

BIOFILMS EVERYWHERE:  
AN AUTOREGENERATIVE LOOP

# BIOFILMS EVERYWHERE

LIVING CONSORTIA, SLIME-ON-SUBSTRATES AND THE CIRCUMPLANETARY CLIMATE CONSORTIUM

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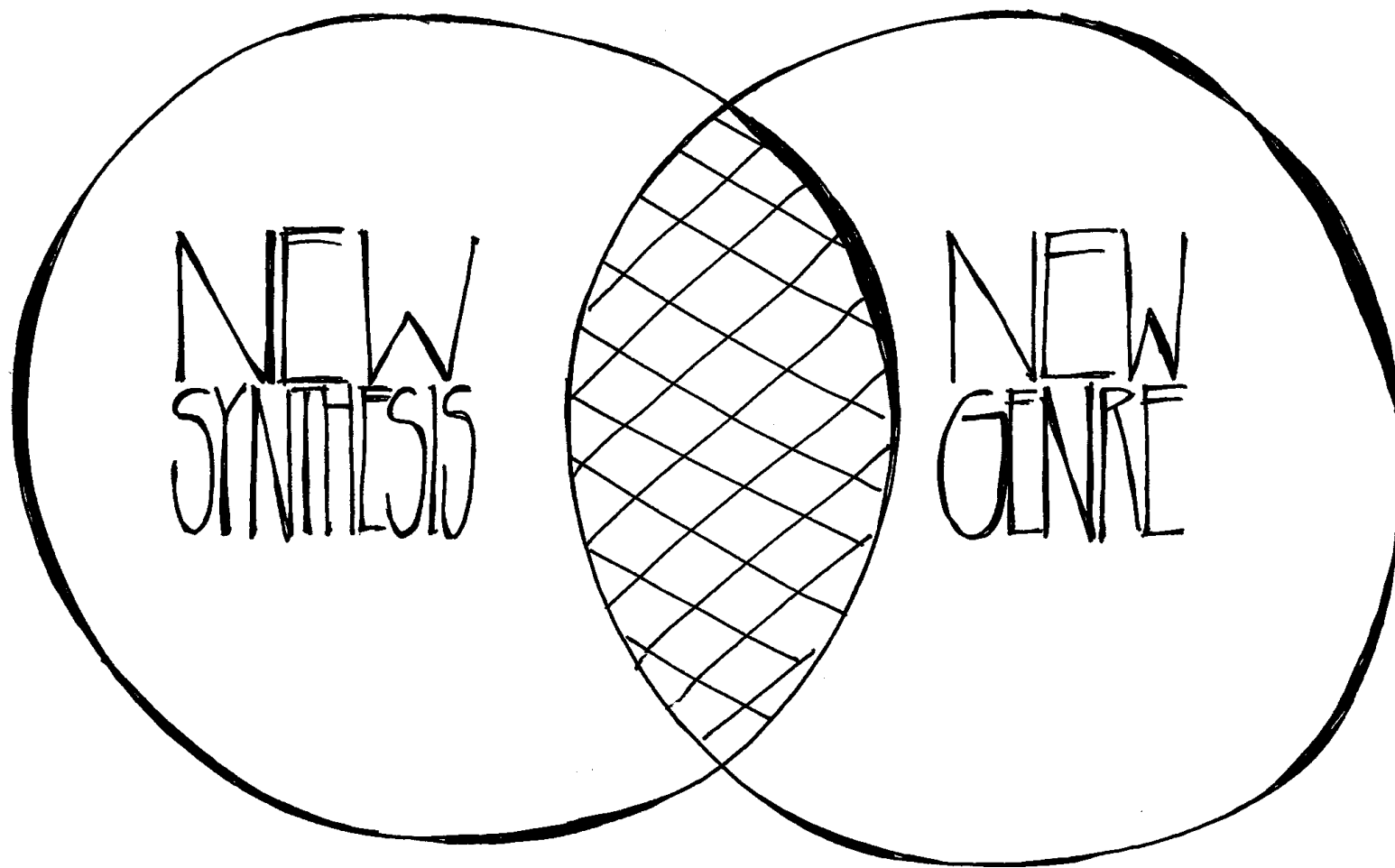
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# WORDS OF INTRODUCTION

1. Earth, Life and Environment: An evidence-based synthesis that is simple, predictive and falsifiable ought to be of interest.
2. Gaia Theory is imprecise, indeterminate and is now perhaps little more than a useful yet problematic metaphor, that has been largely subsumed within Earth System Science (box models).
3. Informed Intuition:
  - a) Earth's Climasphere is somehow, some kind of a very big ecosystem (?).
  - b) Simplicity exists at the core of very much intricacy; we hunger to understand and describe it.
4. Biofilms Everywhere:
  - a) The phenomena of **LIVING** upon **SUBSTRATES** produces and perpetuates **BIOFILMS**, that impact upon and coevolve with Living and Substrates.
  - b) This simple autoregenerative dynamic — described herein — has operated from deep-time to present and occurs from molecular to circumplanetary scales.
  - c) Contrasting The Climate Consortium (this paper) with chemostatic norms.

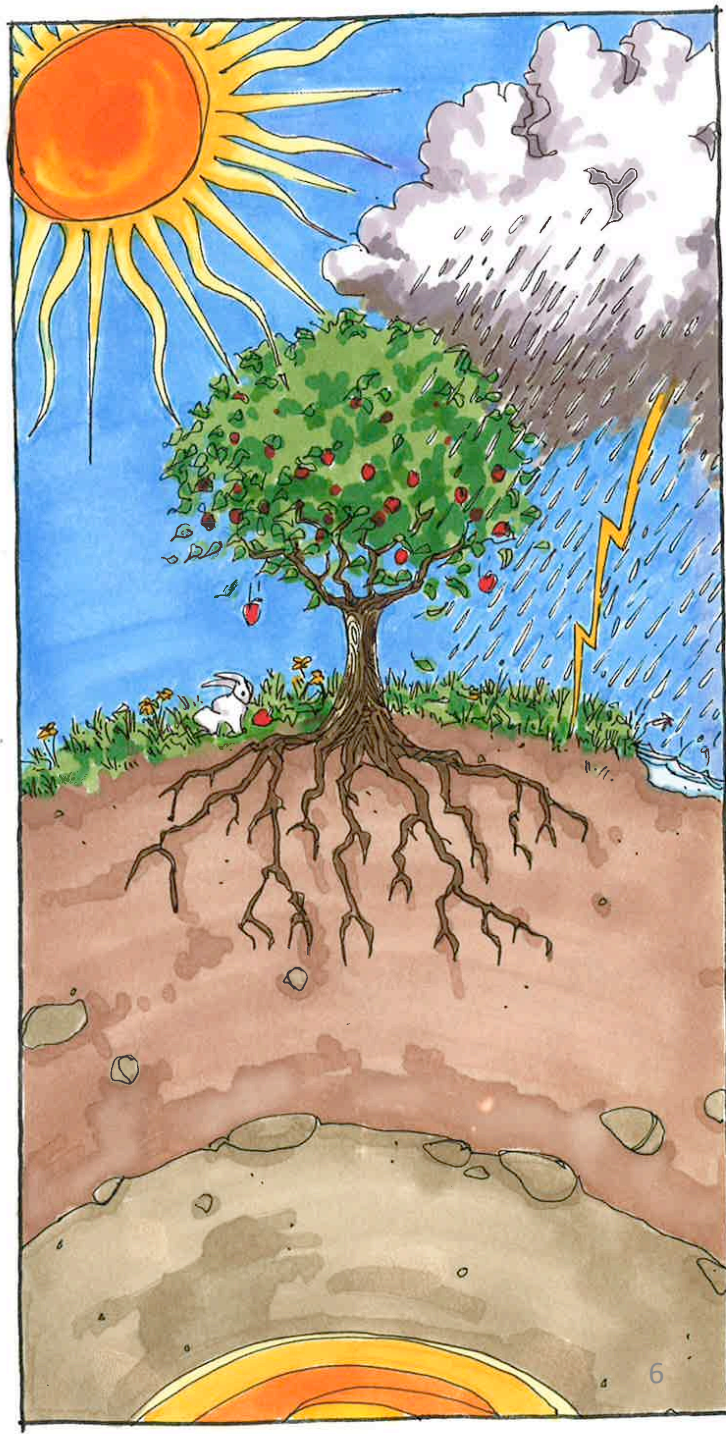
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Buzz Holling Kay Jim Kennett Fritjof Capra  
Robert Ulanowicz Paul Smith Lloyd Burckle William Rees  
Tom Pedersen Araceli Baena Mallen Konrad Lorenz  
Roger Lewin Thomas Kuhn Rus Maynard  
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Richard Dawkins James Lovelock Stuart Kauffman  
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James Gleick Steve Gould Charles Darwin  
Dan Gowe Carol Brooks Jim Merkel  
Schneider Maturana

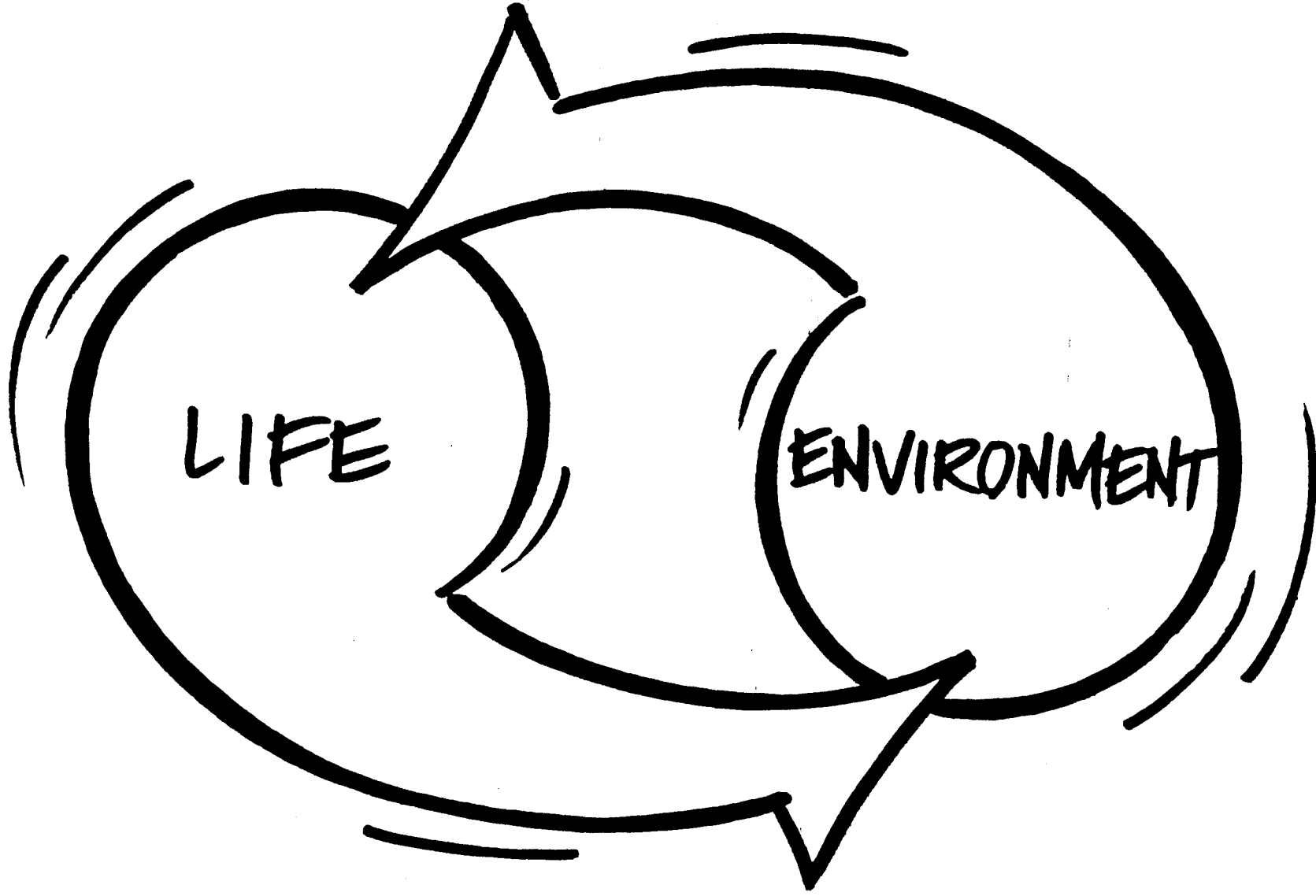


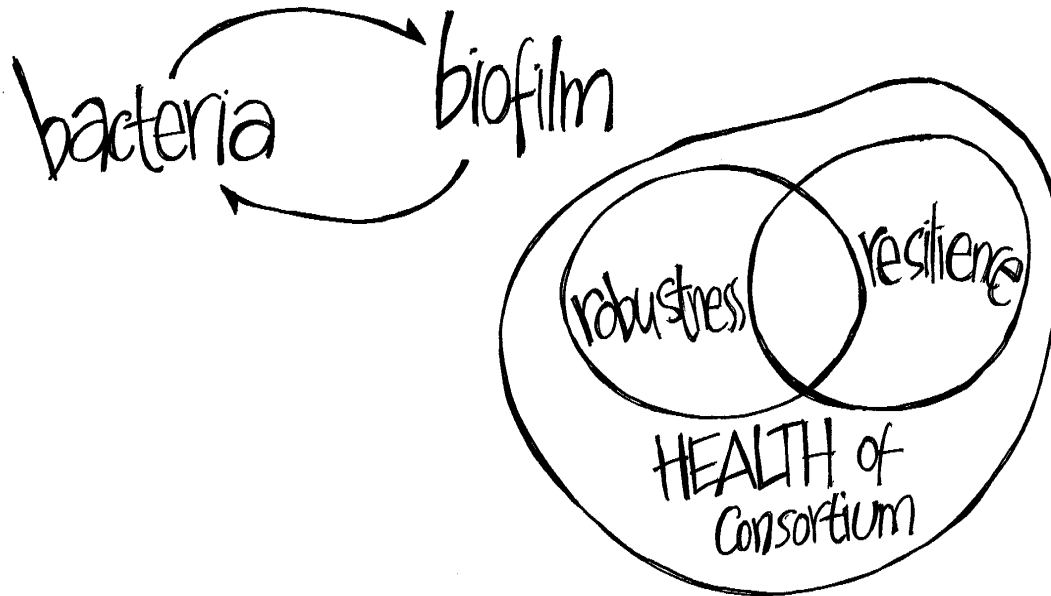
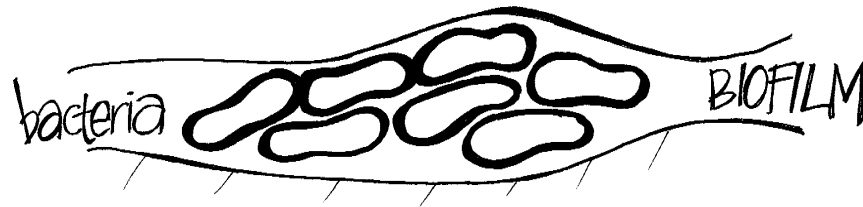
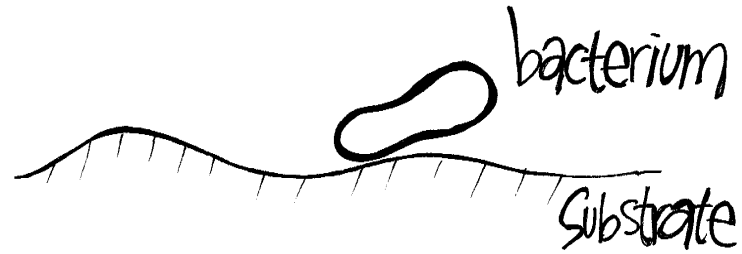
 = NECESSARY



WATER  
ROCK  
ENERGY  
DYNAMICAL EARTH  
PLANETARY LIFE



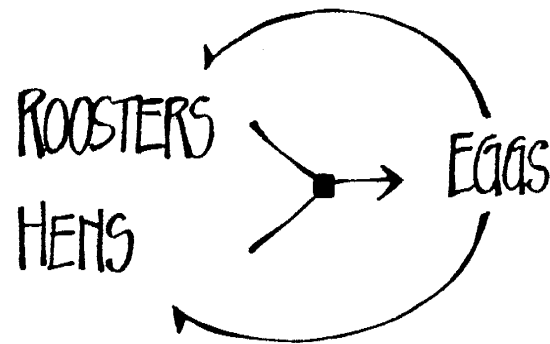




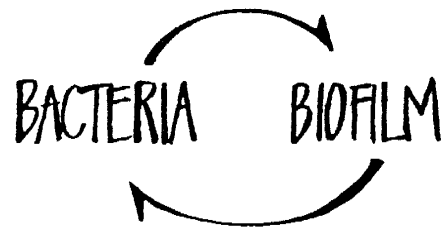


# LIFE

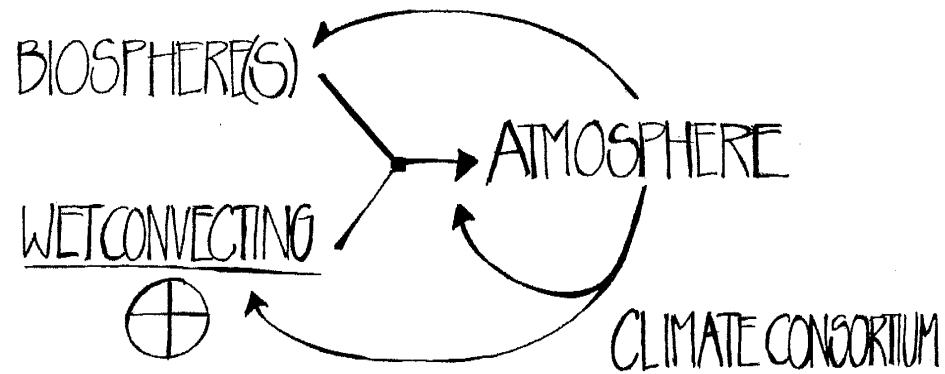
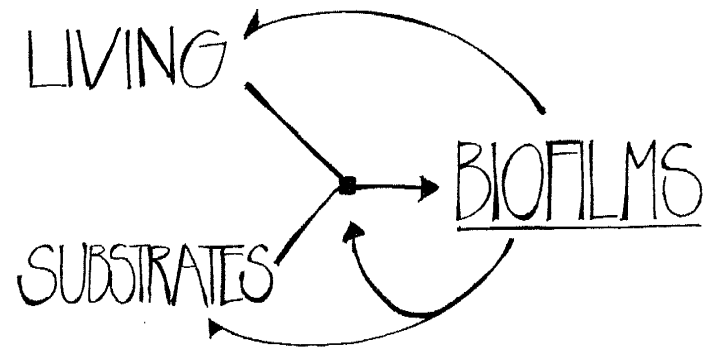
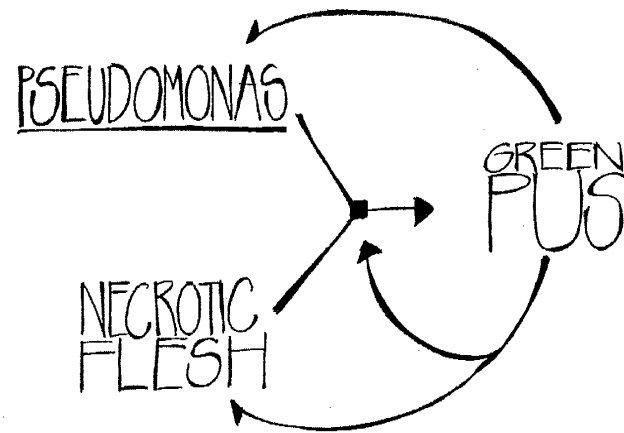
AUTOREGENERATES

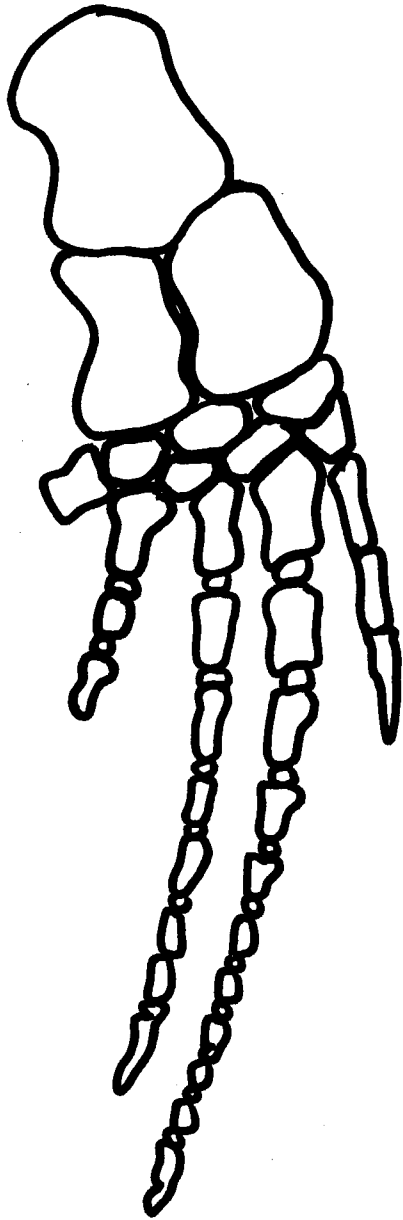


COEVOLVES

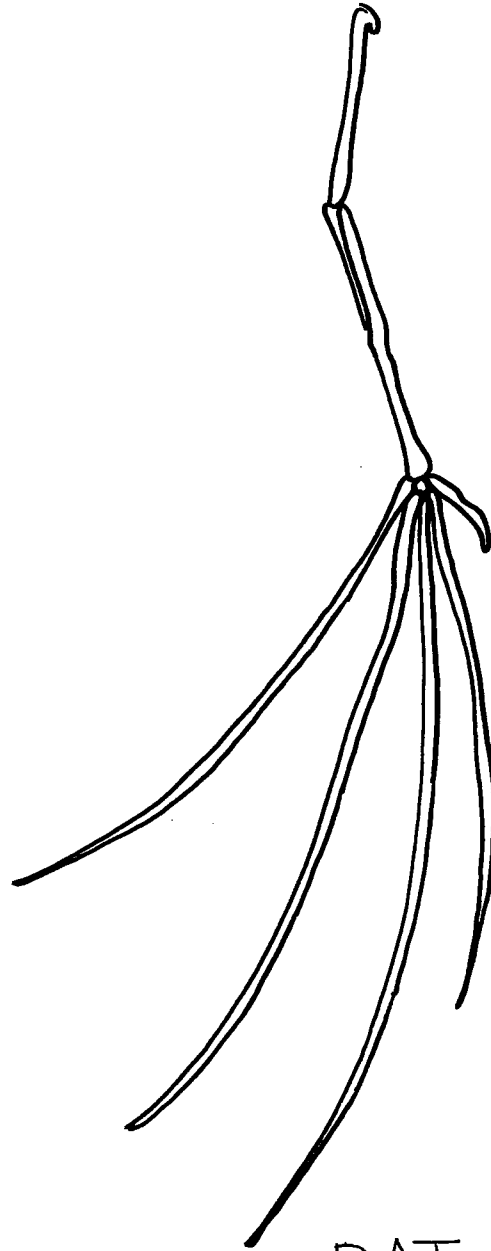


AND CAN HEAL





BLUE  
WHALE

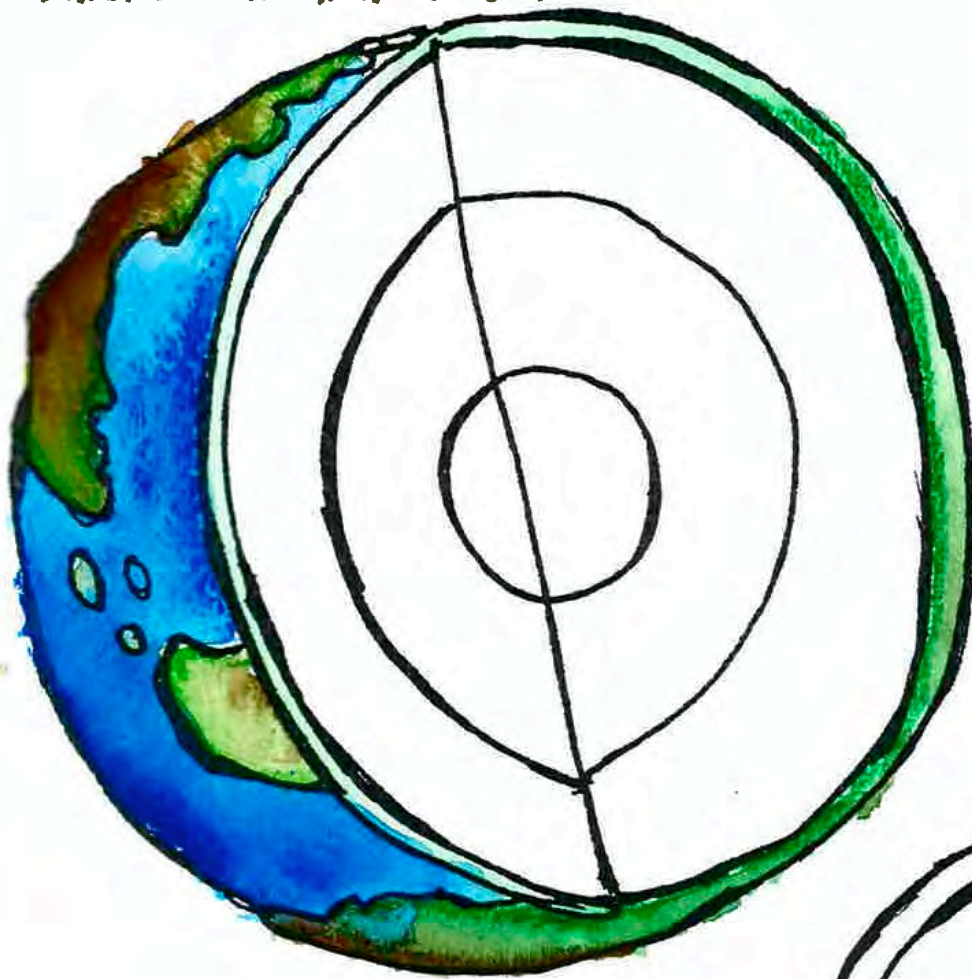


BAT

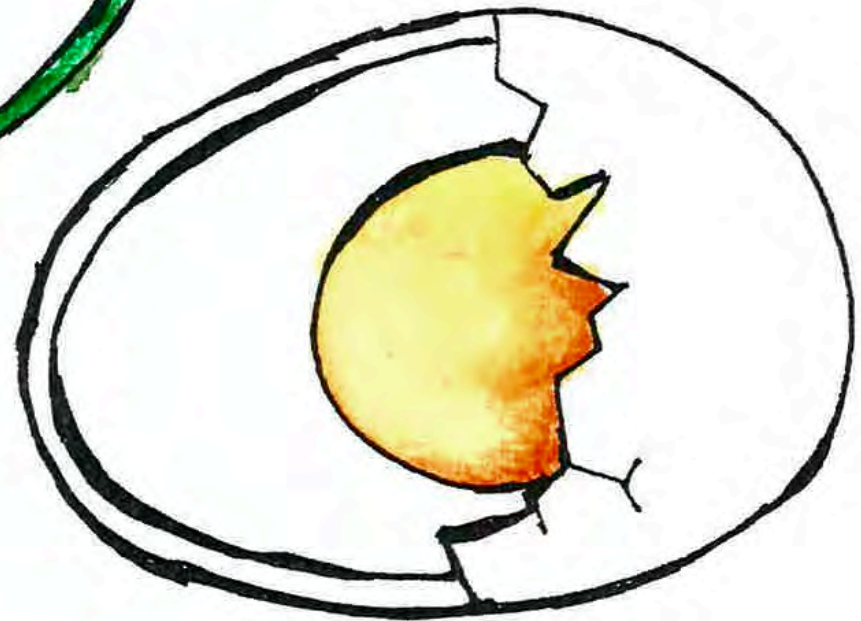
Looking for causal and DeepTime  
Unity in the Natural World...

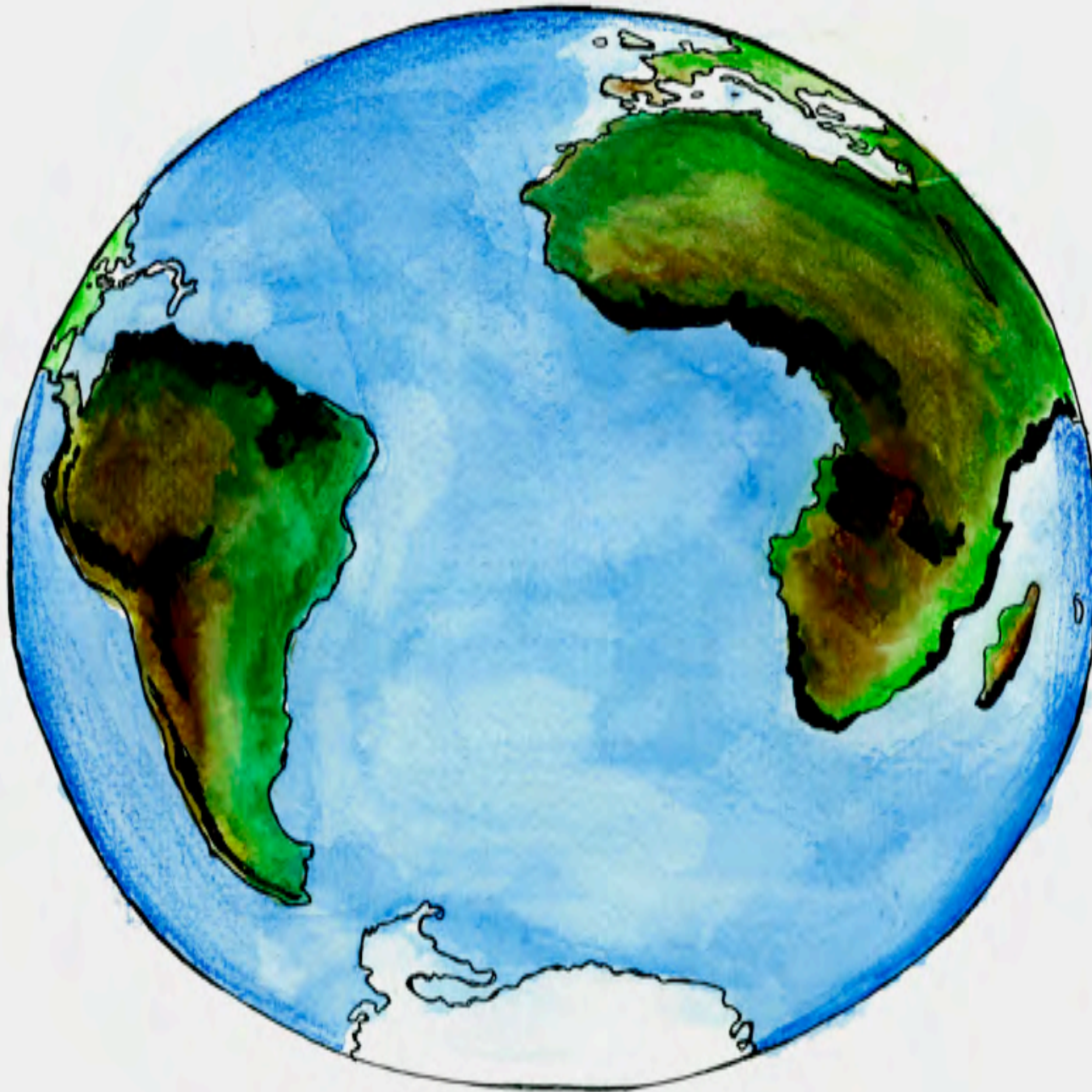
Via  
**FUNCTIONAL  
HOMOLOGIES?**

Very quickly, zip thru some art...



Earth is Layered...





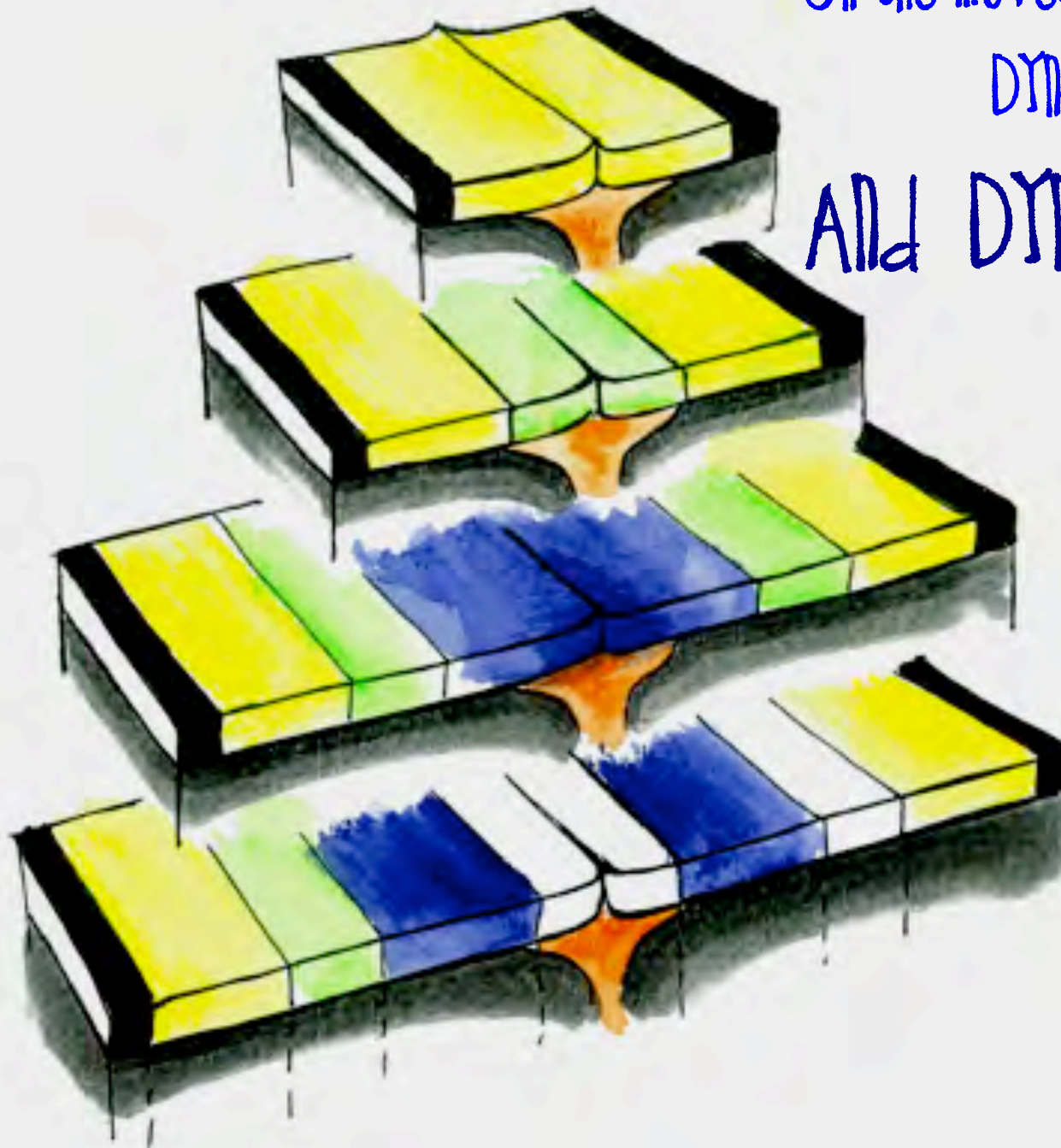
WET...



On the move...

Dynamic....

And DYNAMICAL....



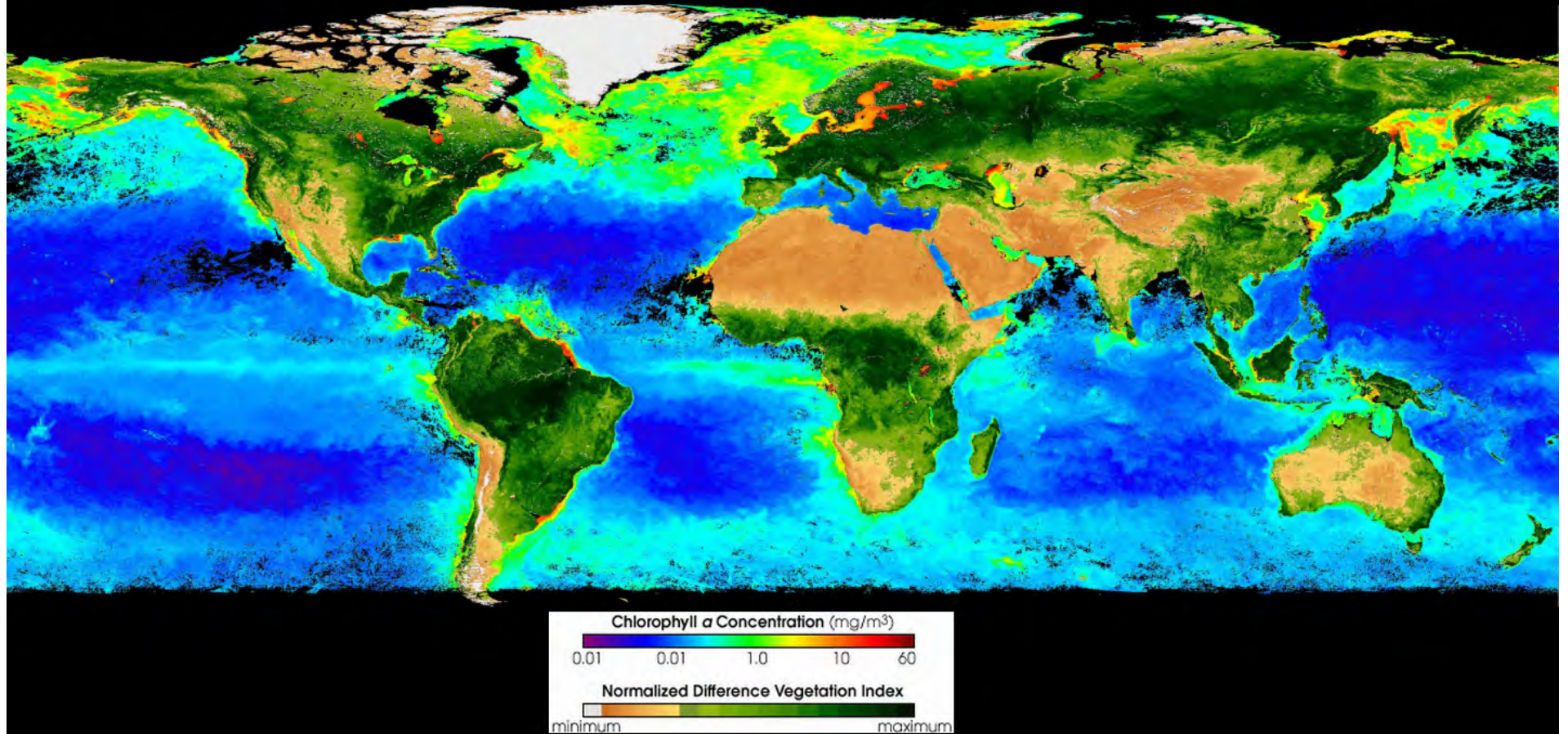


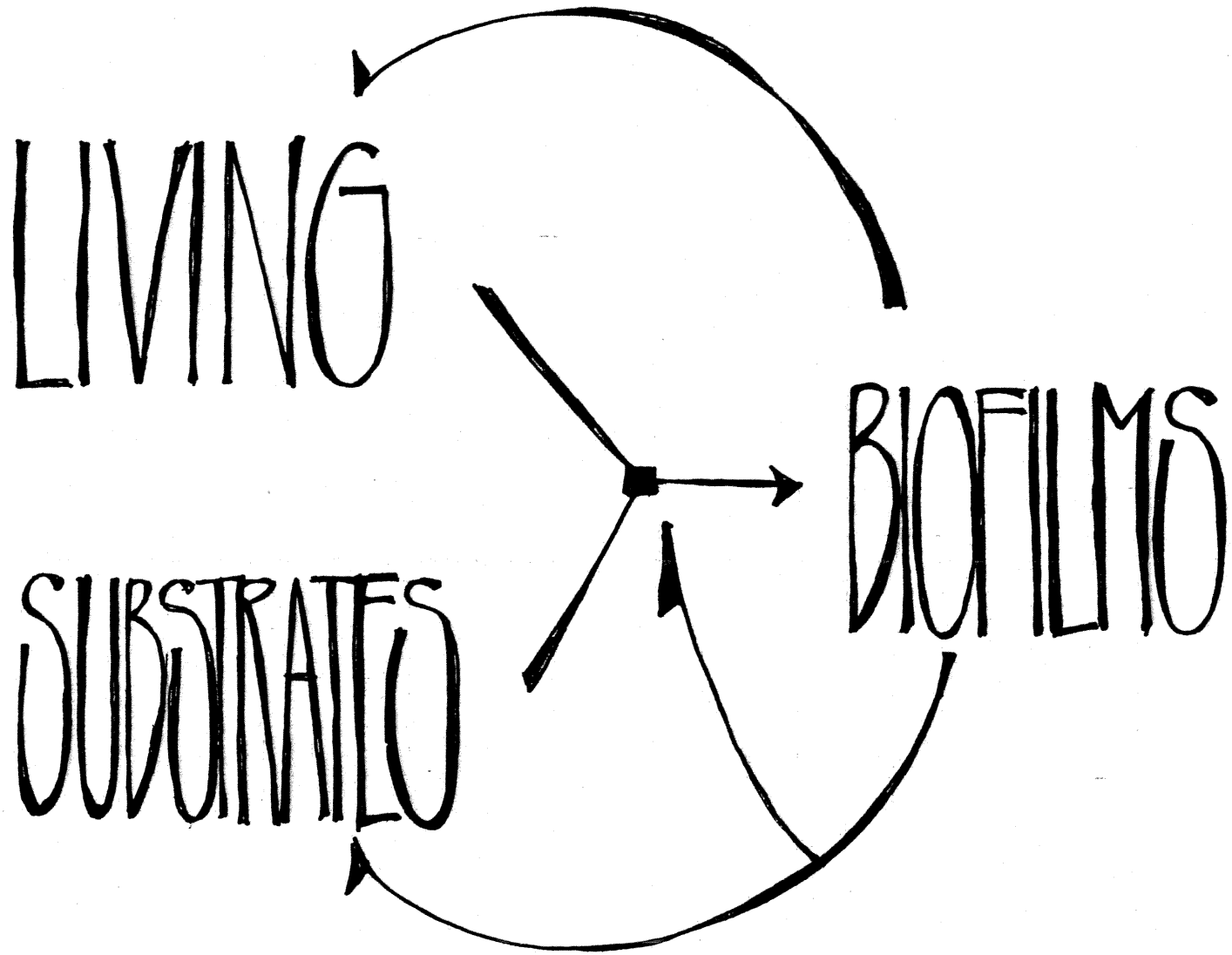
Perpetual Recycling → NEW SUBSTRATES





# LIFE EXISTS, EVOLVES AND COEVOLVES





FOODY BIOFILMS

YOGURT KEFIR

KIMCHEE • KOMBUCHA

CHEESE

BEER WINE

STOMACH &  
INTESTINAL  
MUCOSA

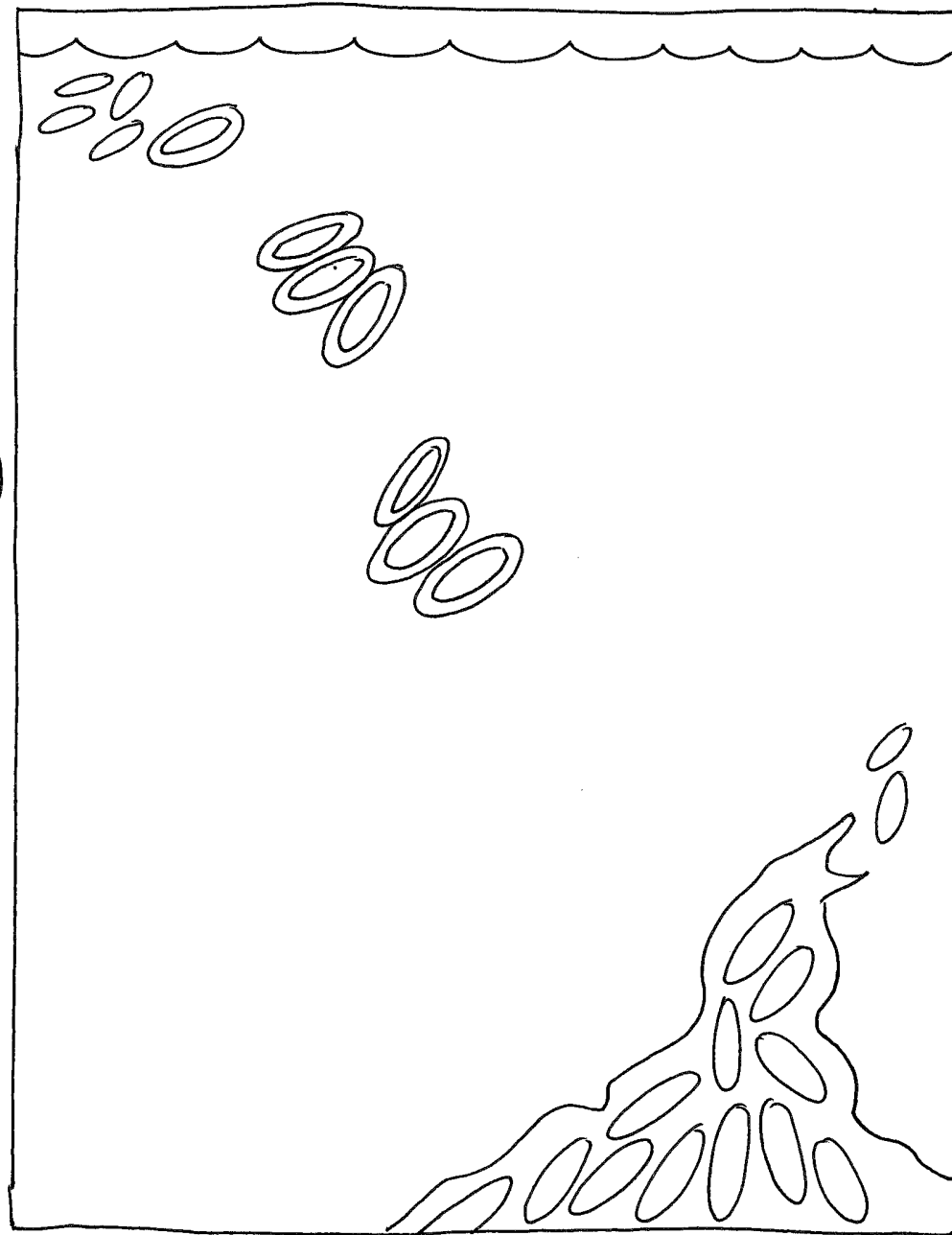
Human Oral Microbiome

LIVING SUBSTRATE  
BIOFILM  
WASTES  
MINERAL  
MATTER  
EXOPOLYMER  
FLUIDS LIQUIDS  
GASES  
BIONEERS  
PROPERTIES  
ROBUSTNESS  
RESILIENCE



PLANKTIC

AGGREGATES

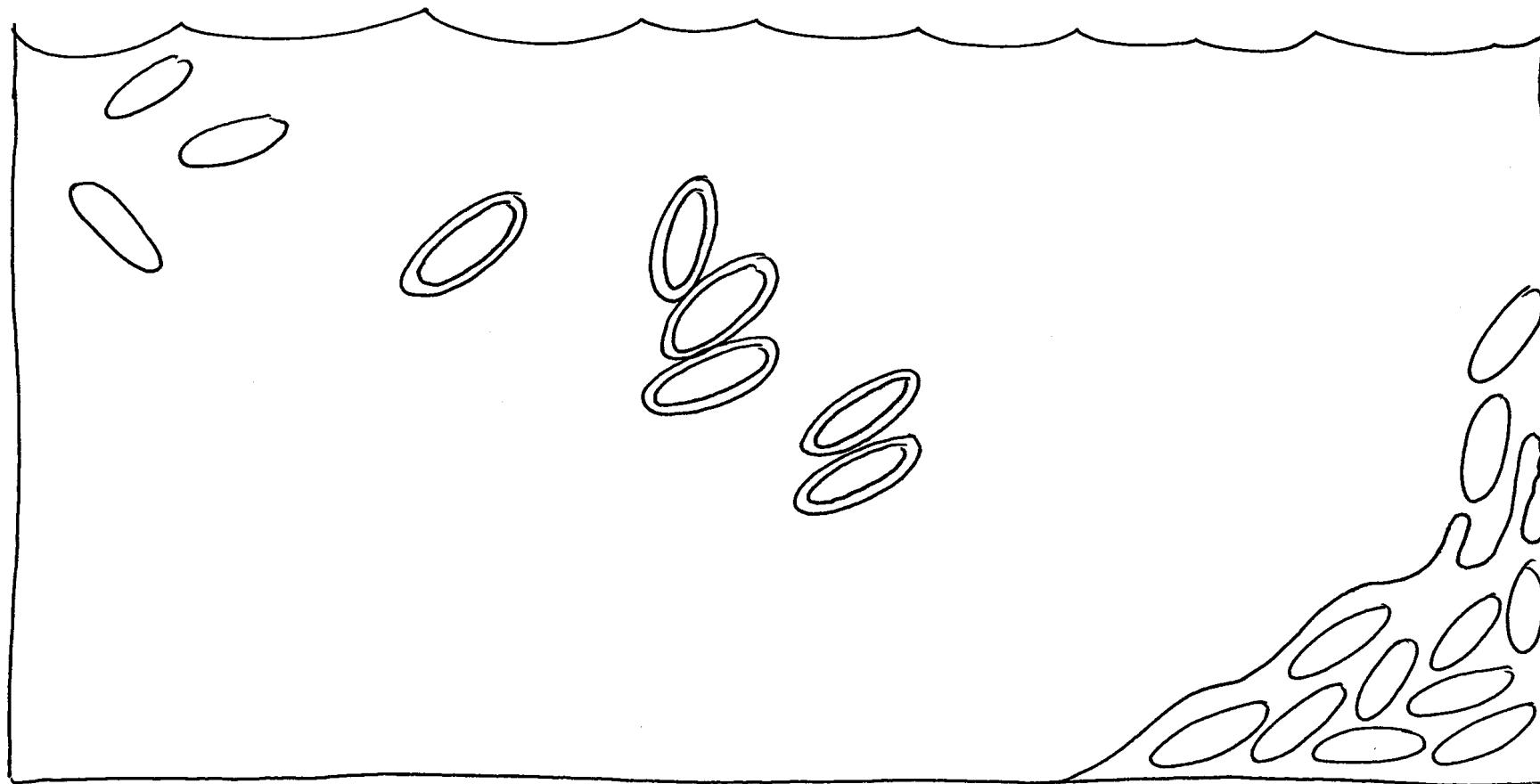


BIOFILM





BRUSH & FLOSS!



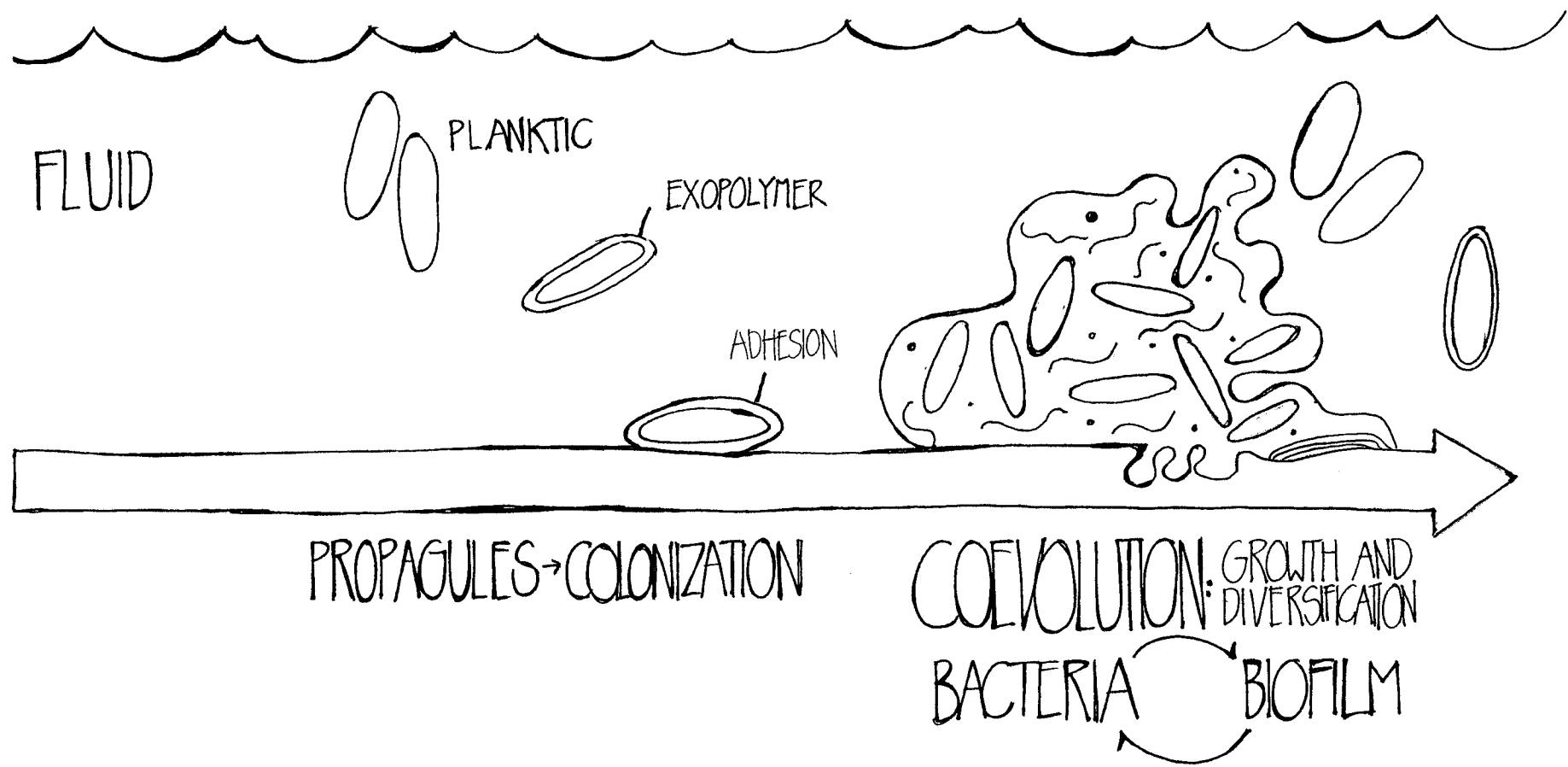
PLANKTIC

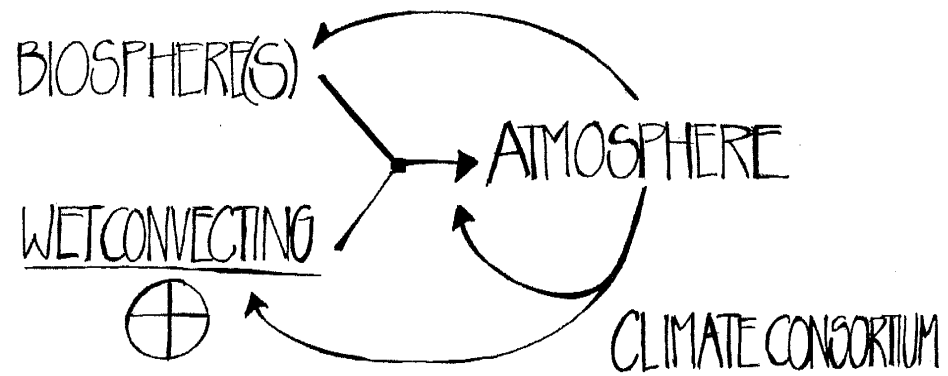
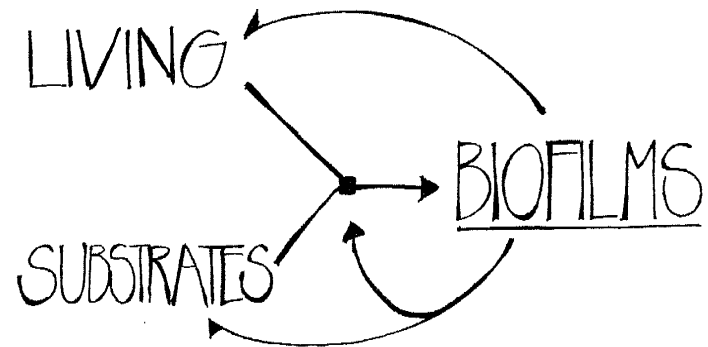
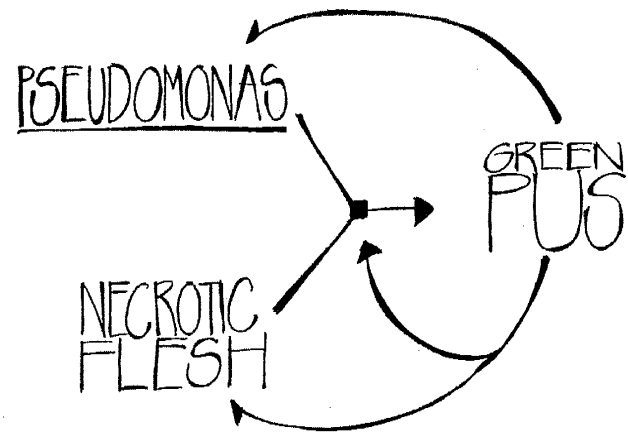
AGGREGATES

BIOFILMS

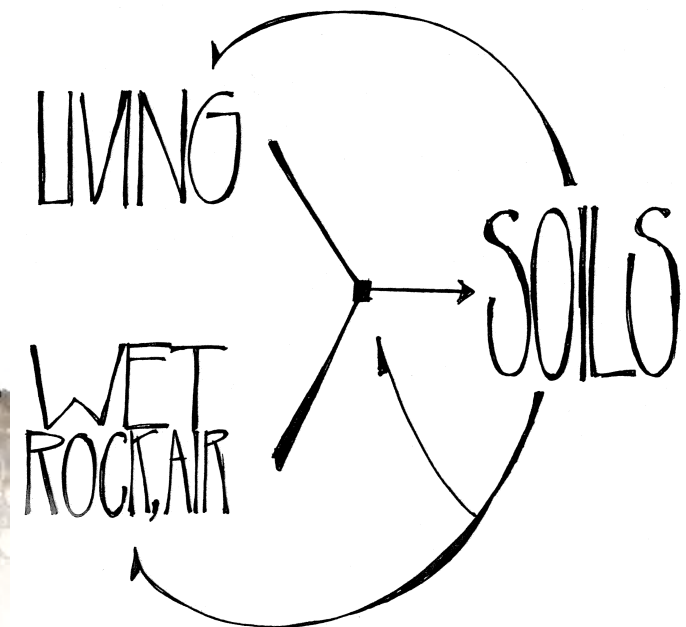
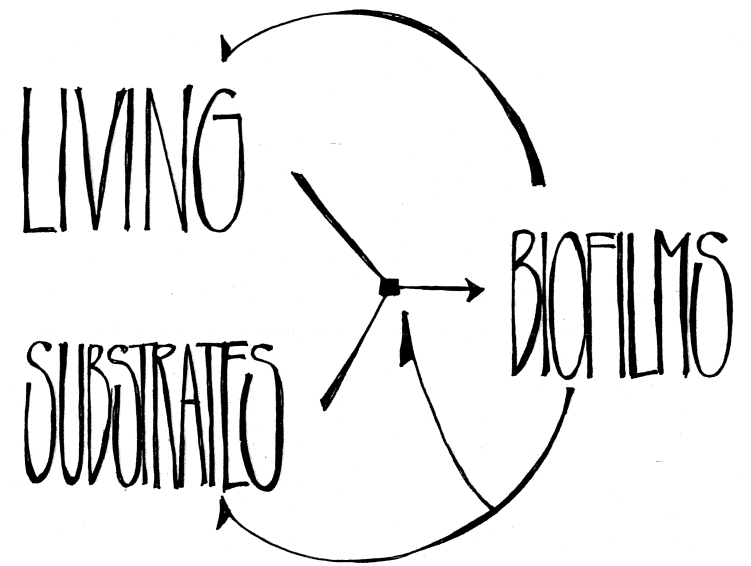
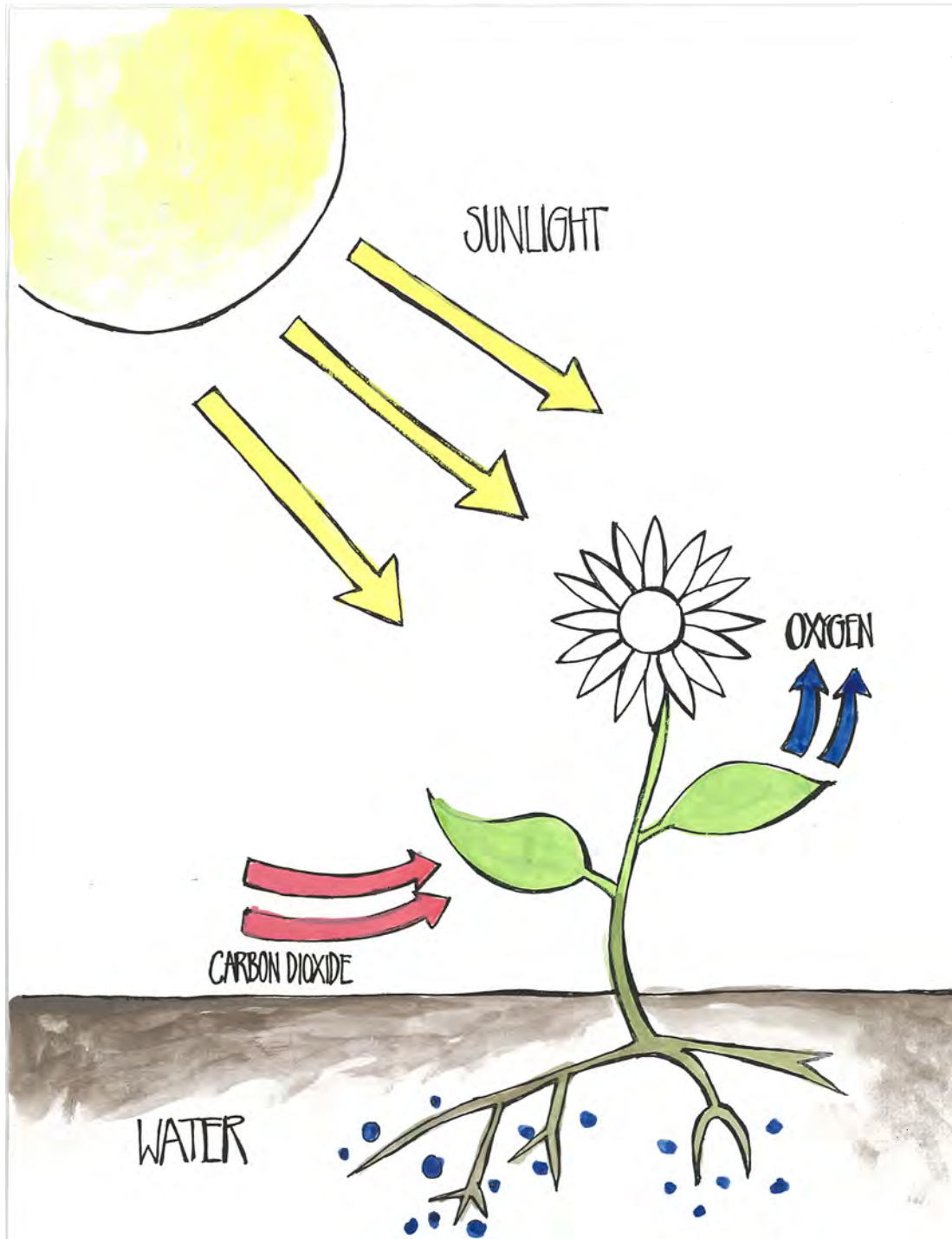


OR DON'T....



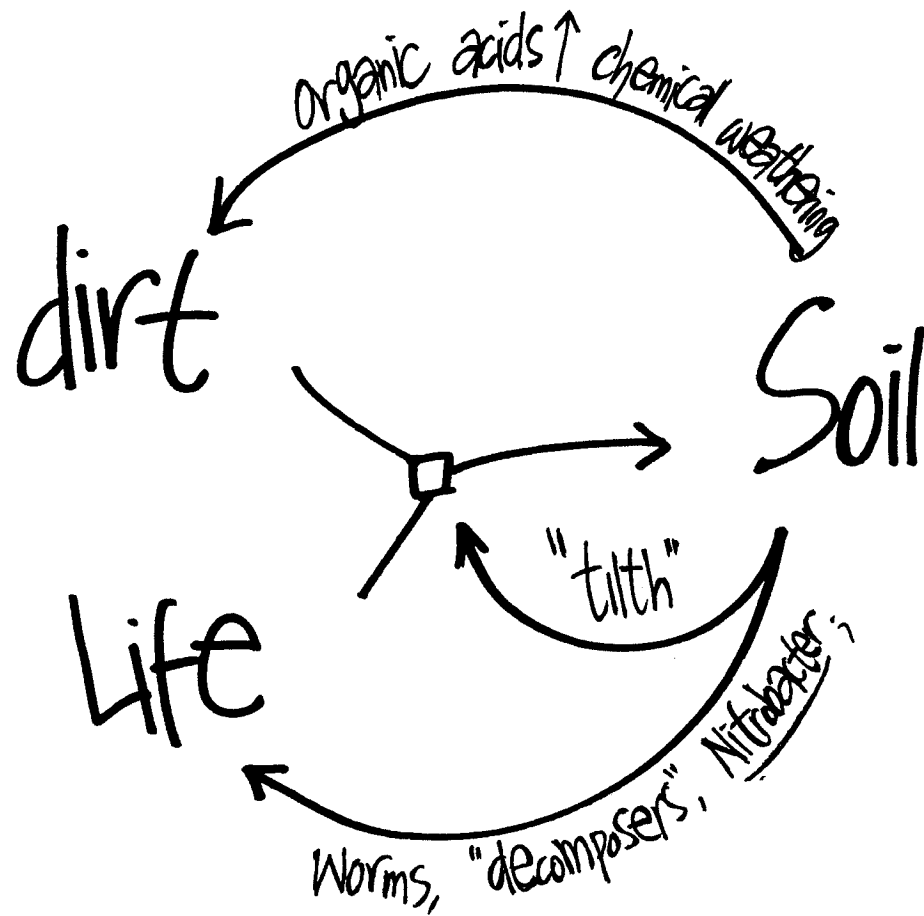






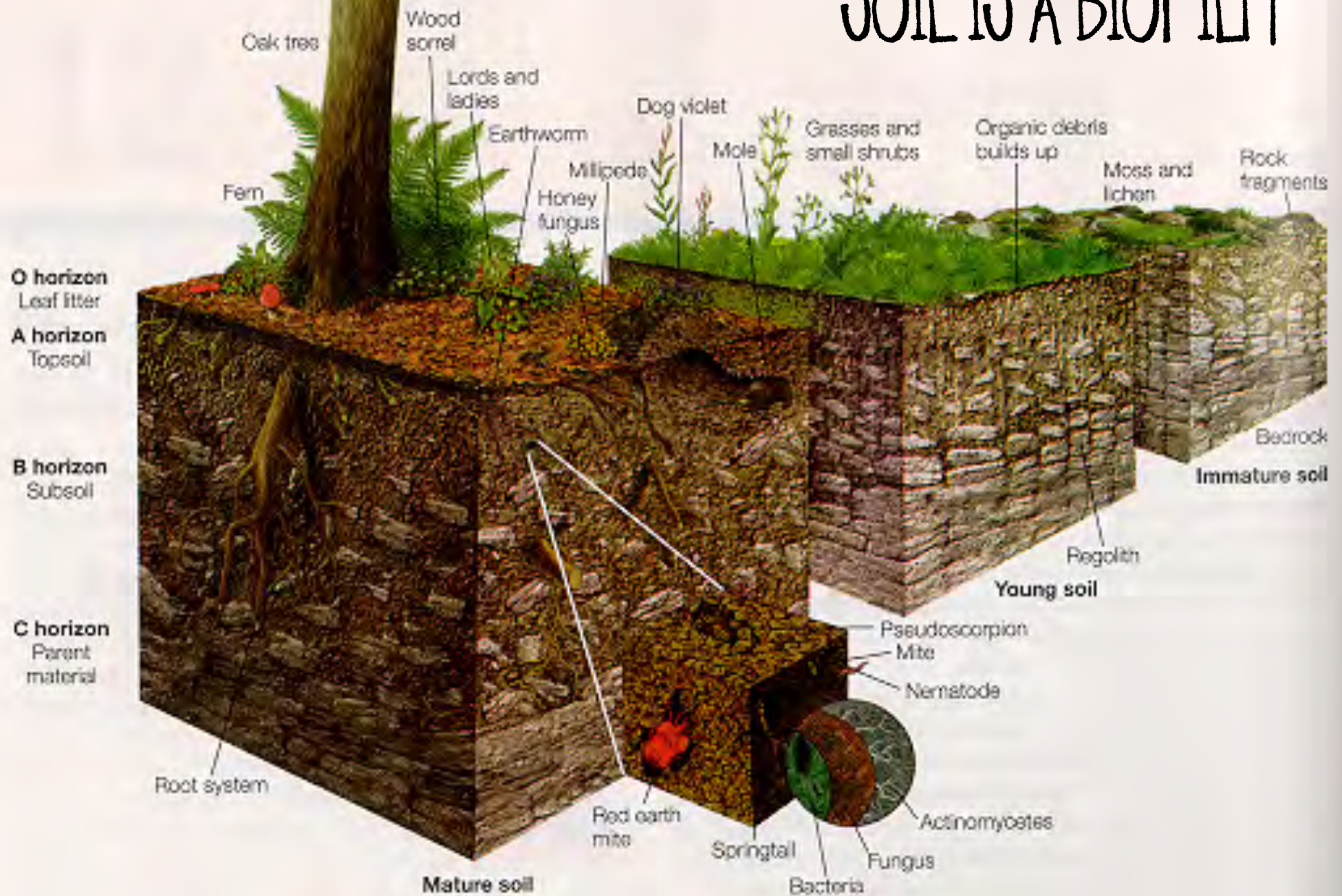


# SOIL AIN'T DIRT



PPP...

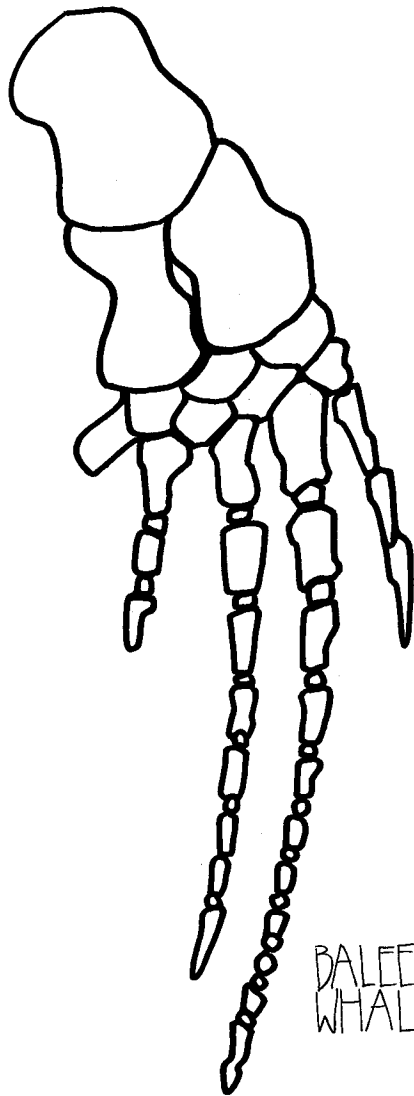
# SOIL IS A BIOFILM



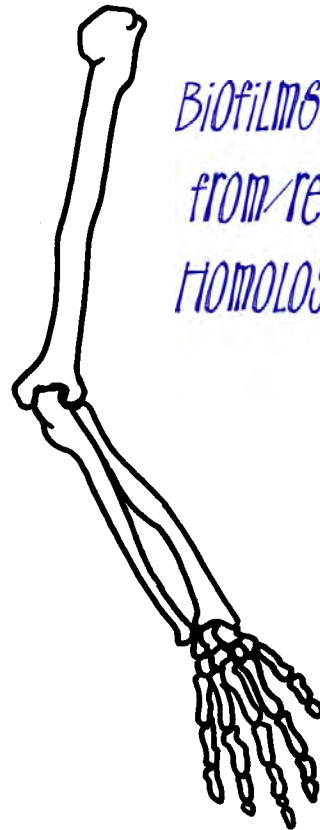
# BIOFILMS: PLANETARY PHENOMENON UNITY & HOMOLOGY

PSEUDOMONAS → GREEN  
TOILET SCUM  
SHOWER SCUM  
DENTAL PLAQUE  
CLOGGED DRAINS  
CYANOBACTERIAL MATS  
STROMATOLITES  
DESERT VARNISH  
LICHEN CRUSTS  
SOIL CRUSTS  
MOSSY CRUSTS

EXTREMOPHILIC BIOFILMS  
SIMPLE FILTERS  
BUILDINGS DECK SLIME  
INDUSTRIAL COOLERS  
MARINE ENCrustATIONS  
(SHIPS PLINGS "REEFS")  
MARINE SEDIMENTS  
AQUATIC SEDIMENTS  
"MARINE SNOW"  
RHIZOBIUM SYMBIONTS



BALEEN  
WHALE



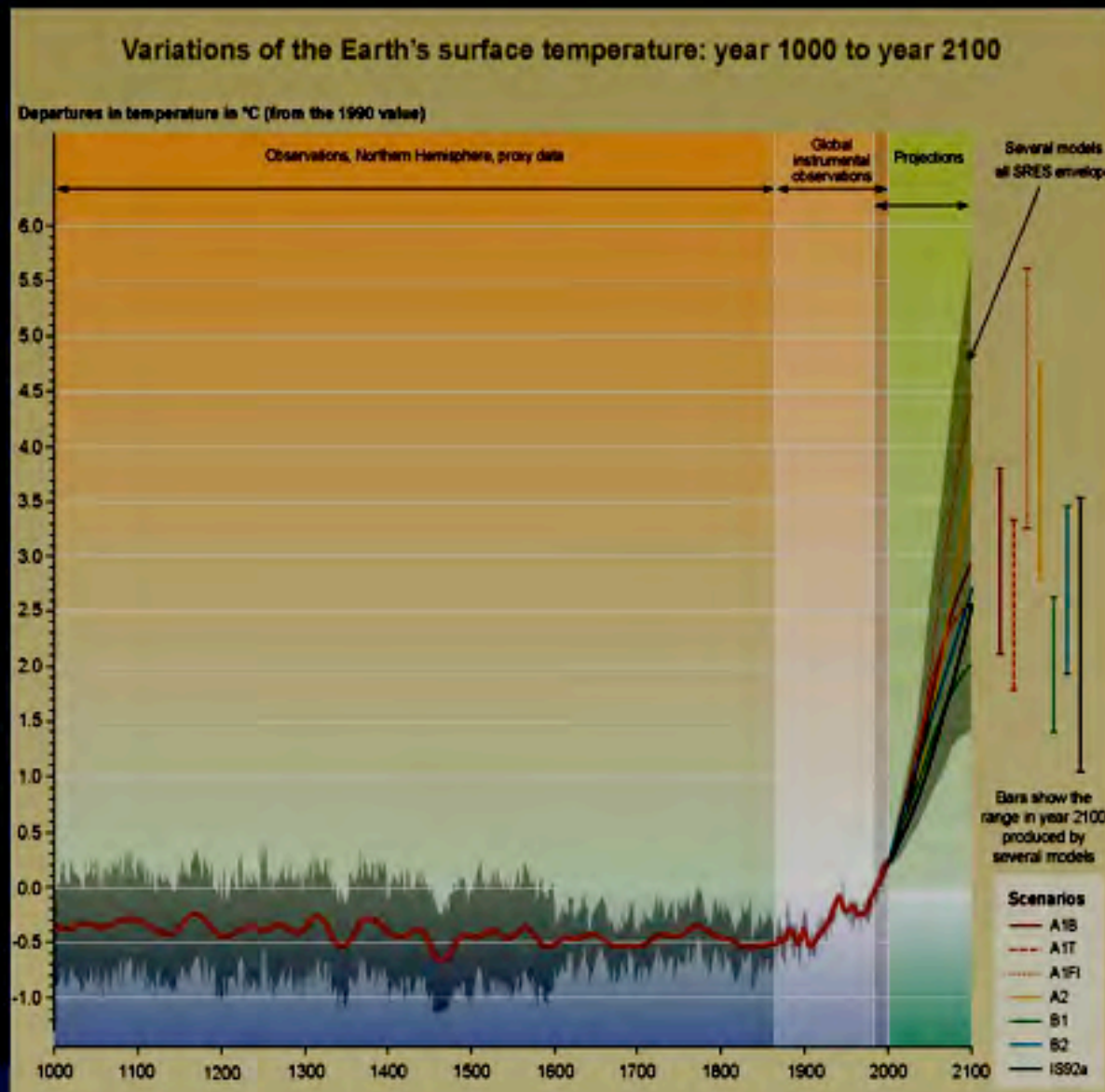
HUMAN

*Biofilms Everywhere: Functional homologies arise  
from/reflect ecoevolutionary relationships.*

*HOMOLOGY: Greek Homo ("the same") logos ("to speak")*

FOREST SOILS  
GRASSLAND  
AGRI-CULTURAL  
VASCULAR PLAQUE?  
ATHLETE'S FOOT  
CYSTIC FIBROSIS  
"SCABBING → HEALING!"  
EARTH'S ATMOSPHERE  
OCEANS



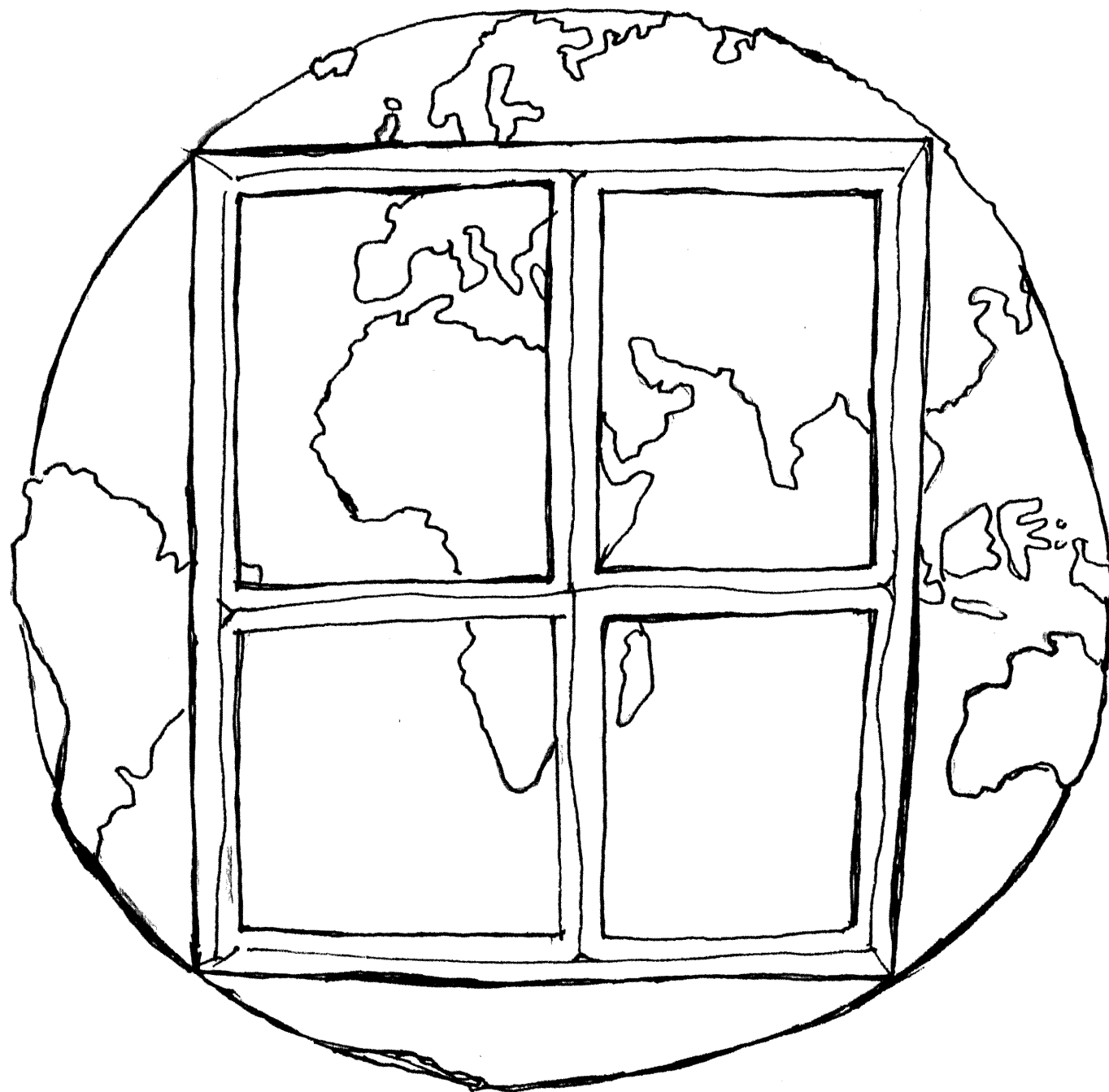


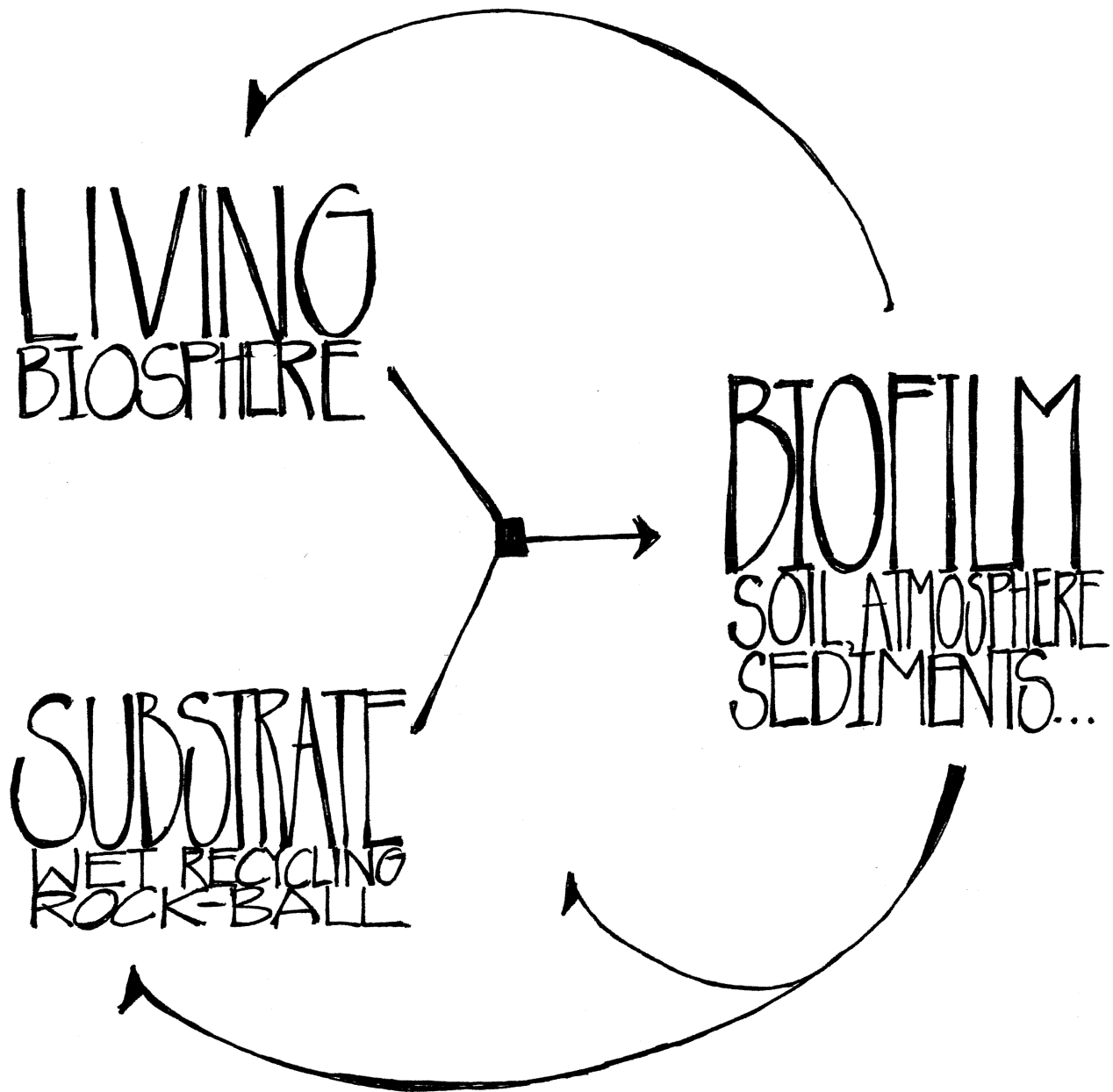
Climate CHEMOSTAT?

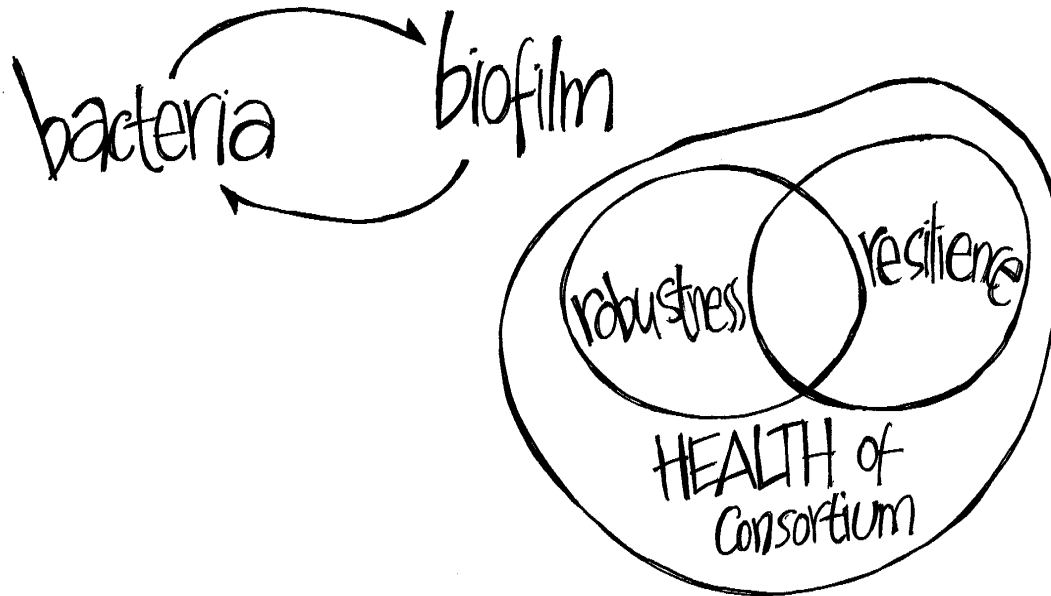
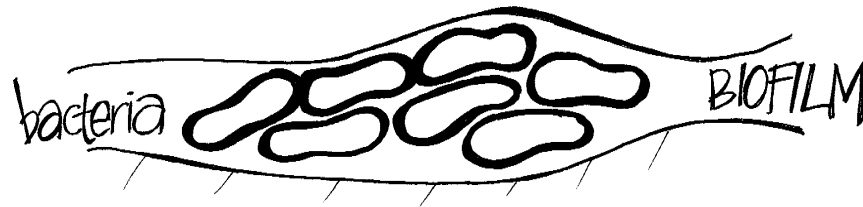
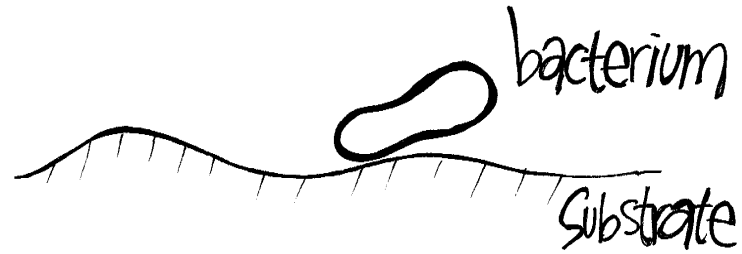
Earth system science?

GAIA: An Indeterminate  
Synthesis, a useful  
metaphor













## CLOUD CONDENSATION NUCLEI (CCN)

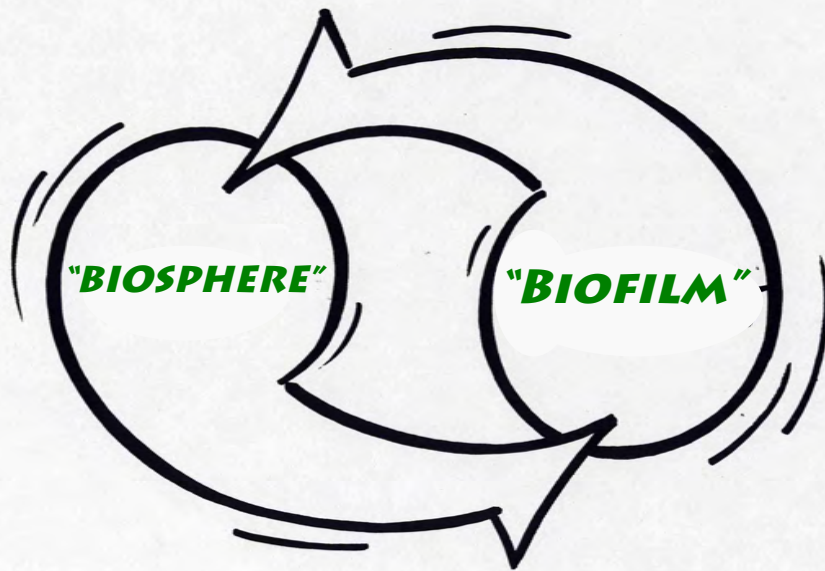
- *DMS AND MANY TERRESTRIAL METABOLITES)*
- *CLOUDS THAT PRECIPITATE*
- *ICN*
- *VIABLE BACTERIA AND FUNGI IN CLOUDS*





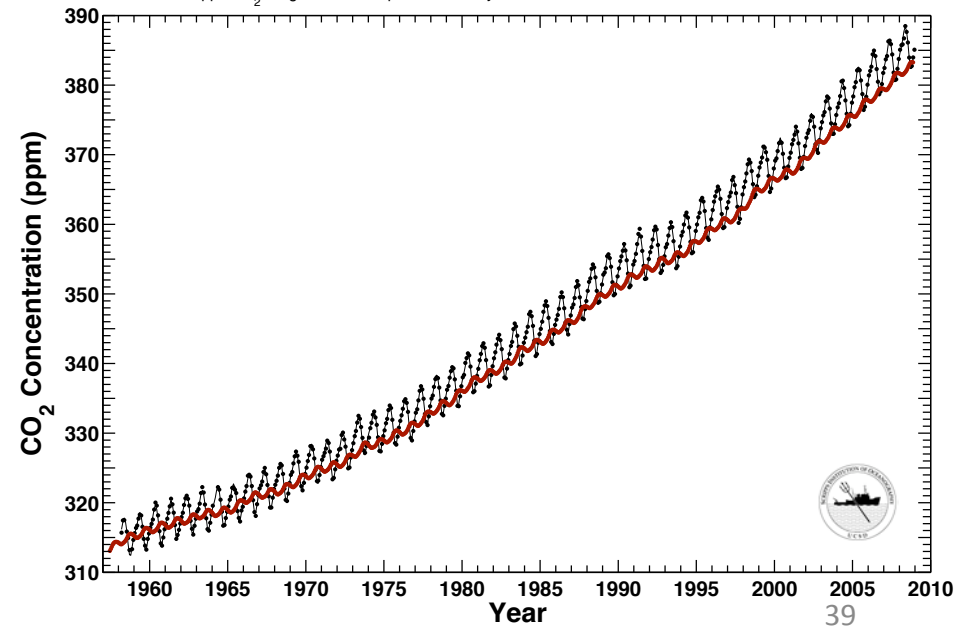
# EARTH'S ATMOSPHERE IS A BIOFILM

THAT REQUIRES & PERPETUATES  
THE CLIMATE CONSORTIUM

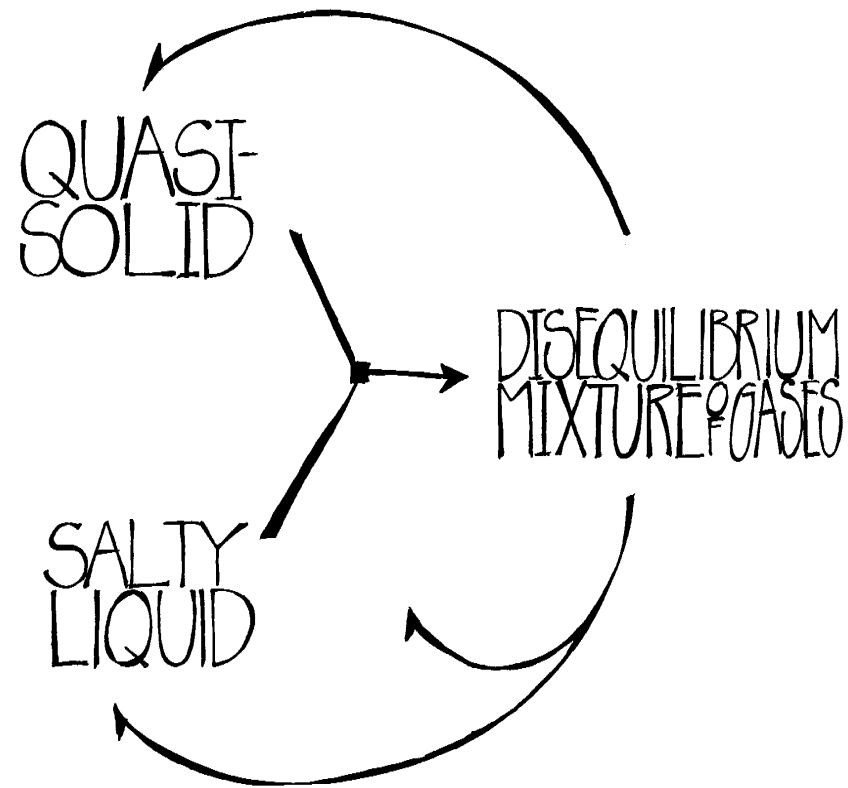
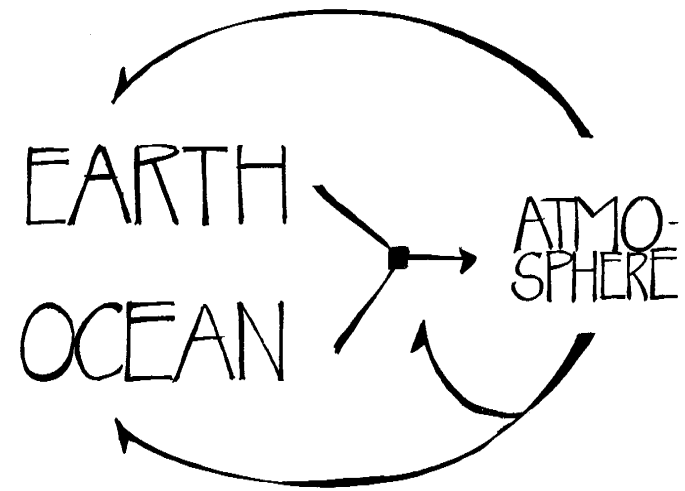


Mauna Loa Observatory, Hawaii and South Pole, Antarctica  
Monthly Average Carbon Dioxide Concentration

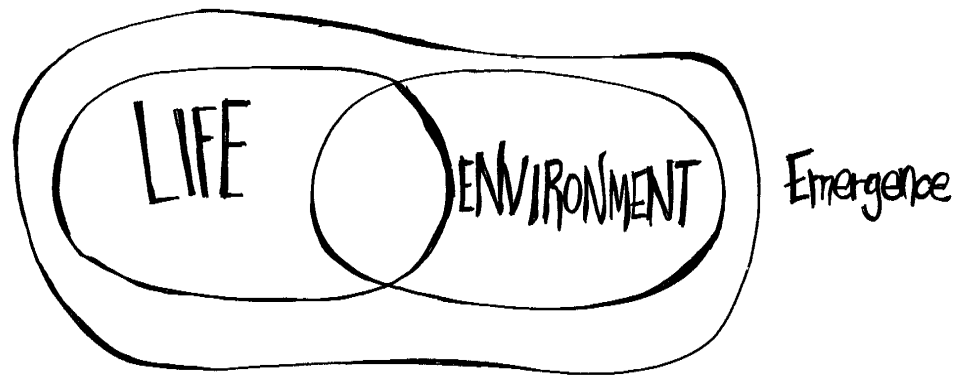
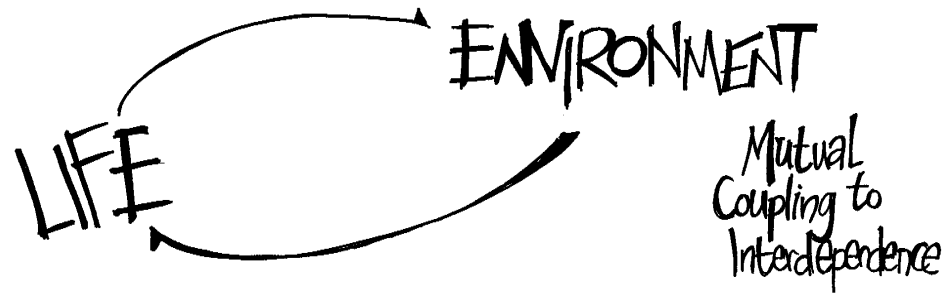
Data from Scripps CO<sub>2</sub> Program Last updated January 2009





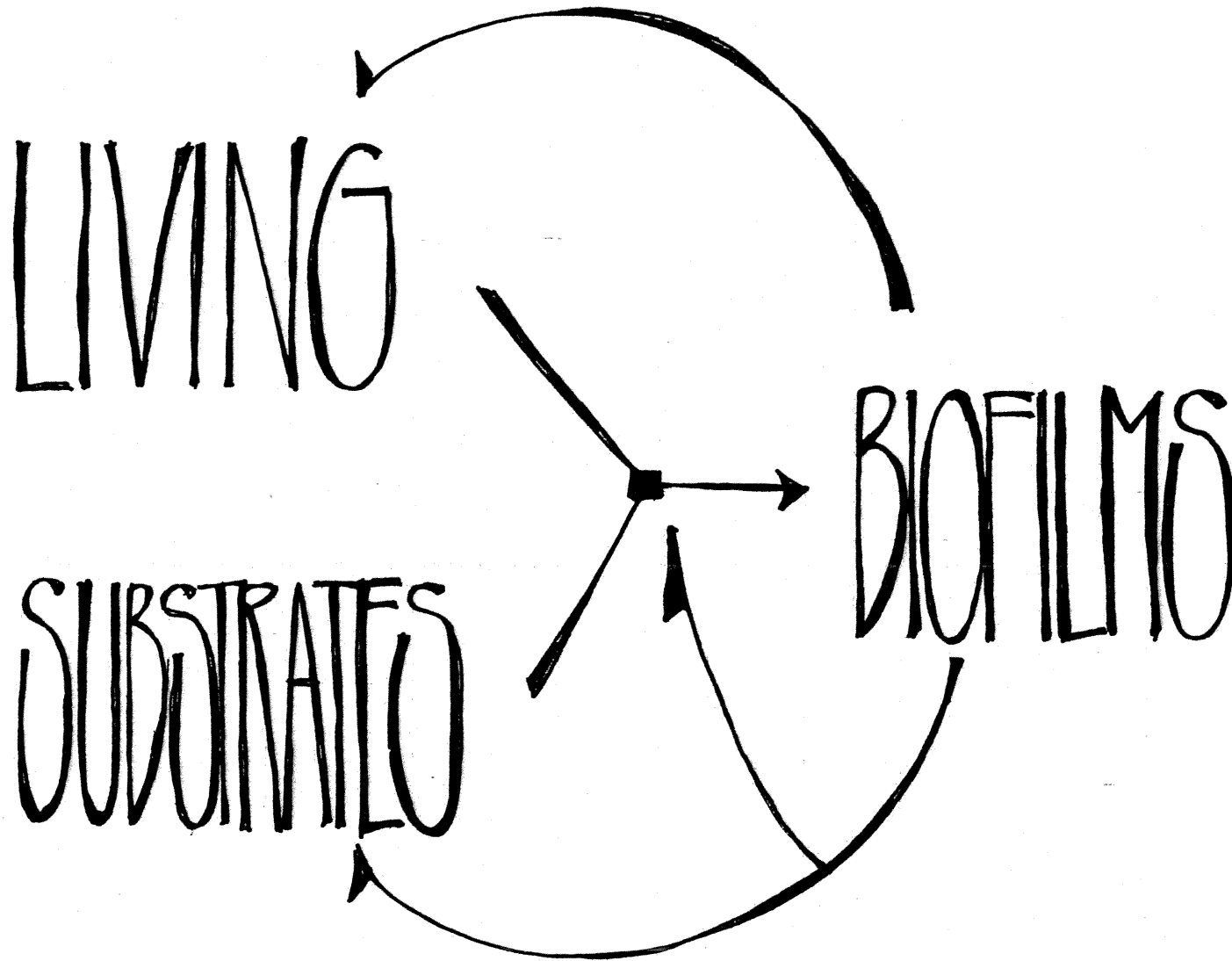


CLIMATE DYNAMICAL: NO TEMPLATE!  
SELF-REGULATION-KEELING CURVE  
PERSISTENCE-1850 PRESENT  
CONSORTIUM ROBUSTNESS OXYGEN CATASTROPHE  
RESILIENCE-KVT BOLLIDE  
ABRUPT  $\Delta \approx$  UBIQUITOUS



Nested  
Organization:  
Functional Autonomy and  
Interdependence

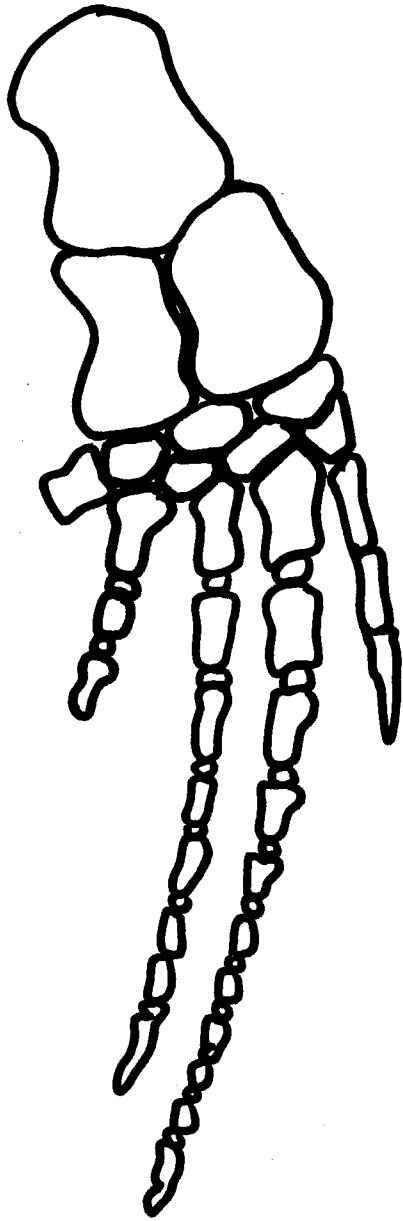




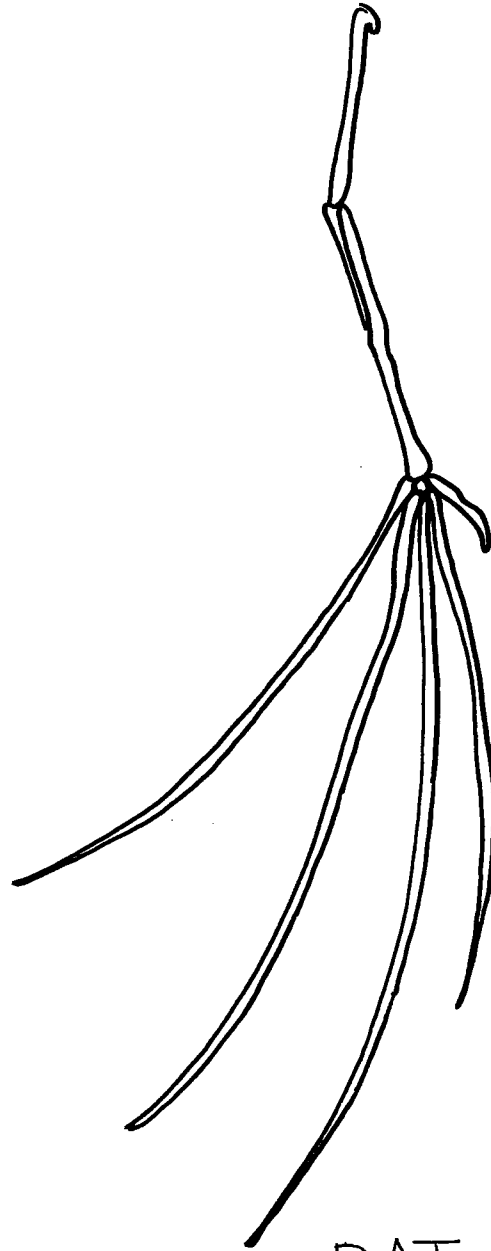
BIOFILMS EVERYWHERE

LIVING SUBSTRATE  
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GASES  
BIONEERS  
PROPERTIES  
ROBUSTNESS  
RESILIENCE





BLUE  
WHALE



BAT

Looking for causal and DeepTime  
Unity in the Natural World...

Via  
**FUNCTIONAL  
HOMOLOGIES?**

<b>LIVING CONSORTIUM</b>	<b>SUBSTRATE(S)</b>	<b>BIOFILM</b>	<b>SOME FUNCTIONS</b>
<i>Pseudomonas aeruginosa</i>	Necrotic flesh	Green pus	Optimal habitat, advances necrosis
"Forests"	"wet granite" & CO <sub>2</sub>	"Soil"	↑H <sub>2</sub> O storage; ↑chemicalwx; ecoevolutionary attractors/pathways ("succession")
Mn-oxidizing bacteria*	arid rock surfaces	Desert varnish	"Shelter" (dessication, UV injury); photocatalysis
Human oral microbiome	saliva-wet teeth & gums	Plaque	"Succession": cariogenic aerobes → periogenic anaerobes &/or biomineralizing associations (dental calculus)
Biosphere	Wet Tectosphere** & CO <sub>2</sub>	Atmosphere	UV protection, accelerated chemical weathering, dynamical self-regulation including hysteresis changing of <u>The Climate Consortium</u> .
<i>Ebola</i> virion consortium	vascular endothelium; macrophages, monocytes & liver cells	EV glycoprotein	Adherence; interrupt immune signaling; propels degradation of vascular integrity; virion (pathogen/disease) transmission.

\* Proteobacteria, Actinobacteria, Eukarya (fungi) and Archaea (Kuhlman et al., 2006)

\*\* Plate tectonics requires and perpetuates the continuous recycling of rocks, water and CO<sub>2</sub> as a dynamical circumplanetary functionality ("The Wet Tectonics hypothesis"; Grimm, 2006).

# BIOFILMS EVERYWHERE: A WORDY SYNOPSIS OF THE ABSTRACT

1. Life is slimy and slime is everywhere; slime and Life coevolve.
2. From shower scum and dental plaque to soils, sediments and atmosphere, organismal consortia (groups of critters) occupy and modify substrates to produce and perpetuate biofilms.
3. Looking for Unity: From mechanical and structural analogies to a spectrum of functional homologies.
4. Every biofilm includes metabolites (including wastes), exuded exopolymers and corpses/body parts of antecedent organisms.
5. Every biofilm constitutes a specific habitat, imparting robustness, resilience and coherent ecoevolutionary function.
6. Biofilms dramatically impact adhesion, cohesion, exchanges, transmissivity (nanowires), and fluid storage/exchange capacities; unite hydrophobic/hydrophilic characteristics; propel dissolution, transformation and precipitation of minerals; permit/facilitate/enhance reproductive success, recruitment and ecological succession.
7. Some examples: *Pseudomonas* infections, dental biofilms, forest soils, atmosphere
8. Hypotheses:
  - A. Biofilms coevolve with every living consortium;
  - B. Biofilms are nested and are everywhere, equalling what we conventionally call “environments”.
  - C. A specific process-pattern operates in the formation of every biofilm;
  - D. The broad spectrum of biofilms are linked (and arose from) a simple functional homology that has operated from deeptime to present, across molecular to circumplanetary scales.
  - E. The atmosphere is a circumplanetary biofilm, produced and perpetuated by The Climate Consortium (CC), a specific ecoevolutionary explicitly defined herein.
  - F. Concerning Climate changing, we need to learn to expect hysteresis changing



Does the CC have all the properties of other biofilms?

1. Prominence of metabolites, including waste products ?

YES: Excepting inert gases (1% Ar), all atmospheric constituents are reactants and/or products of biological processes.

YES: CCN (Cloud Condensation Nuclei):

a. Dimethyl Sulfide linking oceans, biota and atmosphere: Track Andrae et al (1983) → Toon et al (1987) → Charlson et al, 1997 → Kasting et al, 2013.

b. Mohler et al, 2007 and many other publications: Terrestrial and marine metabolites are prominent — and widely predominant — as CCN (and ICN!)

c. Amazon Example: Poschl et al., 2010. Science 329: 1513-1516.

Most terrestrial aerosols are industrial/anthropogenic

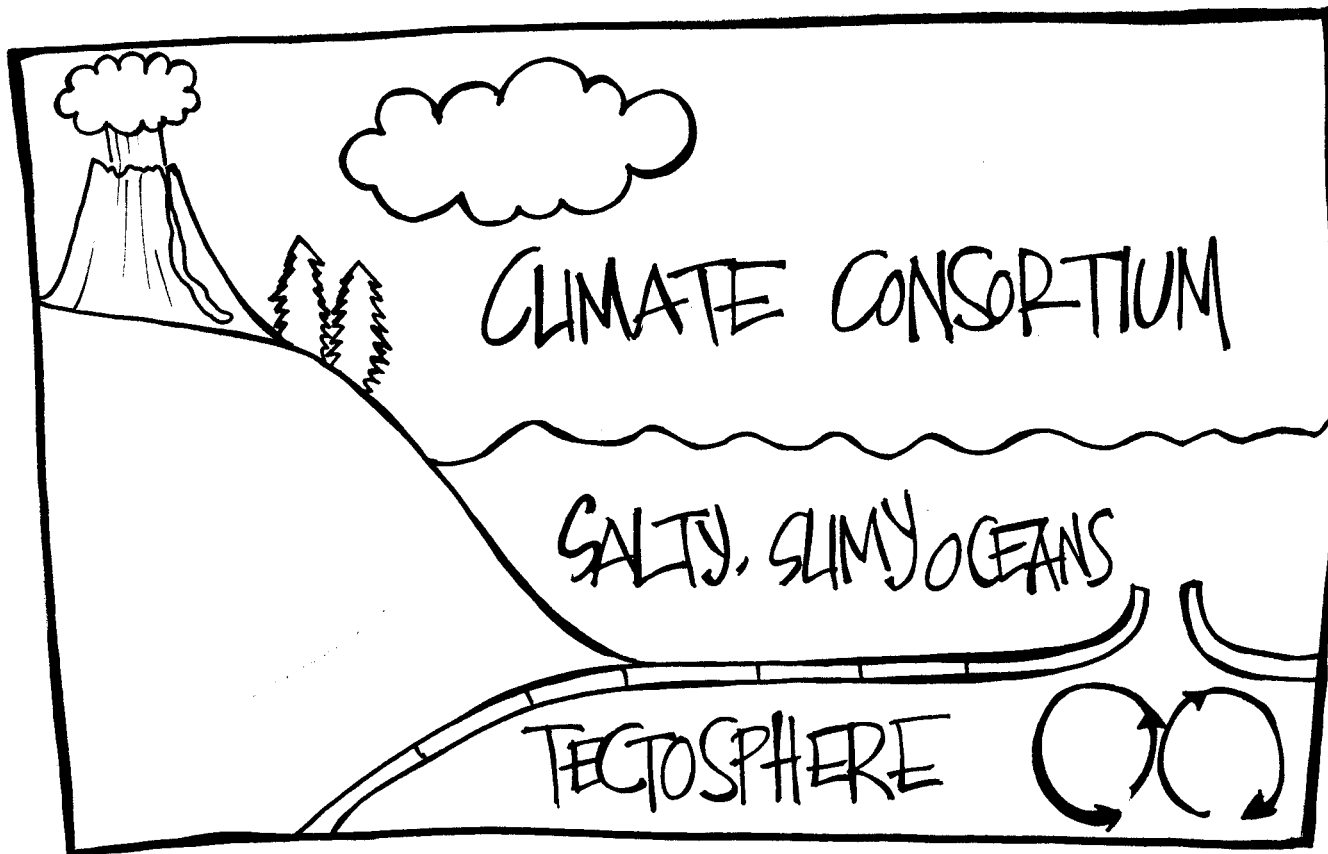
Wet-season Amazon approximates pristine (pre-Anthropogenic) condition.

Most sub  $\mu\text{m}$  CCN are derived from oxidation of gaseous plant metabolites.

Most  $\geq 1\mu\text{m}$  CCN are direct metabolites released by rainforest biota

Conclusion: “Biogeochemical Reactor”: Biosphere  $\leftarrow \rightarrow$  Atmosphere exchanges and photochemistry produce CCN that permit and perpetuate cloud formation, precipitation and local-to-regional, hydrologic recycling [In the language of this paper: An autocatalytic and autoregenerative process].

LIQUID Water OCEANS  
HOT Silicate MANTLE



Strato, O<sub>3</sub> Layer

Base of Asthenosphere

