PIONEERING MARS—LESSON TWO

HYPOTHESIS: Cyanobacteria, a microscopic algae found in extreme conditions in Antarctica, could grow in similar extreme conditions on Mars.

INSTRUCTIONAL GOAL: This lesson will provide students the necessary background in the photobiology of Earth and Mars to begin planning experiments.

Here on Earth, we have a perfectly cyclical system where PRODUCERS and CONSUMERS each live in part off the other's waste output. The only thing we all need and can't produce ourselves is light. Without solar energy, which producers convert to chemical energy that both they and consumers can use, all life would end.

PRODUCERS, aka AUTOTROPHS—organisms engaged in PRIMARY PRODUCTION On the earth, the producers are plants and algae.

PRIMARY PRODUCTION, aka CARBON FIXATION—the production of new organic materials (food) from inorganic molecules, such as water and carbon dioxide.

PHOTOSYNTHESIS—a process that combines carbon dioxide (CO_2) and water (H_2O) using light energy to create carbohydrates (CH_2O), also known as sugars, and oxygen gas (O_2). This is how plants and algae make their own food.

$nCO_2 + nH_2O + light >> (CH_2O)n + nO_2$

- Photosynthesis takes place in the THYLAKOID, a cellular structure typically found in the CHLOROPLAST of plant and algal cells.
- In addition to CO2 & H2O, all plants and algae require small amounts of dissolved nitrogen (N) and phosphorus (P) as vital nutrients necessary for growth. Aquatic plants/algae can absorb these directly through their cell membranes, but terrestrial plants have evolved root structures to enable them to acquire water, along with dissolved nitrogen (N) and phosphorus (P), from the soil.
    - PHOTOPIGMENTS—molecules with intense colors, such as CHLOROPHYLL A, designed to absorb light for use in photosynthesis.
- Plants and algae make their own food using the carbon (C), hydrogen (H), and oxygen (O) from CO2 and H2O. These atomic elements are used in photosynthesis to make SUGARS, or CARBOHYDRATES, which plants and algae burn for energy via metabolism. Any sugars they don't use immediately can be stored in their tissues, which other organisms can later consume.
- FATS, or HYDROCARBONS, are not made through photosynthesis – they must be fabricated within the cell, using the energy and C, H, O released from metabolizing sugars. Fats are usually used as an energy reserve within the plant/algae cells, but these stored fats can also be consumed by other organisms for energy.
- PROTEIN is made by using the dissolved nitrogen, as well as the C,H,O acquired through photosynthesis, to make AMINO ACIDS. There are several different kinds of AMINO ACIDS, which can be linked together in a nearly infinite number of unique combinations, to form a nearly infinite number of different

proteins!   Proteins are very complex molecules which are used primarily to create ENZYMES, which function as “helper” molecules to make critical cellular reactions occur more quickly and efficiently.

- NUCLEIC ACIDS are the building blocks of genetic material, such as DNA and RNA. NUCLEIC ACIDS are built within plant and algae cells using the C,H,O acquired through photosynthesis, as well as the dissolved nitrogen and phosphorus absorbed as vital nutrients.

CONSUMERS, aka HETEROTROPHS, cannot make their own food like the PRODUCERS can, so they must get their chemical energy from another source by ingesting it. Consumers need carbohydrates, fats, proteins, and nucleic acids from outside sources, along with oxygen, to survive.

After consumers' bodies have taken what they need in the form of oxygen gas and food from plants and other animals, they release carbon dioxide and water, as well as nitrogen and phosphorus, back into the environment as waste—which are precisely the same nutrients producers need to survive.

CELLULAR RESPIRATION—a metabolic process by which plants and animals are able to convert the sugar and oxygen gas into chemical energy (ATP). Everything accomplished on a cellular level is powered by ATP.

$$nCH_2O + nO_2 >> nCO_2 + nH_2O + ATP$$

PHOTOBIOLOGY, CYANOBACTERIA, AND MARS

Experiment design issues

Considering that the atmosphere of Mars is only ~1% O2 and is 100X thinner than earth's, CONSUMERS would not be able to survive on Mars. Despite the thin atmosphere of Mars, there is actually more CO2 on Mars than there is on earth, so PRODUCERS which can survive the frigid temperatures should also be able to generate food for themselves via photosynthesis, provided there is enough light and liquid water.

In cyanobacteria, the thylakoids are dotted with PHYCOBILISOMES, specialized pigment domes which have evolved to maximize the capture and utilization of light energy. The phycobilisome possesses several different pigments, each of which absorbs different colors of light. At the core of each phycobilisome is CHLOROPHYLL-A, the universal pigment that drives photosynthesis. Because of this unique design, cyanobacteria can use light across the entire color spectrum. This may be advantageous for life on Mars, where the color and intensity of light is very different than it is on earth.

While several different NASA rovers have recently confirmed the presence of frozen water on Mars, it needs to be available in its liquid state to be useful to cyanobacteria. Since the environmental conditions must be “just right” for water to be present as a liquid, it is more likely that the cyanobacteria may not have access to large pools of water it has in Antarctica, but may have to grow on (or within) wet Martian soil instead.

It is unclear how the soil on Mars corresponds to Earth soils. Since liquid water is very common on earth, most of the salts within earth soils were rinsed out into the sea long, long ago. On Mars, where liquid water is very scarce, the soils may contain much higher concentrations of salt, which might pose a threat to the survival of cyanobacteria. Access to nitrogen and phosphorus, which are commonly found in earth soils, may not be present in the soils of Mars. And without access to nitrogen and phosphorus, life cannot sustain itself.