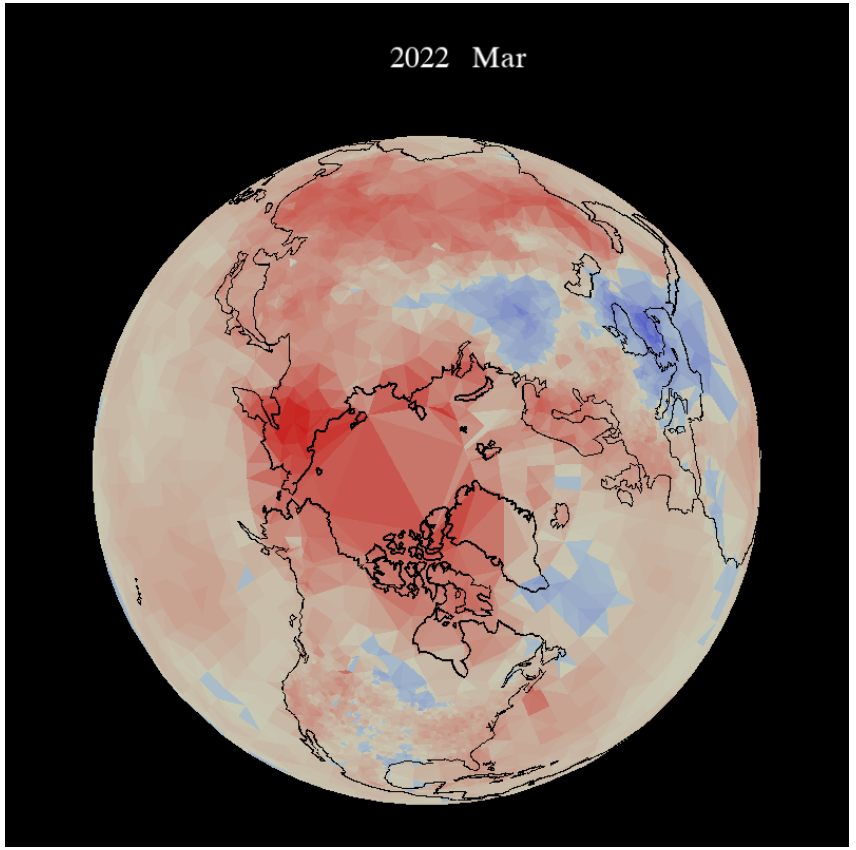
Planetary Health:
Microbes & Ecosystems

Dr. Nick Coleman

Planetary Health: Why should we care?

"We the human species are confronting a planetary emergency--a threat to the survival of our civilization that is gathering ominous and destructive potential... the earth has a fever. And the fever is rising...Indeed, without realizing it, we have begun to wage war on earth itself..." --Al Gore, Nobel Prize acceptance speech, 2007

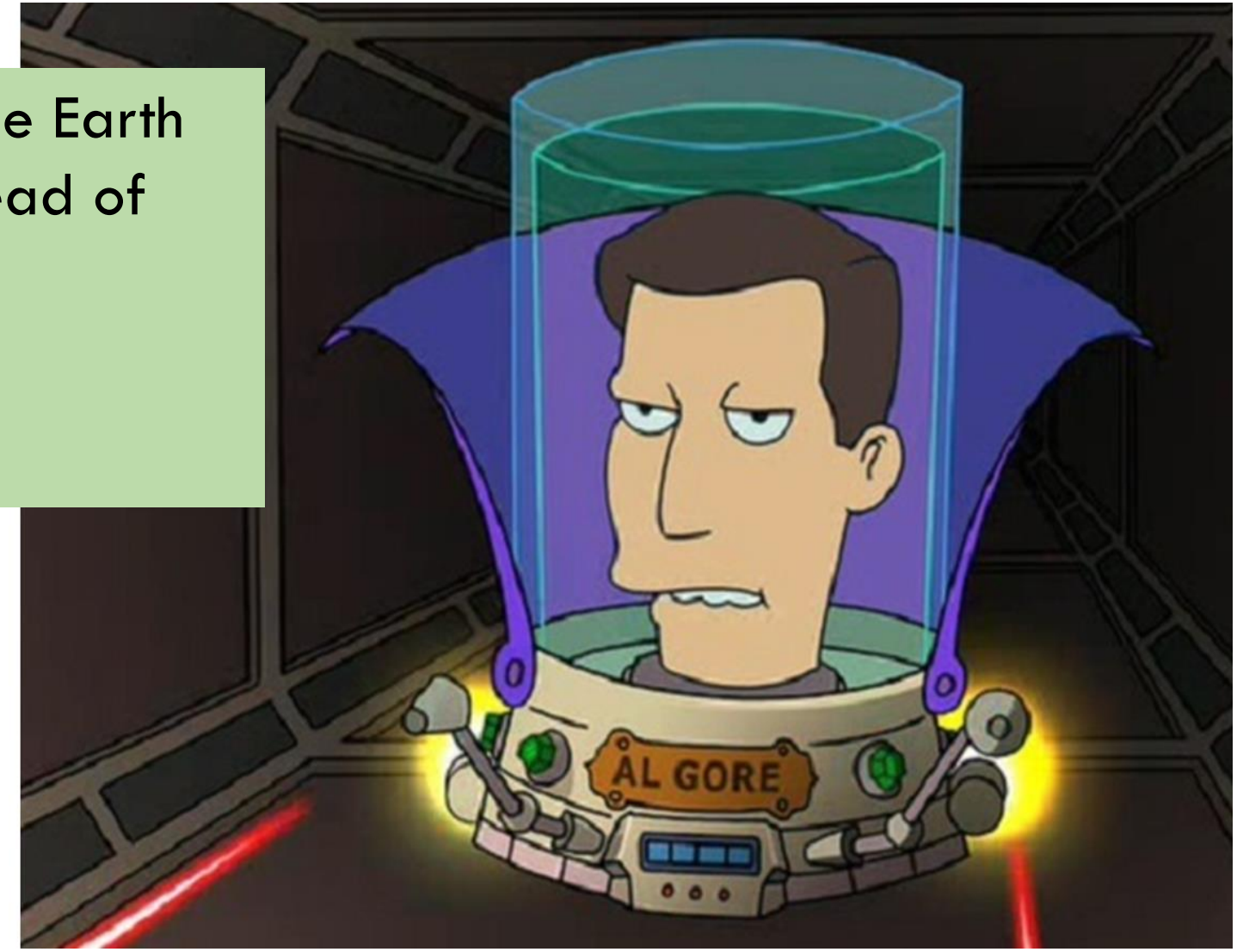


Planetary Health: Why should we care?

"Finally, I get to save the Earth with deadly lasers instead of deadly slide shows"

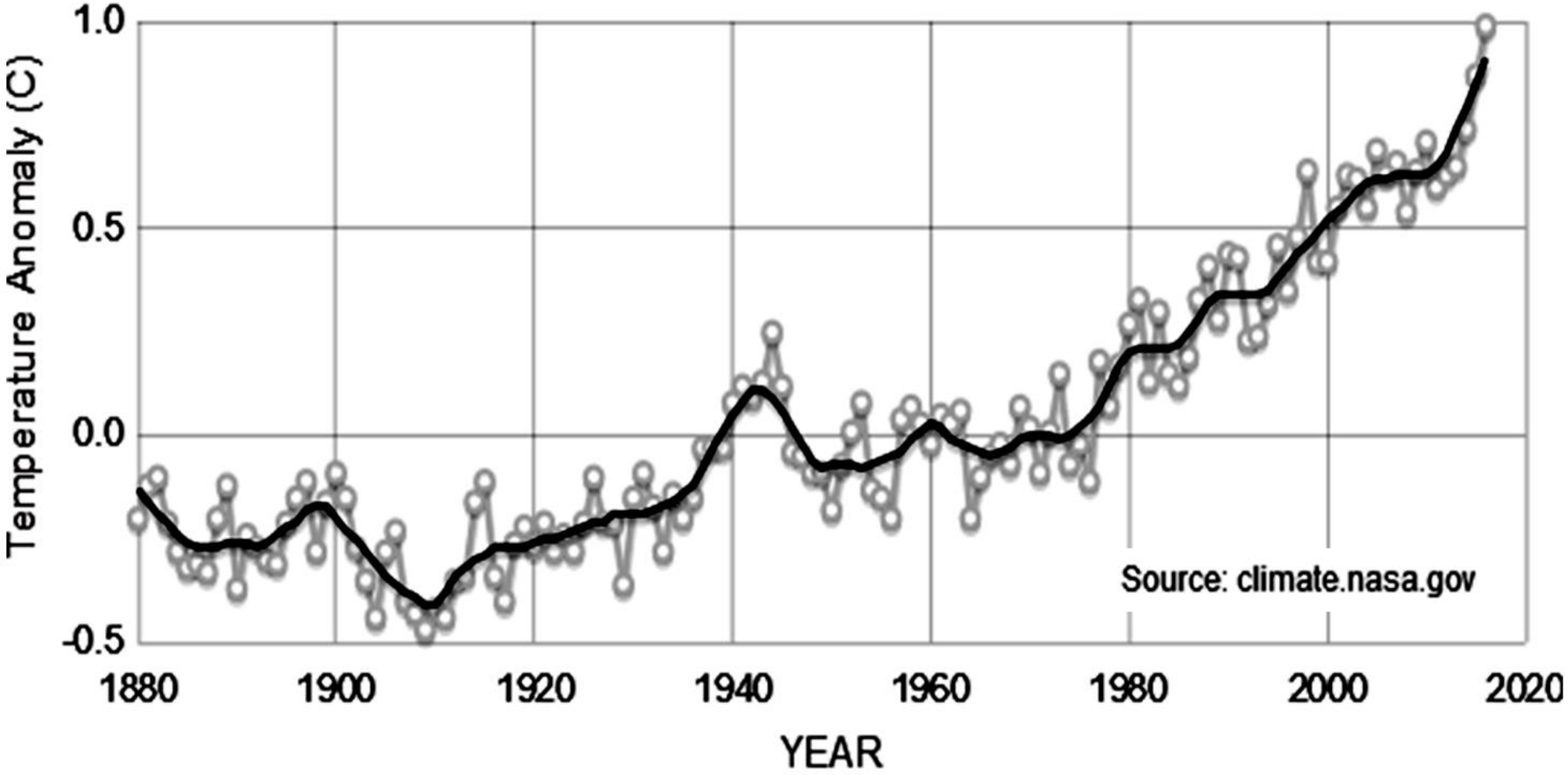
-Al Gore's head

31st century

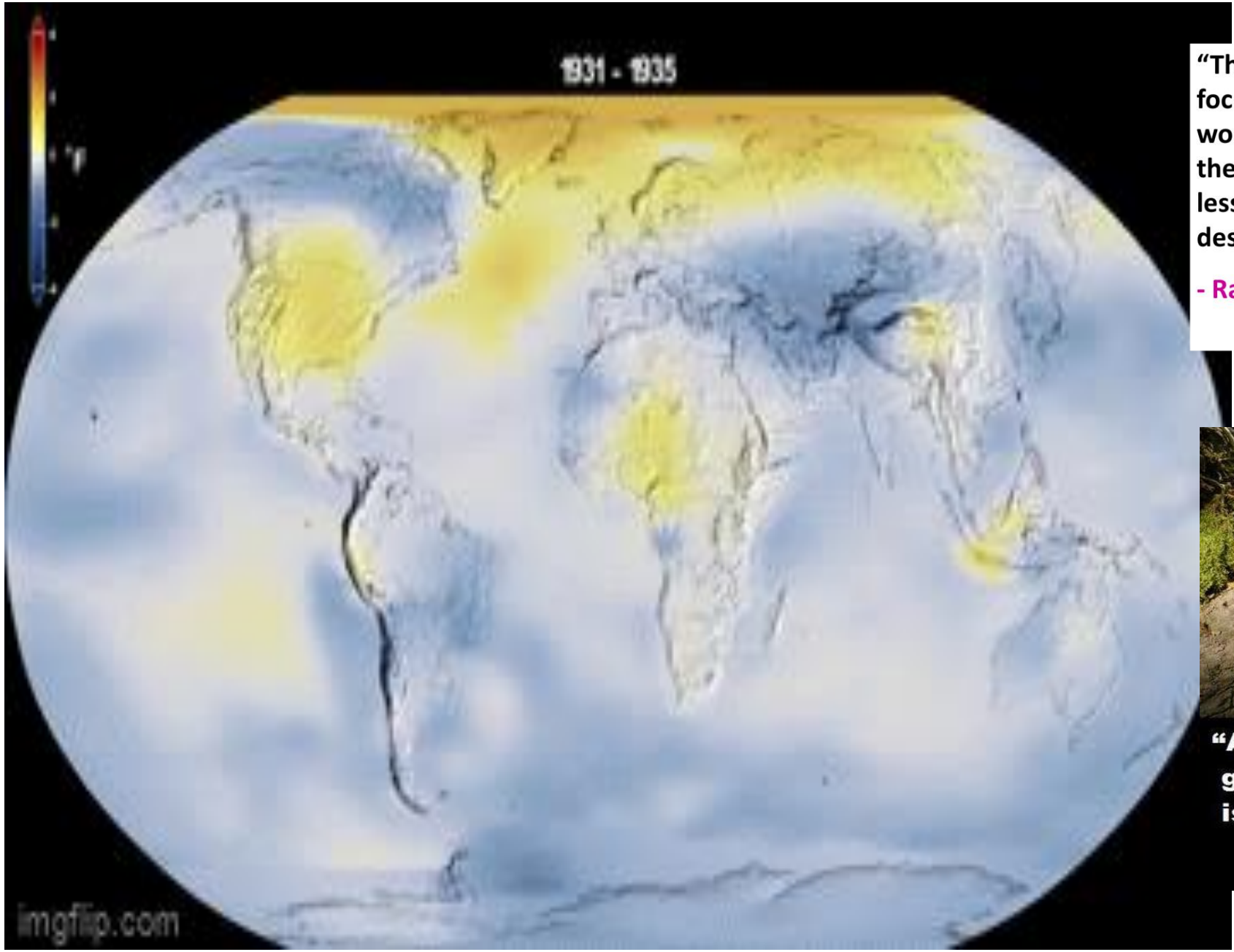


Planetary Health: Why should we care?

- 16 of the 17 warmest years on record have occurred since 2001



Also see: https://svs.gsfc.nasa.gov/4546



"The more clearly we can focus our attention on the wonders and realities of the universe about us, the less taste we shall have for destruction."

- Rachel Carson

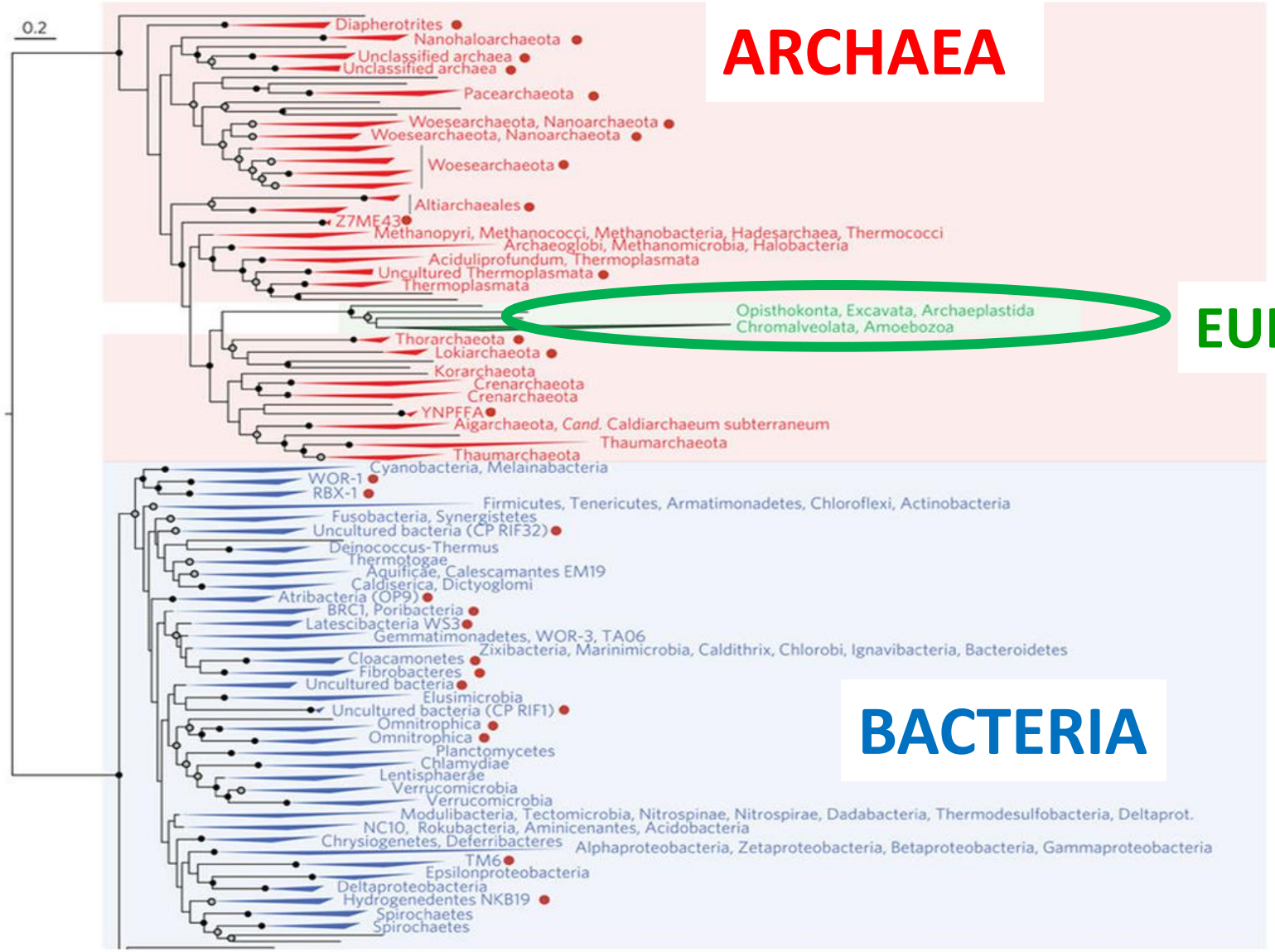
"Anyone who believes in indefinite growth on a physically finite planet is either mad, or an economist."

— David Attenborough

“The wonders and realities of the universe”

Microbes are the true rulers of the Earth (and probably the universe)

"The wonders and realities of the universe"



EUKARYOTES
- ALL plants
- ALL animals
- ALL fungi

Red dots indicate 'uncultured' phyla

MOST PHYLA HAVE RED DOTS !!! ☹

https://www.nature.com/articles/nmicrobiol201648

The true scope of biodiversity

- The vast majority of all biodiversity* is microbes

  * Taxonomic diversity, metabolic diversity, niche diversity

- Most microbes cannot be isolated or cultured

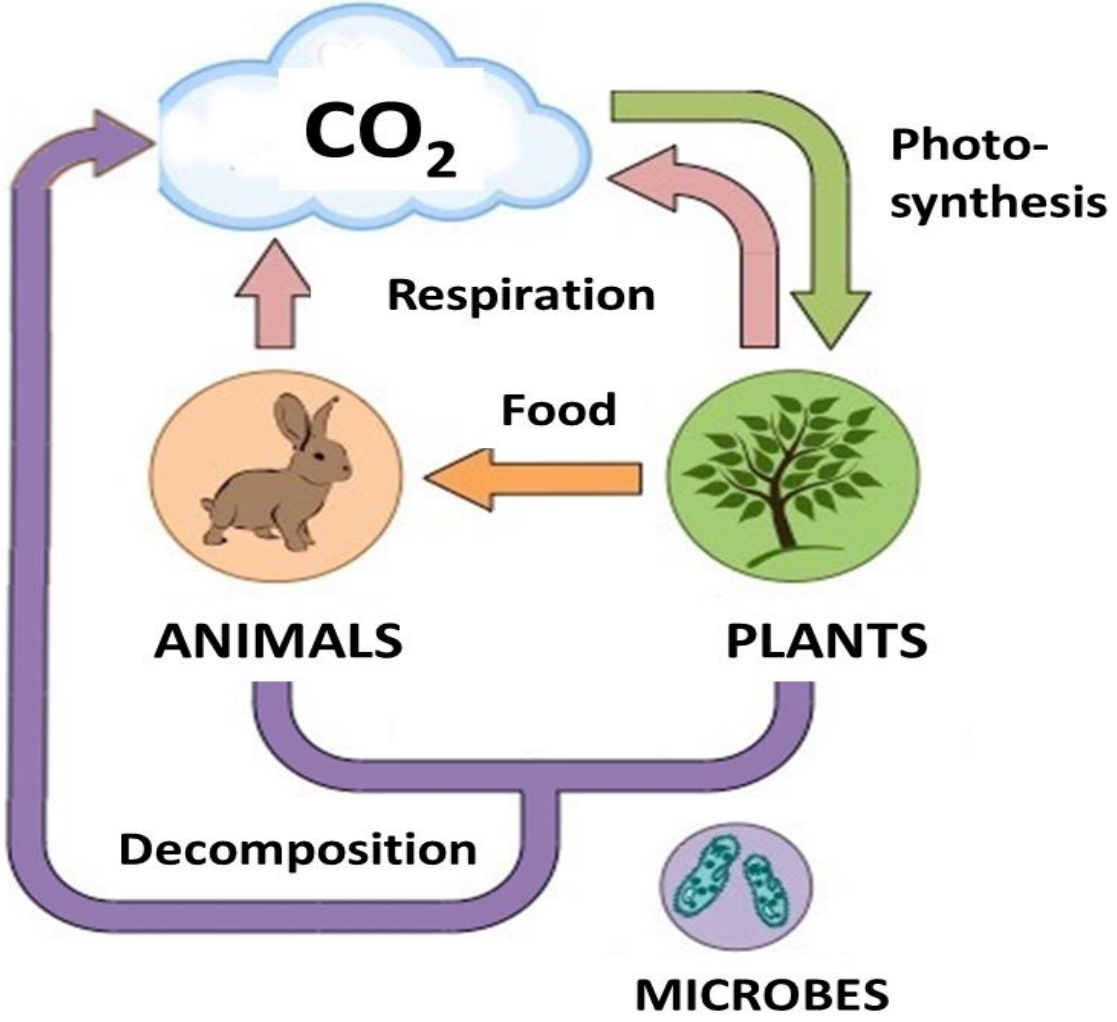
Agar: ~ 20 colony types
~ 10^6 cells per g

Microscopy:
~ 20 cell types
~ 10^9 cells per g

DNA sequences:
~ 10,000 genotypes
~ 10^9 cells per g

What are all these microbes doing? BIOGEOCHEMISTRY !

- Biogeochemistry: where biology, chemistry & geology meet
- i.e. Biological processes that impact chemistry at global scale
- Most of these reactions are done by microbes

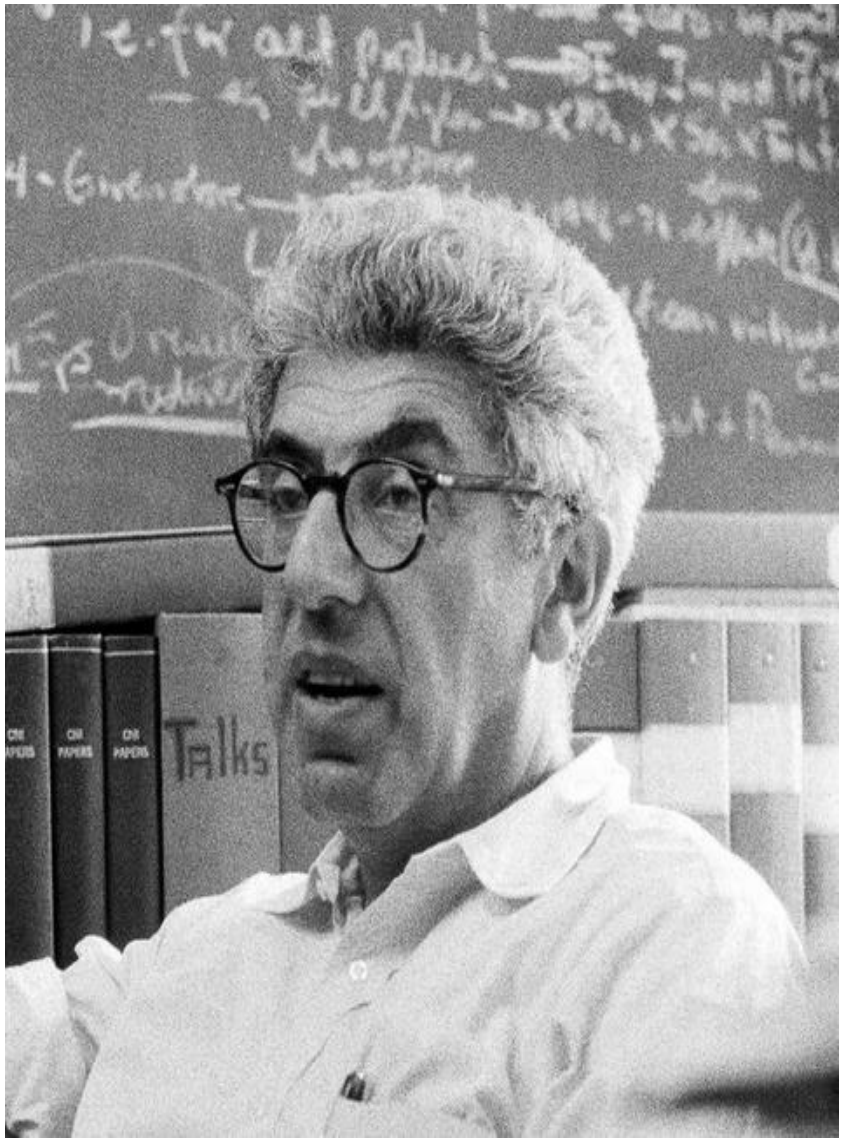


This simplified carbon cycle only tells a very small part of the story of biogeochemistry

The four laws of Ecology

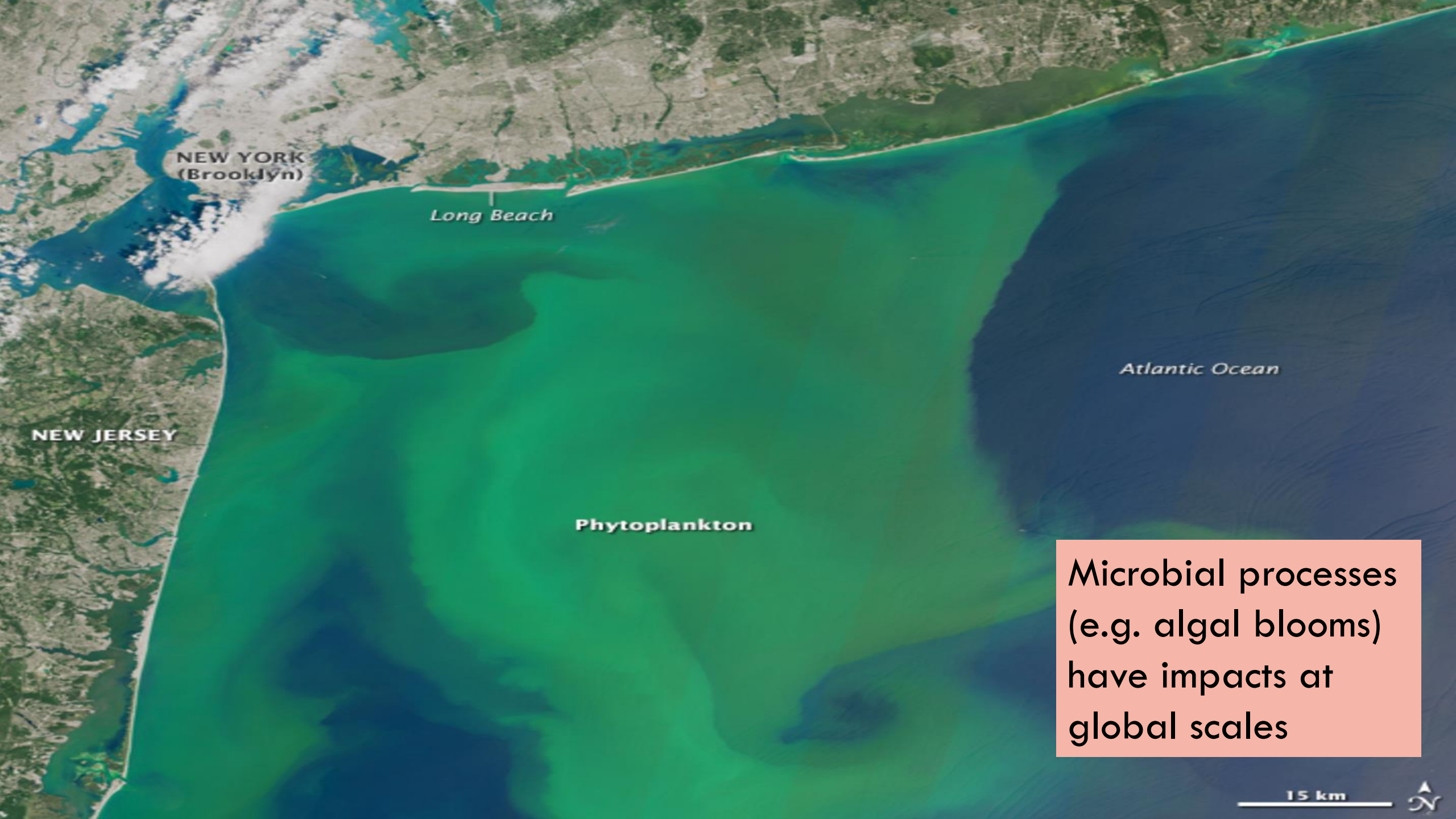
- Everything is connected
- Everything must go somewhere
- Nature knows best
- There's no such thing as a free lunch

- Barry Commoner



Autotrophs in the Carbon cycle – Algae

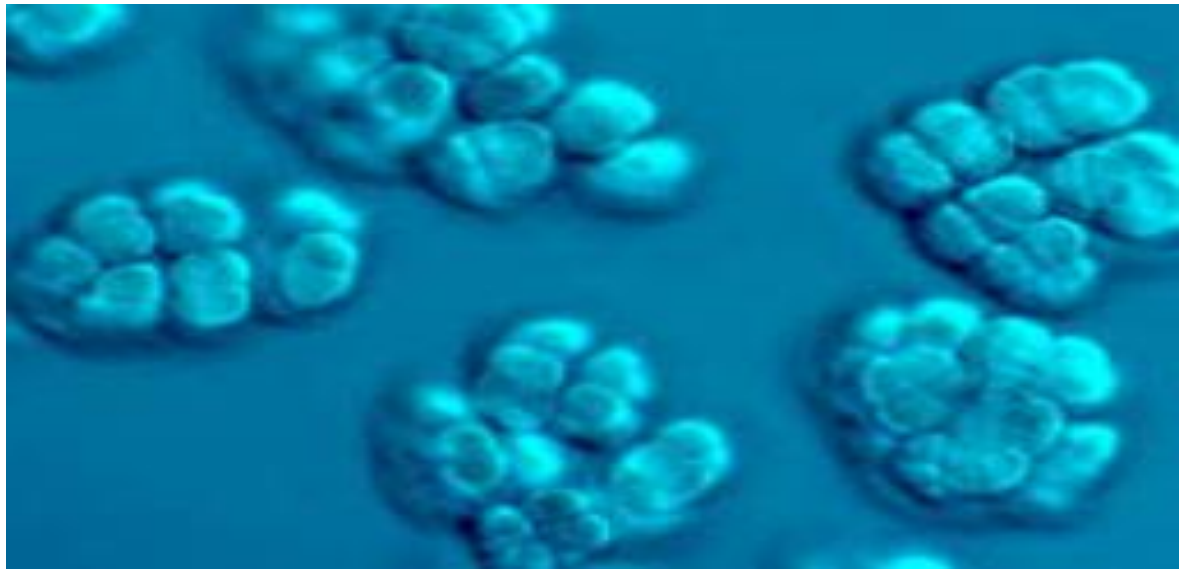
- Autotroph: "Self-feeder" – uses CO_2 as carbon source
  - May use light as energy source (photoautotrophs) or may use chemical energy sources (chemoautotrophs)
  - Autotrophs convert inorganic C to organic C, act as "SINKS" for CO_2 → act to limit climate change



Microbial processes (e.g. algal blooms) have impacts at global scales

Autotrophs in the Carbon cycle – Methanogens

- Methanogens: Consume CO_2 and H_2, produce methane (CH_4)
- Are chemoautotrophs: CO_2 is C source, H_2 is energy source
- Impact on climate change: act as sinks for CO_2 (good), but act as sources of CH_4 (very bad!)…. Overall = bad.



Methanogens: an example of ARCHAEA: the mysterious third Domain of life

Autotrophs in the Carbon cycle – Methanogens

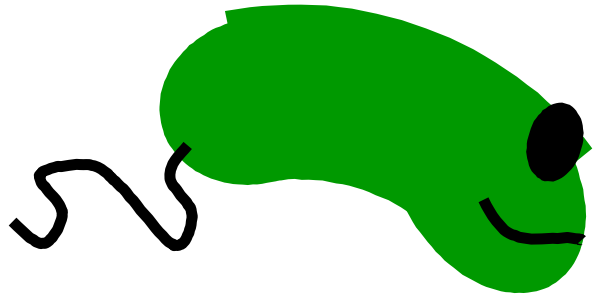
- Methanogens are ANAEROBIC. They are killed by oxygen !
  - Methanogens instead 'breathe' CO_2 and exhale CH_4
    …an ancient mode of metabolism from pre-oxygen Earth
  - This limits methanogens to oxygen-free habitats (deep sediments, soil micro-niches, animal gut)

Methanogens associate with protists in the termite gut

https://www.youtube.com/watch?v=HOx7SDdIqyU

Heterotrophs in the Carbon cycle – Methanotrophs

- Methanotrophs: Consume methane, produce CO_2
- Are heterotrophs*: Methane (the simplest organic compound) acts as both their carbon source and energy source
- Impact on climate change: act as sinks for CH_4 (very good!), but act as sources of CO_2 (bad)…. Overall = good.

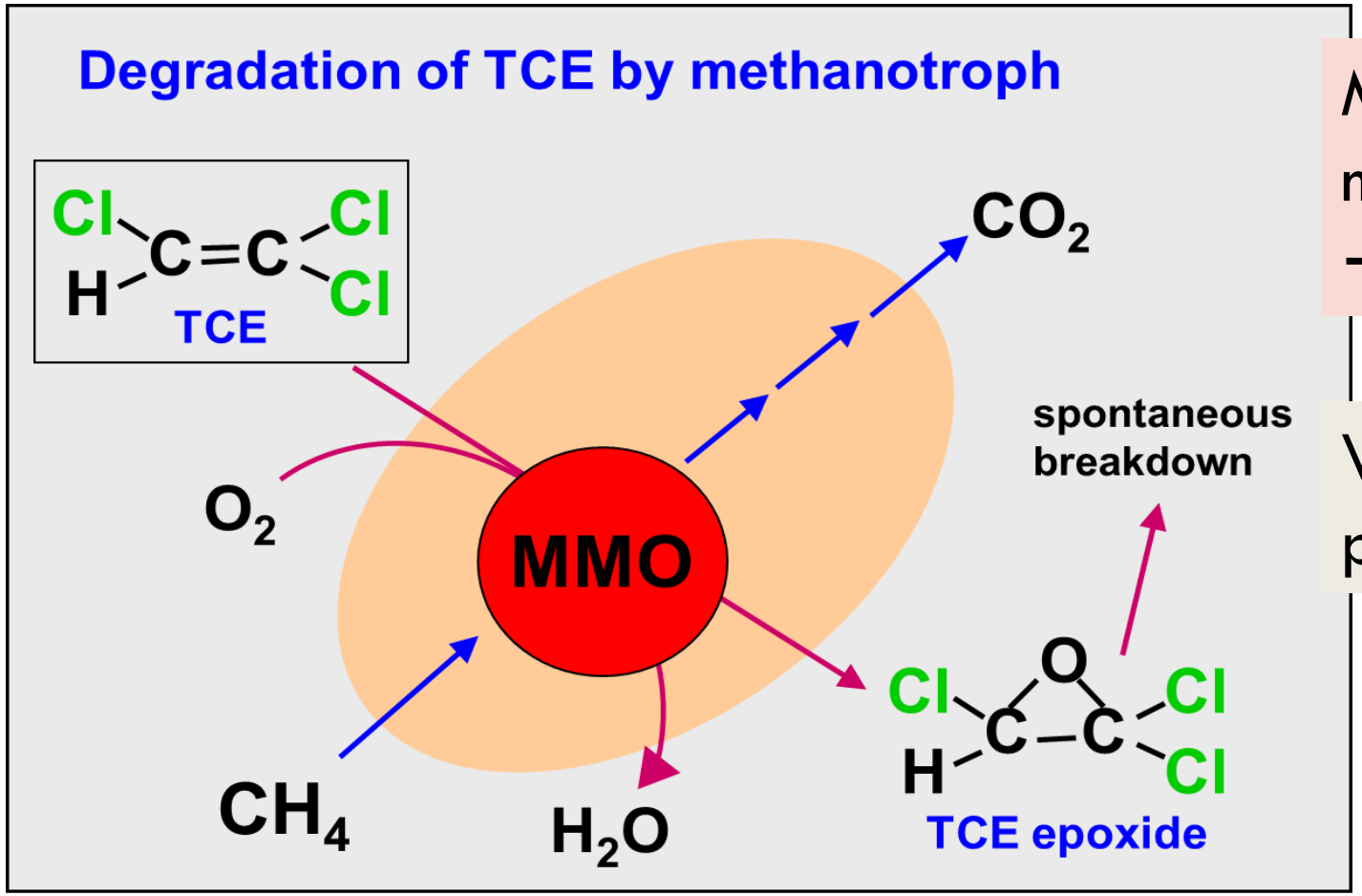


Methanotrophs are "traditional" bacteria ie. Domain BACTERIA

* Heterotrophs will be defined properly on a later slide ☺

Heterotrophs in the Carbon cycle – Methanotrophs

- Methanotrophs are useful for removing methane
- They also attack other more toxic pollutants e.g. trichloroethene (TCE)



MMO = methane monooxygenase enzyme → broad <u>substrate range</u>

We will meet more pollutant-degraders soon …

Heterotrophs in the Carbon cycle – Decomposers

- Heterotroph: "Other-feeder" – needs to eat other organisms, or other organic carbon sources; these also supply energy

- Heterotrophs are SOURCES of CO_2 → bad for climate change

- Decomposers: a key group of heterotrophs; recycle dead cells back to CO_2.

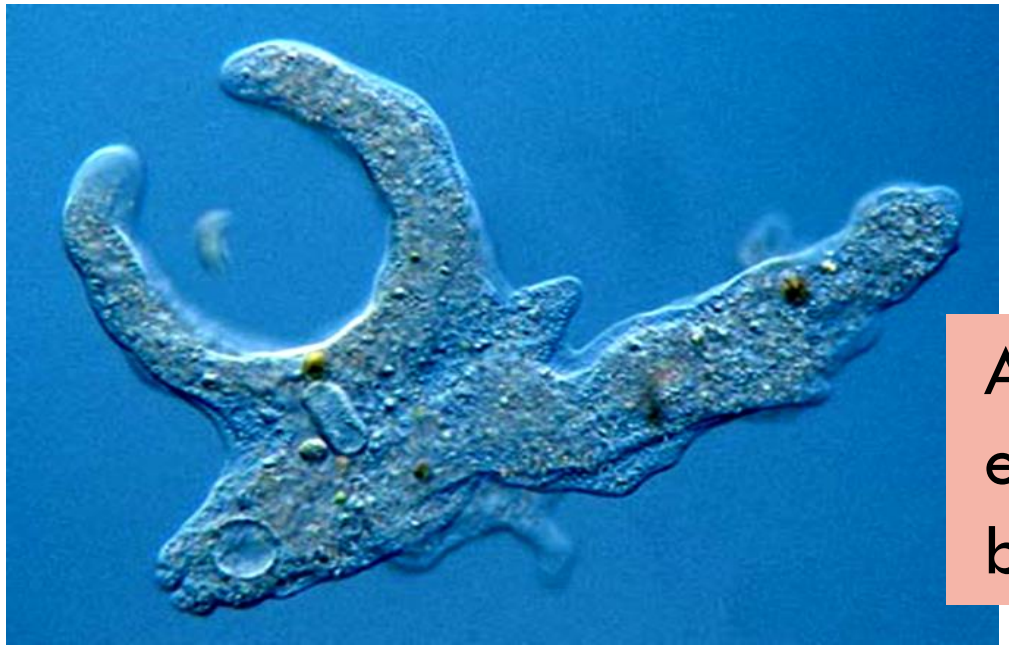
Fungi are major decomposers in terrestrial ecosystems. … are they microbes?

Heterotrophs in the Carbon cycle – Predators

- Protists (protozoa type) are often predators of other microbes; these predators include ciliates, flagellates & amoebae.

- Not all protists are predators, some are 'detritivores' (scavengers), and some are photosynthetic

https://www.youtube.com/watch?v=pvOz4V699gk



Amoebae engulfing bacteria

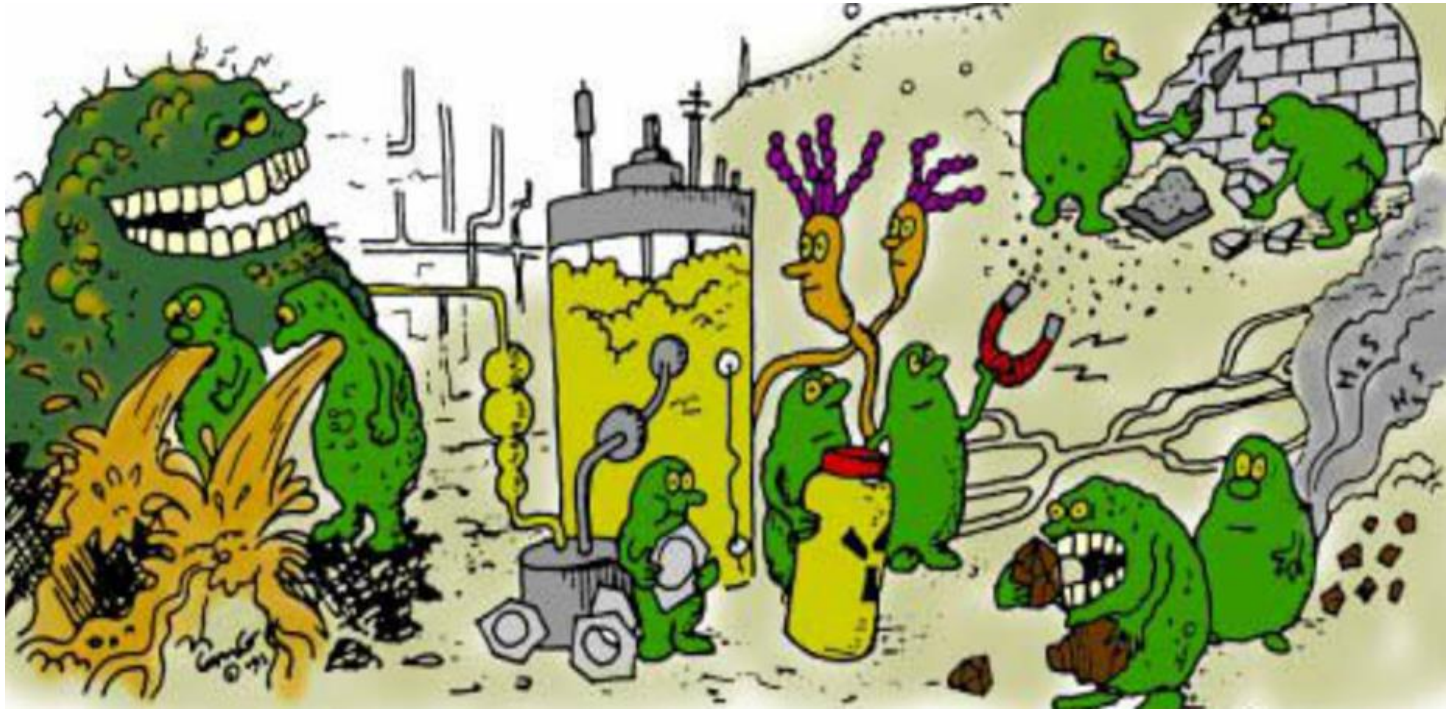
Heterotrophs in the Carbon cycle – pollutant degraders

- Methanotrophs are just one example of bacteria that grow on hydrocarbons as their carbon and energy source.

- Hydrocarbon-degrading bacteria (including methanotrophs) are very useful for "bioremediation"

Perlmon, D. (1980) *Developments in Industrial Microbiology*

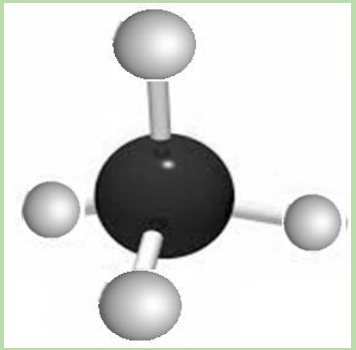
Bioremediation: the cleanup of pollution by microbes



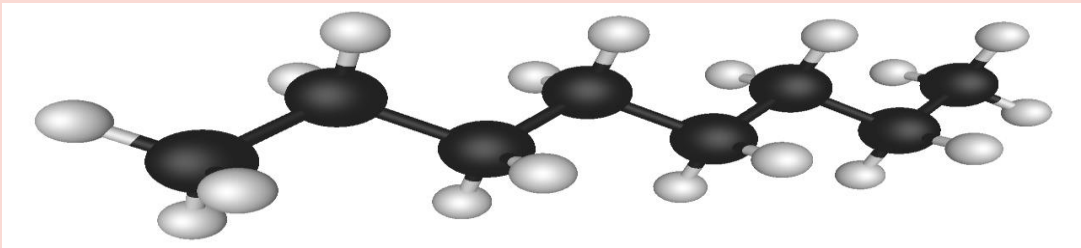
Heterotrophs in the Carbon cycle – Pollutant degraders

- Hydrocarbon-degrading bacteria are heterotrophs that specialise in eating ancient fossilised organic carbon

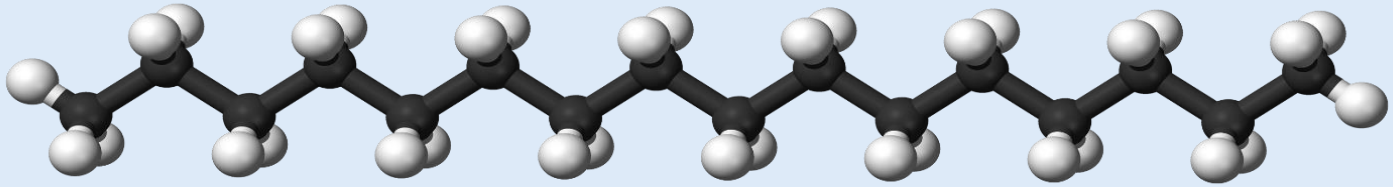
- These are similar to other decomposers, except that they contain special enzymes which can attack hydrocarbons



Methane (both fossil and fresh sources)



Octane (fossil fuel, in petrol)



Hexadecane (fossil fuel, in crude oil)

Auto/Hetero-troph interactions - Coral symbiosis

- Corals are primitive animals (Phylum Cnidaria), which depend on <u>symbiotic</u> microscopic algae to supply them with food
- Algae: photoautotrophs, convert CO_2 + light → sugars
- Coral: heterotrophs, convert sugars → CO_2

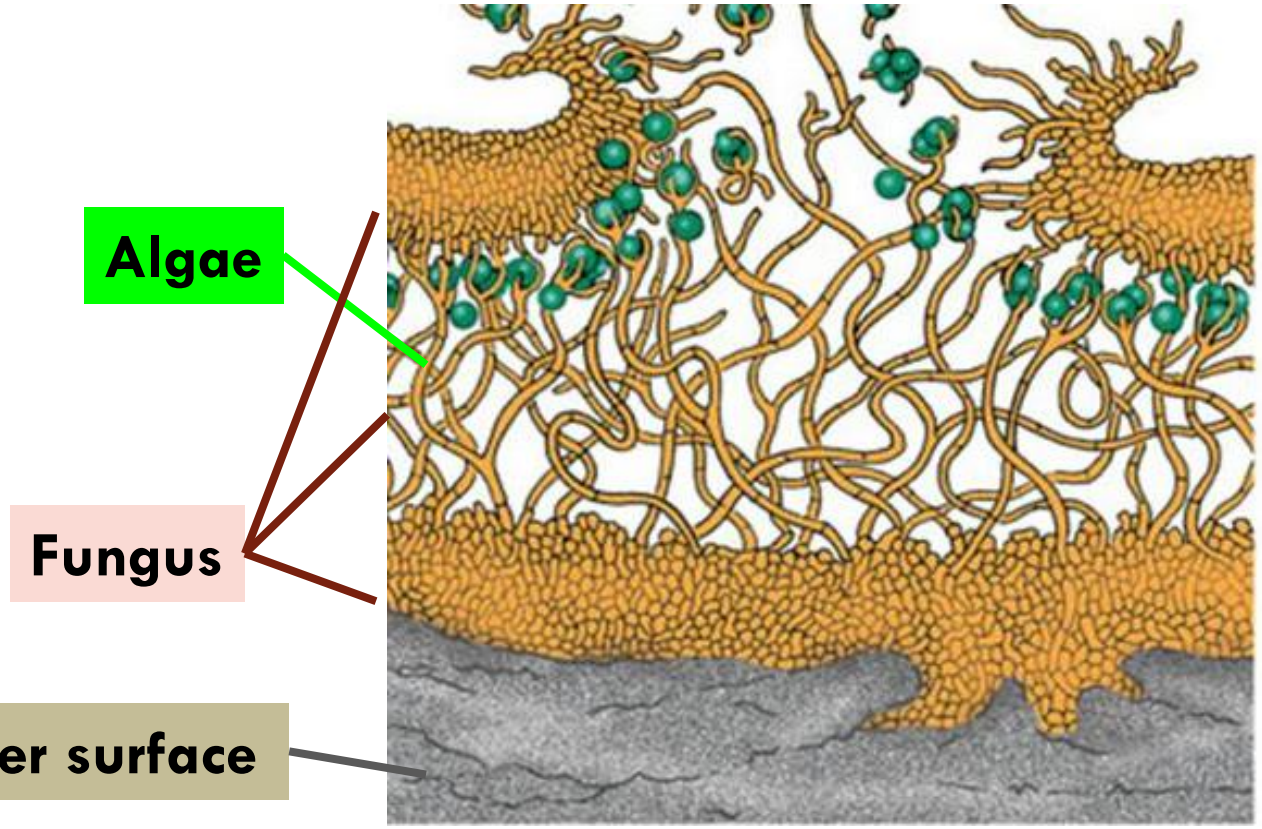
The CNIDARIANS are a fascinating and ancient group of animals (> 580 million years old)

Auto/Hetero-troph interactions - Coral symbiosis

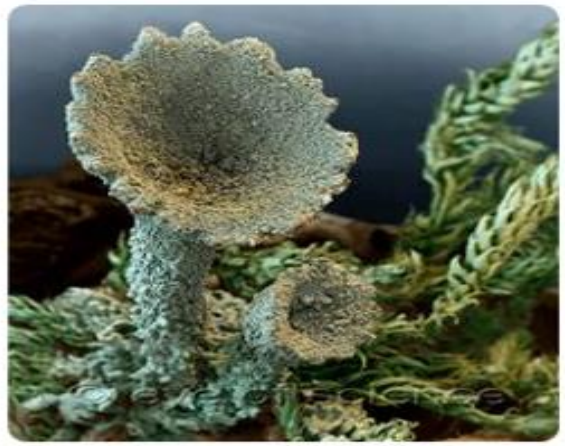
- The coral symbiosis is like a miniature ecosystem… Carbon cycles between organic and inorganic forms, biomass is produced, and both partners 'win'.

Auto/Hetero-troph interactions - Lichen symbiosis

- **LICHENS** are primary producers in some terrestrial habitats, especially in dry environments
  - Photosynthetic, but they are not plants!
  - Actually a symbiosis between two microbes: a heterotrophic fungus and an autotrophic algae

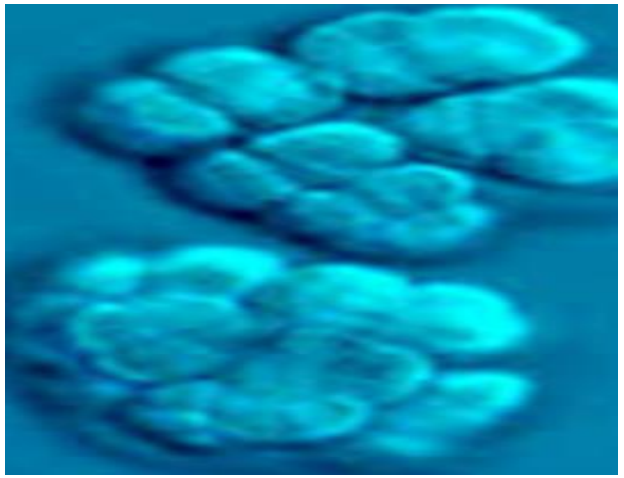


Auto/Hetero-troph interactions - Lichen symbiosis



Summary of microbial autotrophs in this lecture

Algae (free-living)



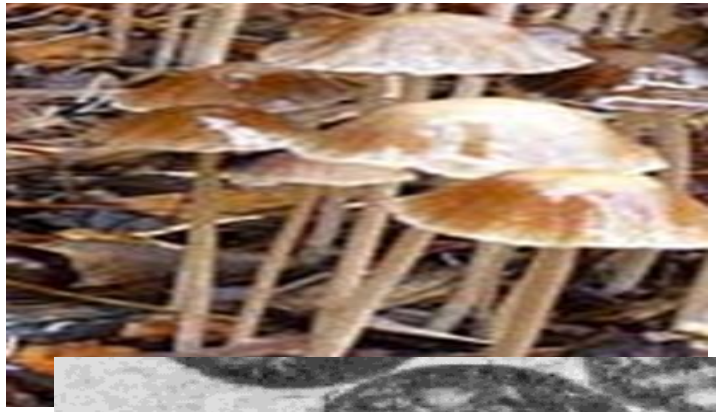
Methanogens

Algae (symbiotic in coral)

Algae (symbiotic in lichen)

Summary of microbial heterotrophs in this lecture

Decomposers (Detritovores)



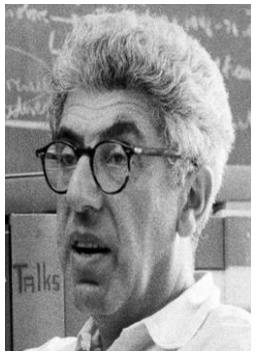
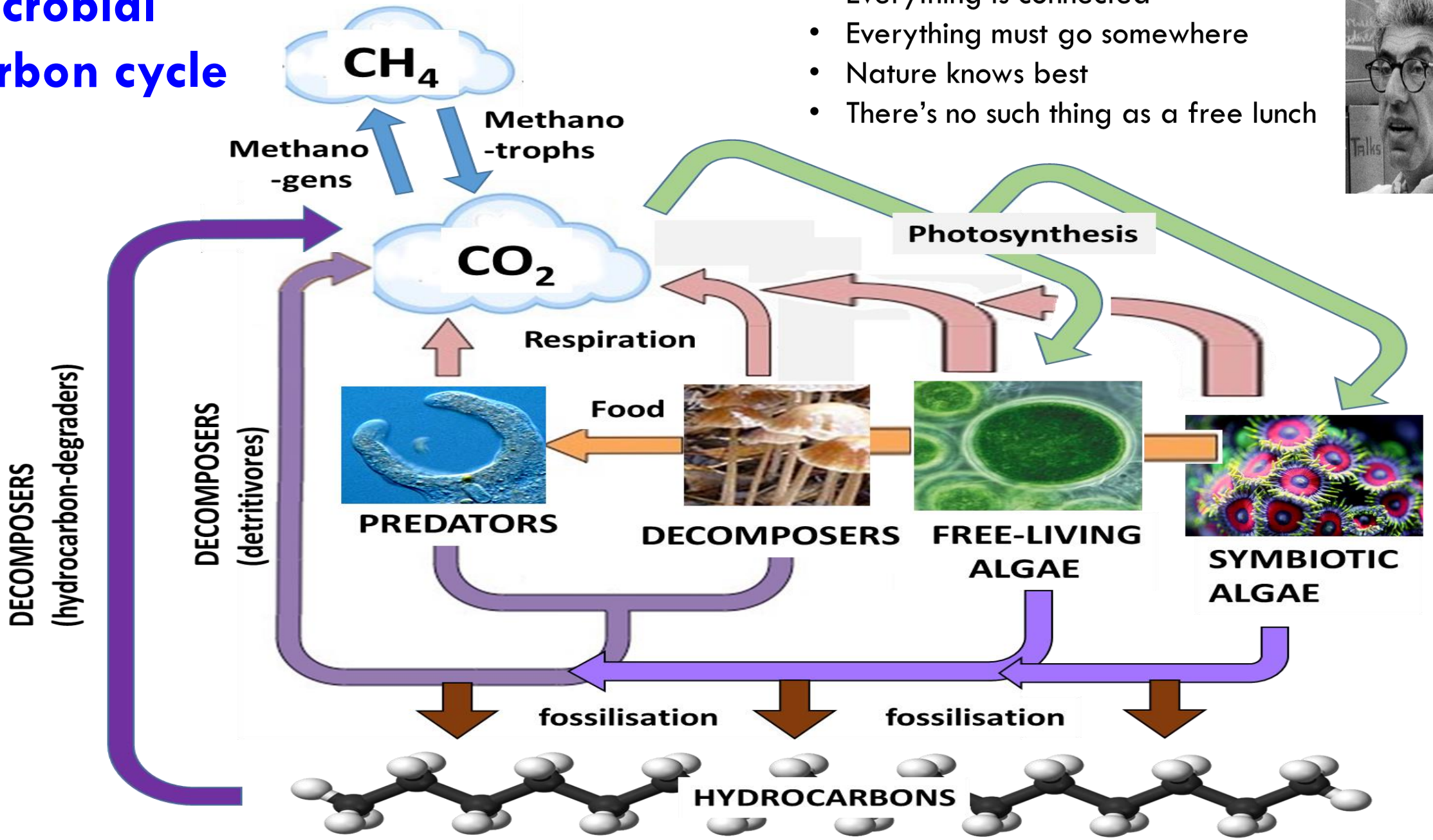
Predators: protozoa

Methanotrophs

Hydrocarbon -degraders

Coral (host animal)

Lichen (host fungus)

Microbial carbon cycle

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