Environmental Consequences of an Emerging Biosphere

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It seems feasible to detect biological signatures ("biosignatures") in other planetary systems using the tools of astronomy. There are at least two types of biosignatures; spectral and/or polarization features created by biological products, and electromagnetic signals created by technology. The latter example of a biosignature requires SETI-like searches. This presentation addresses only spectral signatures of biological products and properties of habitable planets. Spectral biosignatures are indeed promising targets for near-term exploration. They can arise from organic constituents (e.g., vegetation) and/or inorganic products (e.g., atmospheric O_2). Features originating from a planet's surface are likely to be localized in specific regions, whereas gaseous biosignatures can become globally distributed by atmospheric circulation.

Biosignatures should be most abundant within environments that are, or once were, habitable. We currently believe that habitable environments necessarily provide liquid water and biochemically useful energy. However, we do not yet fully comprehend the diversity of features that might arise within these environments that are non-biological in origin, yet mimic biosignatures. For example, atmospheres reflect the events leading to their origins as well as a host of ongoing planetary processes that might include biological activity. We are persuaded that abundant atmospheric oxygen in an environment with abundant liquid water constitutes definitive evidence of life. However, our own early biosphere thrived for more than a billion years in the absence of abundant atmospheric oxygen. The production of other, more reduced, gaseous biomarkers of "young" and/or anaerobic biospheres has not been systematically studied. Biological gas production is strongly controlled by the structure and function of microbial ecosystems. Investigations of microbial ecosystems that are close analogs of ancient communities offer multiple benefits. Such studies can interpret the production of the most important biomarker gases, while simultaneously helping us to understand the formidable array of ecological processes that guided early biological evolution. Astrobiologists must recognize those aspects of biosignatures that truly reflect the most fundamental, and therefore universal, properties of life. We must learn how the environment can modify biosignatures, and how technology can enable an array of biosignatures to be detected remotely within realistic budgetary constraints.

Reference. Des Marais, D. J., Harwit, M., Jucks, K., Kasting, J. F., Lunine, J. I., Lin, D., Seager, S., Schneider, J., Traub, W., Woolf, N. (2002) Remote sensing of planetary properties and biosignatures on extrasolar terrestrial planets. *Astrobiology*, Vol. 2, No. 2, 153-181.