MICB425 Module 1 Writing Assignment

#####Introduction

Microbial life has played a fundamental role in shaping Earth’s biosphere; however, I believe that humanity is more than capable of surviving without the global catalysis and environmental transformation that microbes provide. I will not argue that humanity would be able to adapt and survive following a fantastical, cataclysmic event where only microbial life was extinguished. Rather, I will argue that humanity has the capacity to understand all the biogeochemical processes provided by microbial life with the help of continually-improving computational models. Humanity also has the capacity to understand the influence our own technology has on the global environment, and we can consciously adapt our global actions as necessary to restore order to the global equilibrium. Finally, we can develop new technology to replicate and optimize every biogeochemical process on a global and potentially interplanetary scale. Through these processes, humanity will be capable of controlling and guiding the global environment to ensure the continued survival of our species without relying on evolutionarily-limited, globally-unconscious microbial life.

#####Understanding, Adapting to, and Controlling Earth’s Biosphere

Before we can control the Earth, we must understand it. By learning about the history of Earth, we have been able to discover how biogeochemical cycles have driven global changes in Earth’s environment, which could help us model how it might occur again in the future [1]. It is thought that the changes in Earth’s biosphere that are currently underway are being driven by human activity [2]. This new era has been named the Anthropocene, and if we are to understand the changes underway and attempt to mitigate the damage to the environment and human society we will need to use computational models to simulate global geochemical cycles. Models of this scale are not possible with our current technology, but there has been a continual improvement in the computational power and accuracy of our models for decades. For example, Falkowski et al. noted that, “…we have considerable information about specific aspects of the carbon cycle, but many of the couplings and feedbacks are poorly understood” [3] because we needed a systems/integrative approach, yet not even 20 years later Wang et al. modeled global soil carbon and soil microbial carbon by combining multiple models into one integrative model [4].

Another example of the improvement in our computational models is from meteorological simulations that model atmospheric conditions to predict the weather. Forty years ago, our 3- and 7-day forecast skill were at 80% and 40%, respectively, and as of 2013 those values are at 95% and 70%, respectively [5]. These improvements came from exponential increases in computational power, but there were other major advancements such as the global satellite data gained in the early 2000s [5]. Today, we are at the dawn of using machine learning and artificial intelligence in our predictive models, which recursively improve upon themselves to achieve an accuracy greater than any conventional model can [6]. The atmosphere is an important part of the global biosphere, and the advances in all of our computational modelling technologies will eventually lead to an all-encompassing, global model of the Earth’s biogeochemical cycles.

Humanity’s technological advancement has influenced the global environment at an unprecedented scale, and we need to be able to recognize the influence our own technology has and adjust our actions as a global community to restore order to the Earth’s equilibrium. A prime example of humanity recognizing the influence of our technology on the environment is the crisis of the ozone hole and the signing of the Montreal Protocol. In 1973, it was discovered by the future Nobel laureates Paul Crutzen, Mario Molina, and F. Sherwood Rowland that chlorofluorocarbons (CFCs), a class of compounds commonly used as refrigerants and flame-retardants, were responsible for the depletion of the ozone layer [7]. It took fifteen years, but in 1987, an international treaty known as the Montreal Protocol was agreed upon, which resulted in the phasing out of all CFCs and other related substances in hopes of protecting the ozone layer [8]. Thirty years later we can now say that the Montreal Protocol was a success, and that there has been a decline in Antarctic ozone depletion as well as lower stratospheric chlorine, a byproduct of CFCs [9].

Humanity was able to recognize the influence our technology has on the ozone layer and come together to solve the problem, but we are currently going through another global environmental change due to our technology that requires us to come together as a global community once again. At the World Climate Conference in 1979 it was noted that increased CO2 in the atmosphere can contribute to a gradual warming of the planet [10]. There has been a lot of research on the topic climate change since then, and it can be said without a doubt that there has been a rapid increase in atmospheric CO2 due to human activities [3]. There has been no effective international treaty to reduce the human impact on climate change yet, but the Paris Climate Accord is set to come in to effect in 2020. The Paris Climate Accord is an international treaty that contains plans for greenhouse gas emissions mitigation, adaption, and financing so that humanity can keep the global temperature rise to well below than 2°C [11]. It is unknown at this time if these measures will succeed in mitigating climate change, but measures like these are a sign that humanity is capable of recognizing our own impact on the global environment and can consciously change our global behavior.

While the Paris Climate Accord merely aims to mitigate greenhouse gas emissions, new technology has the potential for us to not only mitigate emissions but to actually reduce the amount of CO2 present in the atmosphere. There are multiple methods of carbon fixation currently under research, and they primarily fall under two related categories: synthetic metabolic pathways and artificial photosynthesis. Schwander et al. designed a continuous synthetic carbon fixation pathway involving “…17 enzymes from nine different organisms and all three domains of life…” [12] that is five times more efficient than the most common natural carbon fixation pathway. A few of the enzymes used were rationally engineered to catalyze the desired reactions, and the pathway clearly demonstrates the ingenuity of humanity to design a “…synthetic alternative that [does] not require the serendipity of evolution to bring together all components in space and time” [12]. Synthetic pathways like Schwander et al.’s can be used in a variety of ways, such as in engineered photosynthetic organisms to improve CO2 fixation or in completely artificial photosynthetic processes like artificial leaves that rely on photovoltaics and other catalytic technologies [13]. Technological carbon fixation is not feasible at a global scale yet, but Rheticus is a new joint research project backed by major electrical and chemical companies to demonstrate the feasibility of artificial photosynthesis by using electricity from renewable sources and genetically engineered bacteria to convert CO2 into specialty chemicals at a pilot-plant scale [14]. Ventures such as this may eventually bring industrial carbon fixation into the same realm as industrial nitrogen fixation by the Haber-Bosch process, which is responsible for half of the Earth’s nitrogen fixation [15].

#####Conclusion

The Earth will continue revolve around the sun no matter what humanity does to it, but it is up to humanity to understand Earth’s biogeochemical cycles and the influence our rapidly-advancing technology has on them if we want to take the captain’s chair on “Spaceship Earth” [16]. Biogeochemical cycles have been a popular field of research for many years, but it’s only been since the dawn of computers that we have been able to create complex computation models. With modern computational tools, we can integrate multiple different models into a single, unified model and use machine learning technology to analyze and make predictions from data sets larger than any human could comprehend. We can also use models to make predictions about the way our own technology and its by-products will affect the global environment. Designing and implementing international treaties such as the Montreal Protocol and the Paris Climate Accord is how humanity demonstrates that it is the true captain of “Spaceship Earth”. Microbes cannot come together as a global community to consciously guide Earth’s biosphere, but humanity has demonstrated it is more than capable of doing so. And as we develop new artificial biogeochemical cycle technologies like synthetic metabolic pathways, artificial photosynthesis, and other unknown advancements, we will continually enhance our capability to guide Earth’s biosphere. In the far future, humanity may have such a firm grasp on synthetic biogeochemical cycles that we not only control Earth’s biosphere but are also capable of terraforming other planets such as Mars or Venus, creating a robust, interplanetary biosphere.

**#####References**

[1] Nisbet, E. G., & Sleep, N. H. (2001). The habitat and nature of early life. Nature, 409(6823), 1083-1091. <https://doi.org/10.1038/35059210>

[2] Waters, C. N., Zalasiewicz, J., Summerhayes, C., Barnosky, A. D., Poirier, C., Gauszka, A., . . . Wolfe, A. P. (2016). The anthropocene is functionally and stratigraphically distinct from the holocene. Science (New York, N.Y.), 351(6269), aad2622-aad2622. 10.1126/science.aad2622

[3] Falkowski, P., Scholes, R. J., Boyle, E., Canadell, J., Canfield, D., Elser, J., . . . Steffen, W. (2000). The global carbon cycle: A test of our knowledge of earth as a system. Science, 290(5490), 291-296. <https://doi.org/10.1126/science.290.5490.291>

[4] Wang, K., Peng, C., Zhu, Q., Zhou, X., Wang, M., Zhang, K., & Wang, G. (2017). Modeling global soil carbon and soil microbial carbon by integrating microbial processes into the ecosystem process model TRIPLEX GHG. Journal of Advances in Modeling Earth Systems, 9(6), 2368-2384. 10.1002/2017MS000920

[5] Bauer, P., Thorpe, A., & Brunet, G. (2015). The quiet revolution of numerical weather prediction. Nature, 525(7567), 47. <https://doi.org/10.1038/nature14956>

[6] Jones N. 2017. How machine learning could help to improve climate forecasts. Nature 548:379–380. <https://doi.org/10.1038/548379a>

[7] Nobelprize.org. (1995, Oct. 11), The Nobel Prize in Chemistry 1995. Retrieved from [www.nobelprize.org](http://www.nobelprize.org)

[8] Ozone Secretariat. (2017). The Montreal Protocol on Substances that Deplete the Ozone Layer. Retrieved from: <http://ozone.unep.org>

[9] Strahan SE, Douglass AR, Newman PA, Steenrod SD. 2014. Inorganic chlorine variability in the Antarctic vortex and implications for ozone recovery. Journal of Geophysical Research: Atmospheres 119. <https://doi.org/10.1002/2014JD022295>

[10] World Meteorological Organization. (1979). Declaration of the World Climate Conference. World Meteorological Organization. <https://library.wmo.int/pmb_ged/wmo_537_en.pdf>

[11] UN Treaty Collection. (2015, Dec. 12). Paris Agreement. Retrieved from: <https://treaties.un.org>

[12] Schwander, T., Schada von Borzyskowski, L., Burgener, S., Cortina, N. S., & Erb, T. J. (2016). A synthetic pathway for the fixation of carbon dioxide in vitro. Science, 354(6314), 900-904. <https://doi.org/10.1126/science.aah5237>

[13] Berardi S, Drouet S, Francàs L, Gimbert-Suriñach C, Guttentag M, Richmond C, Stoll T, Llobet A. 2014. Molecular artificial photosynthesis. Chem Soc Rev 43:7501–7519. <https://doi.org/10.1039/c3cs60405e>

[14] Siemens and Evonik. (2018, Jan. 18). Evonik and Siemens to generate high-value specialty chemicals from carbon dioxide and eco-electricity. Retrieved from <https://www.siemens.com>

[15] Canfield, D. E., Glazer, A. N., & Falkowski, P. G. (2010). The evolution and future of earth's nitrogen cycle. Science, 330(6001), 192-196. <https://doi.org/10.1126/science.1186120>

[16] Archenbach, J. (2012, Jan. 2). Spaceship Earth: A new view of environmentalism. The Washington Post. (Link)[ <https://www.washingtonpost.com/national/health-science/spaceship-earth-a-new-view-of-environmentalism/2011/12/29/gIQAZhH6WP_story.html?noredirect=on&utm_term=.9f633d5c2991>]