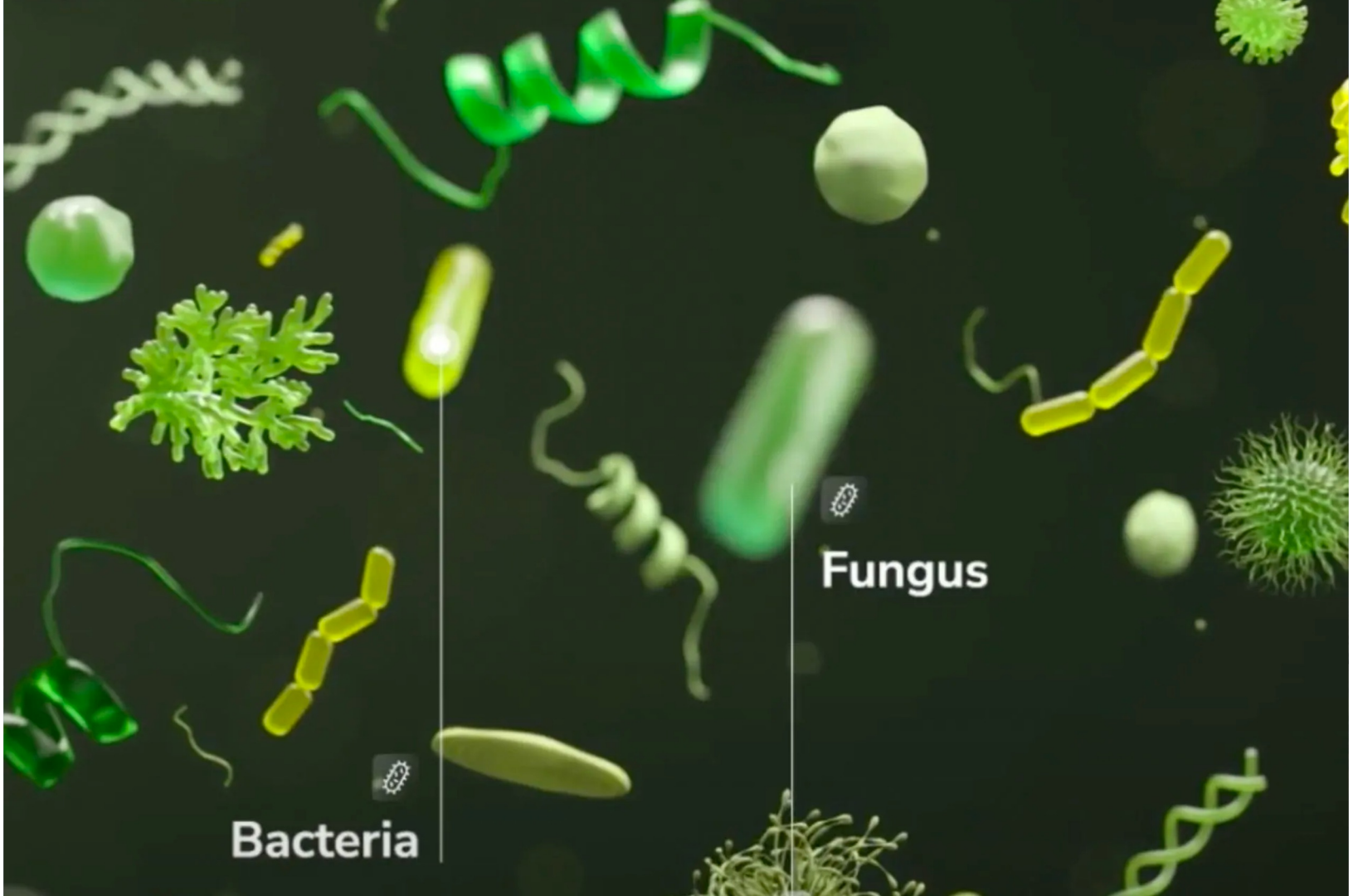
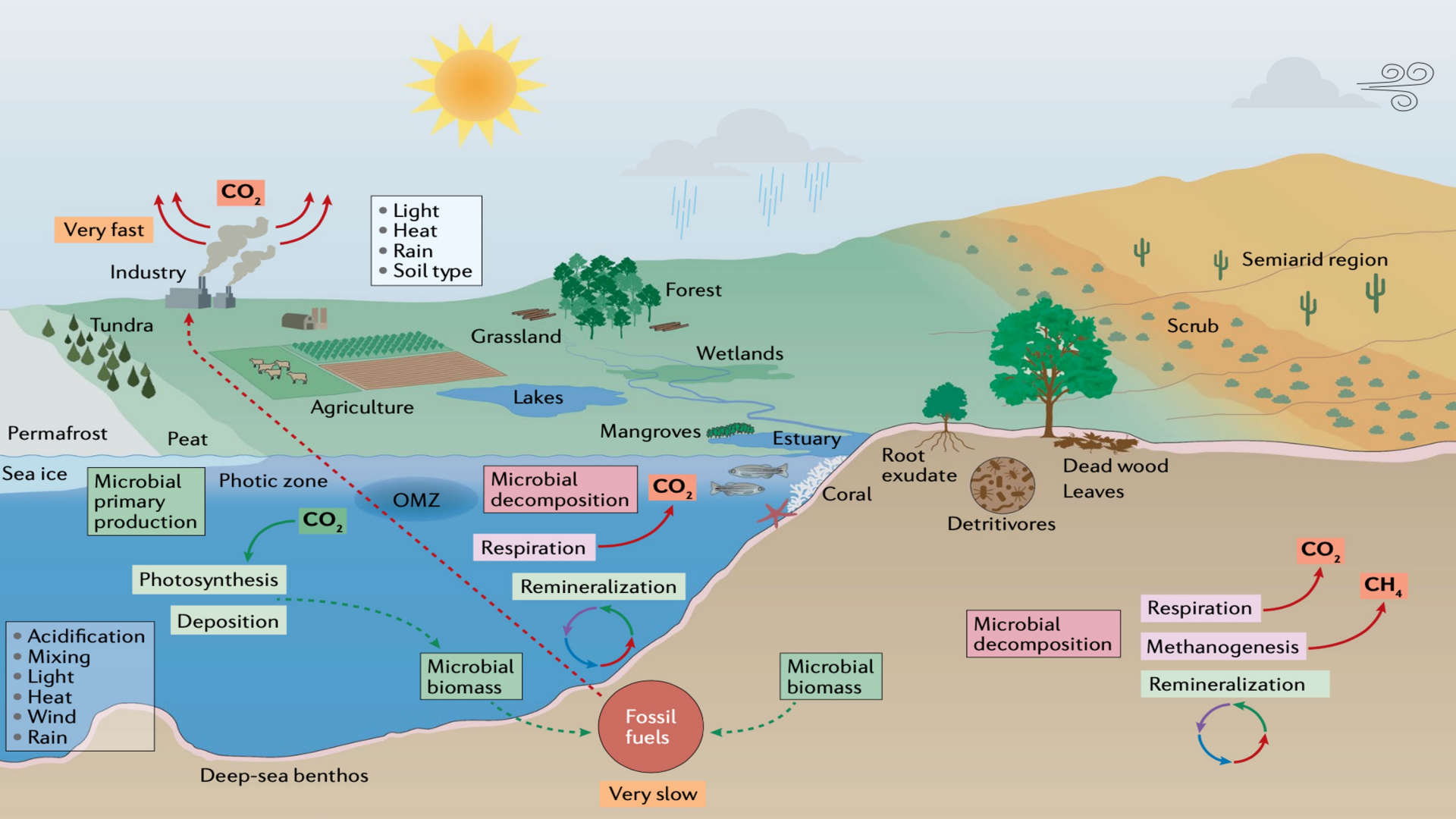
Climate Change and Molecular Evolution

Malika Sharma and Sara Lawrence
BIOL 4130
Feb 27, 2023

What is climate change?


Fungus
Bacteria


CO_2
Very fast
Industry
Light
Heat
Rain
Soil type
Tundra
Forest
Grassland
Wetlands
Agriculture
Lakes
Permafrost
Peat
Mangroves
Estuary
Semiarid region
Scrub
Root exudate
Dead wood
Leaves
Detritivores
Sea ice
Microbial primary production
Photic zone
OMZ
Microbial decomposition
CO_2
Coral
CO_2
Photosynthesis
Respiration
Remineralization
Deposition
Acidification
Mixing
Light
Heat
Wind
Rain
Microbial biomass
Microbial biomass
Fossil fuels
Deep-sea benthos
Very slow
Microbial decomposition
CO_2
CH_4
Respiration
Methanogenesis
Remineralization

3 Pillars of One Health

- Connection between humans, plants and animals - as well as microbes
- Changing relationships and connections to plants, animals and microbes

One Health is the idea that the health of people is connected to the health of animals and our shared environment.

When we protect **one**, we help protect **all**.

www.cdc.gov/onehealth

Why ONE HEALTH is Important

As Earth's population grows, our connection with animals and the environment changes:

People live closer together

Changes in climate and land use

More global travel and trade

Animals are more than just food

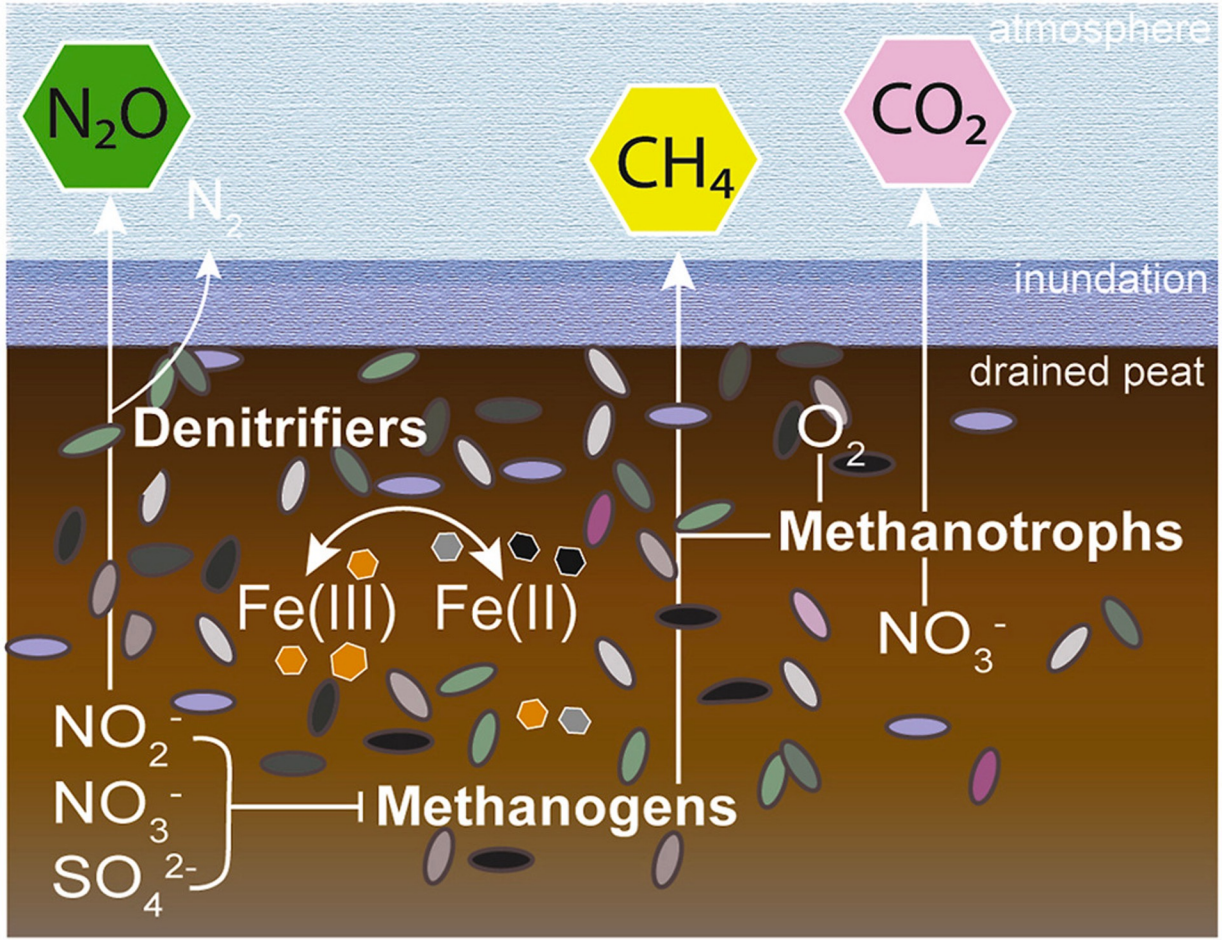
These factors make it easier for diseases to spread between animals and people.

A One Health approach tackles shared health threats by looking at all angles—human, animal, plant, and environmental

www.cdc.gov/onehealth

Microbial impact on climate change

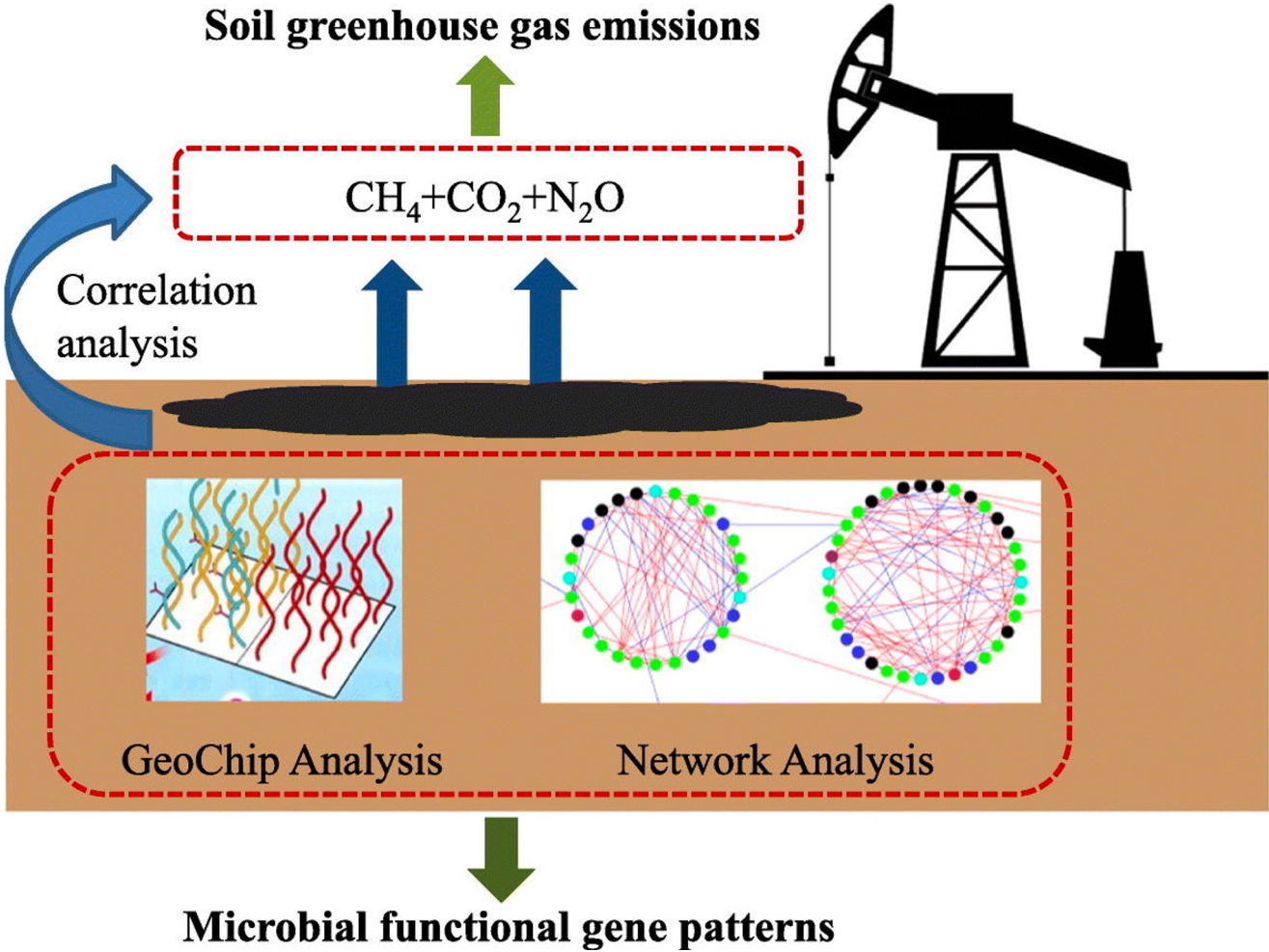
- Microbes can contribute to climate change through greenhouse gas emissions
- For example, the relationship between excess fertilizer and GHG



Source: https://doi.org/10.1016/j.soilbio.2020.107862

Microbial impact on climate change

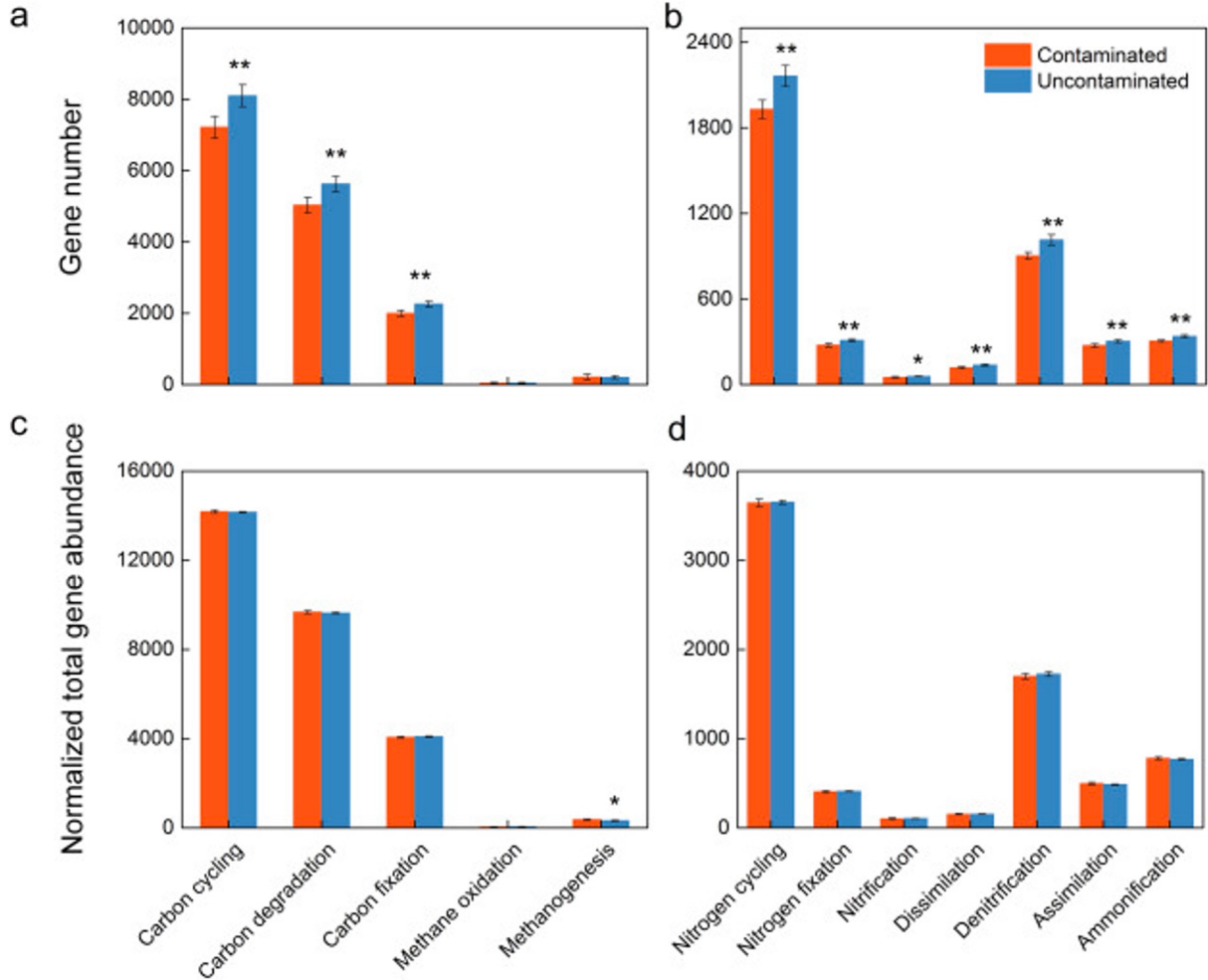
- Paper by Yang et. al
- Determination of microbial GHG emissions in oil contaminated areas vs. non-oil contaminated areas



Source: https://doi.org/10.1016/j.scitotenv.2018.02.007

Microbial impact on climate change

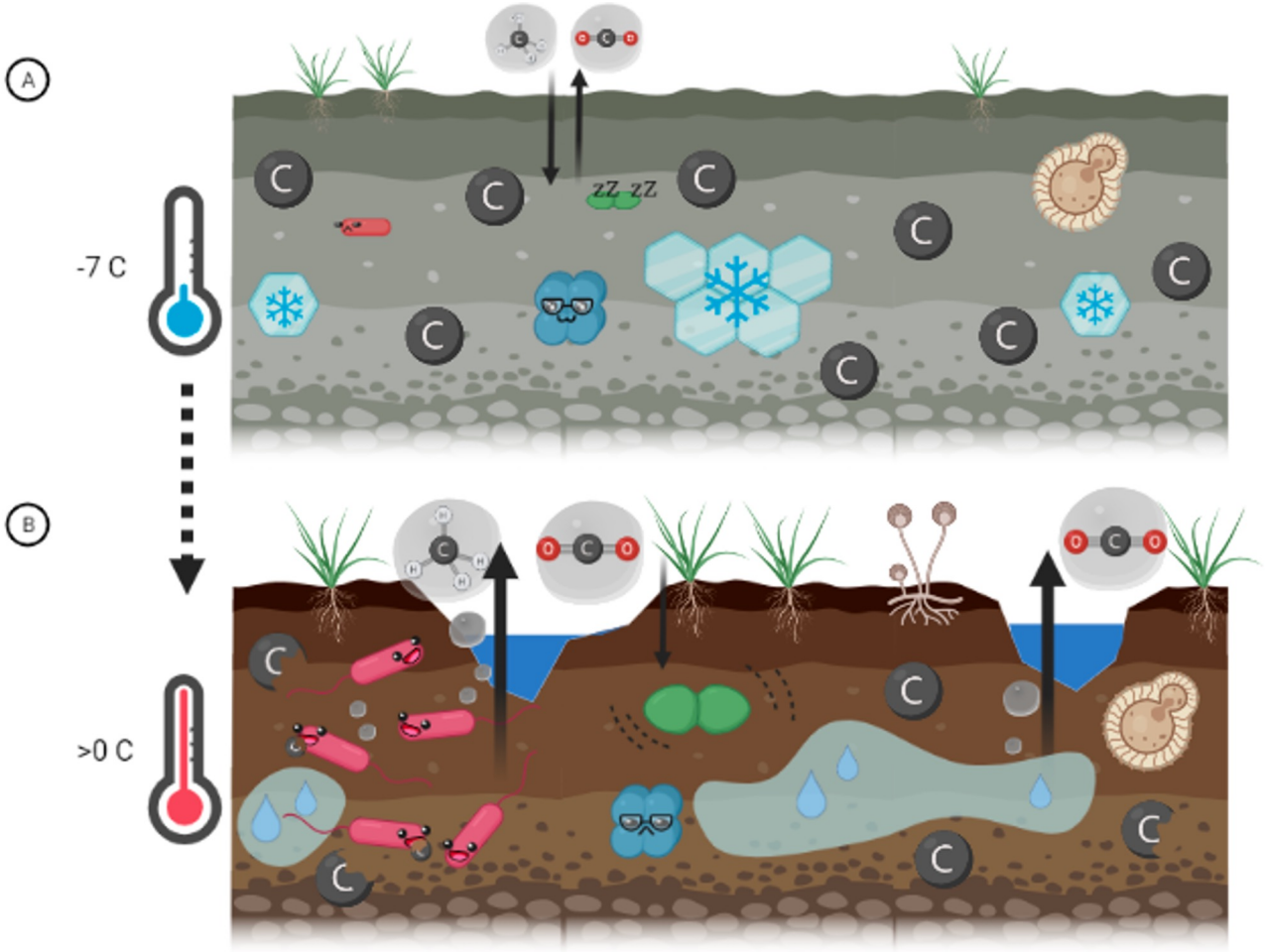
- Different expression of genes related to carbon and nitrogen cycling in contaminated vs. uncontaminated areas
- Adaptation and evolution of microbes to human caused change in environment
  - Potentially leading to even more harmful results



Source: https://doi.org/10.1016/j.scitotenv.2018.02.007

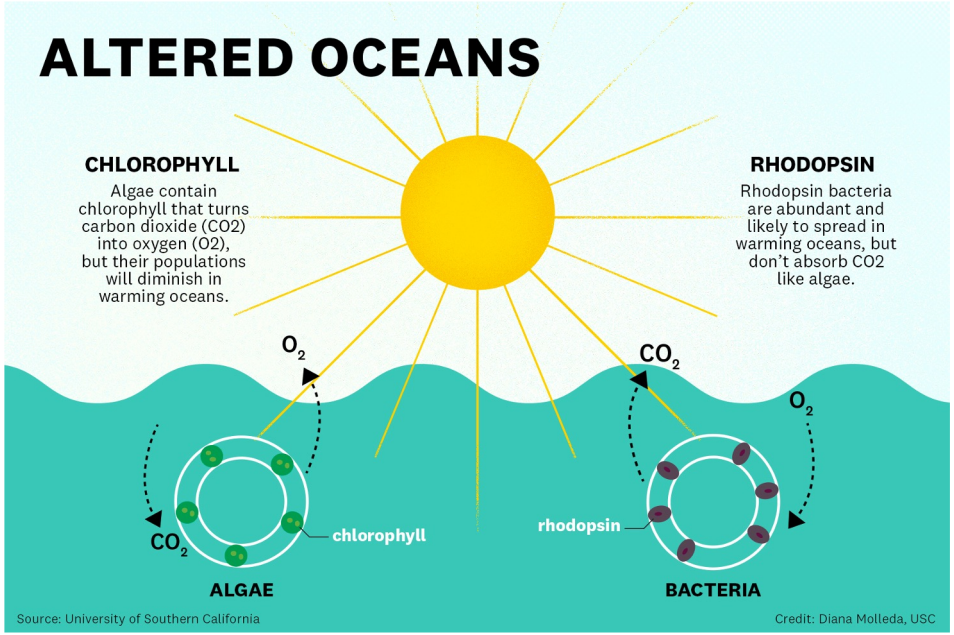
Microbial impact on climate change

- Effect of climate change on microbes found in permafrost
  - Increased temperatures lead to increased release of GHGs from active microbes
- potential release of unknown microbes



Source:https://blogs.egu.eu/divisions/cr/2021/10/22/its-getting-hot-in-here-ancient-microbes-in-thawing-permafrost/

Which microbes are THRIVING?

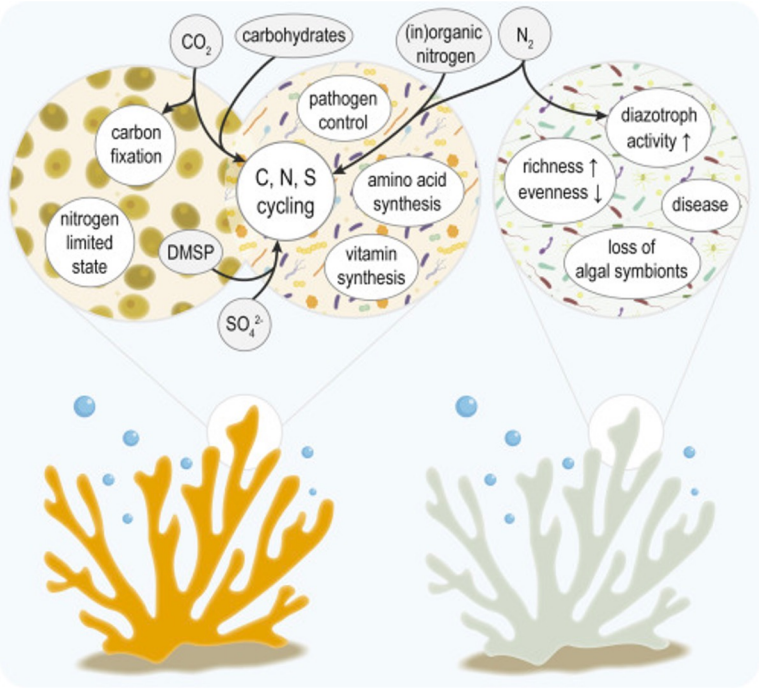


Source: https://news.usc.edu/159287/marine-bacteria-earth-warming-climate-usc-research/

Source: https://phys.org/news/2023-02-fungi-bacteria-binging-soil.amp

Which microbes are DYING?

- Potential extinction of highly specialized microbes or microbes with necessary mutualistic relationships



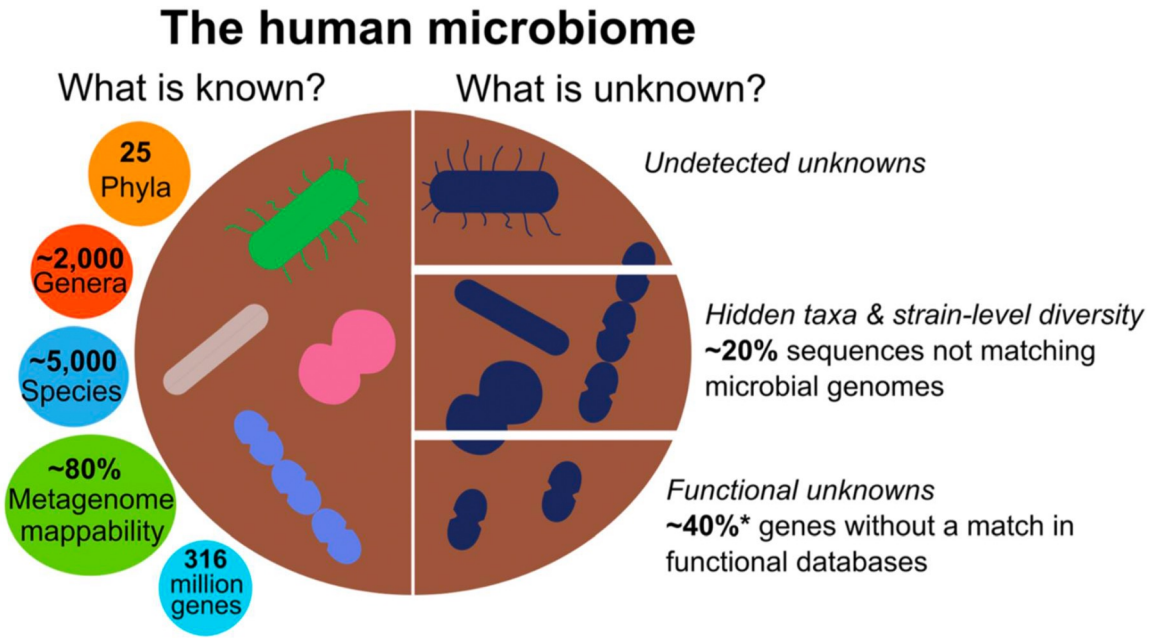
Source: https://doi.org/10.1016/j.isci.2020.100972

Source:https://news.cgtn.com/news/2019-12-12/Why-do-legumes-have-nodules-on-their-roots--MmxlxHWkda/index.html

Which microbes are UNAFFECTED?

Is it possible for any microbes to be unaffected by climate change?

- Could microbes in isolated environments eg. human body, be unaffected?

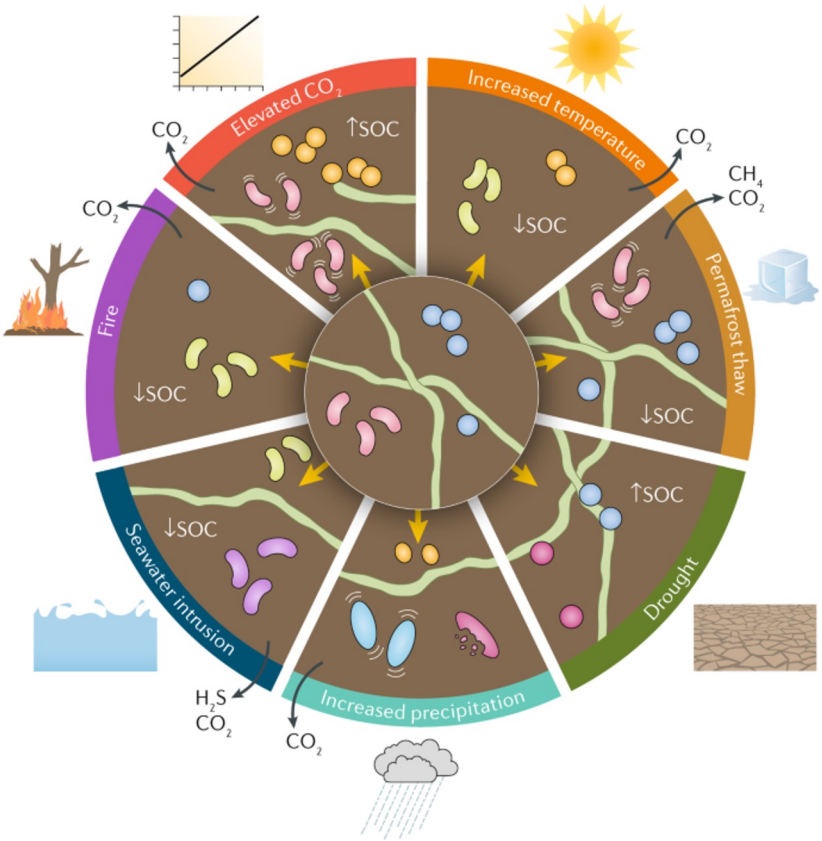


Source: https://www.gutmicrobiotaforhealth.com/the-knowns-and-unknowns-of-the-human-microbiome/

Physiology adaptation of microbes

Short generation time allows for rapid evolution and changes in their physiology. Climate change forces microbes to evolve in ways that suits their fitness and survivability best.

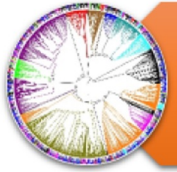
Ex: tundra microbial communities change in the soil layer of permafrost after warming.



Tools we can use to study microbial evolution

Recent advances in meta-omic technology has allowed us to better understand microbial evolution

Eg. use of 16S rRNA sequencing to study changes in microbial composition

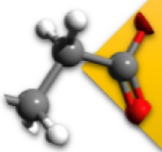


Gene Marker Analysis

Technology Platform: Next Generation Sequencing
Common Software : QIIME, Mothur, VEGAN, phyloseq, DADA2
Pros: Cost-effective, analytical pipelines widely accepted
Cons: Lacks clear functional information, potential errors in differentiation of taxa

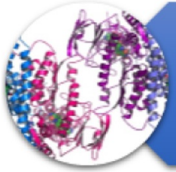
Shotgun Metagenomics

Technology Platform: Next Generation Sequencing
Common Software : IDBA-UD, SPAdes, MEGAHIT, MetaPhlAn2 , MG-RAST, HUMAnN2
Pros: Captures all microbial genomes present within a sample
Cons: Expensive, computationally demanding, no consensus on analytical pipelines



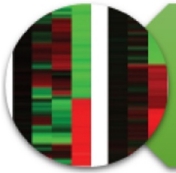
Metabolomics

Technology Platform: LC/GC-MS
Pros: allows for profiling of the metabolites microbiota produce, semi-quantitative
Cons: Origin of metabolite unknown



Metaproteomics

Technology Platform: LC/GC-MS
Pros: Allows for identification and quantification of the proteins within a sample
Cons: Origin of protein unknown

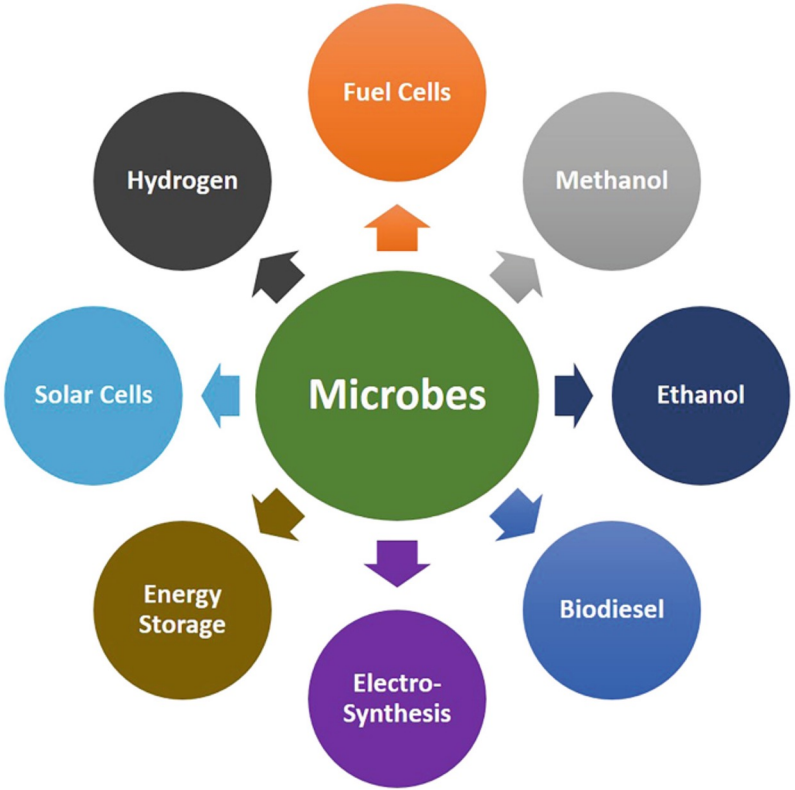


Metatranscriptomics

Technology Platform: Next Generation Sequencing
Common Software : SOAPdenovo
Pros: Allow assessments of gene expression
Cons: Protein expression may depend on translation and post-translational modifications

Source: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7598837/

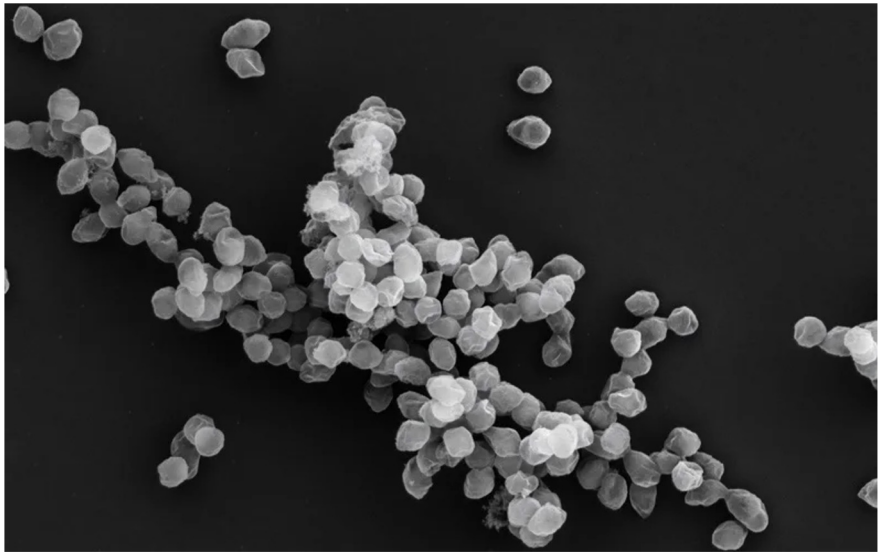
How can we learn from them?



Mitigation

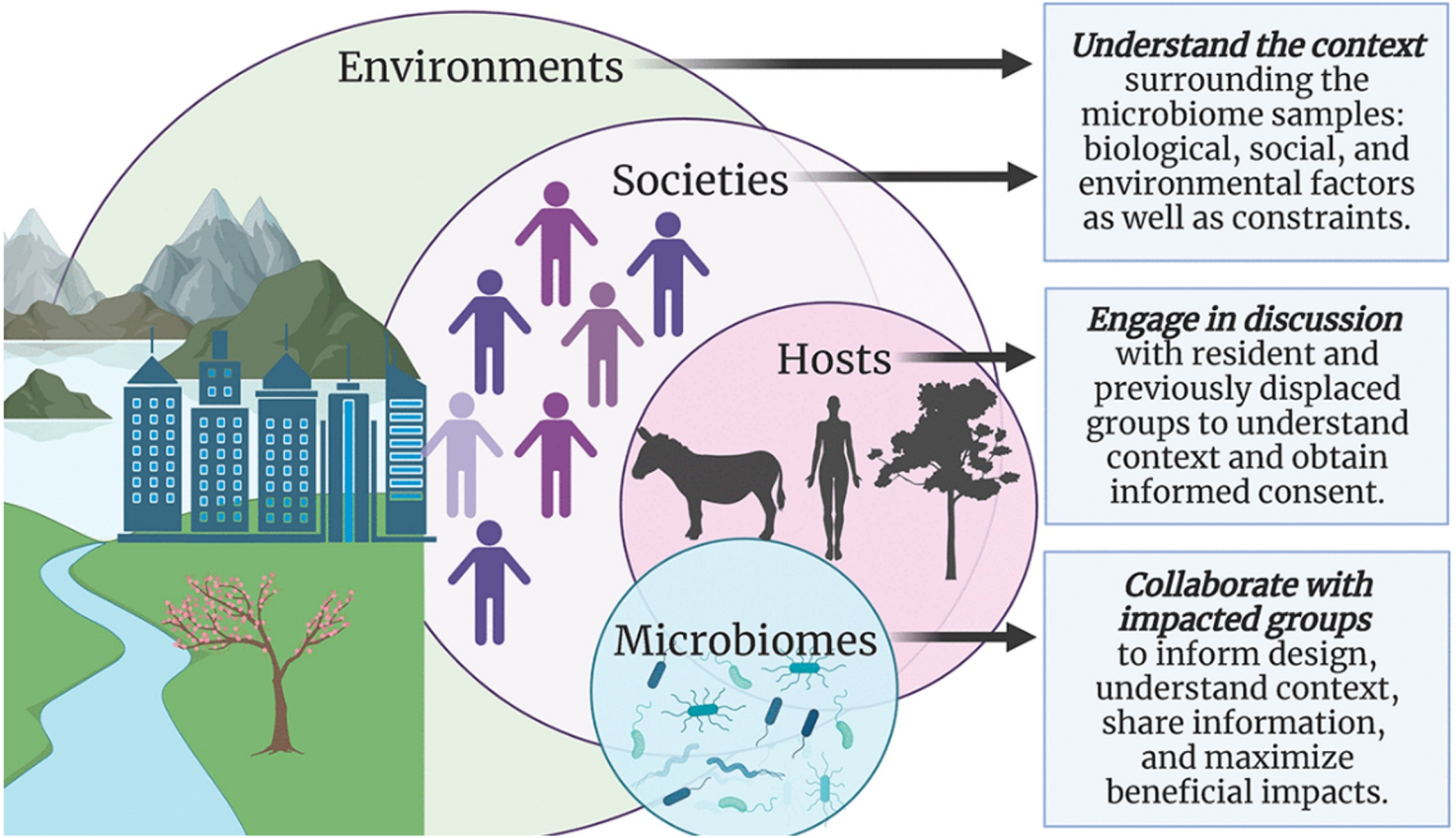
Eg. Ruminating animals produce methane when digesting food. Baby kangaroo feces, when used in tandem with a known methane inhibitor, was shown to **reduce** methane production

https://www.news9live.com/science/microbes-from-baby-kangaroos-can-reduce-methane-emissions-from-cows-au941-2053742



Eg. Photoferrotrophs steal electricity from iron and can absorb carbon dioxide on a large scale

What can we do?



Source: https://doi.org/10.1128/msystems.01240-21

References

- Bernstein, J. 2023, February 7. Fungi and bacteria are binging on burned soil. Phys Org. Available from https://phys.org/news/2023-02-fungi-bacteria-binging-soil.amp [accessed 26 February 2023].
- Cavicchioli, R., Ripple, W.J., Timmis, K.N. *et al.* 2019, June 18. Scientists' warning to humanity: microorganisms and climate change. Nature Reviews Microbiology. Available from https://www.nature.com/articles/s41579-019-0222-5 [accessed 26 February 2023].
- Chase, B., Weihe C., Martiny JBH. 2021, April 27. Adaptive differentiation and rapid evolution of a soil bacterium along a climate gradient. PNAS. Available from https://www.pnas.org/doi/full/10.1073/pnas.2101254118 [accessed 26 February 2023].
- Climate change impacts. 2021, August 21. National Oceanic and Atmospheric Administration. Available from https://www.noaa.gov/education/resource-collections/climate/climate-change-impacts [accessed 26 February 2023].
- Microbes from baby kangaroos can reduce methane emissions from cows. 2023, February 16. News9. Available from https://www.news9live.com/science/microbes-from-baby-kangaroos-can-reduce-methane-emissions-from-cows-au941-2053742 [accessed 26 February 2023].
- One Health. 2023, February 16. Centers for Disease Control and Prevention. Available from https://www.cdc.gov/onehealth/index.html [accessed 26 February 2023].
- Peteghem, LV., Sakarika, M., Matassa, S., *et al.* 2022, April. Towards new carbon–neutral food systems: Combining carbon capture and utilization with microbial protein production. Bioresource Technology. Available from https://www.sciencedirect.com/science/article/abs/pii/S0960852422001821?via%3Dihub [accessed 26 February 2023].
- Polakovic, G. 2019, August 7. A surprisingly abundant type of marine bacteria may speed up climate change. USC News. Available from https://news.usc.edu/159287/marine-bacteria-earth-warming-climate-usc-research/ [accessed 26 February 2023].
- Shade, A., Peter, H., *et al.* 2012, December 19. Fundamentals of microbial community resistance and resilience. Frontiers in Microbiology. Available from https://www.frontiersin.org/articles/10.3389/fmicb.2012.00417/full [accessed 26 February 2023].
- Thomas, AM., Segata, N. 2019, August 15. The knowns and unknowns of the human microbiome. Gut Microbiota for Health. Available from https://www.gutmicrobiotaforhealth.com/the-knowns-and-unknowns-of-the-human-microbiome/ [accessed 26 February 2023].