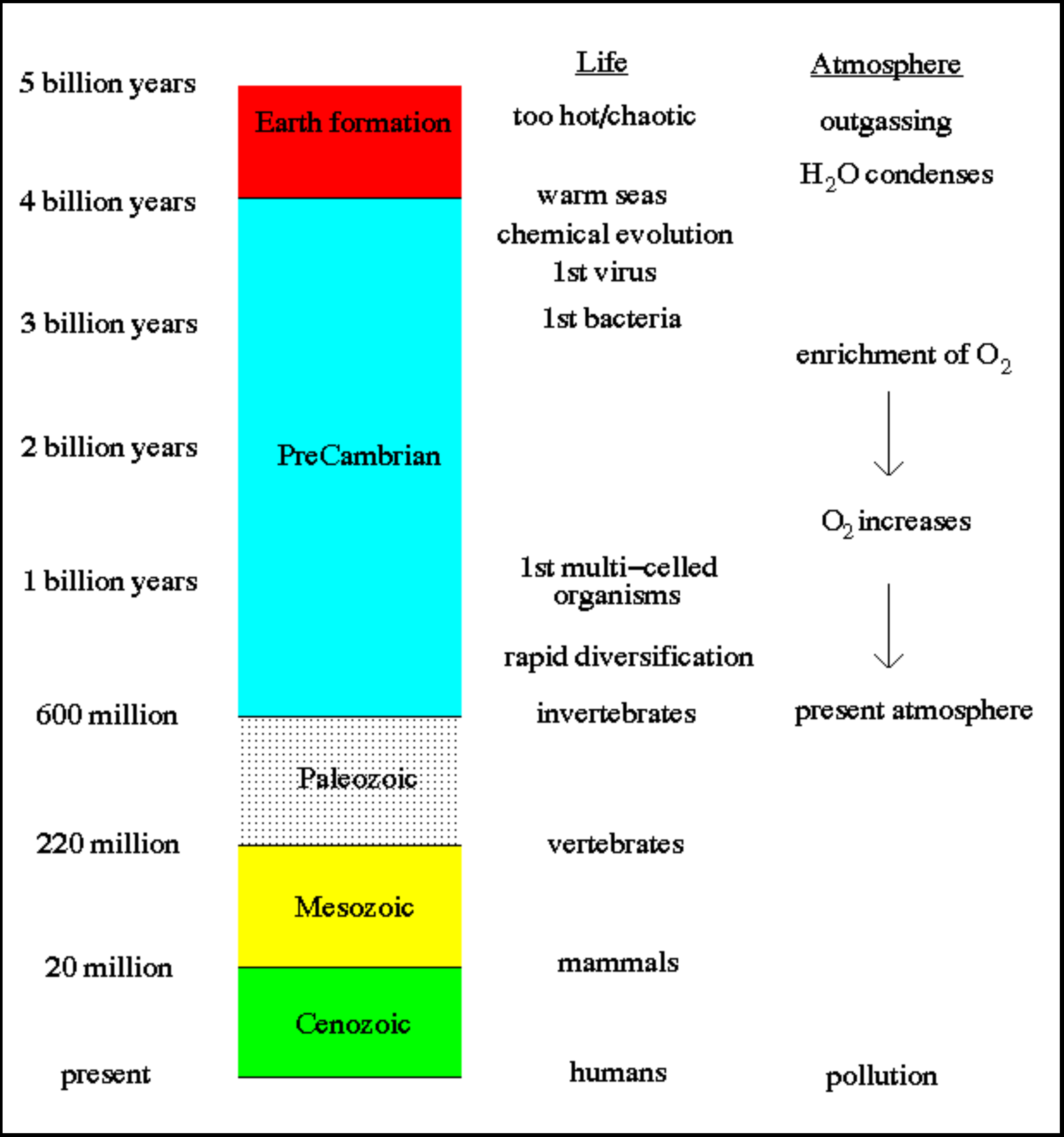


Life
Atmosphere
5 billion years
Earth formation
too hot/chaotic
outgassing
H_2O condenses
4 billion years
warm seas
chemical evolution
1st virus
3 billion years
1st bacteria
enrichment of O_2
2 billion years
PreCambrian
O_2 increases
1 billion years
1st multi-celled organisms
rapid diversification
600 million
invertebrates
present atmosphere
Paleozoic
220 million
vertebrates
Mesozoic
20 million
mammals
Cenozoic
present
humans
pollution

Chemical Evolution on Early Earth

Earth early cools, outgassing

↓

early hot atmosphere that cools and H_2O condenses to form oceans

↓

warm pools rich in CO_2, H_2O, NH_3, CH_4 → primordial soup

primordial soup ↘ ↙ energy (solar, UV, electric discharge, heat)

Miller–Urey experiment

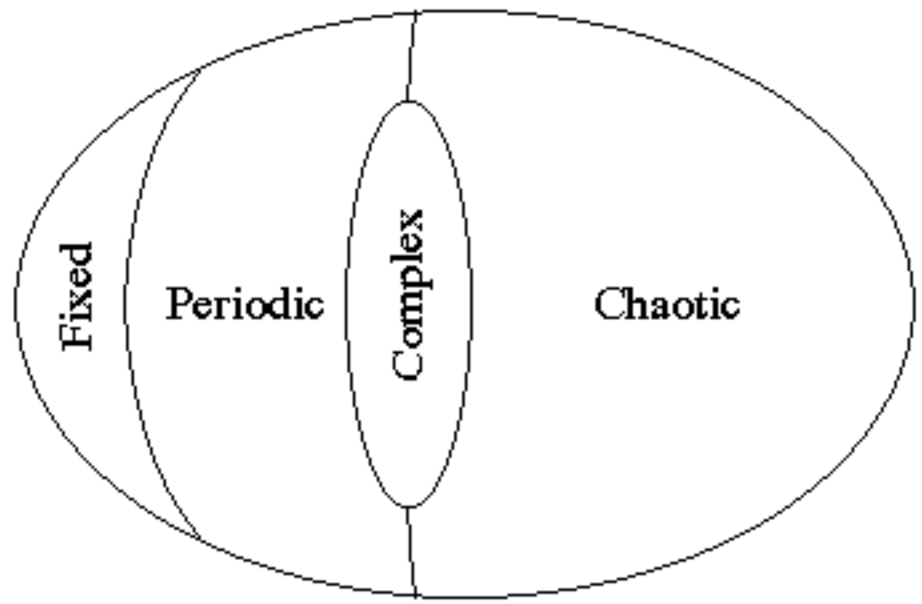
↓

output = organic compounds

- amino acids → proteins
- base purines → nucleic acids
- carbohydrates → polysaccharides
- fatly acids → lipids

↓

building blocks of
self–replicating molecules



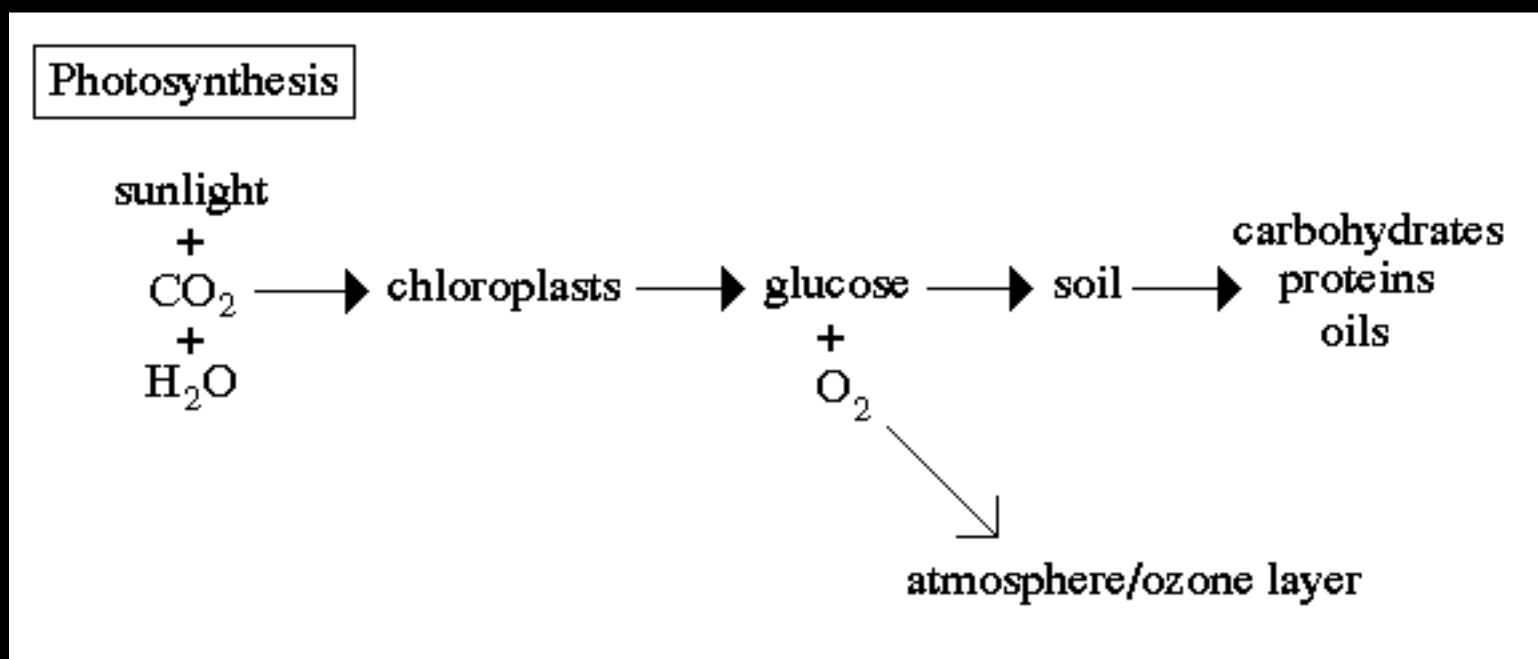
Information movement in complex dynamical systems is such that the regime at the left is where information is frozen, to the right is a flexible regime where behavior such as crystal growth is found. To the far right, information moves so freely that its structure cannot be maintained; the regime is too chaotic. Only in the center region can information be stable enough to support message structure.

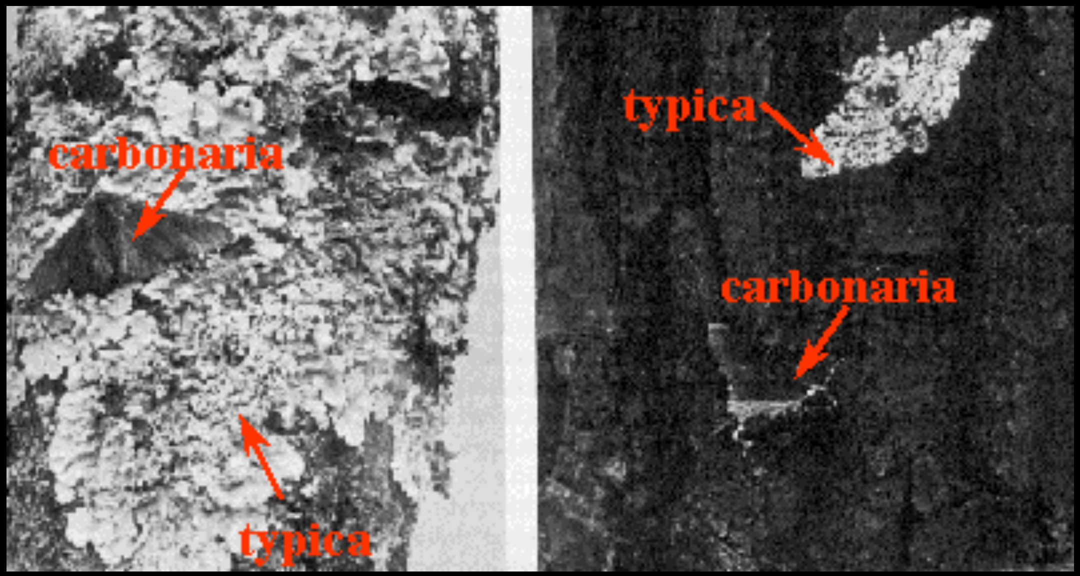
A large number of complex chemical reactions is the underlying process that we call life. The ingredients for life are:

energy source

supply of nutrients (building blocks)

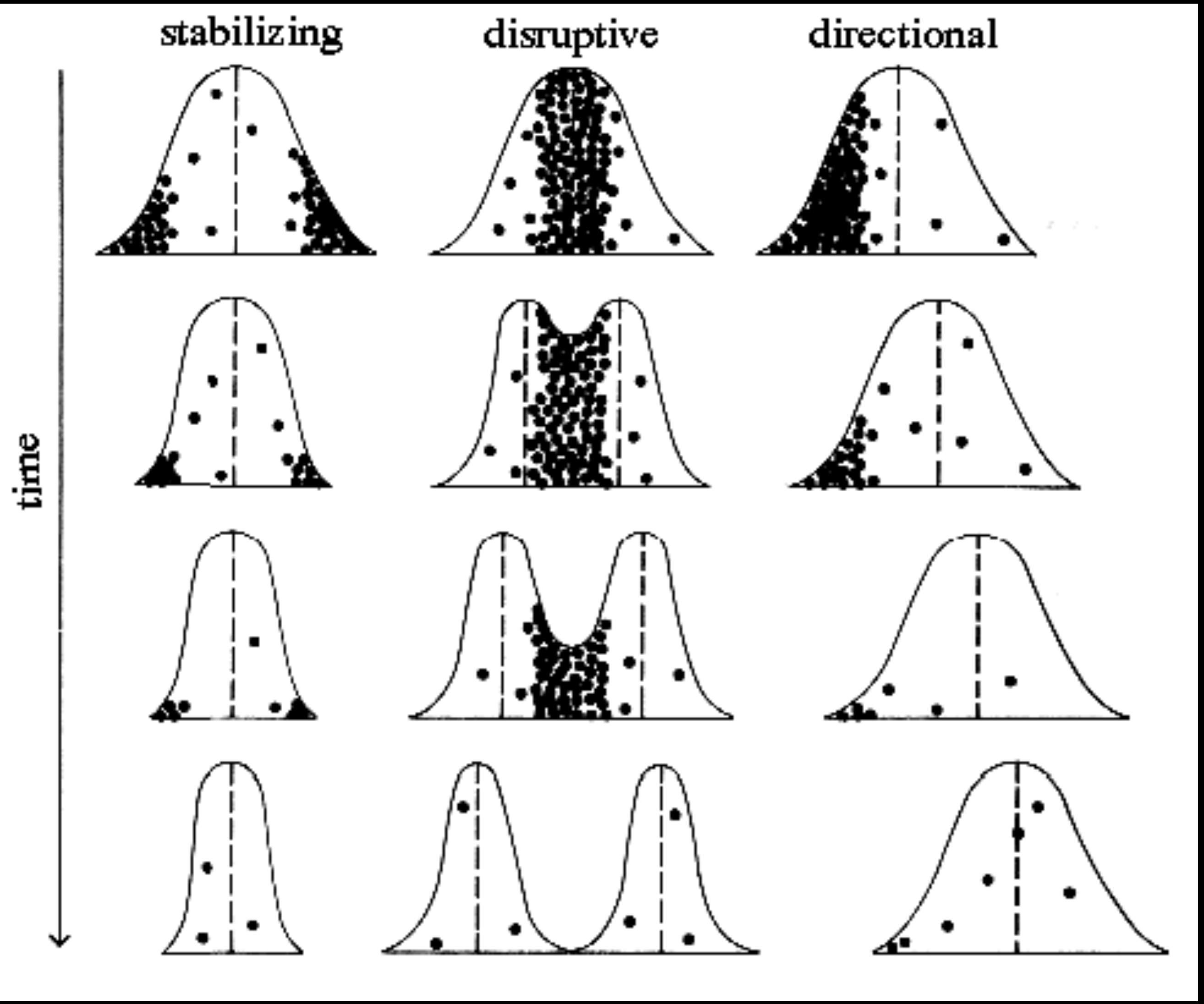
self-regulating mechanisms

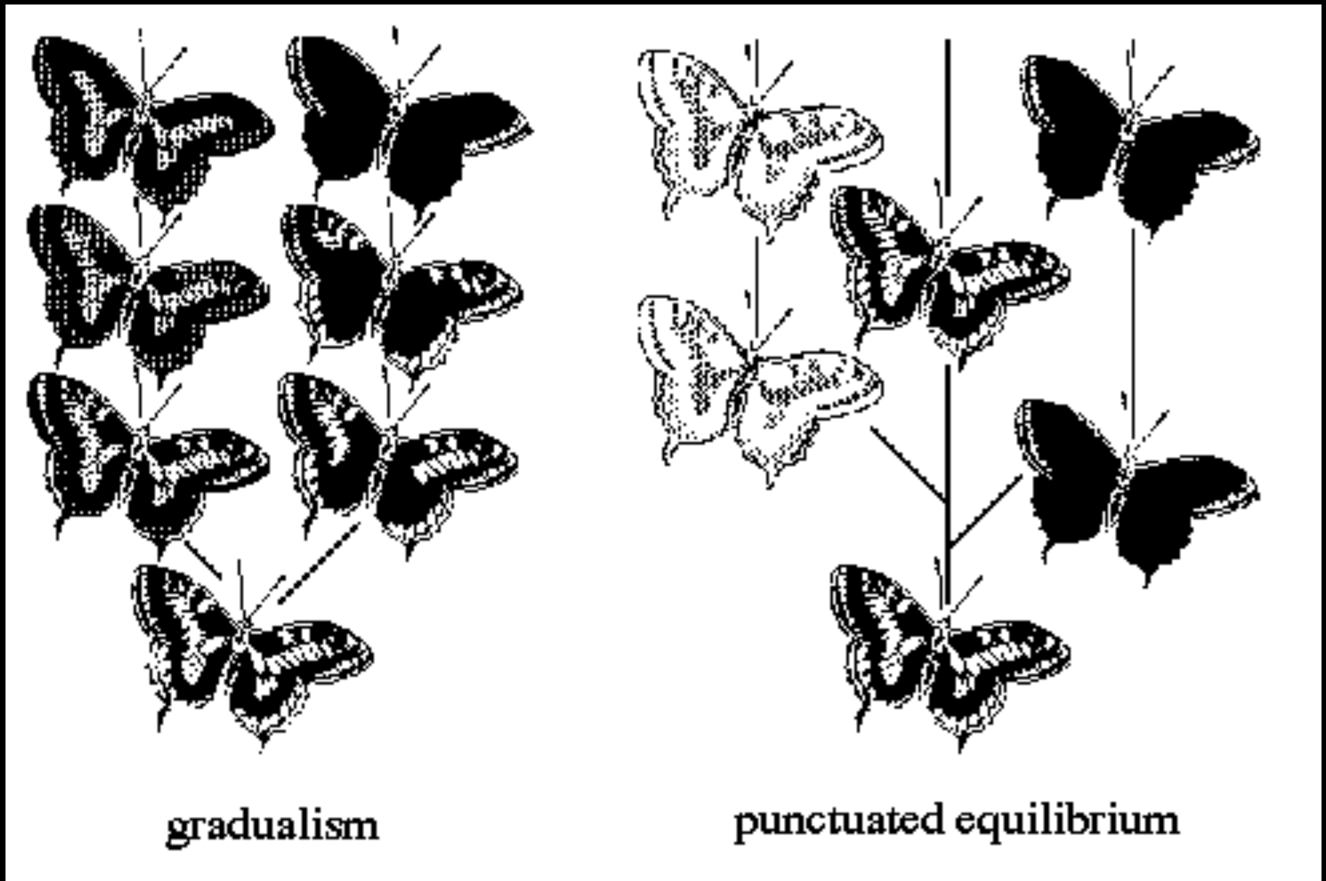

Photosynthesis
sunlight
+
CO_2
+
H_2O
chloroplasts
glucose
+
O_2
soil
carbohydrates
proteins
oils
atmosphere/ozone layer



The English moth, Biston betularia, is a frequently cited example of observed evolution. In this moth there are two color morphs, light and dark (typica and carbonaria). H. Kettlewell found that dark moths constituted less than 2% of the population prior to 1848. Then, the frequency of the dark morph began to increase. By 1898, the 95% of the moths in Manchester and other highly industrialized areas were of the dark type, their frequency was less in rural areas. The moth population changed from mostly light colored moths to mostly dark colored moths. The moths' color was primarily determined by a single gene. So, the change in frequency of dark colored moths represented a change in the gene pool. This change was, by definition, evolution.

Populations evolve, not individuals. In order to understand evolution, it is necessary to view populations as a collection of individuals, each harboring a different set of traits. A single organism is never typical of an entire population unless there is no variation within that population. Individual organisms do not evolve, they retain the same genes throughout their life. When a population is evolving, the ratio of different genetic types is changing -- each individual organism within a population does not change. For example, in the previous example, the frequency of black moths increased; the moths did not turn from light to gray to dark in concert.



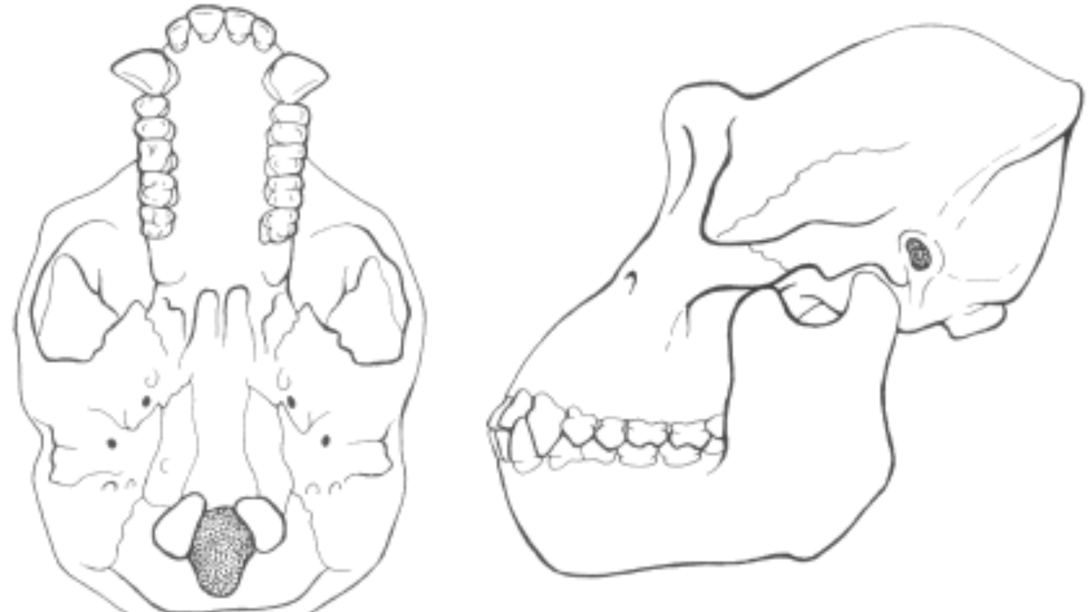

gradualism
punctuated equilibrium

Most of human evolution involves physical evolution, cultural evolution plays a fairly minor role until the Upper Paleolithic, 40,000 years ago. Proto-humans, hominids, were constrained and directed by the same evolutionary pressures as the other organisms they shared the ecosystem with.

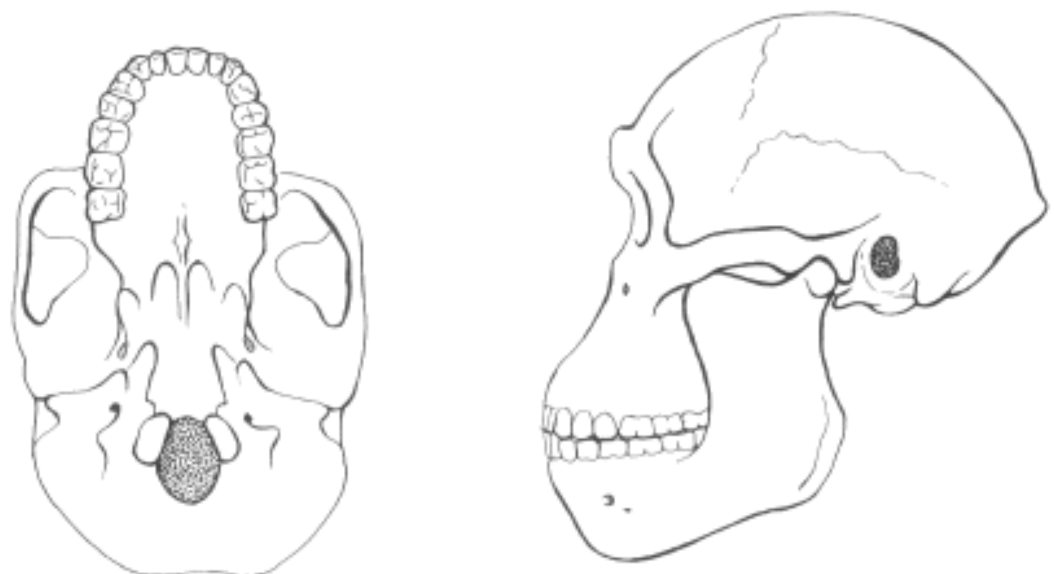
Around 13 million years ago, a tree-dwelling primate developed:

steroscopic vision
high mobility (upright stance)
opposable thumbs

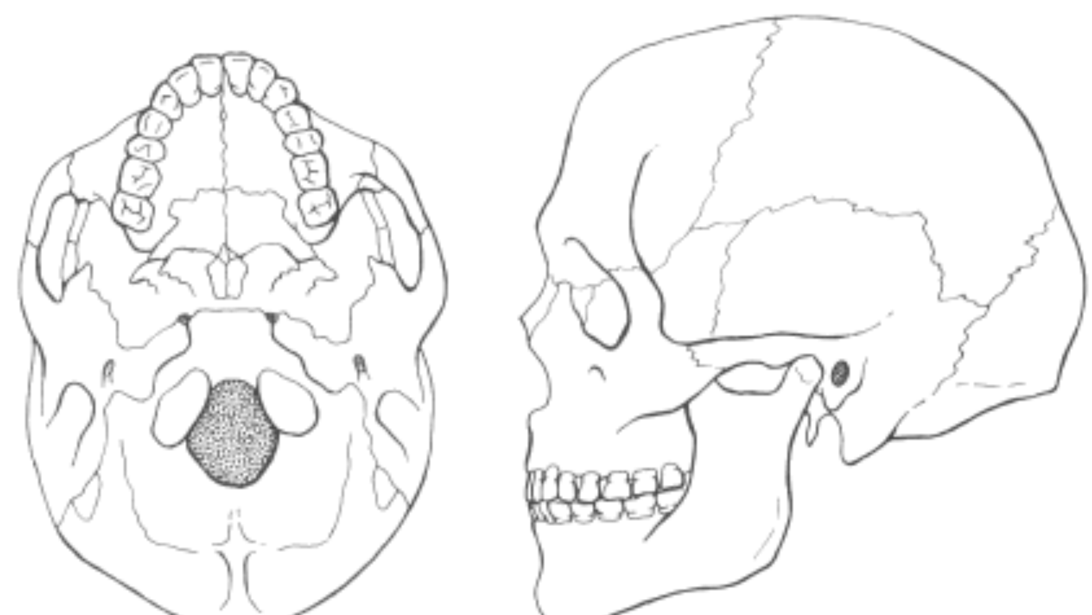
Upright walking was a response to environmental changes in East Africa at the time, the rainforest was turning into steppes due to global weather changes. An upright stance is a survival characteristic to see over tall grasses. About 3.5 million years ago, our first direct ancestor appeared, Australopithecus africanus, whose best fossil example is should below.



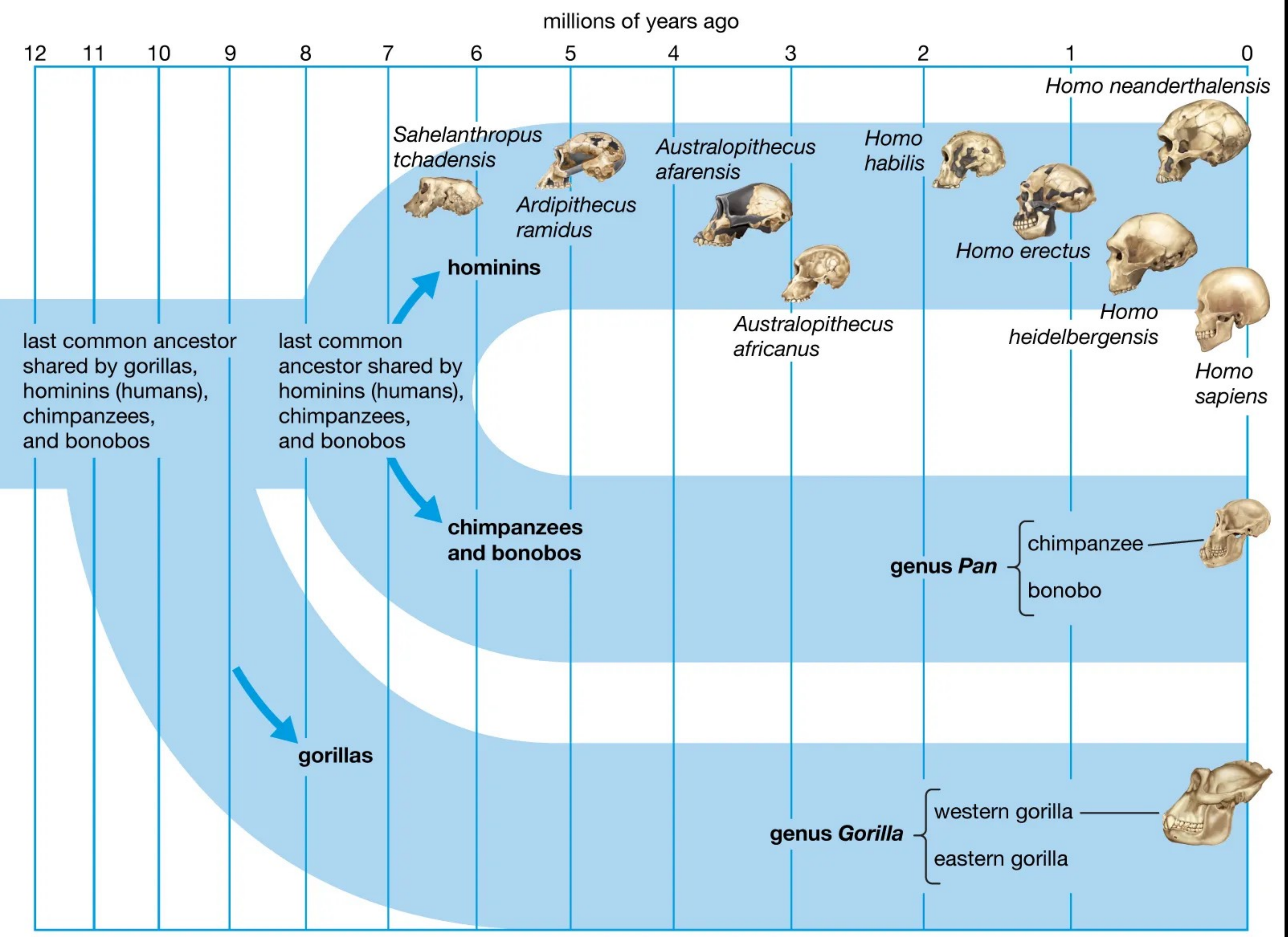
Female Gorilla



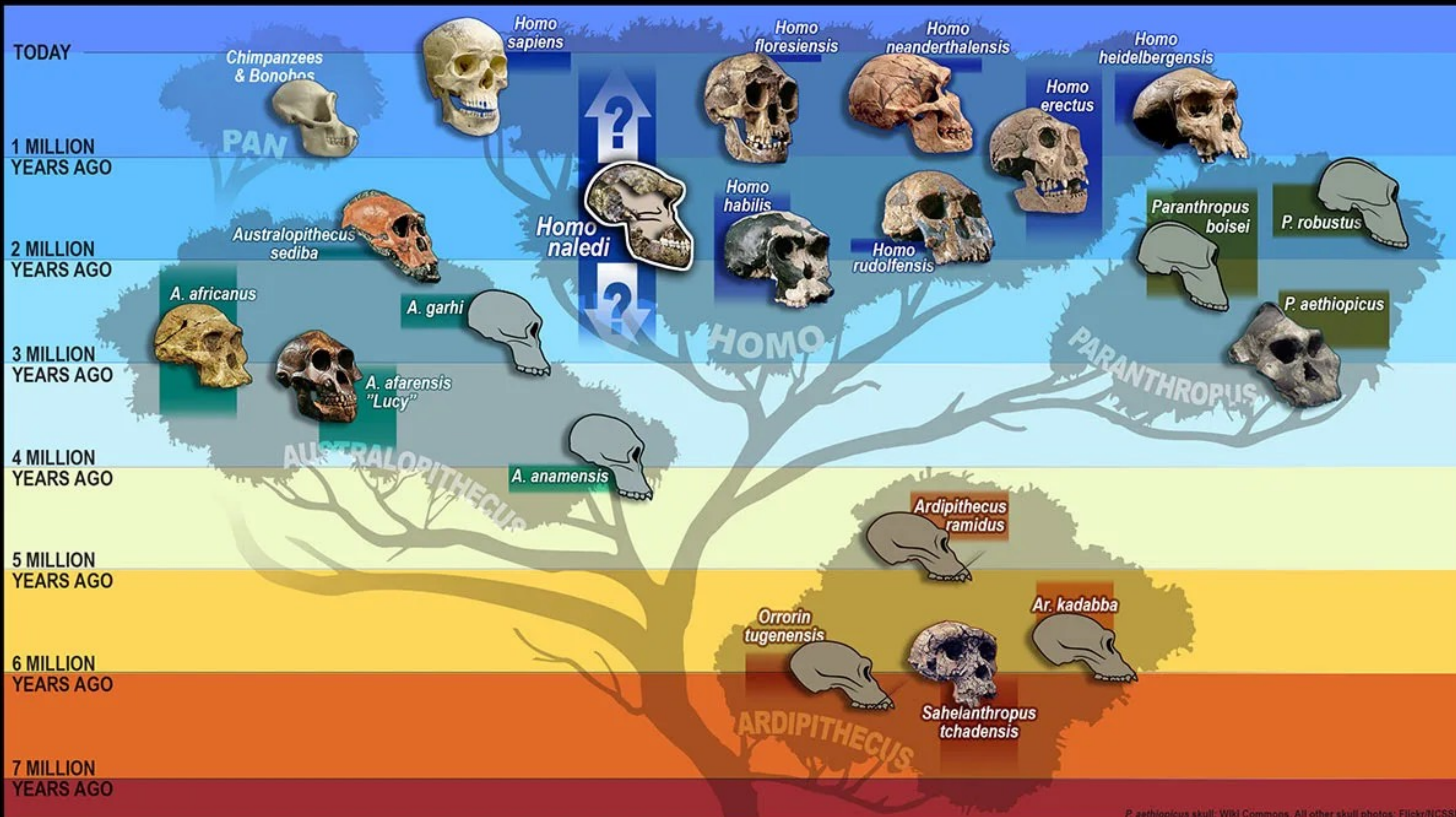
Australopithecus africanus



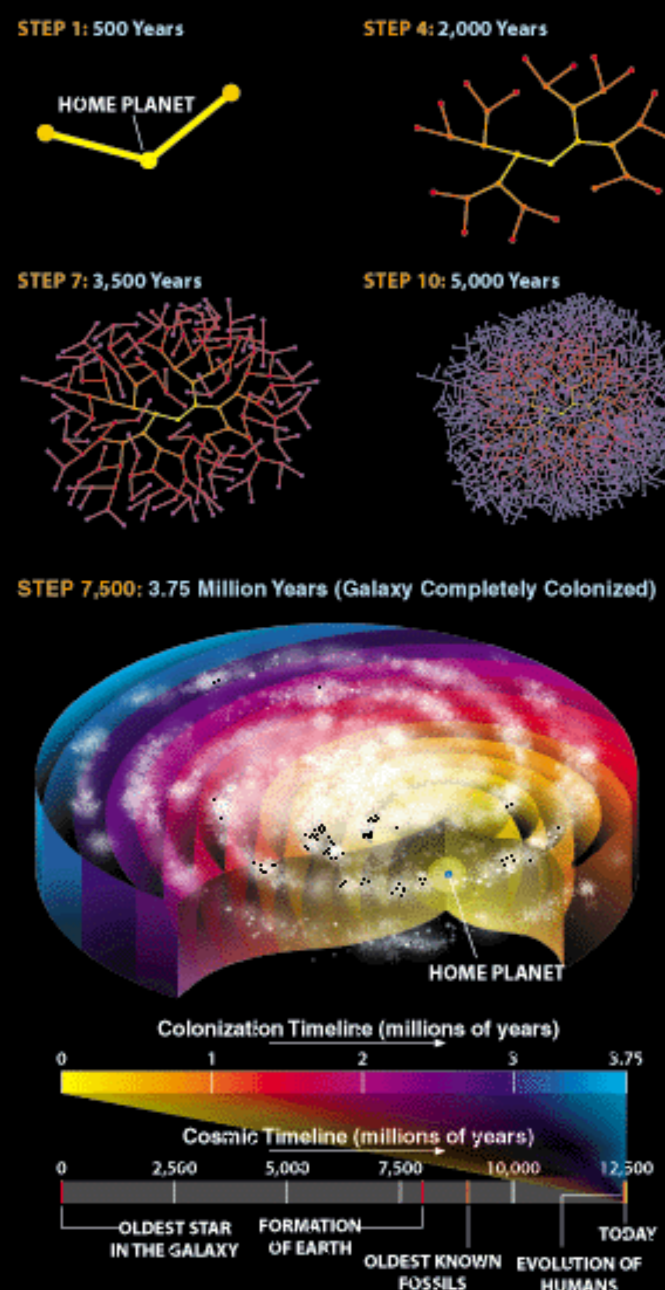
Homo sapiens

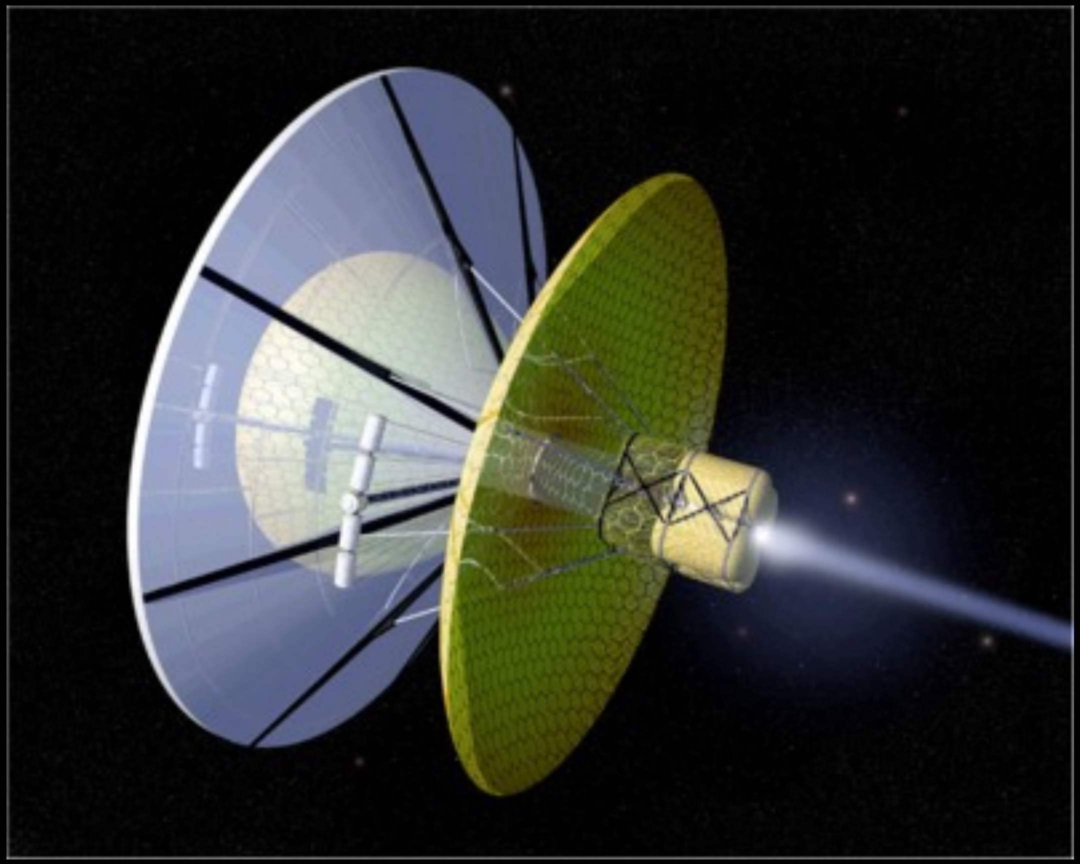


millions of years ago
12
11
10
9
8
7
6
5
4
3
2
1
0
Homo neanderthalensis
Sahelanthropus tchadensis
Ardipithecus ramidus
Australopithecus afarensis
Homo habilis
Homo erectus
hominins
Australopithecus africanus
Homo heidelbergensis
Homo sapiens
last common ancestor shared by gorillas, hominins (humans), chimpanzees, and bonobos
last common ancestor shared by hominins (humans), chimpanzees, and bonobos
chimpanzees and bonobos
genus Pan
chimpanzee
bonobo
gorillas
genus Gorilla
western gorilla
eastern gorilla


TODAY
1 MILLION YEARS AGO
2 MILLION YEARS AGO
3 MILLION YEARS AGO
4 MILLION YEARS AGO
5 MILLION YEARS AGO
6 MILLION YEARS AGO
7 MILLION YEARS AGO
Chimpanzees & Bonobos
PAN
Homo sapiens
Homo floresiensis
Homo neanderthalensis
Homo heidelbergensis
Homo erectus
Homo naledi
?
?
Homo habilis
Homo rudolfensis
HOMO
Australopithecus sediba
A. africanus
A. garhi
A. afarensis "Lucy"
A. anamensis
AUSTRALOPITHECUS
Paranthropus boisei
P. robustus
P. aethiopicus
PARANTHROPUS
Ardipithecus ramidus
Ar. kadabba
Orrorin tugenensis
Sahelanthropus tchadensis
ARDIPITHECUS
P. aethiopicus skull: Wiki Commons. All other skull photos: Flickr/NCSSI

The story goes that, one day back on the 1940's, a group of atomic scientists, including the famous Enrico Fermi, were sitting around talking, when the subject turned to extraterrestrial life. Fermi is supposed to have then asked, "So? Where is everybody?" What he meant was: If there are all these billions of planets in the universe that are capable of supporting life, and millions of intelligent species out there, then how come none has visited earth? This has come to be known as The Fermi Paradox.





Possible solutions to Fermi's Paradox fall in the following categories:

<u>They Do Not Exist</u>

We are the First, Life is New to the Galaxy
Life is new to the Galaxy, evolution takes time, we are the first civilization. Problem: Sun is average star, if other stars formed a million years ahead of us, then They would be a million years ahead of us in technology.

Planets With the Right Conditions are Rare

Planetary systems are rare

Habitable zones, proper distance from star for liquid water, are narrow

Galaxy is a dangerous place (gamma-ray bursters, asteroid impacts, etc)

Earth/Moon system is unique (large tides needed for molecular evolution)

Life Is Rare

Life's Genesis is rare

Intelligence/Tool-Making is rare

Language is unique to humans

Technology/Science is not inevitable

They Are Here

They Were Here and They Left Evidence

UFO's, Ancient Astronauts, Alien Artifacts: all fall under the heading of proposals that aliens are here now or have been here in the recent past. Problem: evidence for aliens is non-existent.

They Are Us

Humans are the descendents of ancient alien civilizations. Problem: where are the original aliens? Where are all the other alien civilizations

Zoo/Interdict Scenario

The aliens are here, and they are keeping us in a well designed zoo (cut off from all contact) or there is an interdiction treaty to prevent contact with young races (us). Problem: scenario lacks the ability to be tested. Takes only one ET to break embargo.

They Exist But Have Not Yet Communicated

They Have Not Had Time To Reach Us

Speed of light slows communication levels, relativity makes space travel long. ET's message may not have reached us yet. Problem: Galaxy has been around for billions of years, even if one ET civilization formed a few million years before us, the Galaxy would be filled with Bracewell-von Neumann probes.

They Are Signaling, But We Do Not Know How To Listen

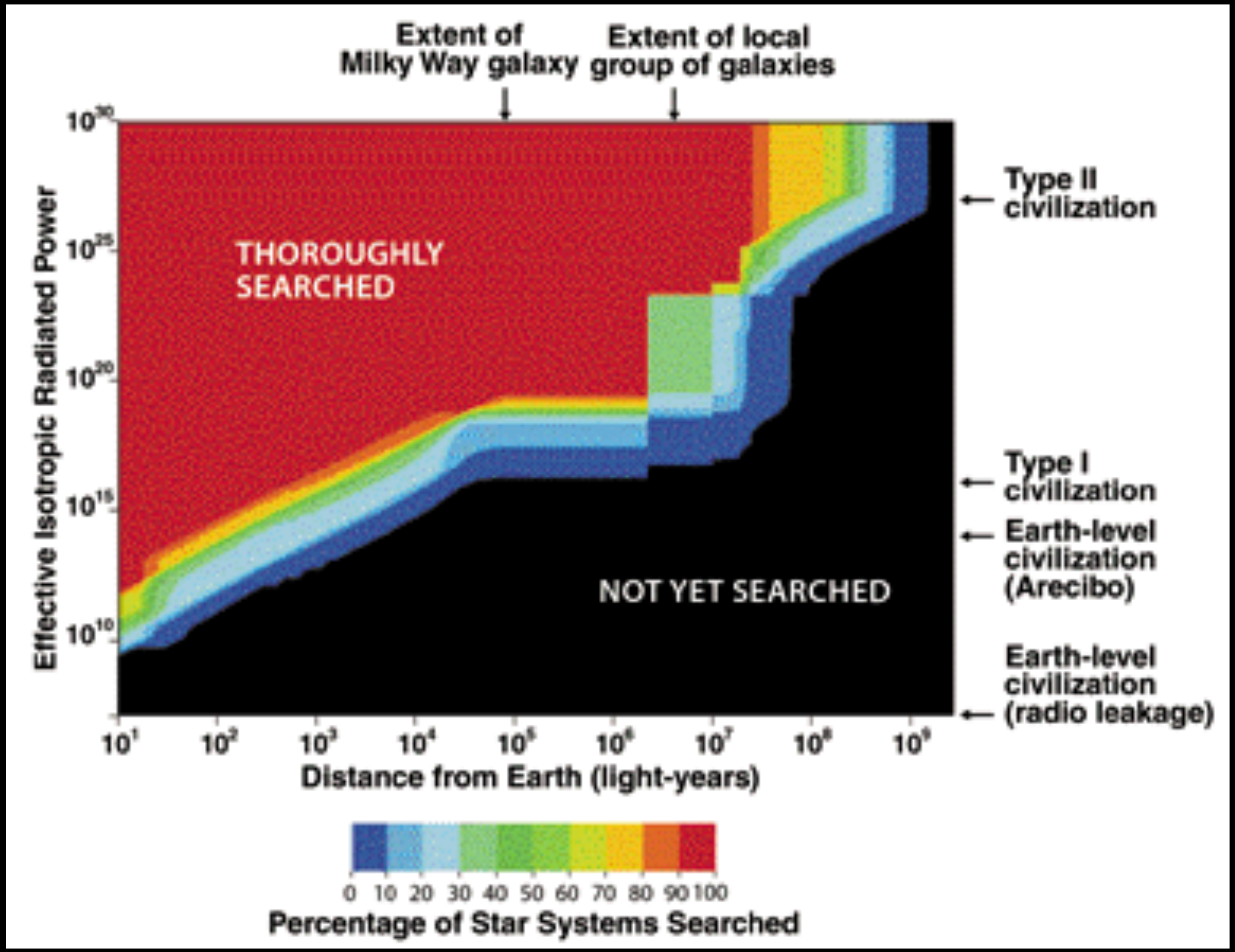
EM radiation, gravity waves, exotic particles are all examples of methods to signal. Problem: they may use methods we have not learned yet, but if there are many civilizations someone would use EM methods.

They Have No Desire To Communicate

ET has no interest in conversing with lesser beings. Problem: with millions of possible civilizations, someone would have some curiosity.

They Develop Different Mathematics

Mathematics is the universal language. But humankind may have a unique system of mathematics that ET cannot understand. Problem: then where are their incomprehensible signals?



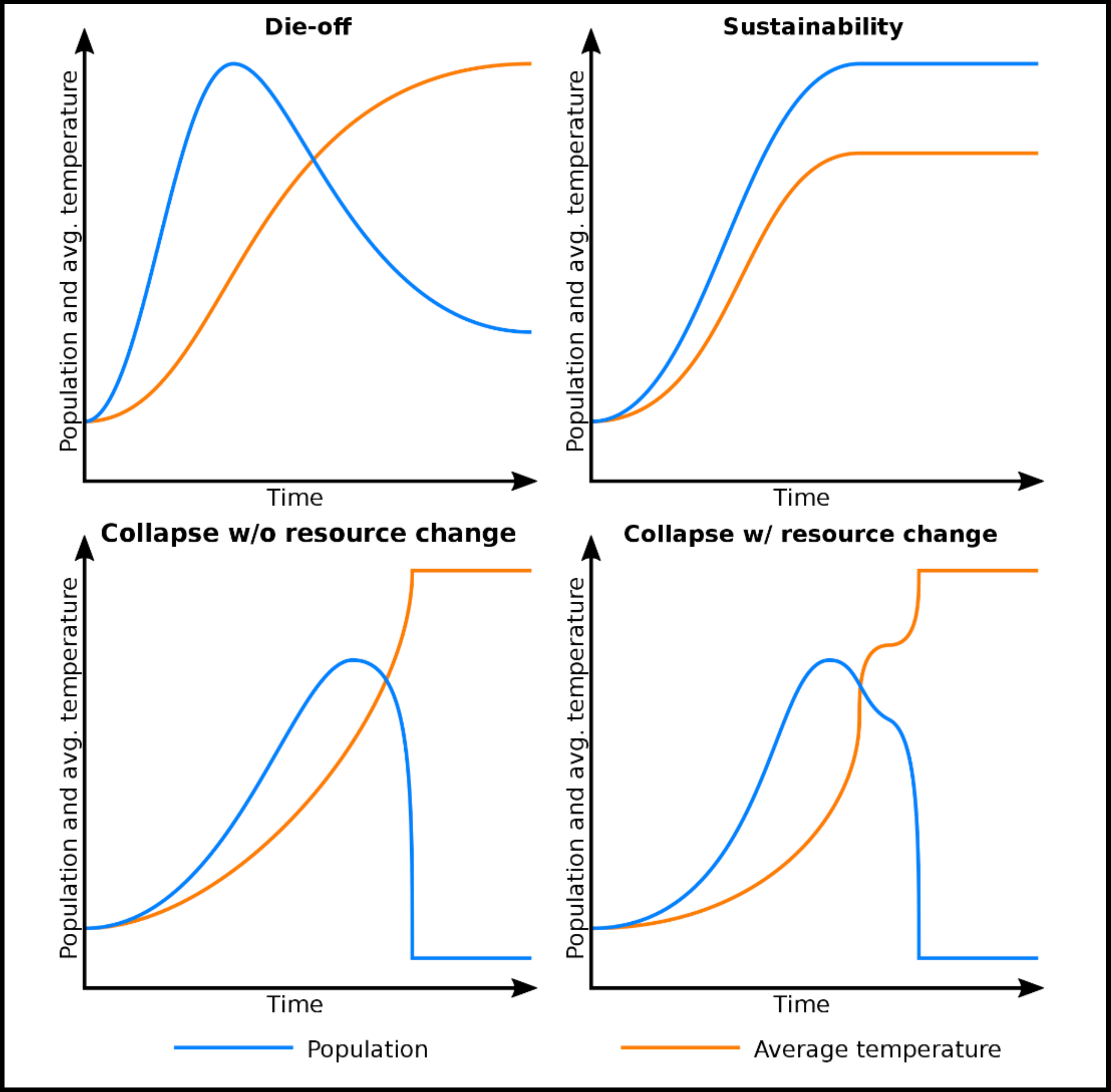
Extent of
Milky Way galaxy
Extent of local
group of galaxies
Effective Isotropic Radiated Power
10^30
10^25
10^20
10^15
10^10
THOROUGHLY
SEARCHED
NOT YET SEARCHED
Type II
civilization
Type I
civilization
Earth-level
civilization
(Arecibo)
Earth-level
civilization
(radio leakage)
10^1
10^2
10^3
10^4
10^5
10^6
10^7
10^8
10^9
Distance from Earth (light-years)
0 10 20 30 40 50 60 70 80 90 100
Percentage of Star Systems Searched

Civilizations only have a limited lifetime, They are all dead.

Overpopulation

Nanobots -> Gray Goo Problem

Dangerous Particle Physics



Scenarios in a mathematical model by Adam Frank et al., 2018, which describes climate change due to GHG emissions by an advanced energy-intensive civilization. From left to right, top to bottom: Die-off: The world population reaches a peak and subsequently declines slowly until an equilibrium is attained. Population can decline by up to 90% after peaking; according to Frank, such a civilization "might well just descend into chaos." Sustainability: Both the world population and average surface temperature rise and then level off. This scenario shows that civilizations can be stable in the long term. Collapse without resource change: A civilization makes no attempt to switch to less GHG-intensive energy and collapses due to runaway climate change, possibly going extinct. Collapse with resource change: A civilization transitions to less GHG-neutral energy, but collapses anyway due to triggering a tipping point in the climate system.