Environmental Science Institute
THE UNIVERSITY OF TEXAS AT AUSTIN

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Chemistry and the Essentials for Life: Looking at Mars

Lesson plan for grades **9-12**
Length of lesson: 88 minutes (not including preparation time)
Authored by: Mohammad Kamyab Javanmardi, Environmental Science Institute, 11/08/13

SOURCES AND RESOURCES:

- Hot Science Cool Talk Lecture #87, The Roving Search for Life on Mars, with Dr. John Grotzinger
  http://www.esi.utexas.edu/k-12-a-the-community/hot-science-cool-talks
- Curiosity Landing Animation
  http://www.youtube.com/watch?v=P4boyXQuUIw
- Popular Science - Chemistry on Mars
  http://www.popsci.com/science/article/2012-12/mars-rover-curiosity-finds-complex-chemistry-mars-cant-confirm-organics-yet
- Organics On Mars: Curiosity Rover Finds Evidence Of Organic Compounds On Red Planet
  http://www.huffingtonpost.com/2012/12/03/organics-on-mars-curiosity-rover_n_2232436.html
- Details on Amino acids
  http://www.di.uq.edu.au/sparqproteins

POTENTIAL CONCEPTS TEKS ADDRESSED THROUGH THIS LESSON:

§112.33 Astronomy, Grade 9-12: 9B
§112.35 Chemistry, Grade 9-12: 3B
§112.34 Biology, Grade 9-12: 2E, 2H, 9A, 9D

PERFORMANCE OBJECTIVES:

Students will be able to:

- compare the planets in terms of orbit, size, composition, atmosphere
- communicate and apply online research of organic compounds to the basic composition of living things
- Study and analyze the 4 main categories of organic molecules on Earth.
- Dissect molecular formulas and take note of various atoms and % composition
- Draw parallels between chemistry on earth and how it might be on Mars

MATERIALS (per group of four):

- **Laptops or Desktops** that have up-to-date web browsers and preferably parental/safety browsing restrictions (students will be free to do online research and look up facts for the exploration section of the lesson). See Preparation section for a count of how devices will be needed.

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- **Mars Lesson Worksheet**

CONCEPTS:

Rover: a type of vehicle that is designed and intended for the exploration of the surface of extraterrestrial bodies such as the moon or Mars
Organic: Obtaining to, or derived from living things
Carbohydrate: any of a large group of organic compounds occurring in foods and living tissues and including sugars, starch, and cellulose. They contain hydrogen and oxygen in the same ratio as water (2:1) and typically can be broken down to release energy in the animal body.
Lipid: any of a class of organic compounds that are fatty acids or their derivatives and are insoluble in water but soluble in organic solvents. They include many natural oils, waxes, and steroids.
Amino Acid: a simple organic compound containing both a carboxyl (-COOH) and an amino ($-NH_2$) group.
Protein: any of a class of nitrogenous organic compounds that consist of large molecules composed of one or more long chains of amino acids and are an essential part of all living organisms, esp. as structural components of body tissues such as muscle, hair, collagen, etc., and as enzymes and antibodies.
Nucleic Acid: a complex organic substance present in living cells, esp. DNA or RNA, whose molecules consist of many nucleotides linked in a long chain.
DNA: deoxyribonucleic acid, a self-replicating material present in nearly all living organisms as the main constituent of chromosomes. It is the carrier of genetic information.

BACKGROUND:
At 1:31 a.m. Eastern time on Monday, August 6, 2012, Curiosity successfully landed on the face of Mars. After 8.5 months of travel (352 million mile journey), the NASA rover was able to capture the attention of viewers around the world as mission control initiated one of the most vital portions of the mission, the landing.

After a nearly perfect landing, the later began a series of test and soil analysis to better understand the chemical nature of Mars. Ironically, these tests brought up even more questions. In an effort to see if Mars could have ever hosted life at some point, there needs to be even more findings of chemical compounds and a better understanding of the % composition of the planet as a whole.

Drawing parallels between chemistry on Earth and chemistry on Mars is one of the best ways to understand they could have co-evolved over millions of years in the same solar system.

PREPARATION:

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1 worksheet per group of students. Students should either work independently or in pairs when it comes to the online research portions of the lesson. Teachers may want to set browsing/search restrictions (or similarly parental restrictions) if they are concerned about the content which students in their classroom may be search. Teachers may also run through this lesson on their own beforehand and customize portions so that it may best fit to their students and time restrictions. A good idea might be to come up with a list of URL addresses that contain relevant content to the lesson and bookmark them in the student's computers beforehand. This could reduce the length of the activity and make it more focused.

ENGAGE: *18 minutes*

Teacher can start off the class by showing the landing animation (see link for “Curiosity Landing Animation" in resources). *Suggested segment for landing is 0:00-3:30*

Teacher: Early on August 6, 2012, NASA was able to land its latest **rover** onto the surface of Mars. Does anyone remember watching this happen or perhaps have heard about this happening?
(Teacher listens for student responses, stories, and remarks)

Well, what do you all think was the purpose of sending a rover 352 million miles across our solar system to a foreign planet?

Possible Student Responses:

- The rover was sent out to see if we can survive on Mars
- Soil and rock samples are being collected to see what the planet is made of
- It might be mapping out the geography on Mars
- I've heard that the rover is in search of extraterrestrial life

Though some of those responses might be true after the official mission of the rover is over, the primary mission of the rover is actually to study the planet on multiple fronts to see if the planet could ever have supported life.

“Curiosity is not designed to find life, just evidence of environments that could have played host to it at some point.” - *Huffington Post, Science*

Teacher: Let's expand on this idea of "life." What do you all think are the criteria for an environment that can support life? Another way of thinking about this is to address what living organisms require to survive.

Possible Student Responses:

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- The environment must have some water in it.
- Living things have carbon in them. Perhaps the environment should have carbon in it.
- There need to be trees and grasses and other plants.
- The temperatures shouldn't be too hot or too cold.
- Animals usually need some kind of a shelter, like how birds live in trees and snakes live in dens.
- There needs to be food and energy and minerals and nutrients for the living things to feed off of and grow

Teacher: I would like to point out that an organism does not necessarily have to be something as complex and large as an animal. In fact, we should recall that life on earth originated at very primitive microbial stages. Over periods that spanned millions of years, these primitive microbes evolved various cellular components and functions that allow them to appear as the bacteria, microorganisms, and somatic cells that we see today. What is preventing us from assuming that any life on Mars may have existed and evolved in a similar matter; that is, if there was even life to begin with.

Let's get a solid list going of essentials to life as we know it on Earth. Firstly, what are the 6 primary "**organic**" elements that we have determined to be in living things?
(wait for student responses...)

Some of you were able to list some of the following, which are the 6 "organic" elements. Please note that these 6 elements also partake in nonorganic compounds.

1. Carbon
2. Hydrogen
3. Oxygen
4. Sulfur
5. Phosphorus
6. Nitrogen

Now that we have pinpointed these key elements let's expand and think about what these elements can be part of that are essential to organism survival and the sustainability of life. In other words, what sorts of larger compounds and molecules do these elements make that we see living things using all of the time, here on Earth.

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EXPLORE: *15 minutes*

Teacher: In front of you and your partner is a computer (see *preparation section* for instructions on this section and student grouping possibilities). Your mission on these computers is to do some research in the next 10-15 minutes to formulate a list of organic compounds that support living organisms or are essential to life. Keep in mind that these compounds should contain at least a few of the 6 "organic" elements. Also, recall the discussion we had earlier about what an organism needs in its environment to survive. Next to each chemical compound that you find, write a description of what it is used to do by the cells or other microorganism.

EX: Glucose ($C_6H_{12}O_6$ contains Oxygen, Carbon, and Hydrogen): This molecule is known as a sugar and can be used by cells to create energy. The energy can act as fuel so that the cell can do various actions.

*teacher may want to provide a list of URL's for the students so that they can limit their searches to certain pages to make this activity easier and faster for the students.

Students: Use the example above (also on their worksheet) as a template for your research findings. Find at least 10 basic organic molecules. Once you have found your 10 molecules, you may continue to find more or simply research more information of the ones you have found until the teacher calls the time on this portion of your activity.

Teacher: Collects the students' attention.
Alright, I want everyone to lower your laptop screens (or put your monitors to sleep). Let's get a list going of some of the things that you found.

Teacher can call on the groups to provide a couple of findings, or the students can simply volunteer their own responses. The teacher should write up a list of approximately 15 or so compounds and select 5 for the next portion of the activity. These 5 may be chosen based on their prevalence, simplicity, function, or purely out of interest.

EXPLAIN : *25 minutes*

Teacher: We have all found some very interesting organic compounds. While there was some overlap with the compounds that the groups found, it seems that there was a great deal of different molecules out there. In fact there are 4 main classes of organic molecules that each give rise to hundreds of thousands of different molecules.

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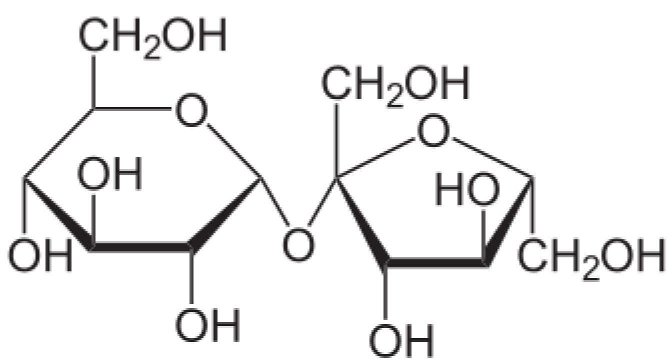
There are

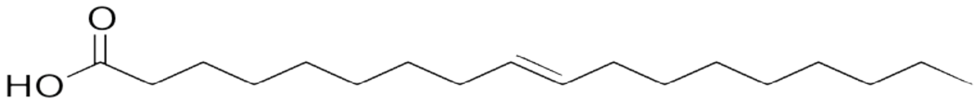
1. Carbohydrates
2. Lipids/Fats
3. Nucleic Acids
4. Amino Acids

These 4 categories encompass many organic molecules but don't necessarily account for all of the molecules necessary to sustain life. For example, oxygen gas is necessary for most animals to respire (breath) and make energy, yet it doesn't fall under either of these categories of molecules. In order to have a better grasp of these categories let's talk about each one.

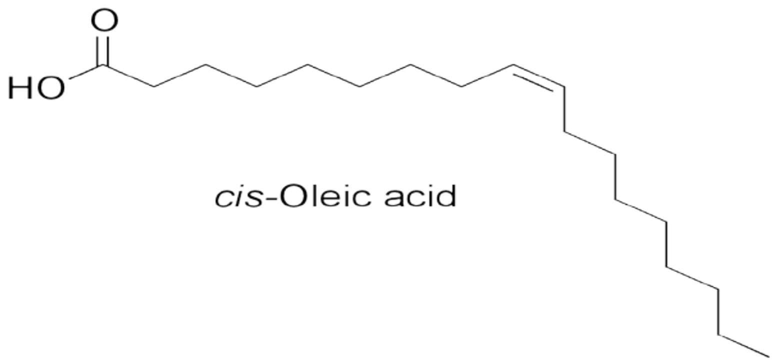
Carbohydrates are extremely common. They are in lots of the foods that you eat, such as pastas, breads, cereal, rice, beans, etc.... These molecules are usually burned, when digested, to make lots of usable energy. For example, a slice of bread may have lots of dietary "carbs" that your body can translate into energy. To better understand this molecule it is best to zoom in and look at it on the atomic scale. A sugar such as sucrose (table sugar) is made up of carbons, oxygens, and hydrogens. The molecular formula for sucrose is $C_{12}H_{22}O_{11}$. This indicates that there are 12 Carbon atoms, 22 Hydrogen atoms, and 11 Oxygen atoms in the Sucrose molecule. For now, it is less important that we know what all of these drawing mean. Rather, we should focus or recognizing what carbohydrates, where they can be found, and what they do for us.



Lipids or fats are very important for several reasons. They are what make up cell membranes as well as what accumulates under or skin and various other parts of our body. Fats can insulate and provide structure; however, they can also be converted into lots of energy for cells to use. However, it is much more difficult to digest a fat than it is to digest a carbohydrate. For this reason, we have to exercise and work hard to reduce the fat levels in our bodies. Fats can be found in lots of fast foods, oils, butter, and other foods, in varying quantities. Fats are usually long carbon chains with lots of hydrogens attached to them. They can vary in length and quantity.

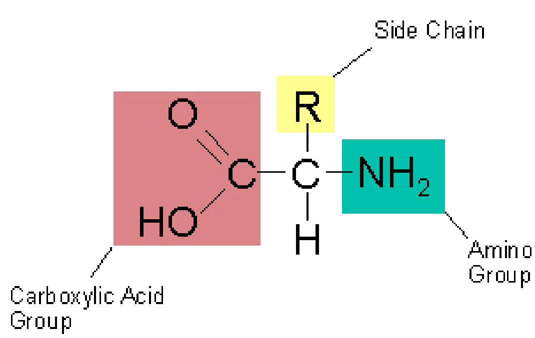


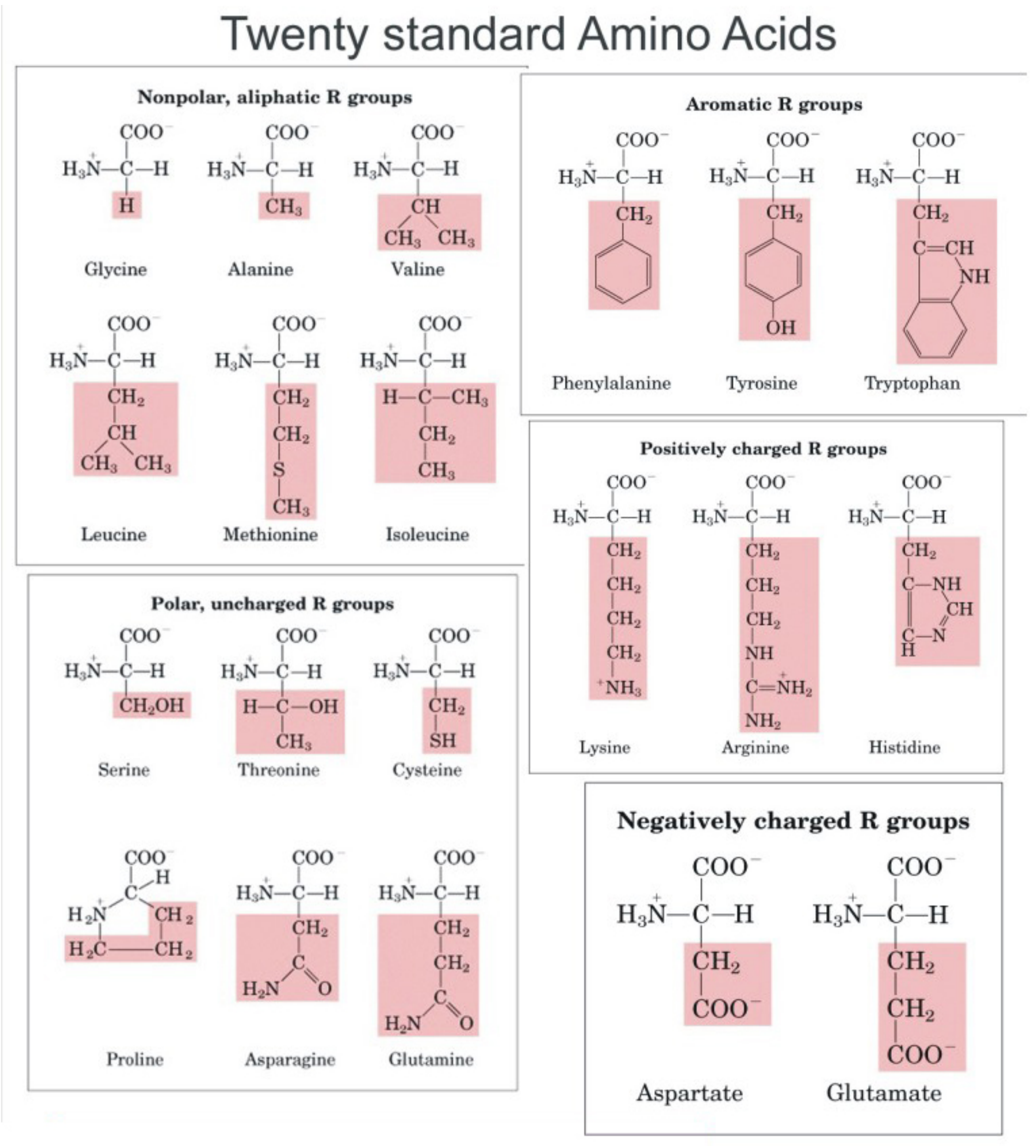
trans-Oleic acid



cis-Oleic acid

Amino acids are very important molecules. There are about 20 fundamental amino acids that make up larger molecules called proteins. We often hear that we are consuming protein when we eat meat, or fish, or various other foods. The truth is that there isn't just a single molecule that we can universally recognize as the protein. There are hundreds of thousands of different types of proteins in our bodies and in the bodies of different animals, plants, and microorganisms. They come in all sorts of shapes and sizes and can perform lots of different functions. For example there is one type of protein that is supposed to help our muscles get structured while there is another that helps us digest lactose (the sugar that is found in cow milk). Once again, let's zoom in to better understand these molecules. Below is a table of the 20 main amino acids that are employed in the human body. These amino acids are also found in almost all organic life on earth. Notice that all of them have a "back bone" that is the same. (+NH3-CH-COO-) The things that are different are the "side chains" or the atoms coming off of the central carbon. Each one has a different chemical property which is what makes proteins so diverse. Now, one peptide can be linked to the other by bonding the COO- end of the spine of one amino acid to the NH3+ end of the other. Imagine doing this dozens even hundreds of times until you get a long chain of amino acids. These amino acids then fold and shape into different structures called proteins. All that we need to focus on for now is recognizing the various molecules that we find in these amino acids.





Last but not least, we must go over Nucleic Acids. These large molecules exist in 5 primary variations that make up the genetic code known as DNA. The first 4 Nucleic acids are called Adenine, Thymine, Cytosine, and Guanine (or abbreviated A,T,C, and G respectively). These simple 4 molecules can be paired up and put into chains of millions upon millions to make up the DNA strands that exist in living cells. The 5th nucleic acid, Uracil

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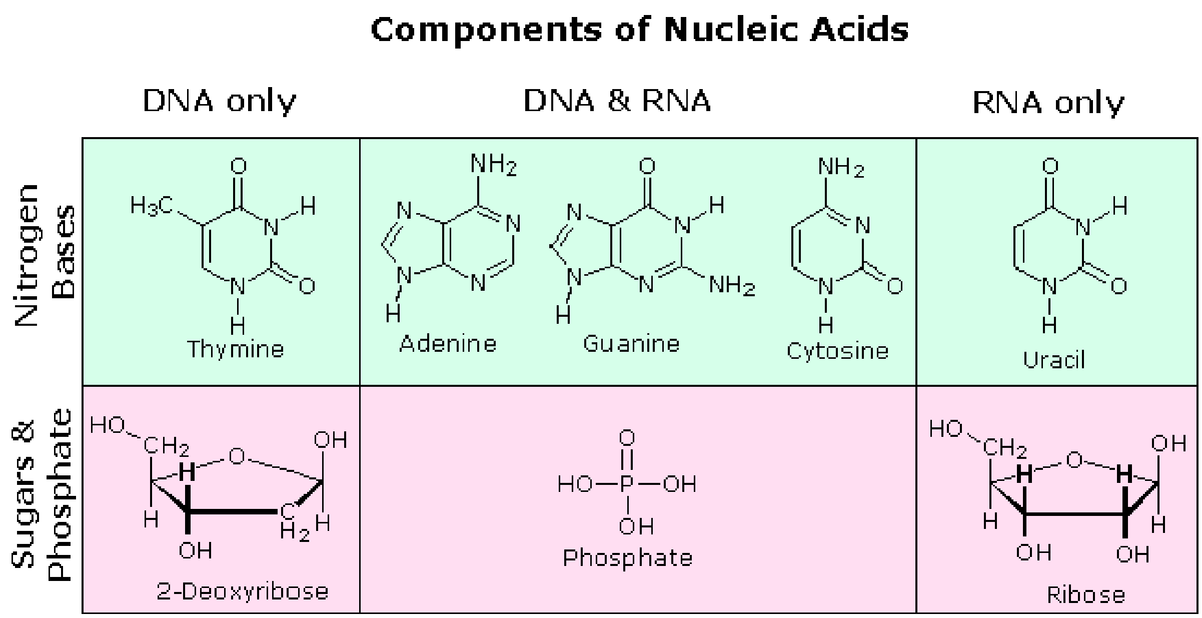
(U), replaces Thymine in a similar macromolecule called RNA. These long strands code for the creation or "synthesis" of different amino acid chains which will become proteins. Below is a picture of the various amino acids. Look at the atoms that are incorporated. Which atoms do you see reoccurring in all of the molecules we have talked about so far?



<u>ELABORATE:</u> *20 minutes*

<u>Teacher</u>: Now, I'm going to ask everyone to open up their computers again and take a look at their worksheets. Now that we have talked about the four main categories of organic molecules on Earth, we are going to find trends in the types of atoms and the reoccurrence of them in these various molecules. For instance, we can notice that the backbone of an amino acid contains a Nitrogen atoms, several Hydrogen atoms, Carbon atoms, and Oxygen atoms. Students will pick 5 molecules of the 15 that the teacher selected from the exploration activity. The worksheet asks you to draw a few of these more simple molecules and count up how many of the various atoms exist in that molecule.

<u>Teacher will be</u>: walking around answering questions and checking to see if students are on topic. Teacher may want to take precautions as explained in the Explore section and Preparation section to limit the search that students can make on the INTERNET devices.

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Once sufficient time has passed (15 minutes or so), the teacher can gather the class for the final portion of the lesson.

<u>EVALUATE</u>: *10 minutes*

<u>Teacher:</u> We have talked about a lot today. We have briefly gone over the Mars rover 'Curiosity' and the mission that the rover is trying to complete. We have also discussed and debated what it takes to sustain life on Earth. Though this discussion led us through various topics such as the environment, temperature, and other factors, we ultimately focused in on the chemistry of life and the various organic molecules that help create and sustain it.

We've talked about:

1. Carbohydrates
2. Lipids/Fats
3. Amino Acids
4. Nucleic Acids

For the past 20 minutes or so, you all were assigned with one last challenge, to figure out what some of these molecules look like and what kind of composition they have in terms of the atoms that make them up. Now is the time to share our findings.

Teacher will call on students or groups of students to see what kind of molecules they chose/found and what the composition of the atoms were in these molecules. Students should talk about how many of each atom they might have found in a single molecule. Let this discussion carry out for a sufficient amount of time or about 10 minutes.

Finally, It's time discuss the potentials for life on Mars. The fact of the matter is that none of these large and complicated macromolecules have been found or probably will be found. We must understand that if life ever did exist on this planet, it happened hundreds of thousands of years ago, which means that these molecules would have degraded by now into its various atomic components. What we can do, however, is think back to the activity we just did. Though life on Mars evolved differently and would most likely not have had the same categories of organic molecules, it is safe to assume that there might have been similar types of molecules. By figuring out what kinds of atoms existed in these compounds and what their % compositions were, we might find similar compounds and molecules on Mars that might have been parts of these former organic molecules. Think of it as finding pieces of glass from a larger plate and trying to see if they could fit together again.

From this activity, you might have actually though of even more questions:

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- How long ago could life have existed on Mars?
- How could the environmental conditions have been different at this time?
- Would we have seen similar organic molecules on that planet? Or would they have been completely different?

These questions and problems are what scientists ask themselves and confront on a regular basis!

Name: _______________________________ Date:__/___/____

Chemistry and the Essentials for Life: Looking at Mars Worksheet

Part 1: Instructions: Fill out the table below. On your computer, research at least 10 different organic molecules. Keep in mind that these molecules should consists of the essential organic atoms that were talked about earlier in discussion (oxygen, nitrogen, carbon, hydrogen, phosphorus, and sulfur).

Molecule Name	Chemical Formula (ie. $C_2H_4O_2$)	Description of the molecule. What does it do? Where is it found? How is it important to living organisms?

Name: ______________________________ Date:__/___/____

Part 2: Instructions: Fill out the table below by first choosing 5 molecules of the 15 that the class presented during the first activity. Next write down the 5 molecule's names in the "molecule name" column. Then, fill out the rest of the table by searching your chosen molecules. Finally, tally up the number of the various atoms present in that molecule. These numbers will be later compared to see what the most abundant atoms are in these organic molecules.

Molecule Name	Molecule Drawing (simplify if necessary)	Atom Count (ex; 5 Nitrogens, 9 Oxygens, 12 Carbons, etc..)