The background features a dark blue gradient with a field of small white stars. Overlaid on this are several faint, light-colored diagrams. These include circular paths with arrows indicating direction, some resembling orbits or celestial cycles. A prominent feature is a large circular scale with tick marks and numerical labels (140, 150, 160, 170, 180, 190, 200, 210, 220, 230, 240, 250, 260) arranged in a semi-circle. Other diagrams consist of concentric circles and arcs, some with arrows pointing inward or outward, suggesting astronomical models or data visualizations.

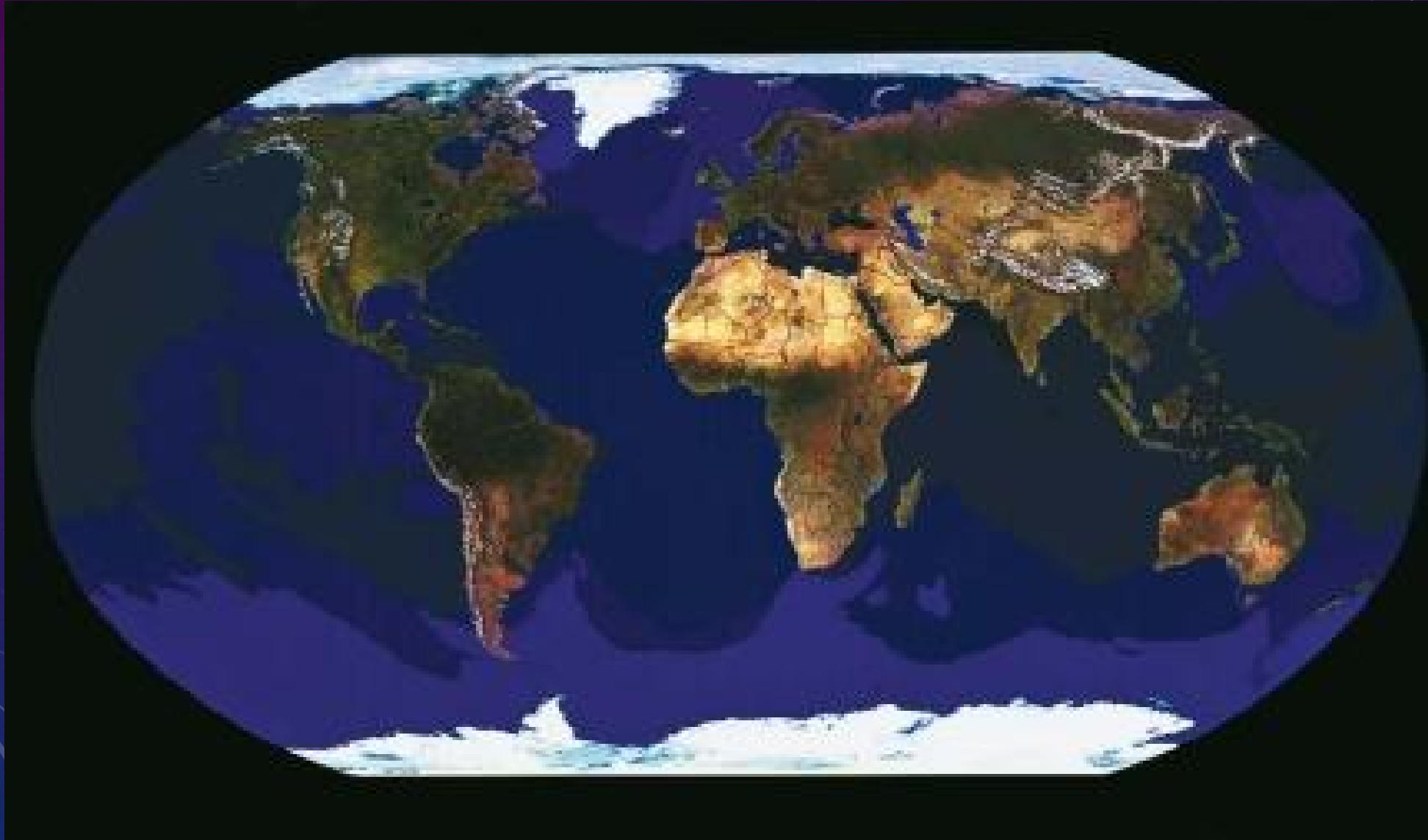
# THE GAIA, AND RARE EARTH HYPOTHESES

**RICHARD NOLTHENIUS, PHD  
CABRILLO COLLEGE ASTRONOMY  
ASTRO 5: "LIFE IN THE UNIVERSE"**

# THE GAIA HYPOTHESIS...

- Developed by James Lovelock and Lynn Margulis in the '70's
- proposes that living organisms interact with their inorganic surroundings on Earth to form a synergistic and self-regulating, complex system that helps to maintain and perpetuate the conditions for life on the planet.

# DOES EARTH AND LIFE SELF-REGULATE TO INSURE LIFE?

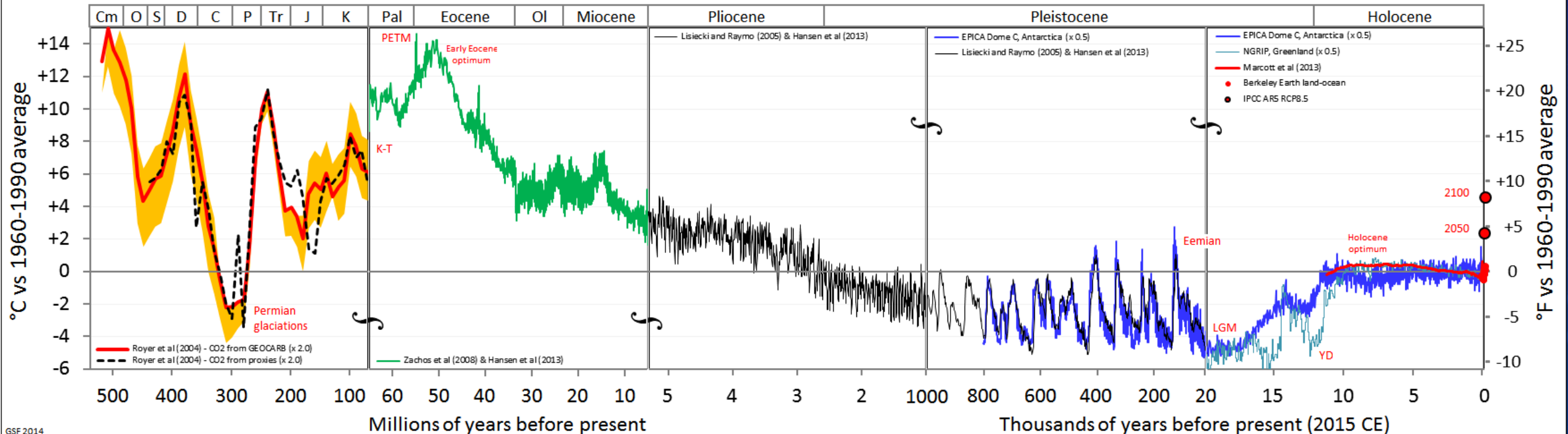


# LOVELOCK CITES CO<sub>2</sub> AND PLANTS AS PERHAPS AN EXAMPLE...

- Cold early Earth must have had more CO<sub>2</sub>, a common molecule, as Greenhouse Warmant
- As plants proliferated they take CO<sub>2</sub> out of the atmosphere, keeping the Earth cooler as the sun's luminosity rises.

EARTH TEMPERATURE WANDERS WITHIN A 20C TEMPERATURE RANGE DURING THE ERA OF COMPLEX EUKARYOTIC LIFE. BUT THAT'S A VERY LARGE RANGE AND HAS PRODUCED MASS EXTINCTIONS SEVERAL TIMES

Temperature of Planet Earth



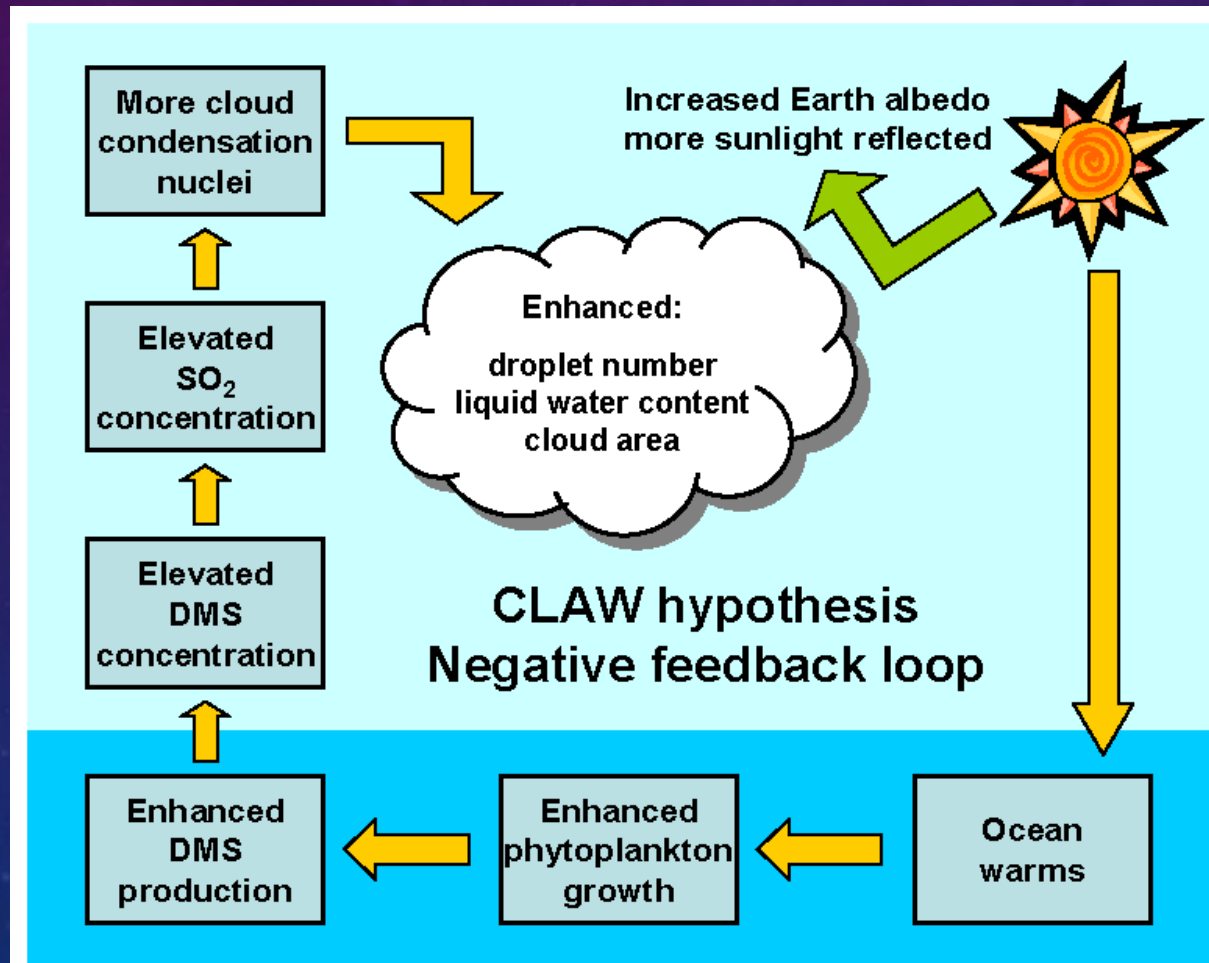
# PUBLICATION IN THE '70'S WAS PERHAPS UNFORTUNATE...

- Certain elements of the Pro-Ecology Movement at the time came to take the general idea rather literally; Earth was a living thing and purposefully made it happy for life
- There is no evidence for this, and is likely an emotionally driven extrapolation.
- This association is widely believed to have hurt the credibility of anything Gaian among most Earth and biology scientists

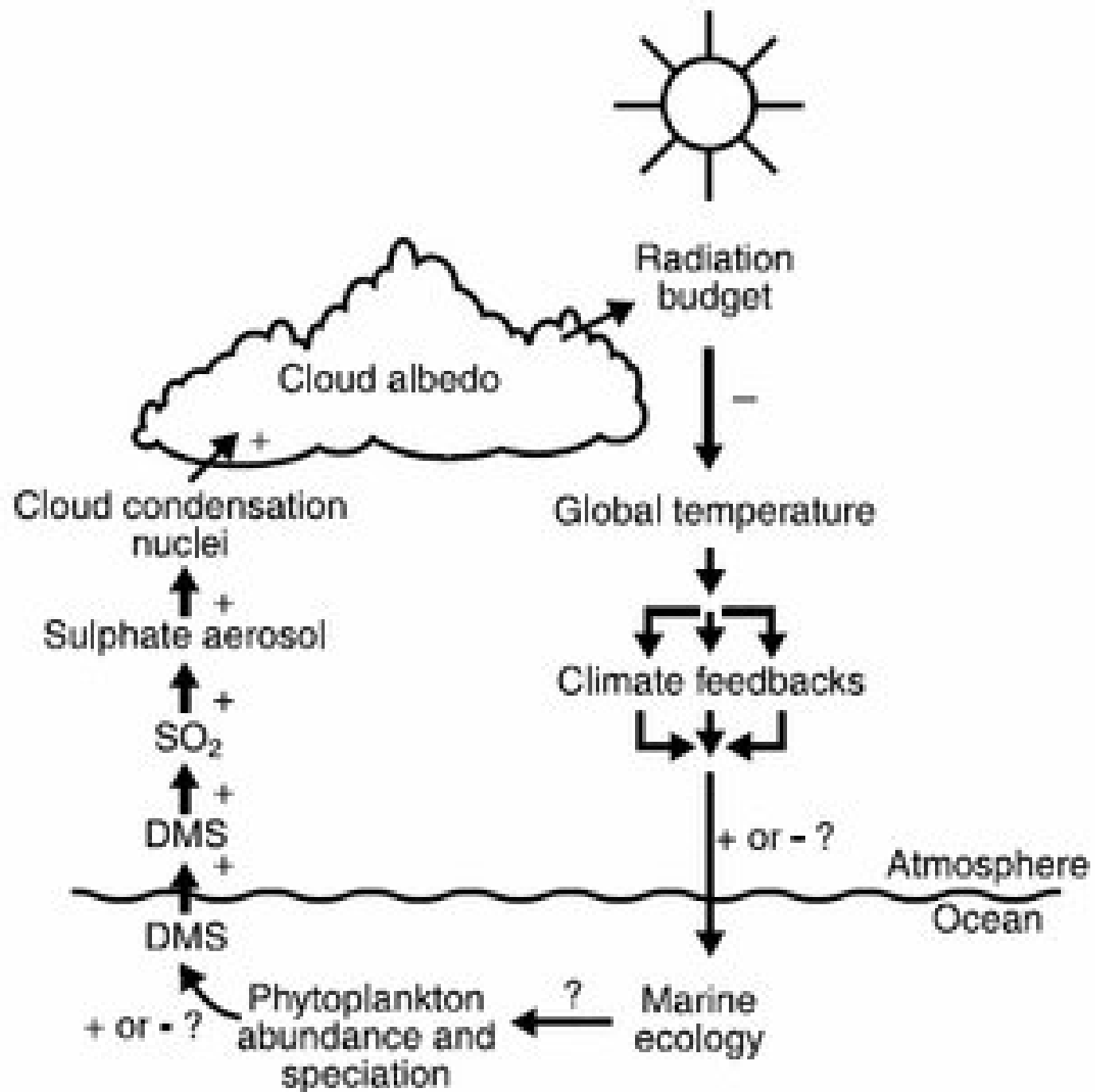
# THE PHILOSOPHICAL PROBLEMS ARE IN THE FRAMING

- What is “purpose”? Doesn’t “purpose” pre-suppose a conscious being which can see, interpret, and control the levers that govern Earth and fix things when they go wrong?
- This idea would then seem to be God put into a non-denominational Eco-form
- The psychological issues that arise in the desire to believe in a God would then seem to be a significant danger in assessing the science in this area, vs. faith and hope.

TO SUPPORT GAIA HYPOTHESIS, SOME CITE THE “CLAW HYPOTHESIS”  
([CHARLESON ET AL. 1987](#)), WHEREBY OCEANS AND CLOUDS ARE SUPPOSED TO INTERACT TO STABILIZE OCEAN TEMPERATURE, THROUGH THE PRODUCTION OF DIMETHYL SULFIDE AEROSOL CLOUD FEEDBACKS



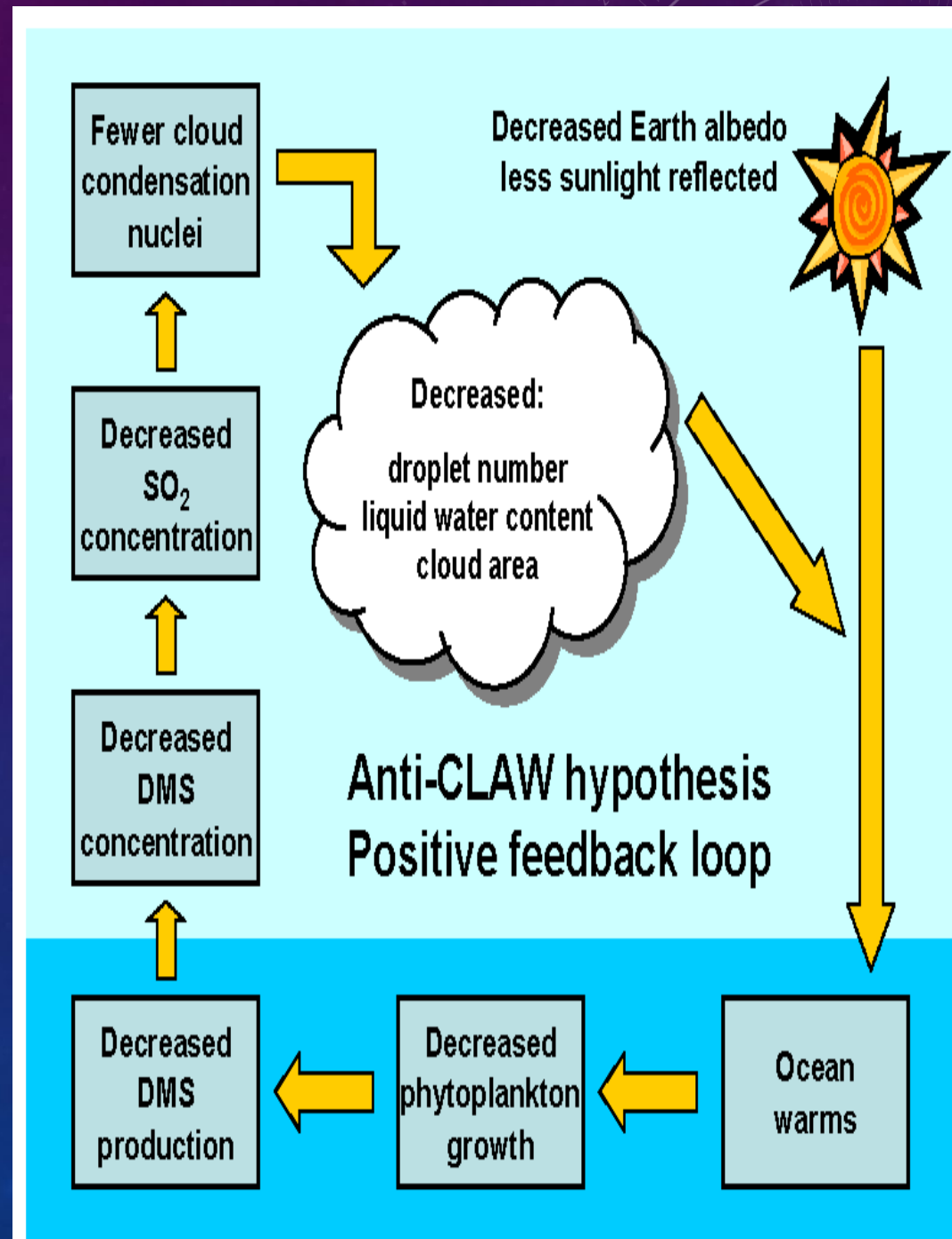




BUT IN 2014 A REVIEW ARTICLE ([GREEN ET AL. 2014](#)) ON THE MANY RESEARCH PAPERS THIS INDUCED, CONCLUDED THE EFFECT, IF PRESENT AT ALL, IS VERY WEAK.

IN 2006, LOVELOCK HIMSELF PROPOSED IN THE GLOBAL WARMING SITUATION WE ARE CAUSING, THAT THE “CLAW HYPOTHESIS” MIGHT INSTEAD BY THE “ANTI-CLAW”, AND WORK TO MAKE CLIMATE EVEN WORSE.

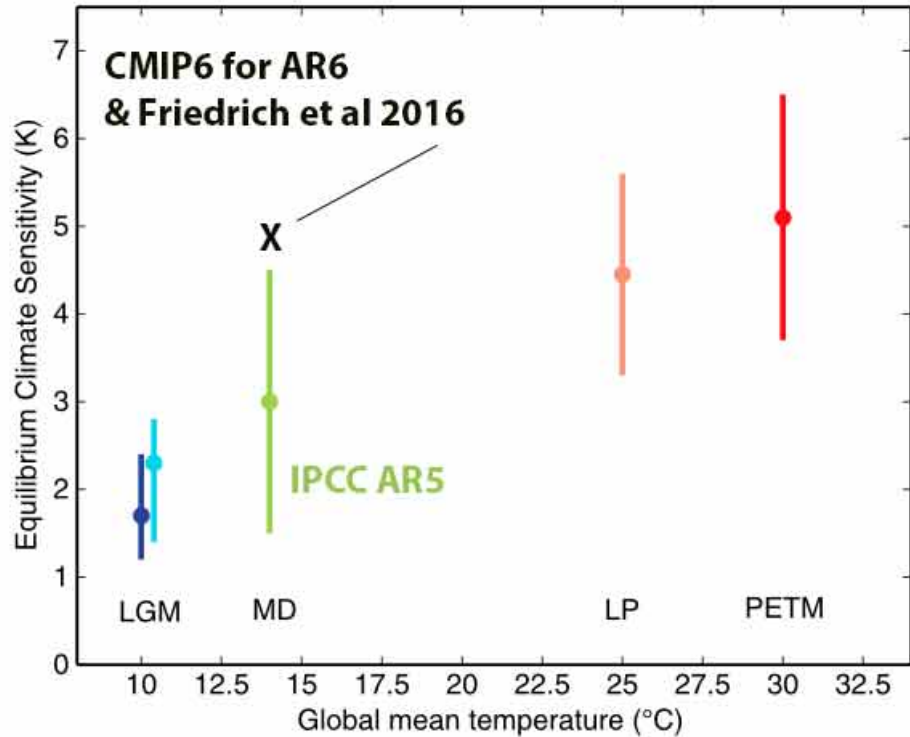
(REMEMBER A “POSITIVE FEEDBACK” IS A VERY NEGATIVE THING! WE LOVE NEGATIVE (STABILIZING) CLIMATE FEEDBACKS, NOT POSITIVE (AMPLIFYING) FEEDBACKS!



THE LATEST CLIMATE MODELLING FINDS THAT CLOUDS ARE A POWERFUL AMPLIFYING FEEDBACK TO CLIMATE WARMING. CERTAINLY NOT IN LINE WITH “GAIA”



- Clouds over the Indian ocean
- Loeb et al. 2018 find that low clouds (like we have here in Santa Cruz summers, and which are powerful coolants to climate) are today being reduced significantly, and consistent with the new satellite measured Energy Budget of Earth imbalance of  $0.83 \text{ W/m}^2$



**Figure 3.** Climate sensitivity range estimates at different global mean atmospheric temperatures. Shown are our pre-PETM/Late Paleocene (LP) and PETM estimates, the modern-day (MD) IPCC estimate [Flato *et al.*, 2013], and several recent Last Glacial Maximum (LGM) estimates (light blue [Schmittner *et al.*, 2011] and dark blue [Annan and Hargreaves, 2013]). The large dots represent the central values for the MD, LP, and PETM estimates and the preferred values in the published analyses for the LGM estimates.

EQUILIBRIUM CLIMATE SENSITIVITY TO CO<sub>2</sub> IS MUCH HIGHER THAN EARLIER THOUGHT, AND LOSS OF LOW CLOUDS IS A KEY REASON, SAYS THE NEW CMIP6 CLIMATE MODELS, BASED ON LOW CLOUD OBSERVATIONS RECENTLY (LOEB ET AL. 2018)

SOMEWHERE BETWEEN 1200 PPM AND 1600 PPM LOW CLOUDS DISAPPEAR ENTIRELY FROM THE OCEANS, AND GLOBAL TEMPERATURE SPIKE AN ADDITIONAL +8C. NOT GAIA FRIENDLY

400 ppm



1,600 ppm



A model of clouds in current and future atmospheric CO<sub>2</sub> concentrations, showing a shift from stratocumulus clouds to scattered cumulus clouds, which would result in strong warming. SCHNEIDER ET AL. NATURE 2019

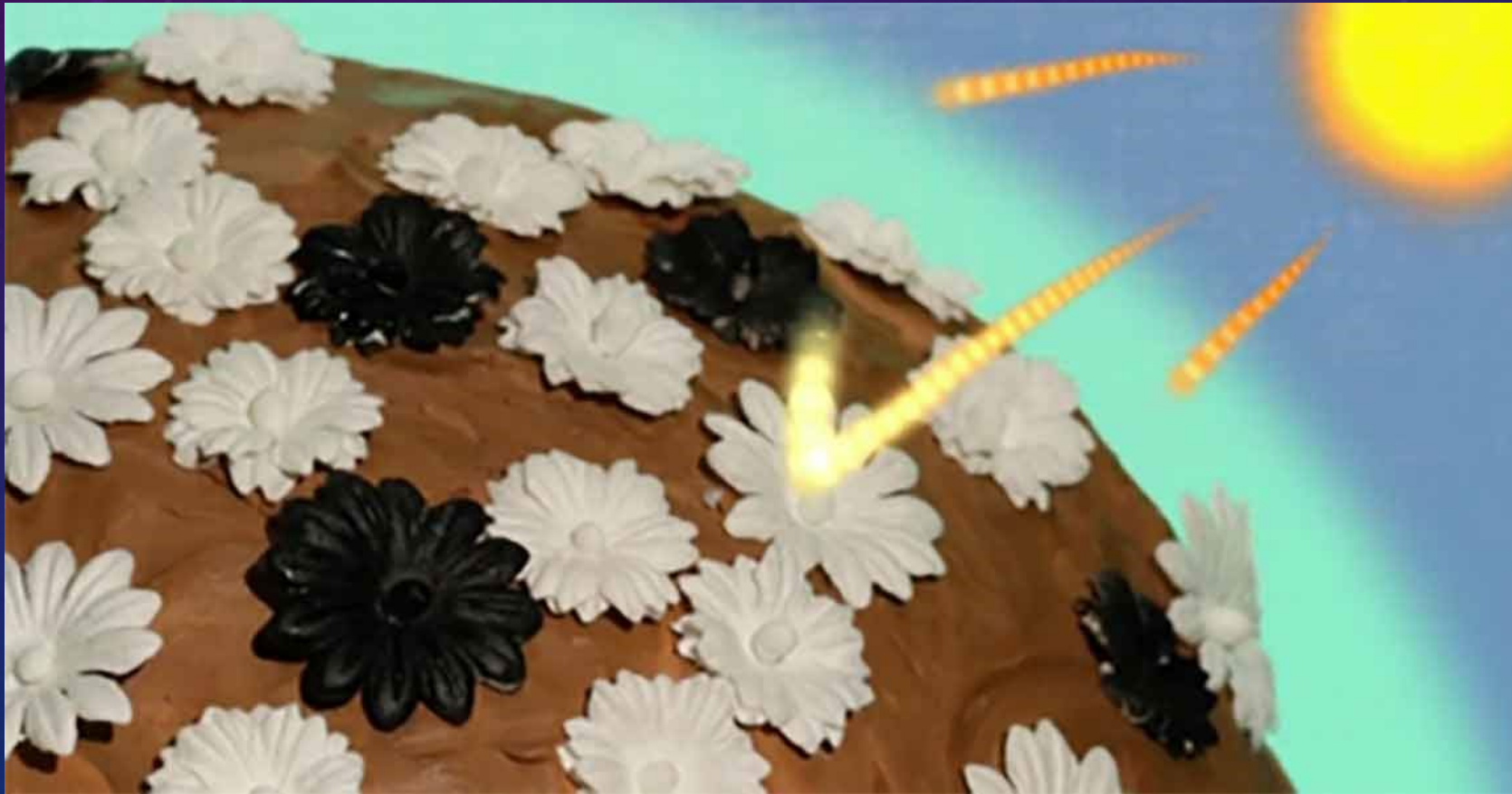
IN RESPONSE TO THE CRITICISM THAT THE GAIA HYPOTHESIS SEEMINGLY REQUIRED UNREALISTIC GROUP SELECTION AND COOPERATION BETWEEN ORGANISMS, JAMES LOVELOCK AND ANDREW WATSON DEVELOPED A MATHEMATICAL MODEL:

DAISYWORLD, IN WHICH ECOLOGICAL COMPETITION UNDERPINNED PLANETARY TEMPERATURE REGULATION.<sup>[21]</sup>

NOT A WORLD WITH NORMAL WHITE DAISEYS, BUT...



BUT A MIXTURE OF BLACK DAISEYS AND WHITE DAISEYS. WHITE DAISEYS PREFERRED WARM CLIMATE, AND BLACK DAISEYS PREFERRED COOL CLIMATE. THE ALBEDO FEEDBACK WOULD THEN FAVOR ONE OVER THE OTHER UNTIL AN EQUILIBRIUM WAS REACHED AT A COMPROMISE TEMPERATURE.



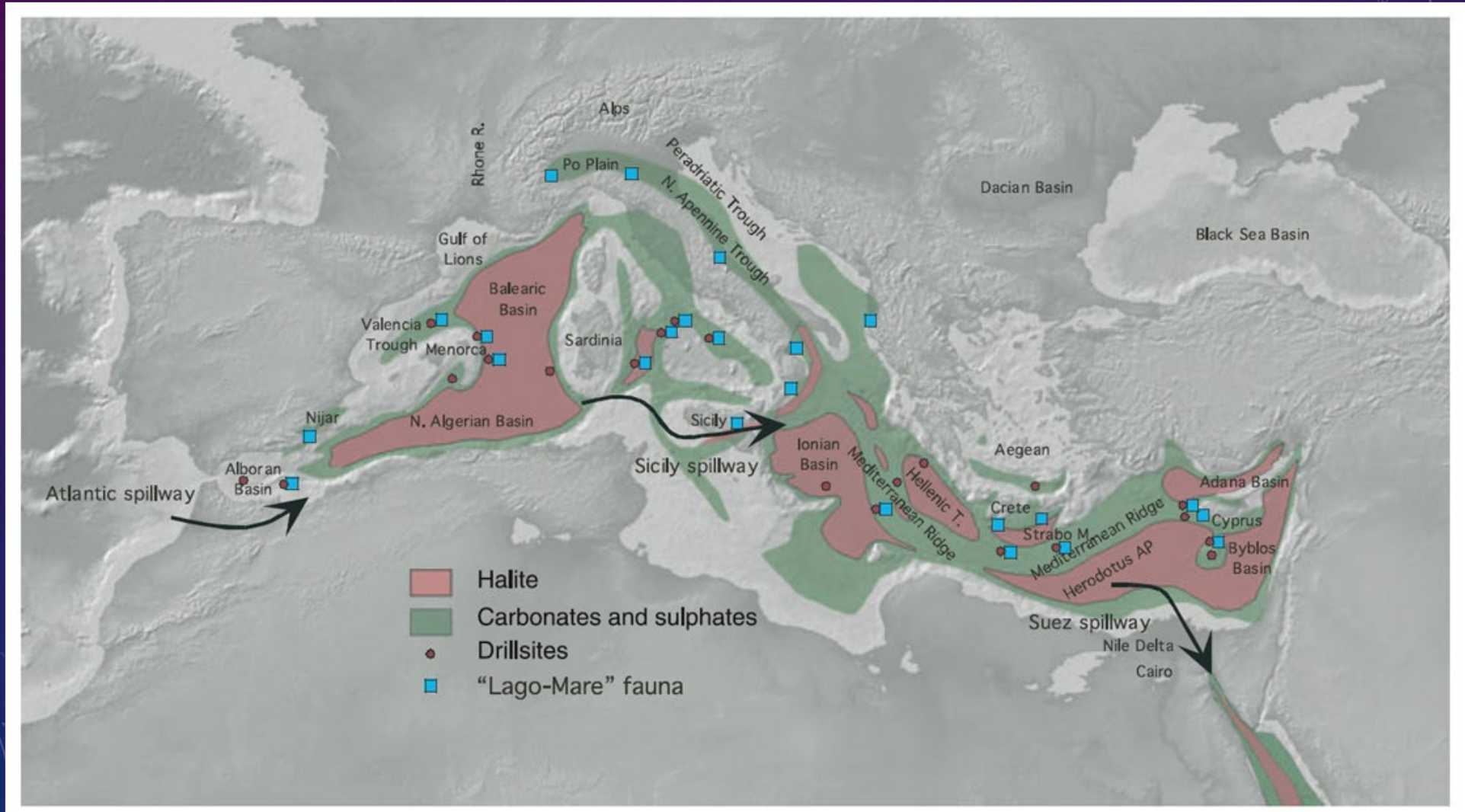


- Lovelock and Watson showed that, over a limited range of conditions, this negative feedback due to competition can stabilize the planet's temperature at a value which supports life, if the energy output of the Sun changes.
- However, a planet without life would show wide temperature swings.
- The percentage of white and black daisies will continually change to keep the temperature at the value at which the plants' reproductive rates are equal, allowing both life forms to thrive.
- It has been suggested that the results were predictable because Lovelock and Watson selected examples that produced the responses they desired. [\[22\]](#)

# SALINITY OF THE OCEANS 3.5% FOR A BILLION YEARS – WHY SO CONSTANT? GAIA'S HANDIWORK?

- Yet rivers are constantly adding minerals from the continents. How does ocean salinity stay so constant?
- One hypothesis is that isolated ocean basins around the Earth have acted to be basins for high salinity, isolating salt in the depths from the life-friendly ocean waters above.

THE MESSINIAN SALINITY CRISIS (EXAMPLE OF A “SALINE GIANT”) AT THE BOTTOM OF THE MEDITERRANEAN SEA, MAY SUPPORT THIS IDEA. FORMED 6 MILLION YEARS AGO



IT IS SUGGESTED THAT OTHER ISOLATED SEAS HAVE SERVED THE SAME FUNCTION IN EARLIER EPOCHS OF DIFFERENT CONTINENTAL ARRANGEMENTS...

- *“The desiccation of the Mediterranean is the evidence of a functioning kidney. Earlier ‘kidney functions’ were performed during the deposition of the Cretaceous (South Atlantic), Jurassic (Gulf of Mexico), Permo-Triassic (Europe), Devonian (Canada), Cambrian/Precambrian (Gondwana) saline giants.”* ([wiki](#))
- Sounds plausible – saline water is more dense, would sink and be trapped in isolated ocean basins in the right circumstances.
- Gaia’s Kidney? But life is not involved here – it’s continental drift and pure physics. I see no Gaian Hand (or kidney) here.

# LIFE REGULATES EARTH'S POST-CAMBRIAN OXYGEN?

- This contention has more support... clearly oxygen is severely out of equilibrium in our atmosphere.
- Without life, O<sub>2</sub> would quickly oxidize rocks and leave the atmosphere. Photosynthesis produces oxygen
- Why seemingly semi-regulated at 15-36% during the past ~300 million years?
- Lovelock's speculation: Higher O<sub>2</sub> would support bigger forest fire conflagrations, reducing plants and photosynthesis and atmospheric O<sub>2</sub>.
- If O<sub>2</sub> gets too low, however, I don't see a mechanism to bring it back up. However, if plants robustly over-produce O<sub>2</sub>, then perhaps the only regulation necessary is to bring it down when O<sub>2</sub> gets too high, e.g. by more forest fires.

THIS SOURCE SUGGESTS ABOVE 23%, FIRES BECOME MUCH MORE DESTRUCTIVE, AND AT LESS THAN 16% O<sub>2</sub>, FIRES WON'T BE SUPPORTED AT ALL. WE'RE AT 21%



# LEADING UP TO ... THE MEDEA HYPOTHESIS – EARTH AS SUICIDAL!

- A big pugnacious, by pugnacious paleontologist Peter Ward, and the details found in Ward and Brownlee’s “Rare Earth”.
- A combination of very lucky accidents, and amplifying climate feedbacks, they argue, convince them that advanced intelligent life is extremely rare in our Galaxy, and probably number only in the dozens, not the thousands or millions that optimists prefer to believe.
- But first... “Inevitable life”? (highly recommended!)

ORGANIZING LIFE NOW, NOT BY WAY OF CELL STRUCTURE AS WE DID EARLIER, BUT INSTEAD BY THE PRIMARY PHYSICAL FACT WHICH RUNS EVERYTHING – ENERGY! THERMODYNAMICS GOVERNS ALL

## ORGANIZATION BY METABOLISM...

- Autotrophs – make food from primary chemicals (plants on land, algae in water, some microbes and prokaryotes). Primary producers from non-living carbon.
- Heterotrophs – eat others for food. All complex animal life are heterotrophs and use oxygen reactions as their primary energy source... like ET intelligent life, most likely.



A CROSS CLASSIFICATION IS BY THE ENERGY MECHANISM – “OXIDATIVE ENERGY”; PLANTS AND ANIMALS DO THIS VERY DIFFERENTLY BUT STILL USE OXIDATION (ELECTRON DONATING) REACTIONS, USUALLY USING OXYGEN. ALTERNATIVE IS “REDUCTIVE ENERGY”

## **Oxidation vs. Reduction**

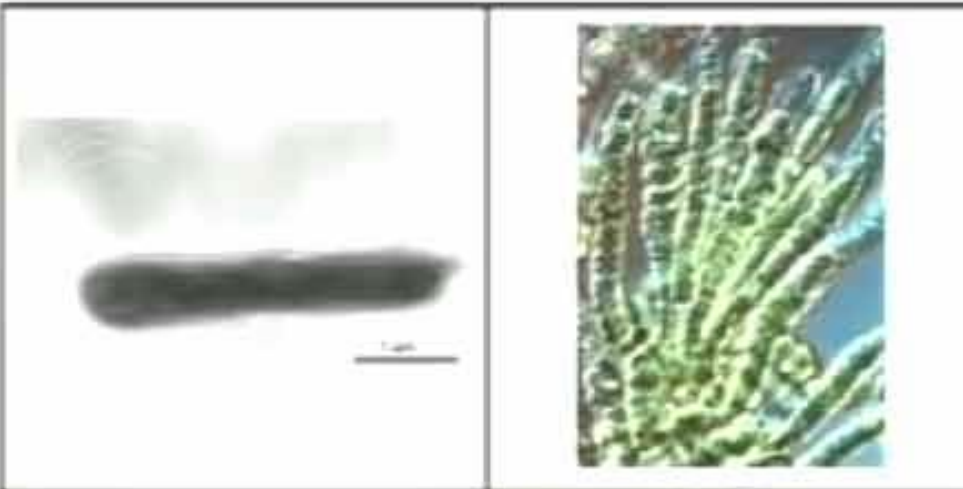
- Reduction and oxidation occur simultaneously in a type of chemical reaction called a reduction-oxidation or redox reaction.
- The oxidized species loses electrons, while the reduced species gains electrons.
- Despite the name, oxygen need not be present in an oxidation reaction.

# THE METABOLIC ORGANIZATION OF LIFE

Reductive metabolisms

Oxidative metabolisms

Autotrophs



Heterotrophs



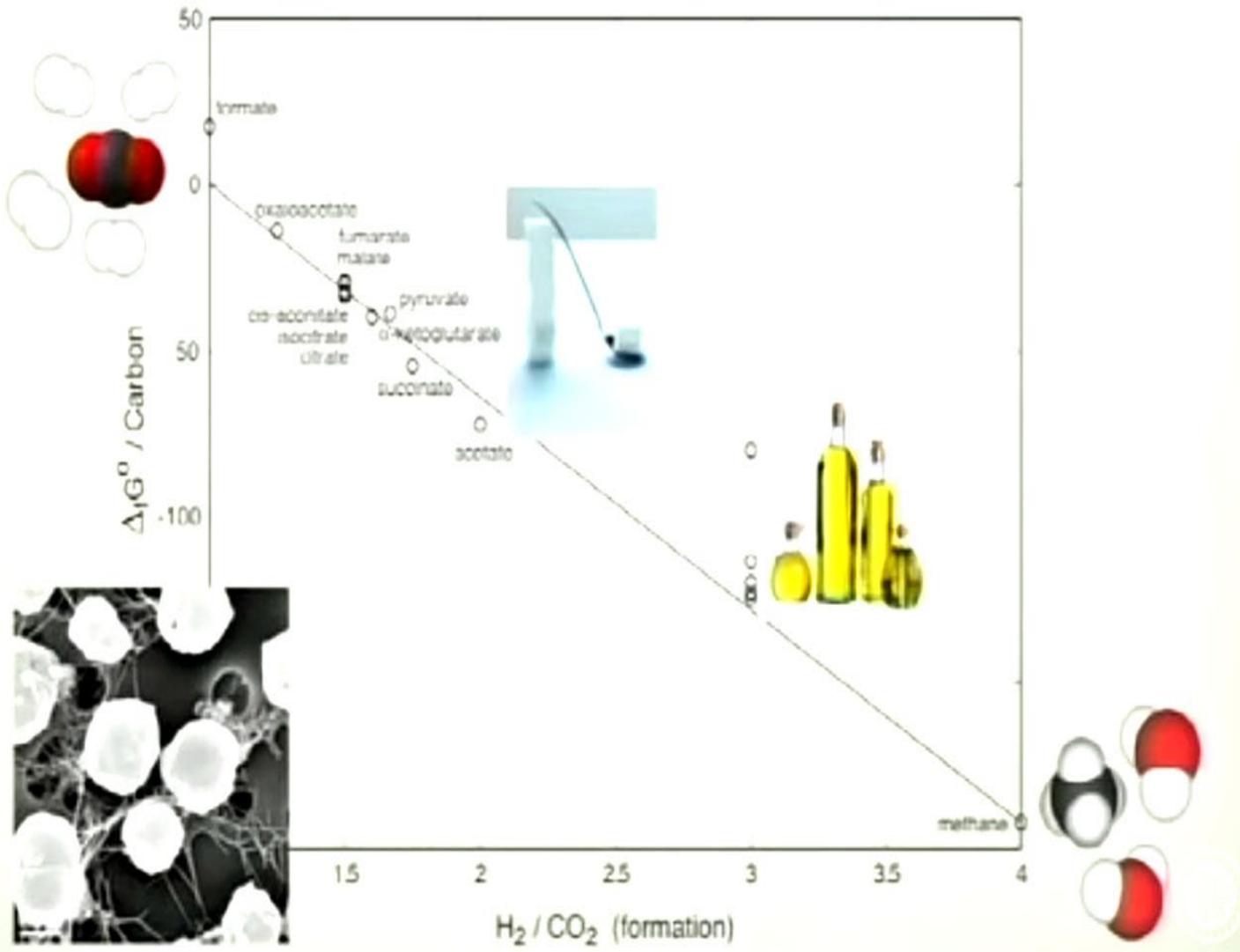
ALL OF LIFE IS DRIVEN BY ENERGETIC ELECTRON FLOWS.

# LIFE'S GOING TO BE ABLE TO GET GOING EASILY ONLY WHEN THE THERMODYNAMIC PATH IS "DOWNHILL"

- Meaning, that the chemical reactions involve an energy flow which is thermodynamically "allowed", and doesn't involve violation of the 2<sup>nd</sup> Law of Thermodynamics

# A FREE LUNCH YOU ARE PAID TO EAT

A VERY PARTICULAR SET OF STEPS IS NEEDED. THESE STEPS ARE “DOWNHILL”, BUT THERE’S MANY STEPS. TAKE THE WRONG STEP, AND YOU GET STUCK. IT WON’T “GO”.



“INEVITABLE LIFE?” – A GREAT LECTURE WHICH WILL BE THE LAST PART OF TODAY’S LECTURE...

- Here’s the video to complete this day’s lecture.  
A great lecture “Inevitable Life” by D. Eric Smith
- [Linked here](#)