3		
Wax	$C_{25}H_{52}$		
Sodium Chloride	NaCl		
Isopropyl alcohol	C_3H_7OH		
Sand	SiO_2		
Sucrose	$C_{12}H_{22}O_{11}$		
Water	H_2O		
Canola oil	$C_{18}H_{30}O_2$		
Cellulose (wood)	$(C_6H_{10}O_5)n$		
Drano	KOH		
Glucose	$C_6H_{12}O_6$		

Questions:

1. What element all organic compounds have in common? (C)
2. What is the most common use for most of the lightweight organic compounds (fewer than 10 carbon atoms) ? (fuel)
3. Can you infer from their formulas which seem more complex, inorganic or organic compounds? Give some examples to defend your answer. (organic = many more elements, some with same formula)
4. How does the composition of organic foods compare to the composition of organic fuels? Explain. (Former tested foods contain C, H. and O; fuels only C and H).