BIOMASS LIMITS ON SUBSURFACE MARTIAN LIFE FROM ATMOSPHERIC GASES. S. F. Sholes[1], J. Krissansen-Totton[1], and D. C. Catling[1], [1]Dept. of Earth and Space Sciences and Astrobiology Program, Box 351310, Univ. of Washington, Seattle, WA (sfsholes@uw.edu).

Introduction: Mars' current atmosphere is characterized by a thermodynamic disequilibrium which is a "free lunch" for potential life. Substantial concentrations of atmospheric CO and O_2, maintained by the photolysis of CO_2 and H_2O, coexist providing upwards of ~140 J/mol of available Gibbs free energy, which could be exploited by microbes[1].

If a large active biosphere were present on Mars it would likely exploit this available free energy, driving the atmosphere towards equilibrium. On Earth, these CO-consuming metabolisms (carboxydotrophs) are relatively simple and widespread leading some to suggest they are ancient with multiple independent origins [2]. In principle, microbes in habitable environments, in diffusive-contact with the atmosphere, ought to evolve to exploit this "free lunch."

As Mars' atmosphere is not in thermodynamic equilibrium, metabolically active life in communication with the atmosphere must be limited (assuming it evolved to take advantage of the abundant free energy). Using a photochemical model, an upper limit of biomass can be found using a model by incrementally ramping up biogenic sinks for the different metabolic species until biologically-mediated, atmospheric gas concentrations deviate from observations. Thus, this atmospheric disequilibrium allows for estimates on the upper limit of extant life.

Previous work by Weiss et al. (2000) [3] provided constraints on the maximum extant biomass, but these were potentially inaccurate as they used fixed values for unknown photochemical model parameters that were tuned to an abiotic Mars (i.e. without biogenic sinks/sources). Here, we greatly improve and expand upon this work primarily by testing over a broad plausible parameter space for these unknown model parameters. Additional improvements in the photochemical code, more precise measurements of atmospheric gas abundances gathered from the *Curiosity* rover, and the inclusion of fluxes for both the metabolic sinks and the metabolic products leads to a more robust upper limit on the possible extant metabolizing biomass in communication with the atmosphere.

Methods: Using a validated 1-D photochemical model for modern Mars [4], we impose a fixed basal sink on each metabolic reactant and a corresponding upwards source flux of the products to simulate metabolizing microbes. Biogenic fluxes are ramped up until the modeled concentrations of CO_2, CO, O_2, H_2, or CH_4 diverge from observations within 2σ.

We test over five dominant net metabolisms (or net metabolic ecosystems): aerobic and anaerobic carboxydotrophy, methanogenesis, hydrogenotrophy, and a combined aerobic carboxydotrophy and methanogenesis ecosystem. Methanotrophs without methanogens are not modeled and assumed infeasible given the low background abundance of CH_4 (< 1 ppb). Metabolisms that source gases not detected in the atmosphere (e.g. H_2S from sulfate reducers) are similarly not modeled.

Our new optimized-parameter version of the model tunes unknown model variables (deposition velocity, surface temperature, and ionospheric flux) with the assumption of a biological sink on CO or H_2.

Results & Discussion: We find that the aerobic carboxydotrophy ($4CO+2O_2 \rightarrow 4CO_2$) and hydrogentrophy ($O_2+2H_2 \rightarrow 2H_2O$) metabolisms allow for the greatest biogenic sinks of 1.5×10^8 and 1.9×10^8 molecules cm^{-2} s^{-1} for CO and H_2, respectively. Conversion of these fluxes into a maximum total biomass requires a cellular basal power requirement (BPR). Using the lowest measured BPR of $\sim3\times10^{-23}$ kJ s^{-1} $cell^{-1}$ (close to a theoretical limit to prevent racemization of amino acids) [5], we find a maximum possible metabolizing biomass of $\sim10^{27}$ cells. Conservative estimates of ~14 fg $cell^{-1}$ convert this to $\sim10^{11}$ kg or the equivalent of ~1 million blue whales biomass.

This upper limit is robust to uncertainties in the photochemical code and represents only a tiny fraction, $\sim10^{-5}$, of Earth's total biomass. It is also likely an overestimate, as it assumes near-absolute minimum energy requirements and does not account for additional costs such as reproduction and inefficiency.

Modeling the atmospheric diffusion into the subsurface shows that gases are able to diffuse at much higher rates than calculated via the photochemistry. This suggests that any life in the upper regolith is not taking full advantage of the available free energy and would be limited by some other factors (e.g. lack of liquid water or temperatures that are too cold).

Overall, we provide robust constraints on the maximum allowable biomass for actively metabolizing subsurface life in diffusion-contact with Mars' atmosphere at low latitudes [6]. Microbial communities sealed off from the atmosphere or dormant might also exist but would not be detectable via atmospheric constraints.

References: [1] Krissansen-Totton et al., *Astrobiology* 16, 2016. [2] Ragsdale, *Crit. Rev. Biochem. Mol. Biol.* 39, 2004. [3] Weiss et al., *PNAS* 97, 2000. [4] Sholes et al., *Icarus* 290, 2017. [5] LaRowe and Amend, *Front. Microbiol.* 6, 2015. [6] Sholes et al., *Astrobiology*, in review, 2018.