Module 1 Writing Assignment **Peter Truong | 36645133**

In a world void of microbes, in terms of Bacteria, Viruses, and Archaea, macroscopic life would continue to persist albeit with lower quality. Although microbes have proved over time that they are capable of sustaining life on Earth as a result of their influence on biogeochemical processes and role in biological systems, their transformative abilities are not absolutely necessary for human survival in the short term. Major proponents would argue that a microbe deficient world would result in depletion of the oxygen rich atmosphere, diminish current livestock, and accelerate climate change. However, through exponential technological advancements, we now have tools in our arsenal to combat these concerns if the challenge arises. It is processes like the Haber-Bosch process, recombinant bioengineering, and selective interventionalism that detail why humans are at the helm of spaceship Earth and not microbial communities. As a result, in this paper, the topic of how direct human interventionalism can significantly influence nutrient cycles, sustain small-scale nutritional demands for humanity, and accelerate the process of reversing climate change will be discussed.

One of the first major concerns of a microbe-void Earth would be its inevitable consequence on the oxygen rich atmosphere. Theoretically, without microbes, global photosynthesis would begin to decline rapidly leading to a depletion in atmospheric oxygen. Photosynthetic plants are heavily dependent on fixed nitrogen which can be obtained symbiotically through nitrogen-fixing bacteria. Despite losing this contribution of fixed nitrogen from bacteria, human intervention on nutrient cycles provides an alternative solution that allows aerobic life to persist on a smaller scale. This is largely because we now have large-scale industrial processes like the Haber-Bosch process that can initiate global ammonia fertilization schemes (Erisman et al., 2008). Currently through this process, humans produce ammonia at a rate of 9.5×10^{12} mol/ per year (Canfield et al., 2010). This is slightly greater than the 8×10^{12} mol per year produced through terrestrial nitrogen fixation and is comparable to the 10×10^{12} mol per year fixed by marine organisms (Cyanobacteria) (Canfield et al., 2010). As a result, by increasing the amount of ammonia production globally through the Haber-Bosch process, this can help offset any significant losses of photosynthetic life. Furthermore, humans possess the technology to fill in for unidentified microbial niches that enable specific metabolic transformations. There are many predicted microbial pathways, predicted solely on the basis of thermodynamics, which have yet to be found (Falkowski et al., 2008). It is believed that some of the reactions, like the oxidation of N_2 to NO_3-, have yet to be found due to their kinetic constraints within biological systems (Falkowski et al., 2008). As a result, human intervention has the capacity to significantly influence environmental metabolism in a way that microbial communities are unable to through directing these predicted pathways. Additionally, one may also argue that the loss of Cyanobacteria will be severely detrimental to oxygenic photosynthesis. However, according to Gilbert & Neufeld (2014), assuming humans could distribute nitrogen globally, algae and plants could continue to produce as much as 50% of the available atmospheric oxygen**.** As well, we currently possess the intellectual capacity and technology to engineer synthetic leaves that are capable of artificial photosynthesis (Mack, 2014). One of the major drivers for developing an artificial photosynthetic system was to be able to produce oxygen in space that could withstand the rough nature of interstellar expedition. However, in the event that microbes are no longer present to catalyze this process, what is there to stop humanity from heavily investing into this type of technology to upscale oxygen production on Earth?

The second concern of a microbe-void Earth would be its detrimental effect on humanity's nutritional demands. Livestock play a vital role in supplying nutrients to the global population. Ruminants in particular, heavily depend on their commensals to provide them with nutrients derived from a cellulose-rich diet (Flint et al., 2012). In the absence of microbial symbionts, ruminants will most likely perish. However, direct human interventionalism can potentially supply ruminants with the enzymes and nutrients they need through recombinant engineering biotechnology. *Ruminococcus* is a major commensal of ruminants and it plays an integral role in the degradation of cellulose. Cellulase enzymes from *Ruminococcus* catalyze the degradation of cellulose, releasing glucose which can be readily used by the ruminants (Flint et al., 2012). Humans can supply exogenous cellulase through using expression systems like yeast as a surrogate host (Gilbert & Neufeld, 2014)**.** Another possibility is using genetic engineering tools like CRISPR to develop next-generation ruminants that possess all of the necessary enzymes that are capable of sustaining their nutritional demands from a cellulose-heavy diet. CRISPR technology has recently seen an exponential increase in its uses and applications. As a result, leveraging CRISPR to re-engineer ruminants is still within the realm of possibility. In the event that human interventionalism is unable to meet the nutritional demands of livestock, we could also fallback on cultured meat. Throughout the past decades, an initiative was launched to develop in vitro meat as an effort to reduce animal cruelty (Zaraska, 2013). However it turns out that lab cultured meat has a variety of benefits. Lab grown meat can cut down on the amount of land that would normally be required to house ruminants which could then be allocated towards plantations. Furthermore, lab grown meat will also cut down on greenhouse-gas emissions. Ruminant livestock are estimated to be responsible for approximately 35-40% of annual methane emissions (Steinfeld et al., 2006). Methane is a potent greenhouse gas, however, its negative effect on the climate is 23 times higher than that of CO_2 (Koneswaran & Nierenberg, 2008). Although lab grown meat is currently very expensive to produce, if a selectional pressure arises, such as diminished symbiotic relationships in ruminants, humans will meet the demand by increasing the research and development of this technology.

Finally, proponents argue that without global environmental microbial catalysis, this would further intensify the negative effects of climate change. Ultimately the net effect of climate change on ecosystem carbon budgets depends on the balance between photosynthesis and respiration (Bardgett et al., 2008). With the loss of photosynthetic microbes, this will have a detrimental effect on the carbon cycle due to diminished carbon assimilation. However, it is also important to consider the effects of climate change on microbial sequestration of root-derived soil carbon. Interestingly, in the event that environmental microbial catalysis perishes, this could also potentially be a minor positive contribution in the context of today's Earth towards reversing climate change. Microbes play a significant role in soil organic matter decomposition which ultimately contributes to the efflux of CO_2 to the atmosphere. Soil respiration is thought to be more sensitive to temperature than primary production (Bardgett et al., 2008). As a result, increases in atmospheric CO_2 due to increased respiration, increases the amount of plant photosynthesis and transfer of carbon to soil heterotrophic microbes which further drives respiration (Heath et al., 2005). Therefore, it is predicted that climate warming will increase the net transfer of carbon from soil to atmosphere, thereby creating a positive feedback on climate change. Furthermore, while humans may be responsible for the imbalances in biogeochemical cycles, we are also the only ones that can reverse these effects in a timely manner through intervening in specific processes that contribute to climate change. From the Mauna Loa CO_2 data reports, it is evident that humans have a substantially larger impact on the environment compared to microbes (Schrag, 2012). As climate change continues to progress, natural selection will also run its course which will further propagate the destabilization of ecological equilibriums. Natural selection on microbial engines is unlikely to return imbalances in the carbon cycle towards conventional levels, rather it will promote the stabilization of a new ecologically distinct equilibrium point. This can be seen through anthropogenic history, where dramatic microbial shifts stemming from drastic environmental changes resulted in differential establishments of atmospheric gas compositions over time (Canfield et al., 2010). We have the capacity to act in a directional manner where we can collectively decide on specific environmental catalytic steps to intervene on, whereas microbes are unable to operate in this selective manner. Ultimately, it is this directionality that is the deciding factor that will make human intervention successful in challenging climate change.

It is important to come to the realization that humans are truly at the helm of spaceship Earth. As humanity continues to advance, so does the expansion of our intellectual libraries which provide us with the necessary tools to tackle global issues. In the event that nitrogen fixation contributions from microbial communities diminish, humanity will be prepared to offset fixed nitrogen loss through the Haber-Bosch process. In turn, oxygenic photosynthesis will continue to persist albeit on a smaller scale. Additionally, biotechnology and genetic bioengineering will provide the necessary tools to sustain populations of livestock that contribute to the nutritional demands of humanity. Most importantly, our significant influences on the carbon cycle far outmatches the contributions from microbial engines. Humanity's capacity for selective interventionalism is what will ultimately become the deciding factor in reversing current imbalances in the carbon cycle and accelerating it towards healthy equilibriums in a reasonable timeframe. However, an important consideration for human intervention would be how long would we be able to sustain these practices before we run out of resources? Furthermore, how much of Earth's biodiversity will we be able to maintain? Human interventionalism is limited in terms of protecting all walks of life as it is virtually impossible to directly intervene in every symbiotic relationship. There are many eukaryotic species, like the Termite, that will become extinct as they depend on symbionts for their nutritional and cofactor demands. In spite of these challenges, it is vital to remember that the human race is resilient. If there is one thing that our ancestors have shown us, it is that when selectional pressures arise, humans are perseverant and will continue to come out on top despite the challenge on hand. Taken together, while human intervention in a microbe-void Earth may not be able to sustain the biodiversity, human populations, and quality of living that we see today, the human race will likely continue to persist.

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