Problem Set\_02

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version February 06, 2018

### Problem set\_02 Microbial Engines

#### Learning objectives:

Discuss the role of microbial diversity and formation of coupled metabolism in driving global biogeochemical cycles.

#### Specific Questions:

#### \* What are the primary geophysical and biogeochemical processes that create and sustain conditions for life on Earth? How do abiotic versus biotic processes vary with respect to matter and energy transformation and how are they interconnected?

The earth’s tectonic and atmospheric photochemical processes form the geochemical cycle that allows life to exist. These processes allow for molecular interaction and for chemical bond formation and breaking to allow for equilibrium to never be reached and thus substrates would continually be renewed for life to use. Life influences the earth’s climate and composition by redox reactions. Microbes catalyze these redox reactions and fundementally alter the earth’s redox state. In turn, the earth cycles back these redox reactions to create the feedback cycle in which both activities are linked.

#### \* Why is Earthâs redox state considered an emergent property?

Fluxes of five elements: H, C, N, O, S are controlled primarily by redox reactions that are carried out by life. These reactions initiated by microbes fundementally alter the redox state of the surface of the planet. The earth’s current redox state is an emergent property because it exists at a point of balance between the redox state created by the tectonic activity of the earth, and the redox state that would be due to microbial activity. Therefore, the earth’s redox state exists only because of the existence of life on earth.

#### \* How do reversible electron transfer reactions give rise to element and nutrient cycles at different ecological scales? What strategies do microbes use to overcome thermodynamic barriers to reversible electron flow?

Elemental cycles are often controlled by a series of redox reactions in tension with each other. Identical or near-identical cycles are used for both forward and reverse directions of reactions that maintain the cycles. Microbes utilize synergistic cooperation with other species in order to propogate these cycles, with one microbe using one direction of a cycle for energy production, while the other microbial species uses the opposite direction for bioassimilation, which in the process expends energy. These activities are able to thus able to overcome barriers to reversible electron flow by sacrificing efficiency of energy transfer for continuation of the cycle. Another contributive source of energy used to overcome many of the energetic barriers to electron flow is the use of light energy for photooxidative processes.

#### \* Using information provided in the text, describe how the nitrogen cycle partitions between different redox ‘niches’ and microbial groups. Is there a relationship between the nitrogen cycle and climate change?

Nitrogen fixation allows for the conversion of N2 gas into NH4+, which is a reductive process. The highly evolutionarily conserved nitrogenase enzyme allows for this step to occur, and is inhibited by oxygen. This step occurs in anoxic environments. Oxidation of NH4+ to NO2- occurs only in the presence of oxygen, and thus an oxygenated environment. Different bacteria then further oxidize nitrogen to NO3- in an . NO2 and NO3 is also used as a source of oxidation in the abscence of oxygen, returning it to N2. This process thus occurs in an anoxic environment. The emergence of the nitrogen cycle as giving rise to the most prominent gas currently existing in the atmosphere would have lowered CH4 levels, causing a decrease in global temperatures, along with the rise of oxygen levels.

#### \* What is the relationship between microbial diversity and metabolic diversity and how does this relate to the discovery of new protein families from microbial community genomes?

Metabolic diversity to an extent drives microbial diversity. This is because oxidative and reductive metabolic processes often exist in different organisms. As such, one organism exists as utilizing either the reductive or oxidative portion of an elecmental cycle while another uses the other half. It is known that metabolic proteins or even whole metabolic pathways can be transferred horizontally from one microbe to another. The extent of this is controlled by nutrient and bioenergenic selective pressures (whether or not such evolution would result in an greater ability to utilize or obatain energy). The discovery of new protein families in microbial community genomes indicates that we have only begun to scratch the surface regarding the evolutionary diversity in nature arising as a result of these selective pressures. This discovery process is roughly linear with the number of new genomes sequenced. As it currently stands, there is a potentially unlimited quantity of genetic diversity in microbes. However, their distribution would be limited by the environments they are found in, with the caveat that a large portion of the relevant cellular machinery for all different kinds of metabolism are harbored in microbes not necessarily actively using them for energy production.

#### \* On what basis do the authors consider microbes the guardians of metabolism?

Microbes are the guardians of metabolism on the basis that they are responsible for maintaining the core planetary gene set, which are all the genes encoding the metabolic machinery to take advantage of every single metabolic environmental niche on the planet. They do this because viable bacteria of any particular functional type can re-grow from almost any environmental niche, even if that environment cannot initially support its growth. This is attributed to the relative slow decay of microbial biomass relative to its propagation through dormancy or through sporulation.