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Module 1 Origins and Earth Systems
Evidence worksheet_01 "Prokaryotes: The unseen majority"

Learning objectives:

- Describe the numerical abundance of microbial life in relation to the ecology and biogeochemistry of Earth systems.

General Questions:

• *What were the main questions being asked?*

How do we estimate the prokaryotic population of the world? And what is it made up of?

What are the uncertainties that come with this measurement?

Which environments contain the most prokaryotic biomass?

How does this biomass affect global nutrient cycles? (e.g. P, C, N)

• *What were the primary methodological approaches used?*

Prokaryotic estimates were based upon average data from the following four environments: aquatic environments, soil, subsurface, and "other habitats" including in or on animal or plant surfaces or in the air. They used experimentally derived values to perform these calculations, but interestingly, not the same value sets for each environment. For example, some calculations included cell volume, while others included just the area of the environment. Vi

Also, they compared their calculated values with some from other papers, which resulted in some differences that they attempted to explain.

• *Summarize the main results or findings.*

They found that prokaryotes contain about half of the organic carbon on earth, and 90% of the nutrients (compared to plants)
In brief, the prokaryotic biomass and thus their contribution to global cycles is very large - doubling estimates of the amount of carbon stored in living organisms globally. They broke down the calculations into four environments: aquatic environments, soil, subsurface, and "other habitats".

Aquatic environments- this includes the open ocean, sediment in the ocean, freshwater and saline lakes (3 orders of magnitude less) and polar regions. Prokaryotes are ubiquitous in these environments - 1180 x 10^26 cells.

Soil- surprisingly, there are less prokaryotes in forest soils than in other soils. The estimates varied by ecosystem. 255.6 x 10^27 cells.

Subsurface- e.g. terrestrial habitats below 8 m and marine sediments below 10 cm. (this includes groundwater too) This environment is difficult to estimate because it is difficult to obtain uncontaminated samples. However, it has been suggested to be enormous. 3.8 x 10^30 cells.

Other environments - discussed the prokaryotes that live on animals, insects, and plants, and also those in the air/atmosphere. 53.024 x 10^23 cells (several orders of magnitude smaller)

These large numbers mean that not only carbon, but N and P are stored in globally significant amounts in prokaryotes.

Disproves Kluyver's estimate that 1/2 of the living protoplasm on earth is microbial - likely this number is far too conservative. The paper also discusses growth rates to estimate cell turnover, and fluxes in and out of these environments.

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• *Do new questions arise from the results?*

In subsurface environments, the turnover time of cells seems exceedingly large, is this a good estimate?

Where does the energy in the subsurface environments come from? Photosynthesis? Chemolithotrophy?

From the passage "in the polar regions, a relatively dense community of algae and prokaryotes forms at the water-ice interface" - why does this occur?

How accurate can these calculations be if they are based upon just a few estimates?

How much flux occurs among all of these prokaryotic environments? Especially the subsurface environment, if so many cells are hypothesized to be metabolically inactive, how much flux can occur? Is it more of a pool than a flux?

• *Were there any specific challenges or advantages in understanding the paper (e.g. did the authors provide sufficient background information to understand experimental logic, were methods explained adequately, were any specific assumptions made, were conclusions justified based on the evidence, were the figures or tables useful and easy to understand)?*

The estimates described in the paper introduce a large amount of uncertainty because no matter how many samples you collect, you are still having to generalize this data for the entire earth. You cannot possibly collect enough data to have any degree of accuracy in your prediction. However, otherwise, their experimental logic made sense.

Lastly, the estimates for each environment were likely collected using different methods- and by different people. Therefore, each method probably has its own pros and cons, and contributes its own level of uncertainty to the proceeding estimates.