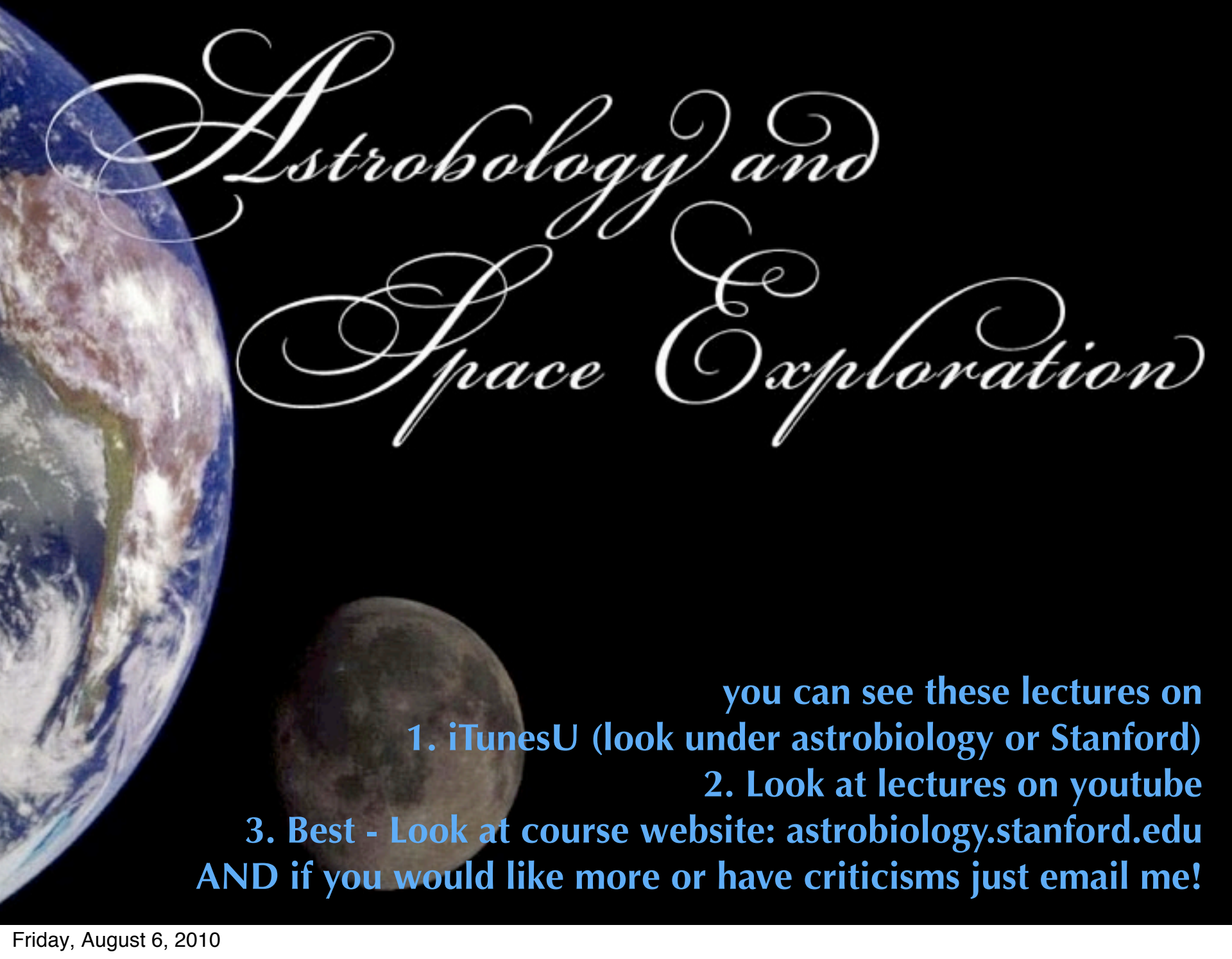
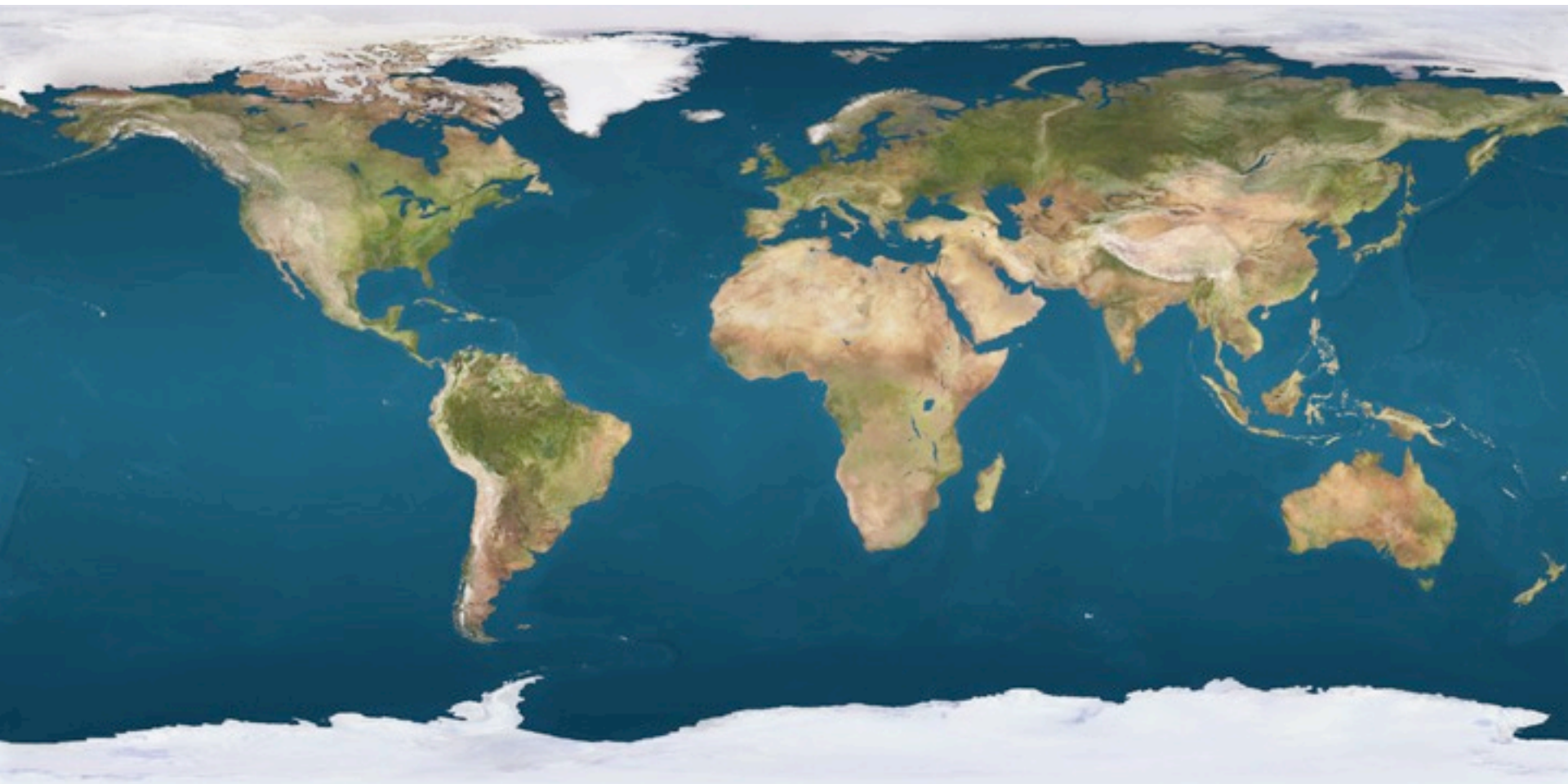

Astrobology and
Space Exploration
you can see these lectures on
1. iTunesU (look under astrobiology or Stanford)
2. Look at lectures on youtube
3. Best - Look at course website: astrobiology.stanford.edu
AND if you would like more or have criticisms just email me!

introducing the professor

introducing the professor

"We laughed at first, but now it seems NASA is terribly interested."

introducing the professor



Friday, August 6, 2010

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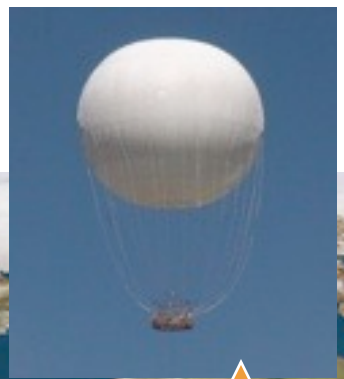
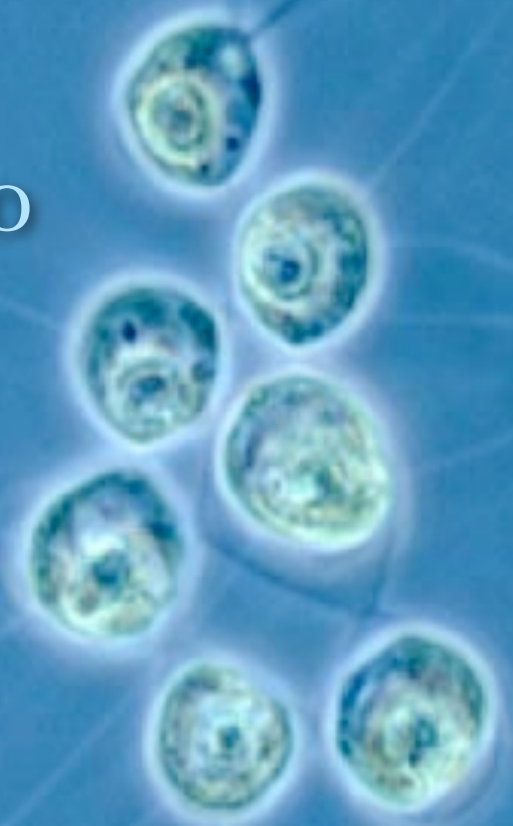


introducing the professor

I ask:

- What was life like on the ***EARLY EARTH***?
- How do organisms respond to their ***ENVIRONMENT IN NATURE***?
- Can life survive and travel ***BEYOND EARTH***?
- My organisms? ***MICROBES.***



Scope of astrobiology

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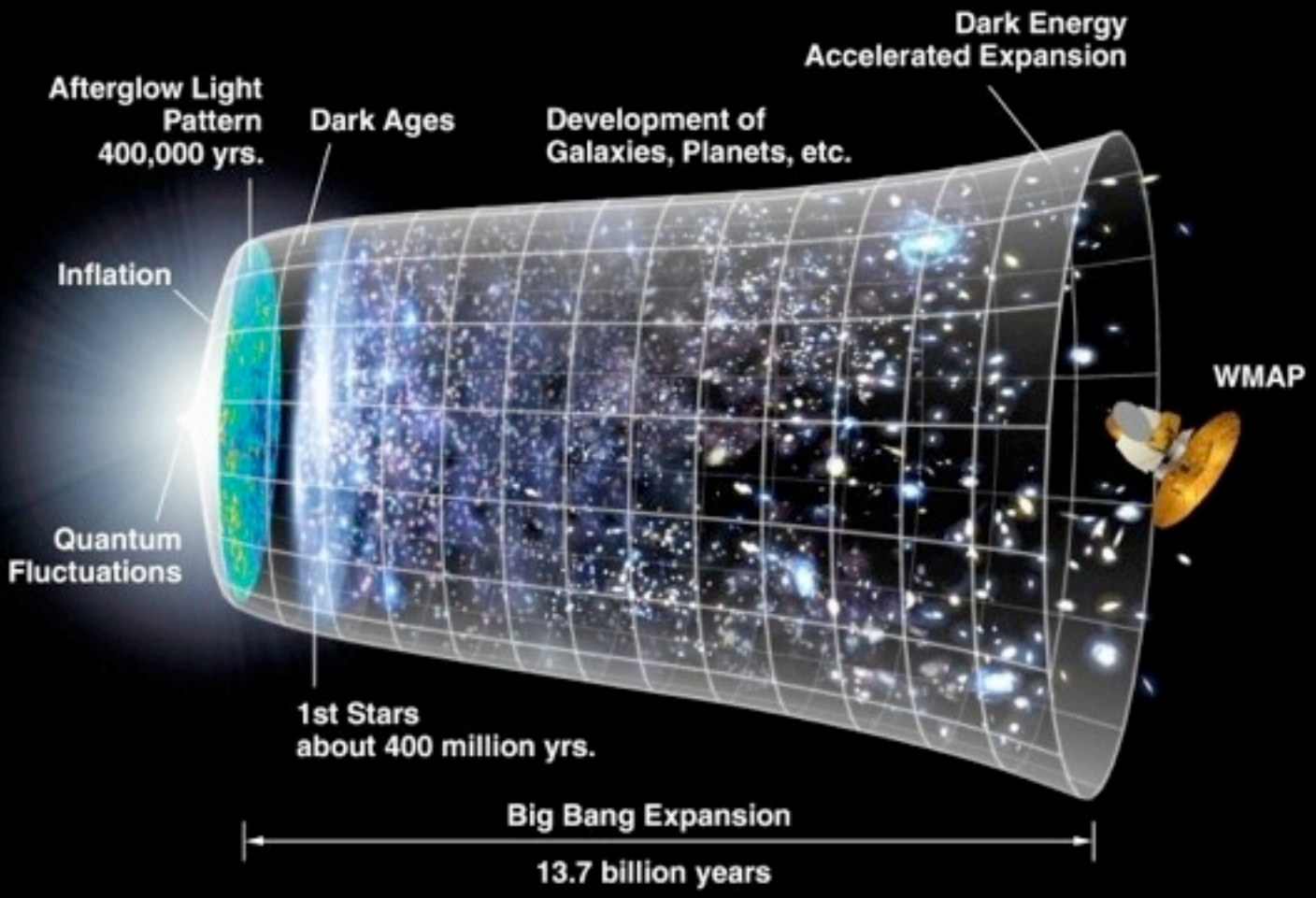

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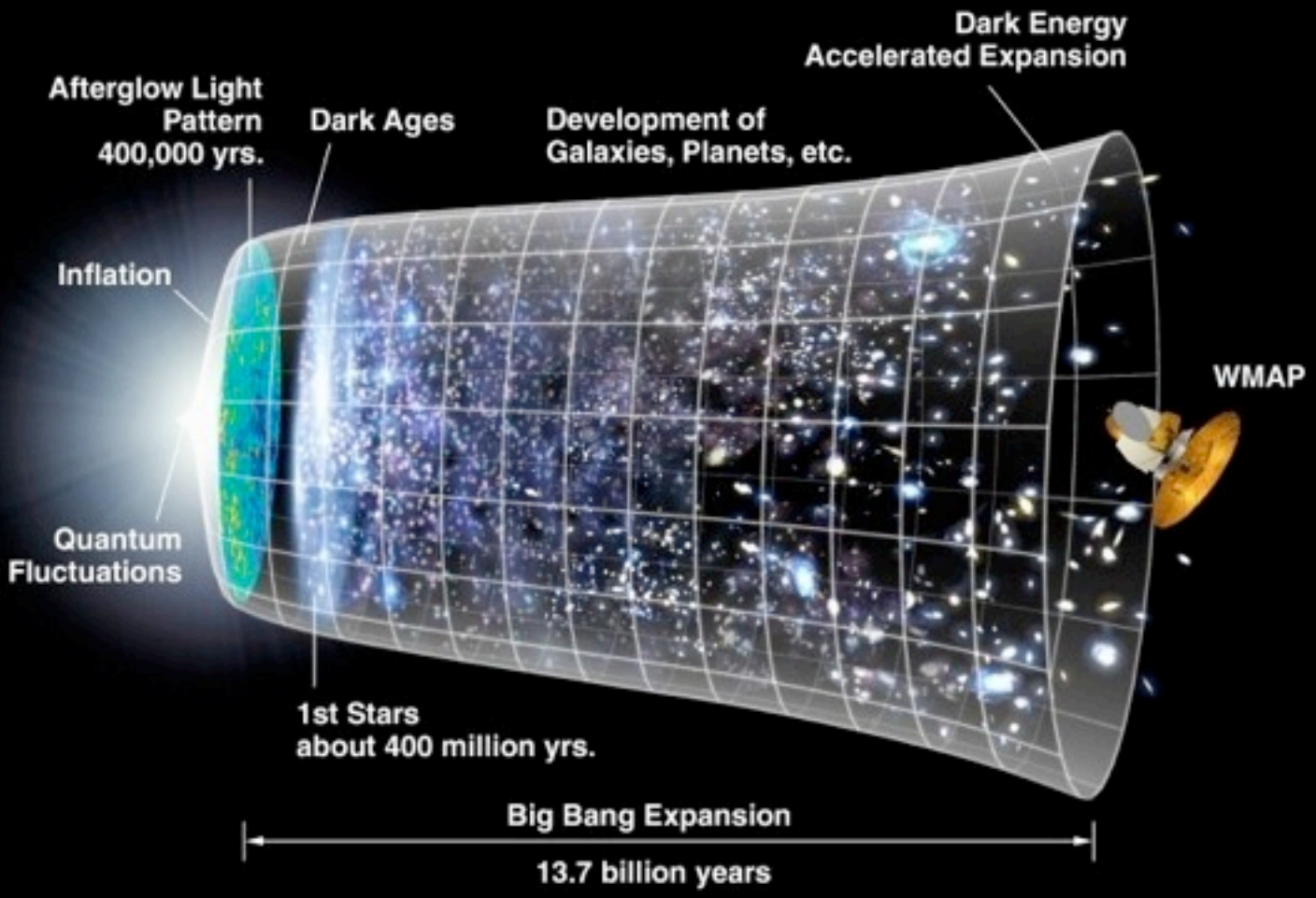

and beyond!

What is Astrobiology?

Overview: Rothschild, L.J. (2001) "Astrobiology". McGraw Hill Encyclopedia of Science & Technology, 2002. pp. 21-24.

Where do we come from?

Where do we come from?

★How did we get the biogenic elements?

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- ★How did we get the biogenic elements?
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- ★How did we get the biogenic elements?
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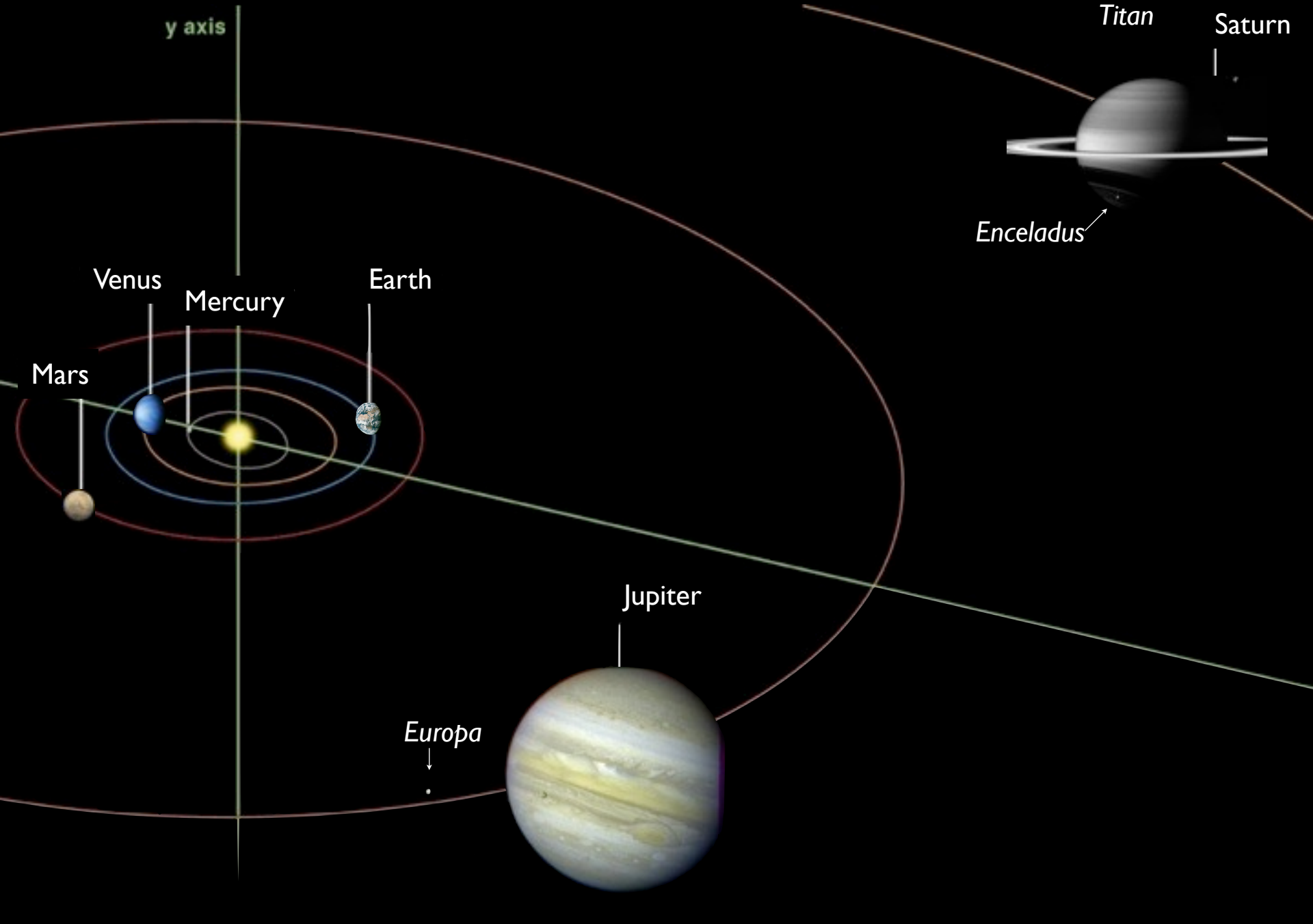
- ★How did life originate and evolve on earth?
- ★Could it happen again?

Are we alone? We'll start in our own neighborhood


y axis
Titan
Saturn
Enceladus
Venus
Mercury
Earth
Mars
Jupiter
Europa

What is the future of life?

Interaction among the environment, biosphere and us

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Interaction among the environment, biosphere and us

★**Environment of earth**

What is the future of life?

Interaction among the environment, biosphere and us

- ★Environment of earth
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- ★Fate of our universe

Key events in the history of Astrobiology*

- Earliest humans
- NASA - Dan Goldin
- NAI
- ESA and today

Strick, J. (2004) Creating a cosmic discipline: The crystallization on consolidation of exobiology. J. Hist. Biology 37: 131-180.
Strick, J. and Dick, S. (2004) The Living Universe: NASA and the Development of Astrobiology.

Discover Magazine's top 100 for 2009

Many are astrobiology or space exploration for example, from 50-100...

Discover Magazine's top 100 for 2009

#56: Earth-like Storms Mysteriously Appear on Saturn's Moon Titan

"For so long, it was cloud-free. Then, all of a sudden, they dramatically appeared."

#59: Amazing Images of the Heart of the Milky Way

Earth's placement on one of the outer arms of the galaxy gives us a view of what's happening in the center.

#62: Sooth-Saying Science—First-Ever Prediction of a Meteor

Telescopes spotted it, computers traced it, onlookers watched it, and students picked up the pieces.

#63: Did NASA's Phoenix Find Liquid Water on Mars?

If fluid water does persist on Mars, life could be hanging on in thin layers of salty water just beneath the surface.

#65: Hot Climate Produced Giant, Croc-Eating Snake

The 40-foot monster is helping scientists figure out what happened in our hotter past—and perhaps what awaits us in the future.

#67: Where Do Enceladus' Mysterious Geysers Come From?

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#69: Science Sets Its Eyes on the Prize

Big money awaits innovators who can build rockets, sequence genomes, predict people's movie preferences, harvest energy from the tides, or explore the Moon.

#70: Ancestral Whales May Have Given Birth on Land

Modern whale babies come out tail first to prevent drowning. A new fossil suggests ancestral whales came out the other way.

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In the harsh dry air, the hermit crab-like animals needed shields to keep their gills warm.

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Discover Magazine's top 100 for 2009

#73: Venus Has a Secret Earth-Like Past

A few billions of years ago, the planet may have had water, plate tectonics, and volcanism—and might have been a decent place to live.

#76: Leaping Flying Lizards

Pterosaurs could fly 40 up to miles an hour but were unable to launch themselves like modern birds. So how did these prehistoric giants get off the ground?

#77: Did an Early Pummeling of Asteroids Lead to Life on Earth?

Early organisms apparently survived the Late Heavy Bombardment—which may have made our planet a comfier place to live. (Note News & Views by Prof. Rothschild)

#85: Fossilized Plankton Show the Effect of Fossil Fuels

Researchers develop a clever new technique to more accurately gauge historical levels of CO2 in the atmosphere.

#91: The Strange Process That Made Earth's Oxygen

Less volcanism led to a "nickel famine," which led to the downfall of methanogens, which led to the rise of cyanobacteria, which led to the boom in oxygen, which led to us.

#97: Tropical Heat Speeds Up Evolution

"The biggest, most obvious pattern in nature" is that there are more species in warmer areas. But why that's the case has been a mystery—until now.

#98: First Molecule of Life Discovered?

In the beginning there was RNA. RNA begat DNA, and DNA begat lipids, carbohydrates, and proteins: That's Genesis according to the “RNA world” hypothesis.

#100: Hubble's New Mind-Blowing 'Scopes

The Hubble Space Telescope's new equipment, including the Wide Field Camera 3, provide better images of the heavens.

Astrobiology Magazine Top 10 Science Stories 2009

(astrobio.net)

Astrobio.net top 10 stories of 2009

#1: LCROSS Confirms Water on the Moon
Our top story of the year was the discovery of large amounts of water ice on the Moon. The water will be a vital resource for astronauts as NASA develops a permanent lunar outpost.

#2: Europa First
The announcement of the next mission to the outer solar system: Jupiter's icy moon Europa. Astrobiologists hope to investigate the ocean of Europa for evidence of alien life.

#3: Starlight, Star Bright
The launch of Kepler, a new NASA telescope that will aid in finding extrasolar planets. Scientists are already looking beyond Kepler for the next generation of telescopes that could show alien worlds in greater detail.

#4: Too Salty to Freeze
Evidence of liquid water droplets forming on the leg of the Phoenix lander. Scientist had assumed ice turned directly into water vapor on Mars' surface, but the water droplets on Phoenix tell a different tale.

#5: Reanimating Extinct Genes
Research to insert ancient genes into modern bacteria. Will the bacteria evolve the same way it did in the past, or will it take an entirely new path?

#6: Double Discovery: Super-Earth and Ocean World
Double discovery of potentially habitable extrasolar planets orbiting the star Gliese 581.

#7: Searching for Alien Life, on Earth
Research conducted at Mono Lake, near Yosemite National Park. With one of the highest natural concentrations of arsenic on Earth, this spot is a good place to look for "alien" life.

#8: Glycine in the Grid
The amino acid glycine was found in samples from a comet. This supports the theory that some of the ingredients for life were delivered to the Earth by comet and meteorite impacts.

#9: Astronometry Finally Finds a Planet
Astrometry, a technique to find extrasolar planets. After 50 years, astrometry spots its first planet – a milestone that could have implications for the proposed NASA mission SIM Lite.

#10: Hot Debate over Icy Moon
Debate about icy plumes emanating from Saturn's tiny moon, Enceladus. Are the plumes evidence that the moon could have a liquid water ocean beneath the ice?

Friday, August 6, 2010

This week in Campos do Jordao

Astrobiology tackles three of mankind's oldest questions, "Where do we come from?", "Where are we going?" and "Are we alone?" using a range of approaches and techniques from a variety of disciplines. Four lectures are proposed that cover these questions, as well as Goals 3-6 of the NASA Astrobiology Roadmap (Goals 1 and 2 are likely to be covered by Michel Mayor and Tom Beers)

1. Introduction to Astrobiology. This lecture will introduce the students to Astrobiology, cover a little of the history of the discipline, set the scene for life, and discuss possible definitions of life.

2. Where do we come from; the evolution of life on earth including the role of the physical environment.

3. Life in the extremes and what that means for looking for life elsewhere. An introduction to extremophiles, the potential for life in our solar system and beyond.

4. Replaying the tape and the future of life. What if life were extinguished – would it re-evolve in a similar fashion? This helps us understand evolution here, elsewhere and what the future may hold. Finally we look at the future with the same perspective as we did in 2 and 3 – how will evolution play out in light of a changing environment? What role will humans play (synthetic biology etc.)

Roadmap draft, Jan 2007

- GOAL 1 - Understand the nature and distribution of habitable environments in the Universe. Determine the potential for habitable planets beyond the Solar System, and characterize those that are observable.
- GOAL 2 – Determine any past or present habitable environments, prebiotic chemistry and signs of life elsewhere in our Solar System. Characterize the history of any environments having liquid water, chemical ingredients and energy sources that might have sustained living systems. Explore crustal materials and planetary atmospheres for any evidence of past and/or present life.
- GOAL 3 - Understand how life emerges from cosmic and planetary precursors. Perform observational, experimental and theoretical investigations to understand the general physical and chemical principles underlying the origins of life.
- GOAL 4 - Understand how life on Earth and its planetary environment have co-evolved through geological time. Investigate the evolving relationships between Earth and its biota by integrating evidence from the geosciences and biosciences that shows how life evolved, responded to environmental change, and modified environmental conditions on a planetary scale.
- Goal 5 - Understand the evolutionary mechanisms and environmental limits of life. Determine the molecular, genetic, and biochemical mechanisms that control and limit evolution, metabolic diversity, and acclimatization of life.
- Goal 6: Understand the principles that will shape the future of life, both on Earth and beyond. Elucidate the drivers and effects of microbial ecosystem change as a basis for forecasting future changes on time scales ranging from decades to millions of years, and explore the potential for microbial life to survive and evolve in environments beyond Earth, especially regarding aspects relevant to the President's Vision for Space Exploration.

Astrobology and Space Exploration

Let's start with our moon

What good is the moon? An evolutionary biologist's perspective.

Lynn J. Rothschild
NASA/Ames Research Center
Stanford University
Lynn.J.Rothschild@nasa.gov

Nature red in tooth and claw, but Extraterrestrial factors can

Sun & other stars

Mars

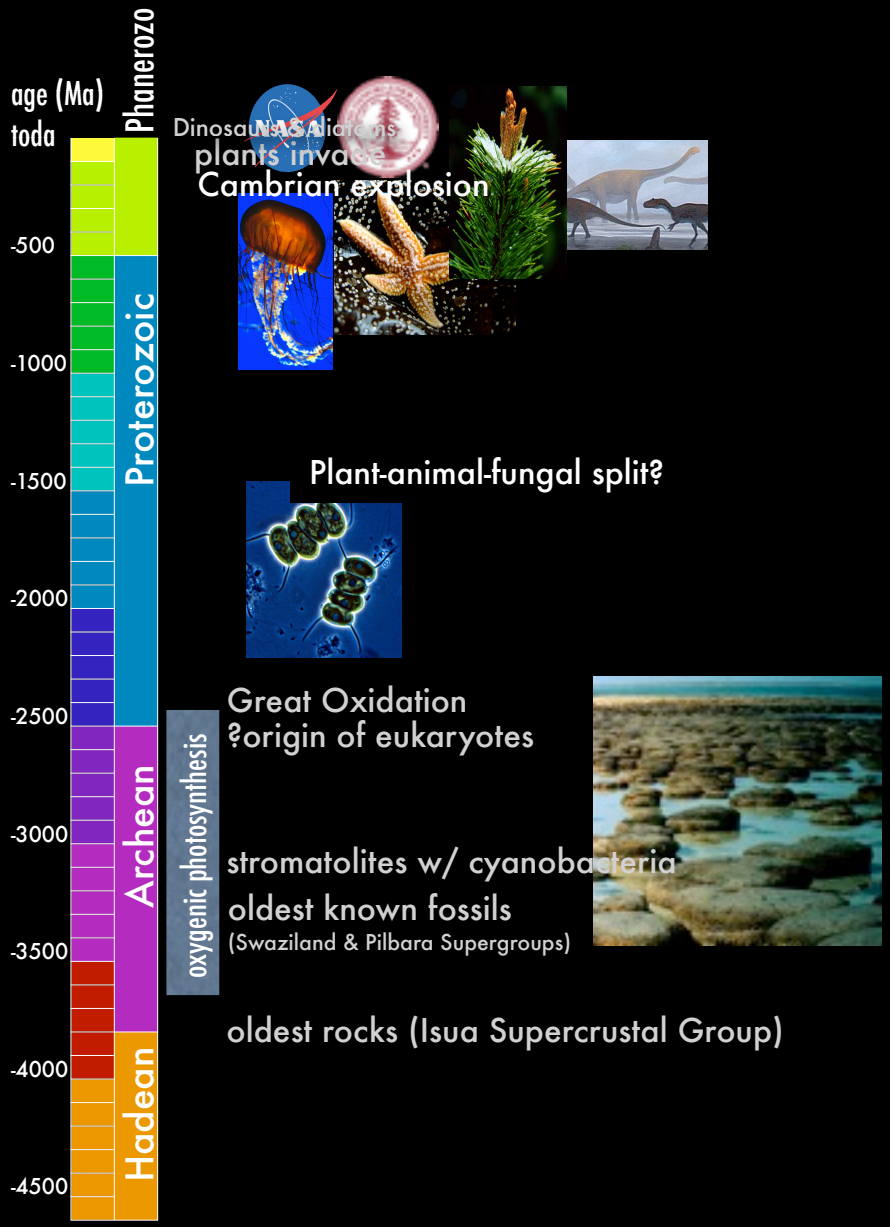
Comets

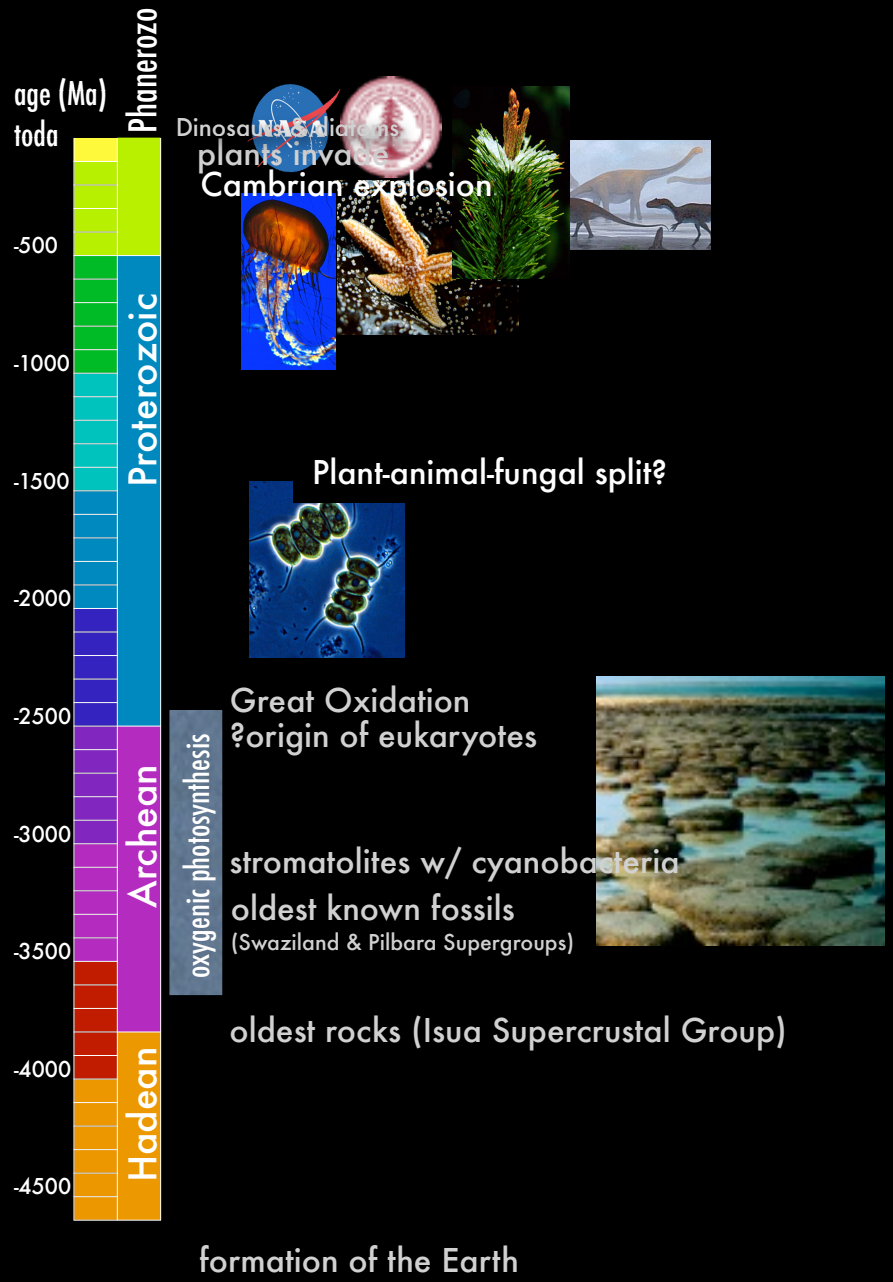
Asteroids & meteorites

Moon

Other????

History of the





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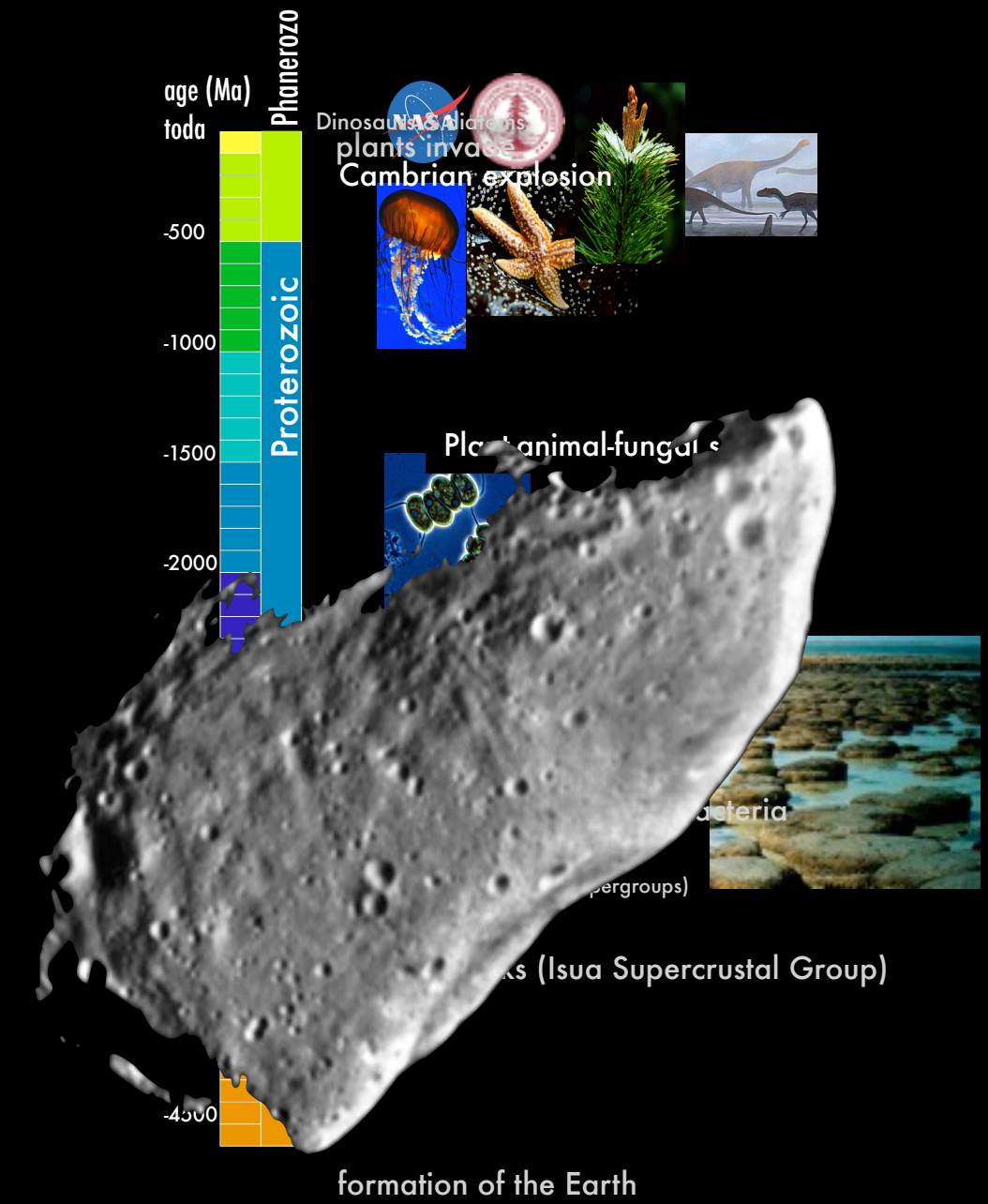
Which was the worst day ever?



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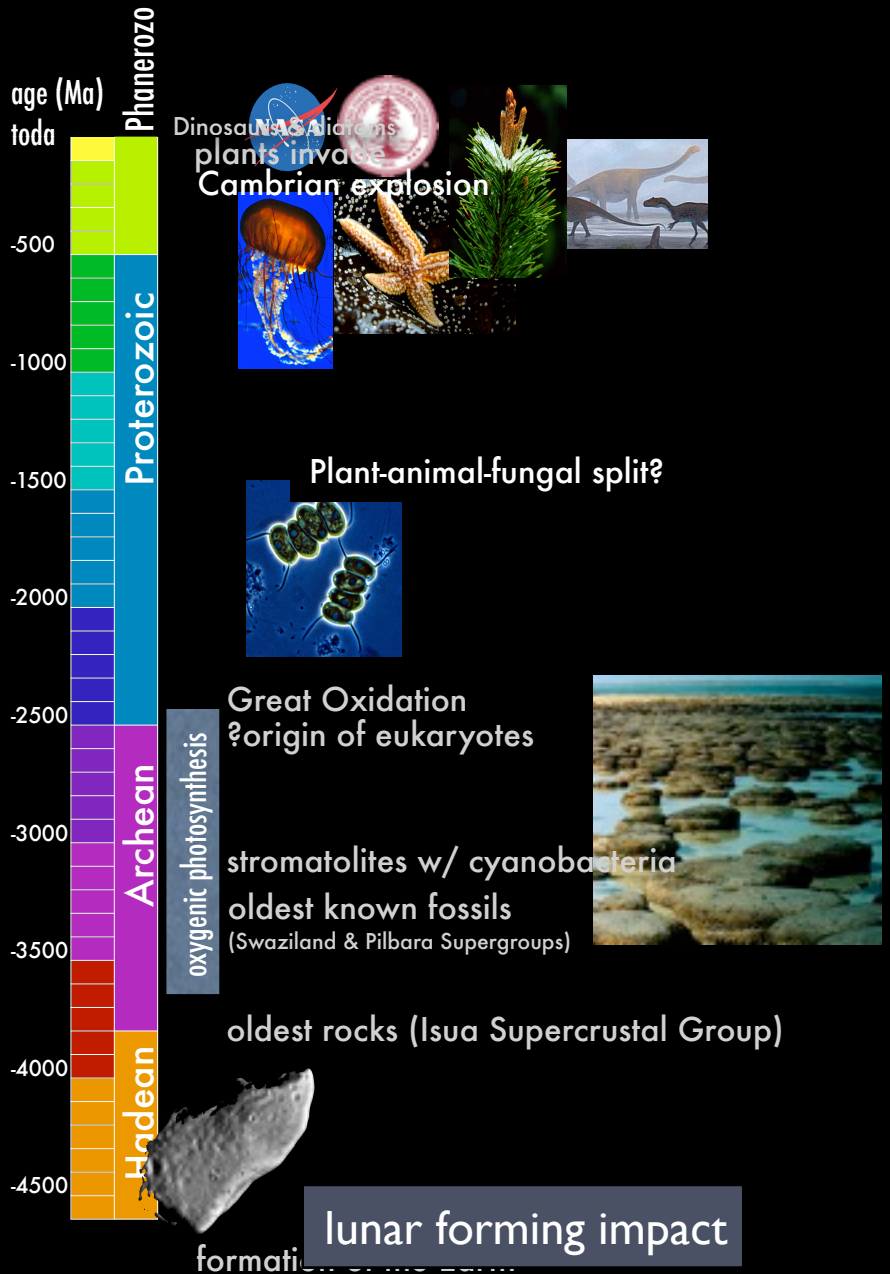
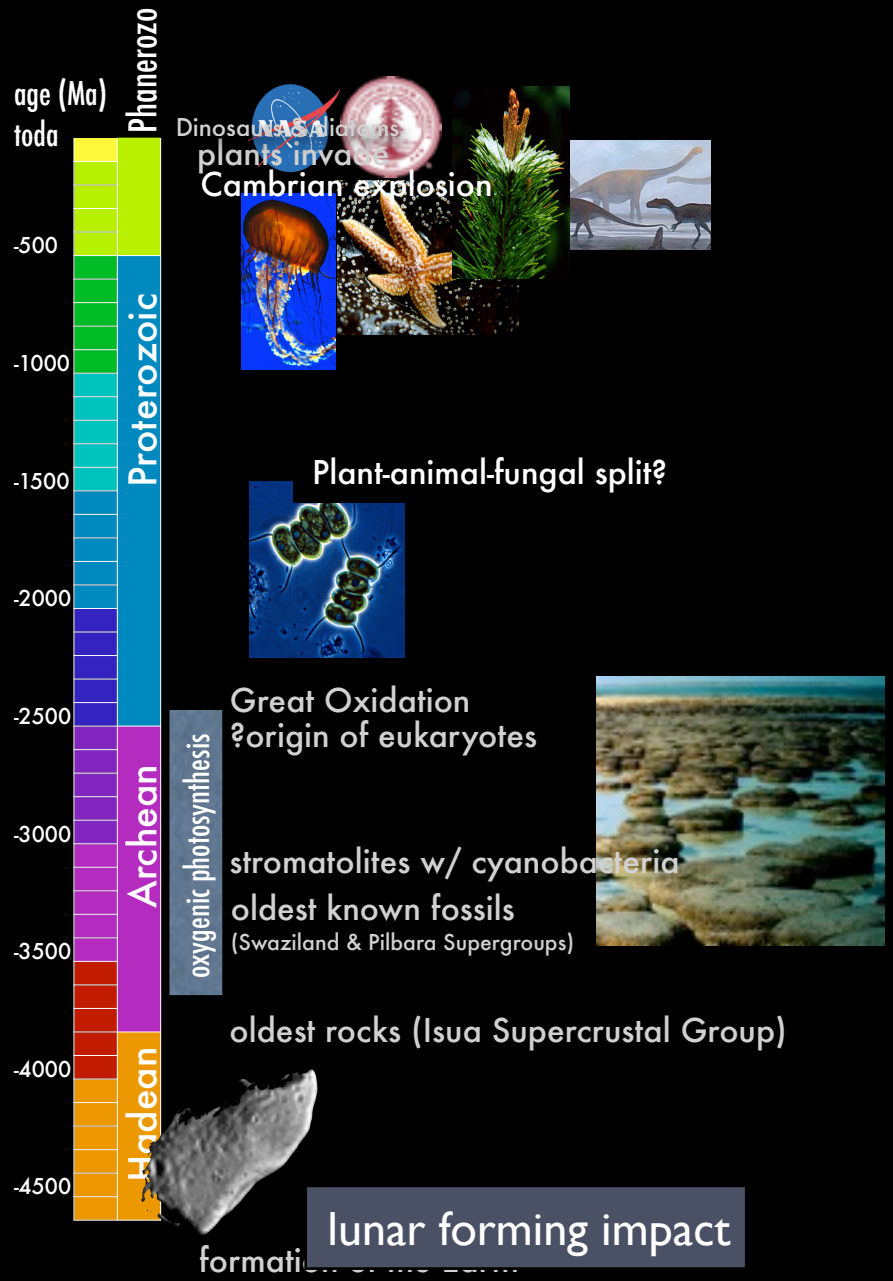
History of the Earth



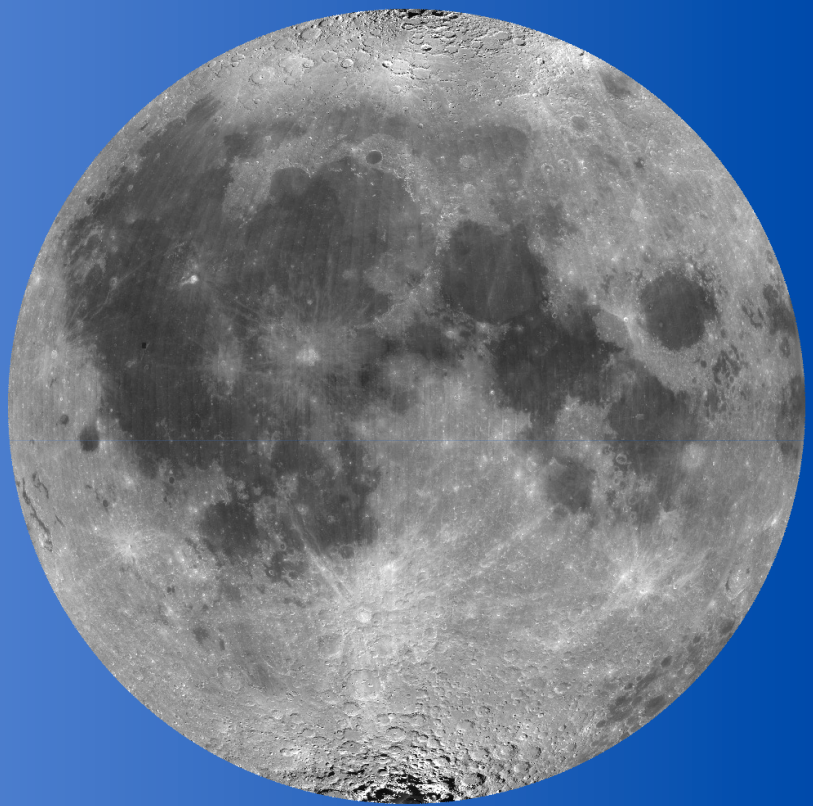


History of the Earth

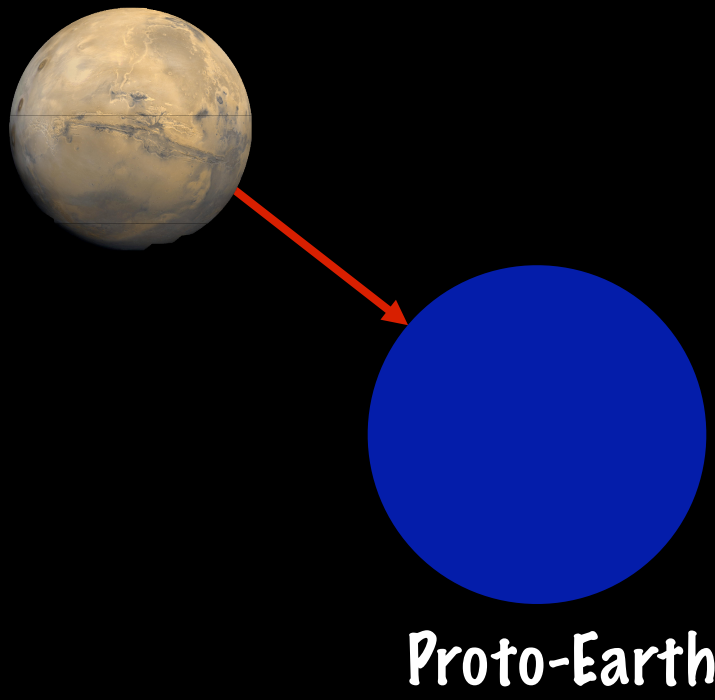
Which was the most important day ever?

The moon is lifeless and always has been, but ….

- *Would there be life on Earth without the moon?*
- *What would life be like without the moon?*
- *Would humans be here without the moon?*



How did the moon form?



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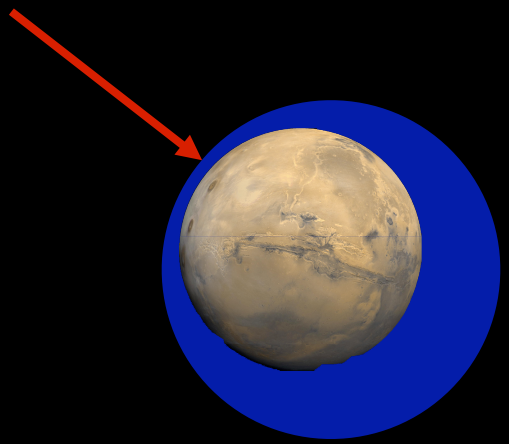

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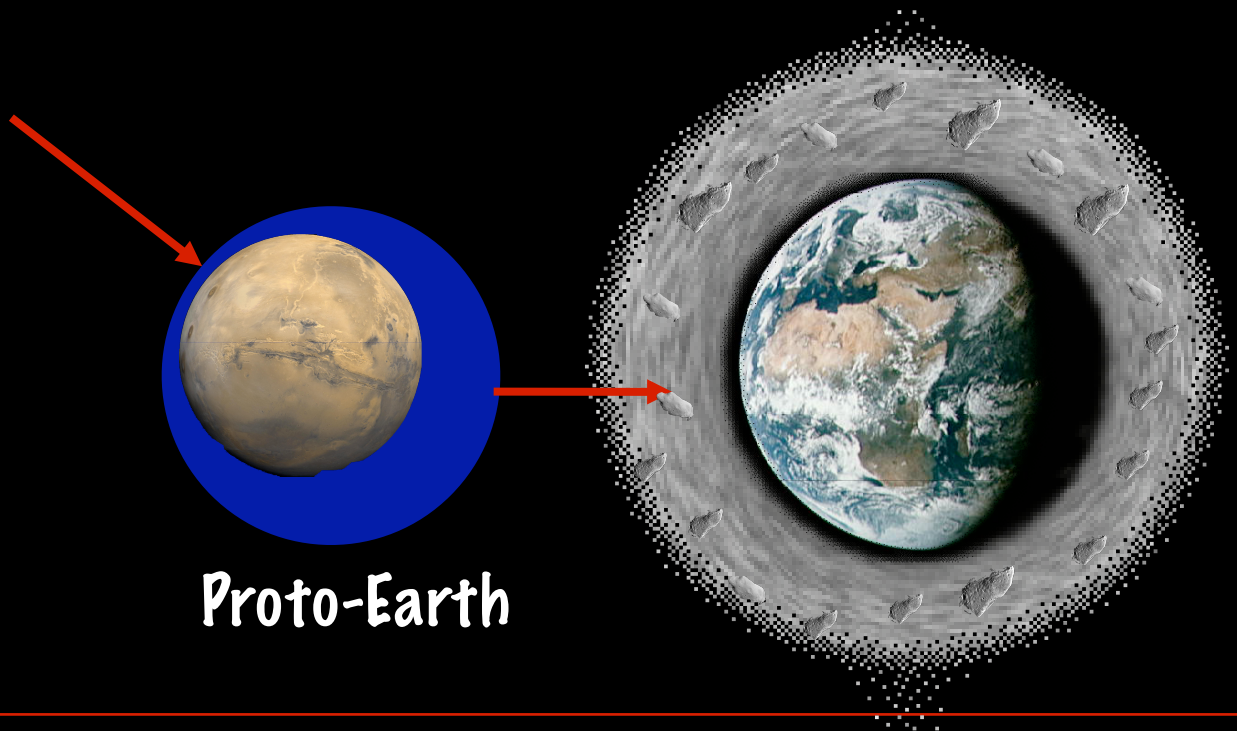

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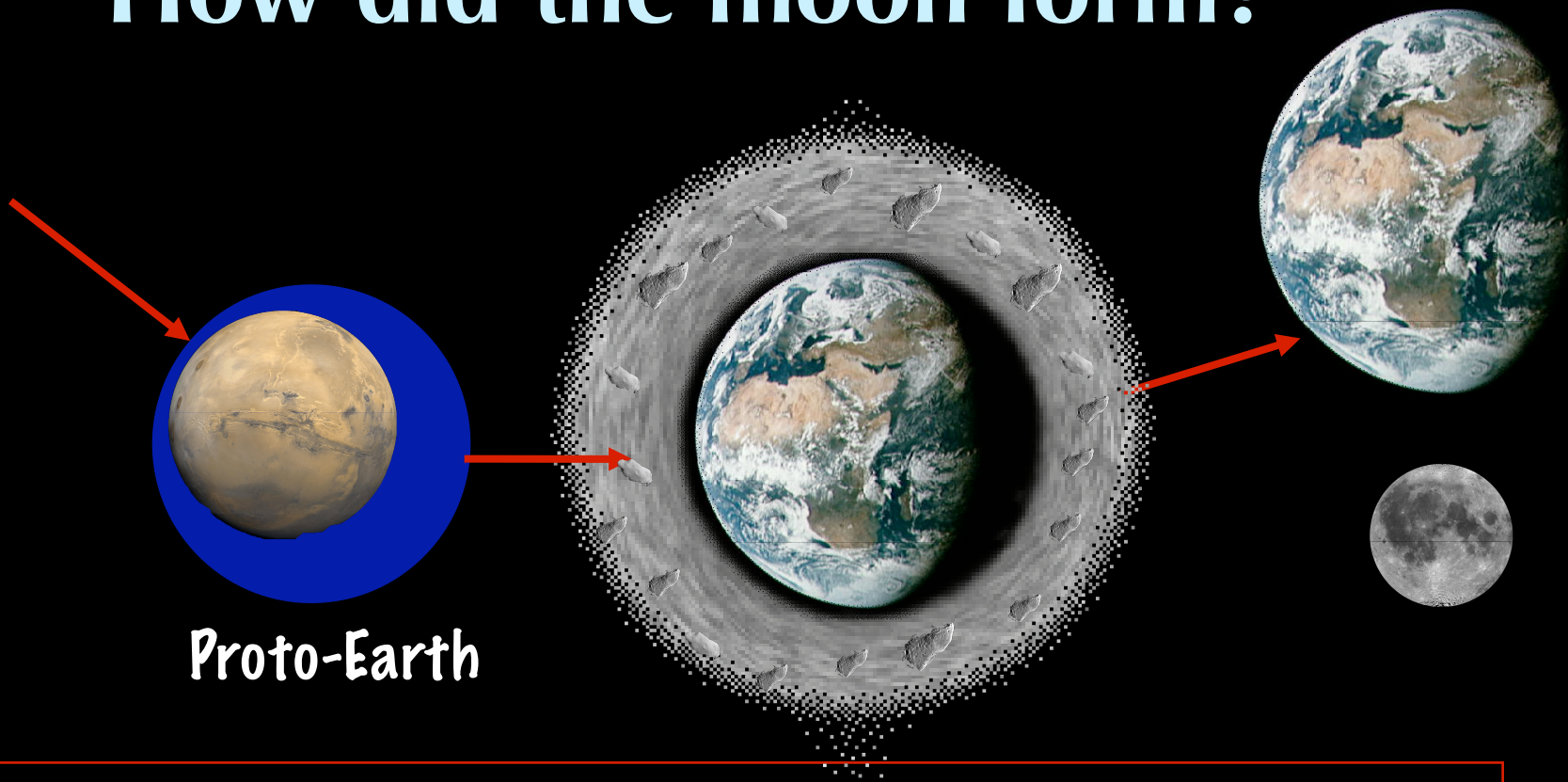

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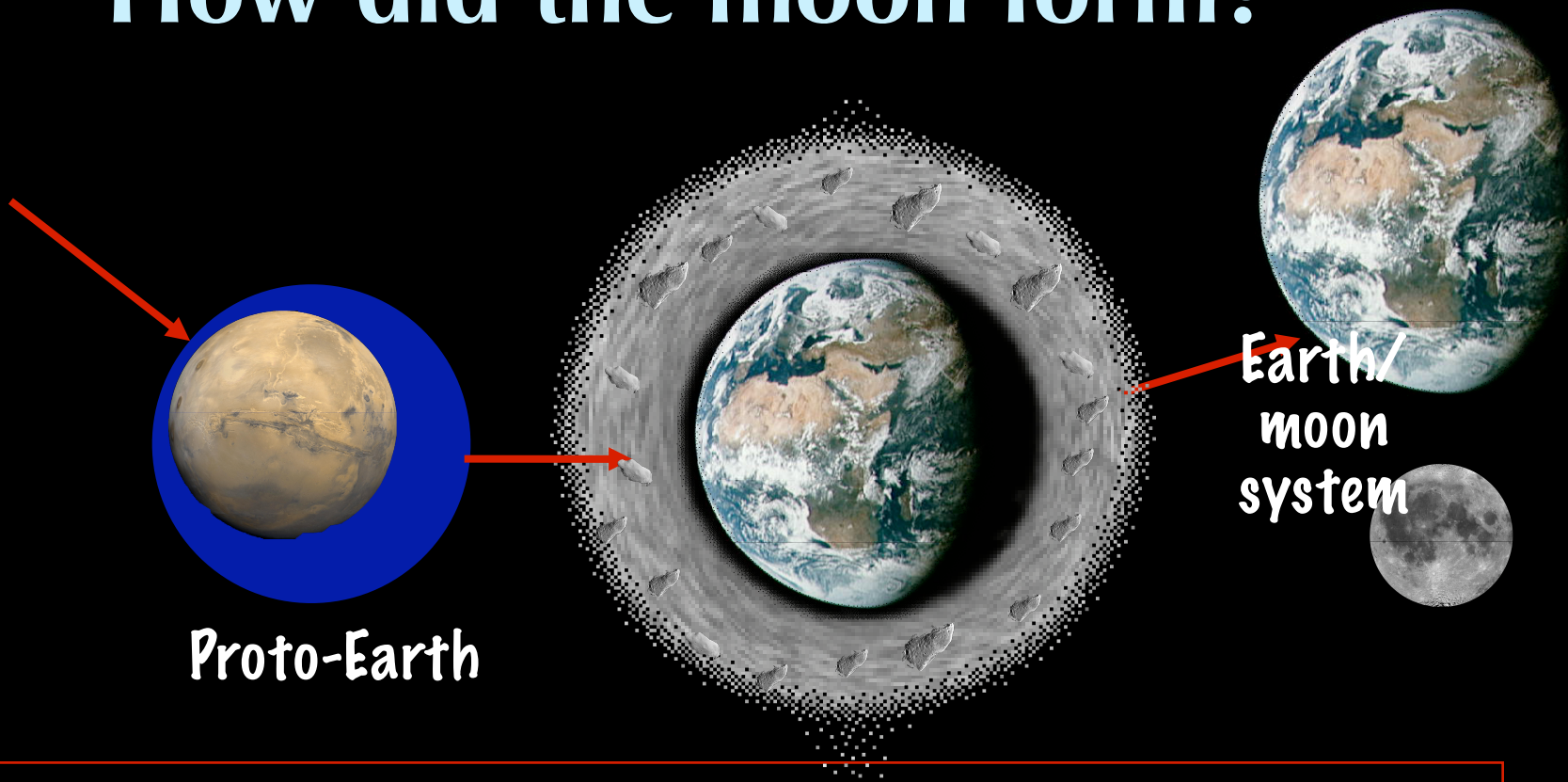

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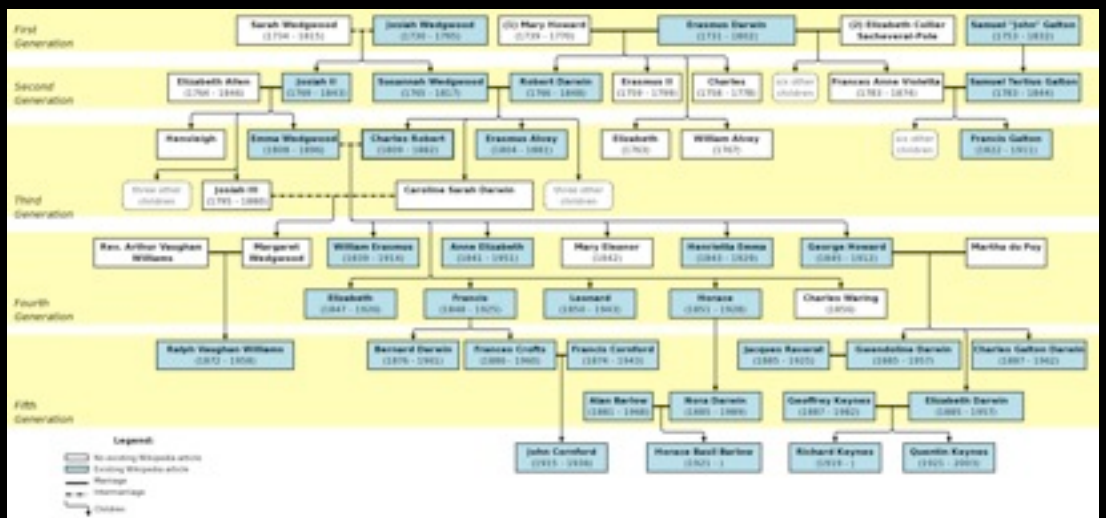

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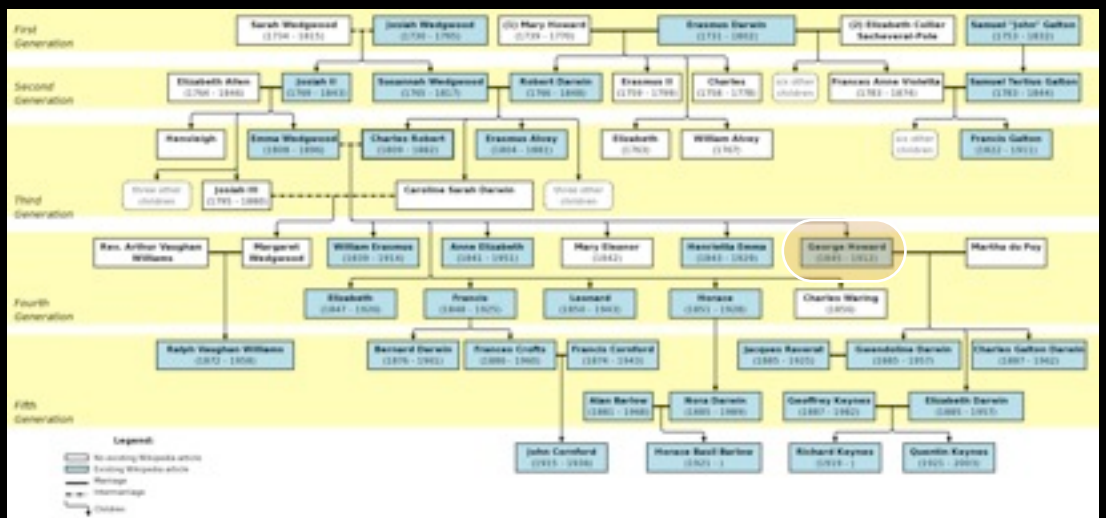

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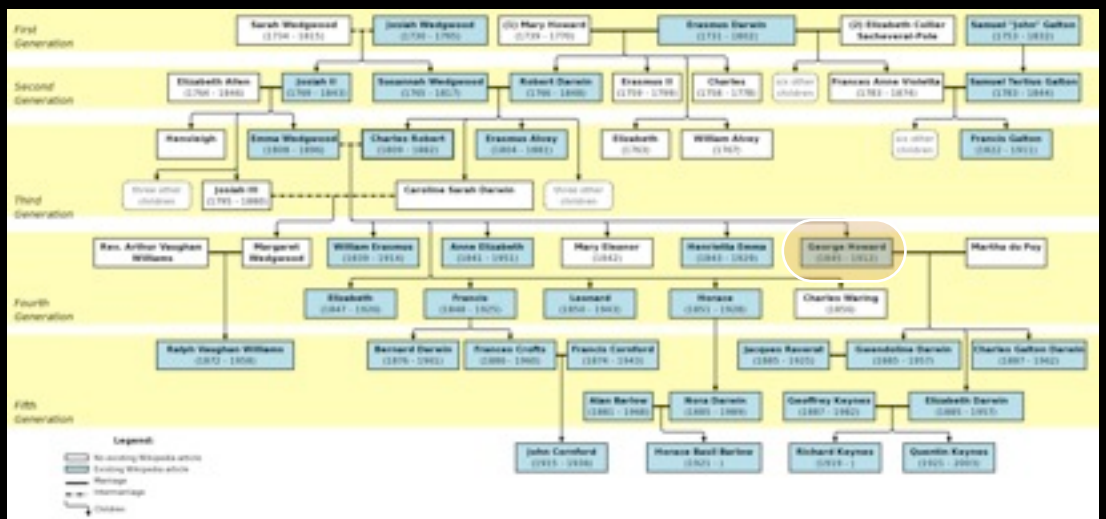

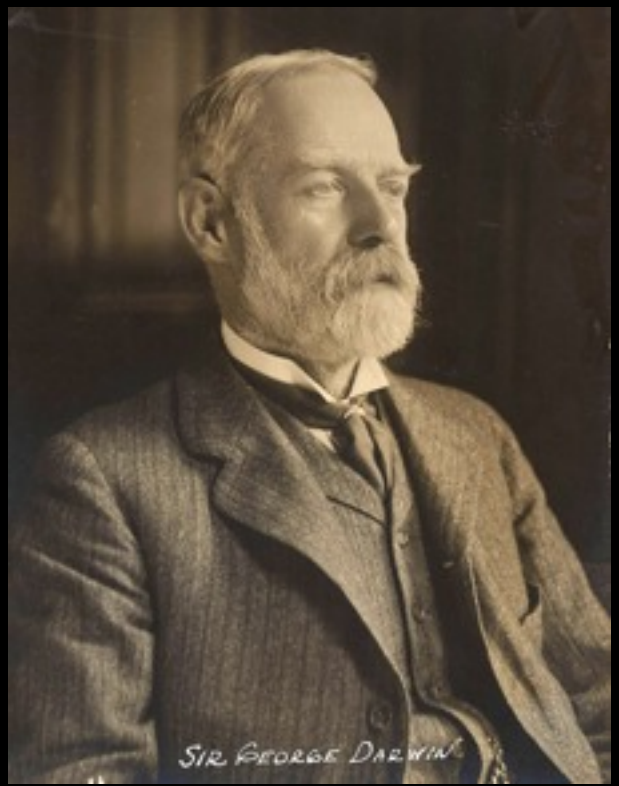

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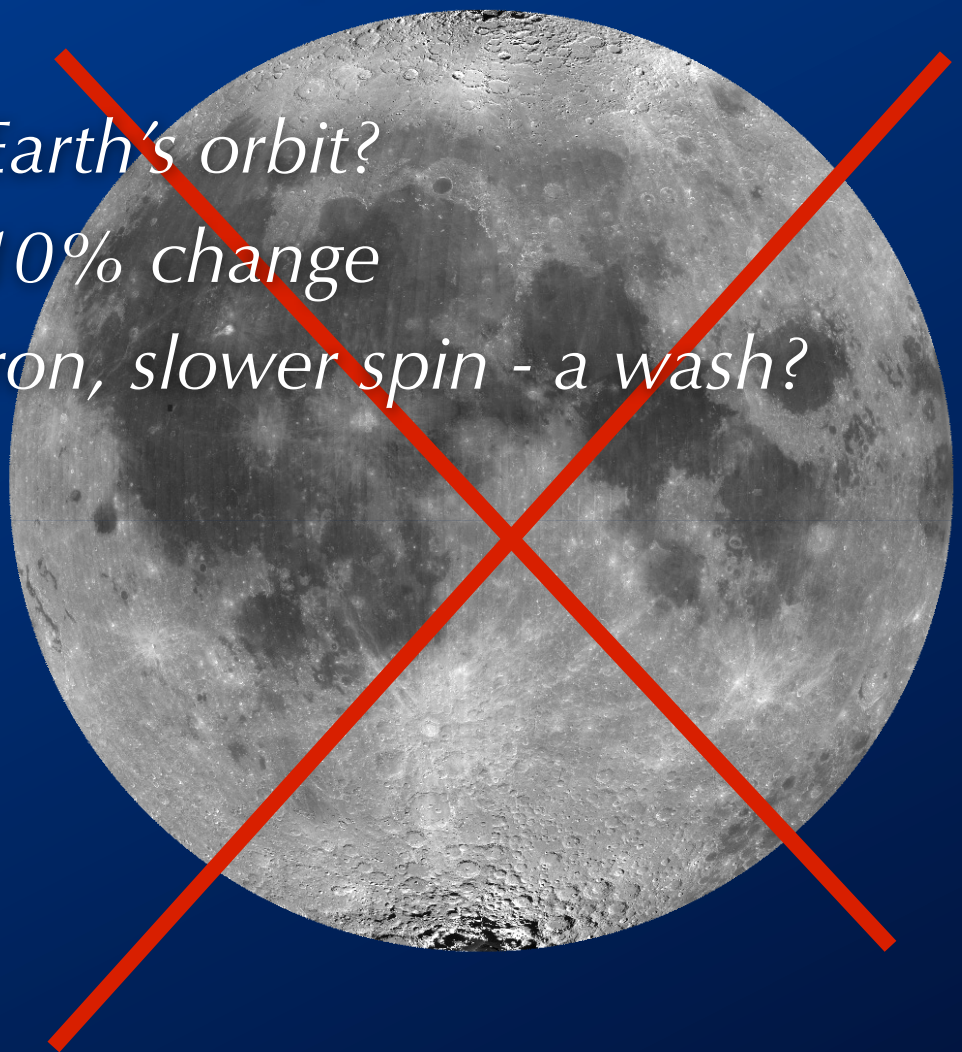

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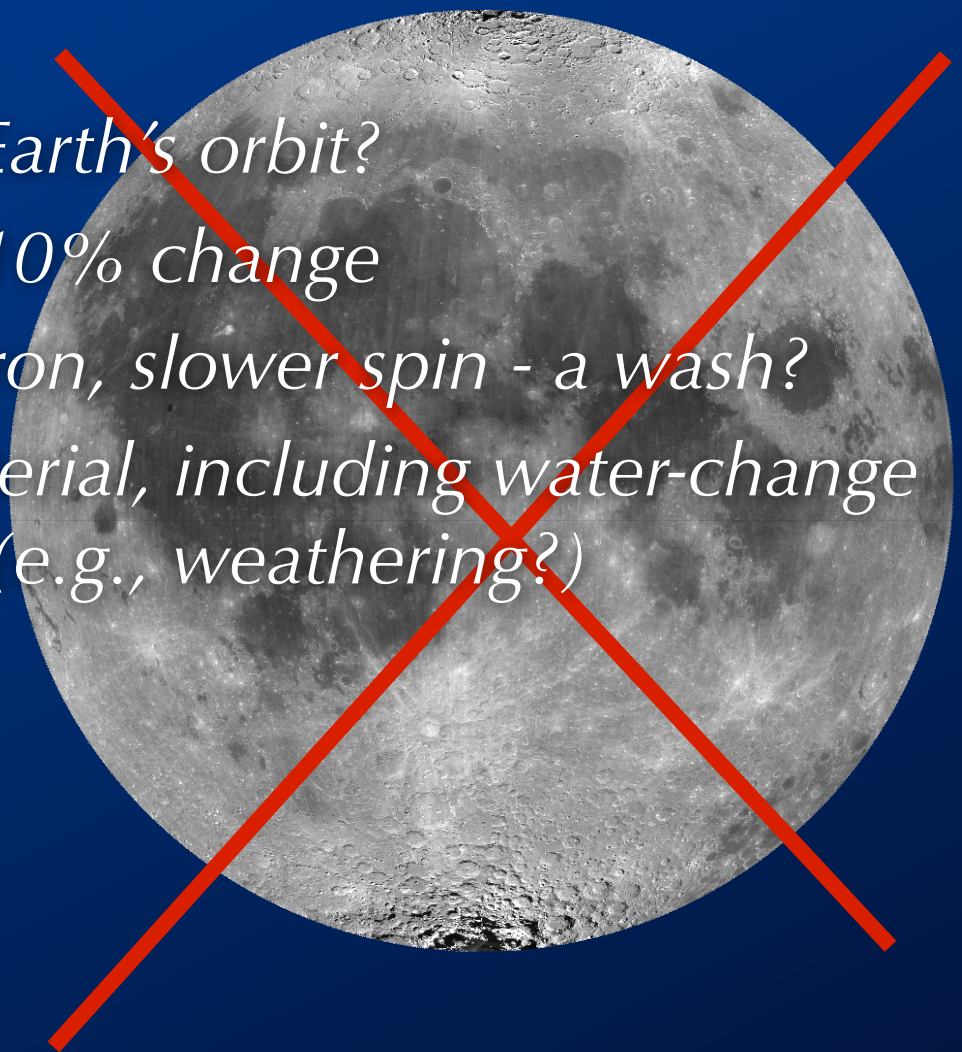

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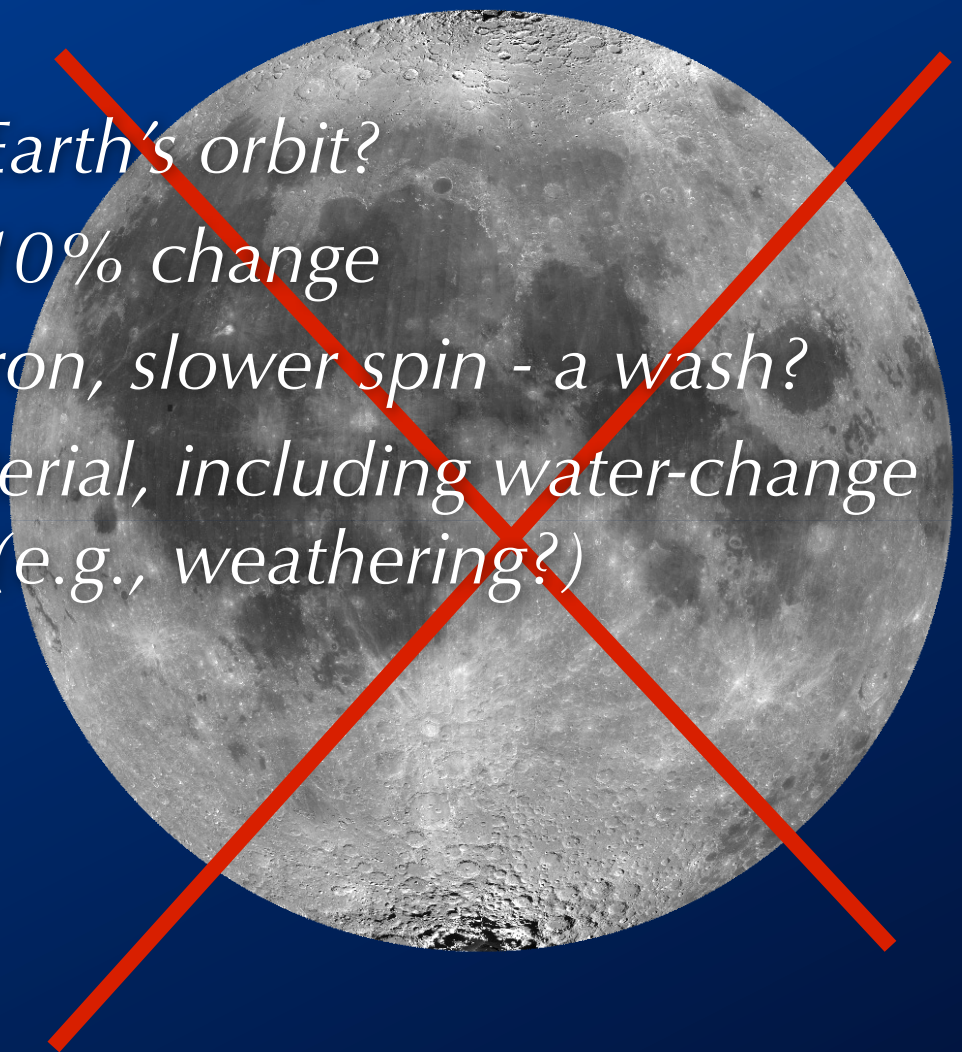

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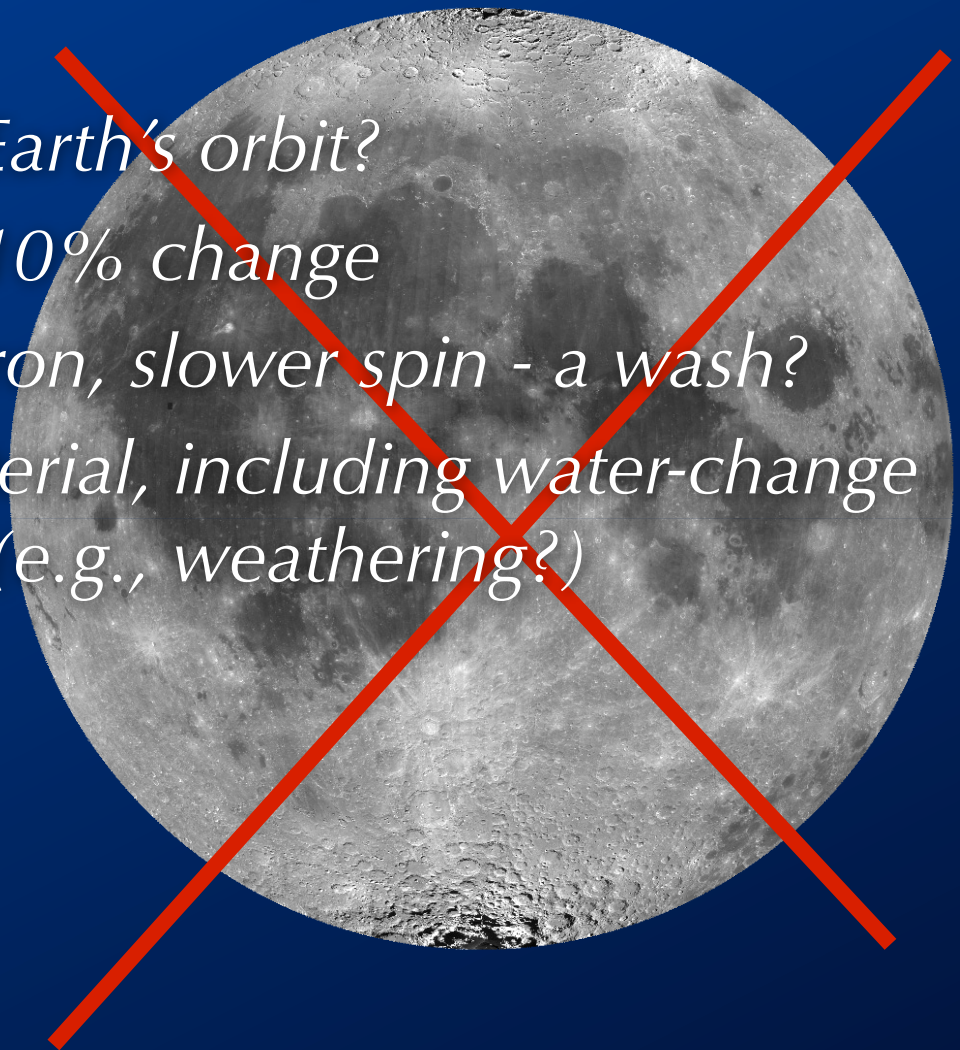
- *Oceans: tides - climate*
- *Moon as a clock.*



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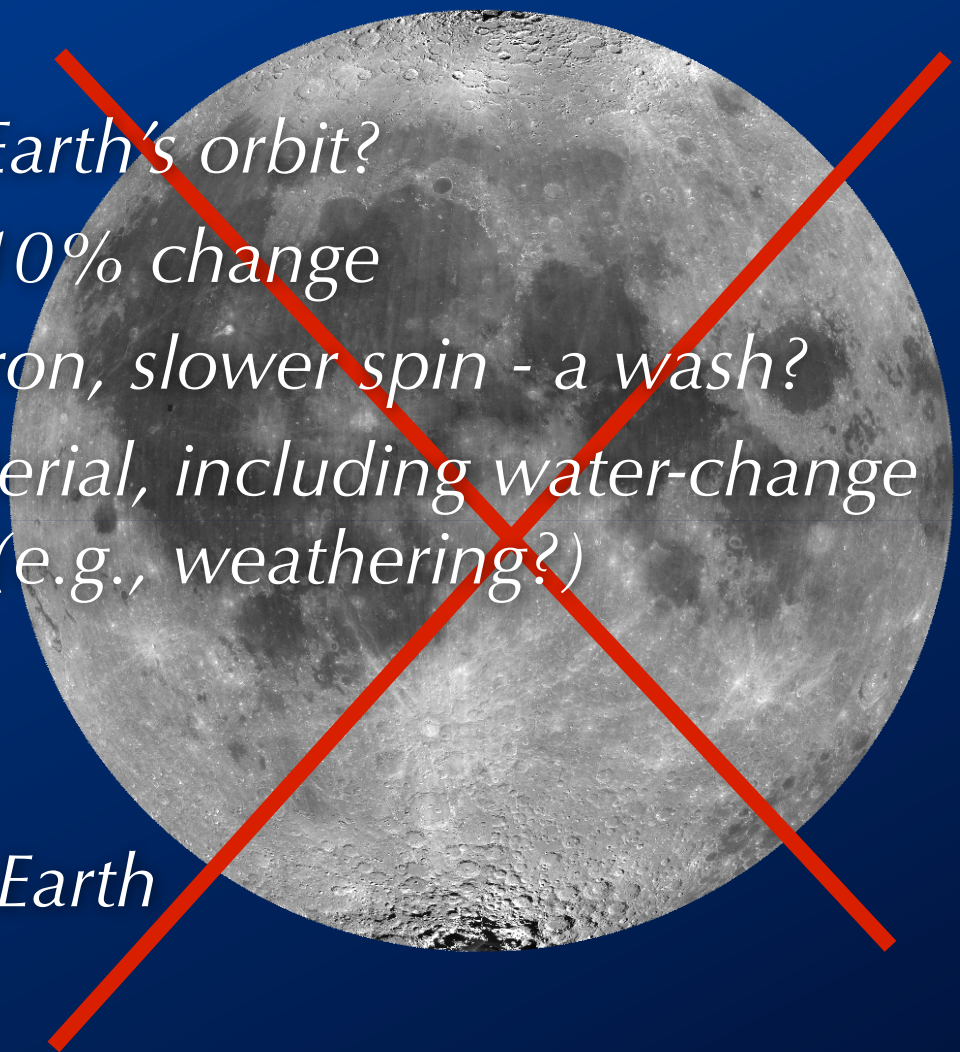
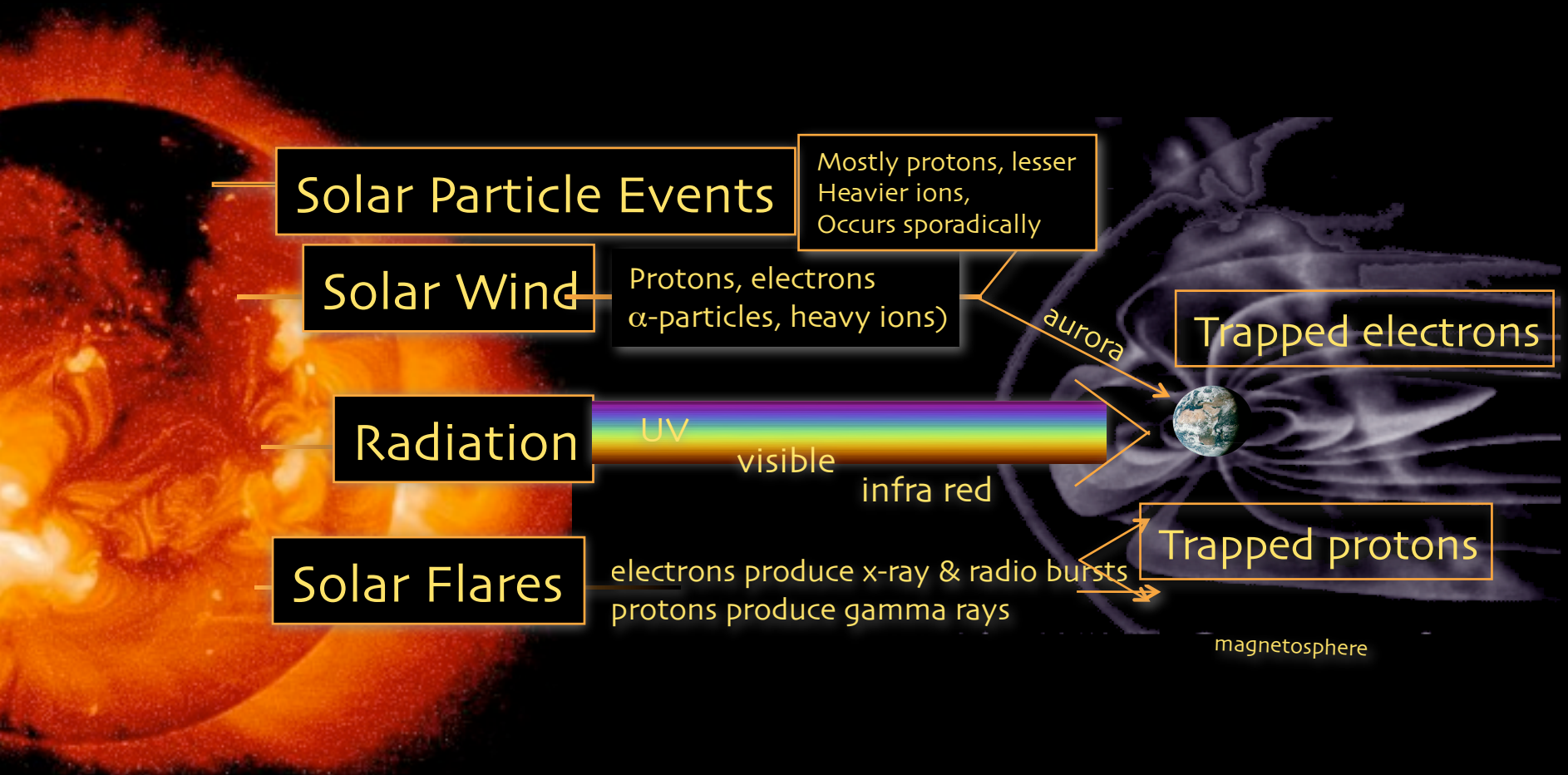
- *If Orpheus didn't hit Earth 4.4 Ga, could it have hit later?*
- *Could LFI have altered Earth's orbit?*
- *Gravity - maybe about 10% change*
- *Magnetosphere: more iron, slower spin - a wash?*
- *LFI blew off surface material, including water-change in geochemical cycling (e.g., weathering?)*
- *Oceans: tides - climate*
- *Moon as a clock.*
- *Rotational speed of the Earth*



Importance of the magnetosphere



Moon as a clock

Moon is used as a clock for feeding (marine iguanas in Galapagos) or for sex (e.g., release of gametes, as in Dictyota*). The effect of the moon may be direct (moonlight) or indirect (e.g., tides).*

The moon is a nice clock, but there are others, and the tides would be <u>more</u> regular without moon.

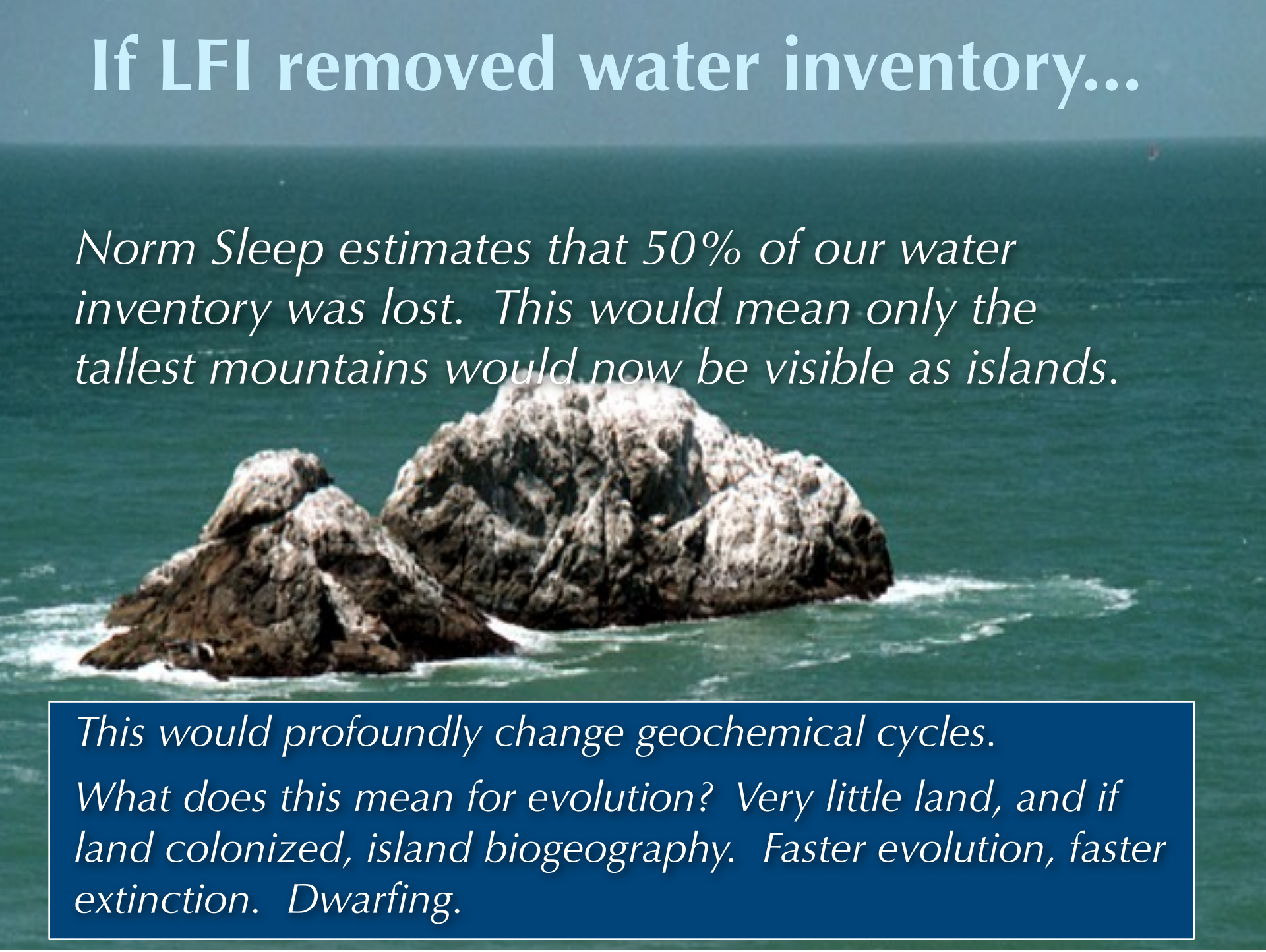
Has moon been a shield?

Has the moon intercepted any impactors that otherwise would have hit the earth and caused mass extinction?

This is statistically unlikely, but impossible to prove. And, after all, it only takes one giant impact to cause an extinction.

If LFI removed water inventory...

Norm Sleep estimates that 50% of our water inventory was lost. This would mean only the tallest mountains would now be visible as islands.



This would profoundly change geochemical cycles.

What does this mean for evolution? Very little land, and if land colonized, island biogeography. Faster evolution, faster extinction. Dwarfing.

Did moon affect transition to land?

Transition to land of plants and animals occurred in freshwater, not in the intertidal. Problem was solubility of gasses (CO_2 and O_2). This would be true at high temperatures.

Earth's rotational speed affects life

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- ✓ *With shorter (15 to 21 hour) day, must get all activities done faster. Especially important for activities that rely on Sun (e.g., photosynthesis).*

Earth's rotational speed affects life

- ✓ *With shorter (15 to 21 hour) day, must get all activities done faster. Especially important for activities that rely on Sun (e.g., photosynthesis).*
- ✓ *Good news is less exposure to solar UV - go into period where can repair damage (e.g., excision repair; recombinational repair) without new damage occurring.*

Did moon affect transition to land revisited. Wind.

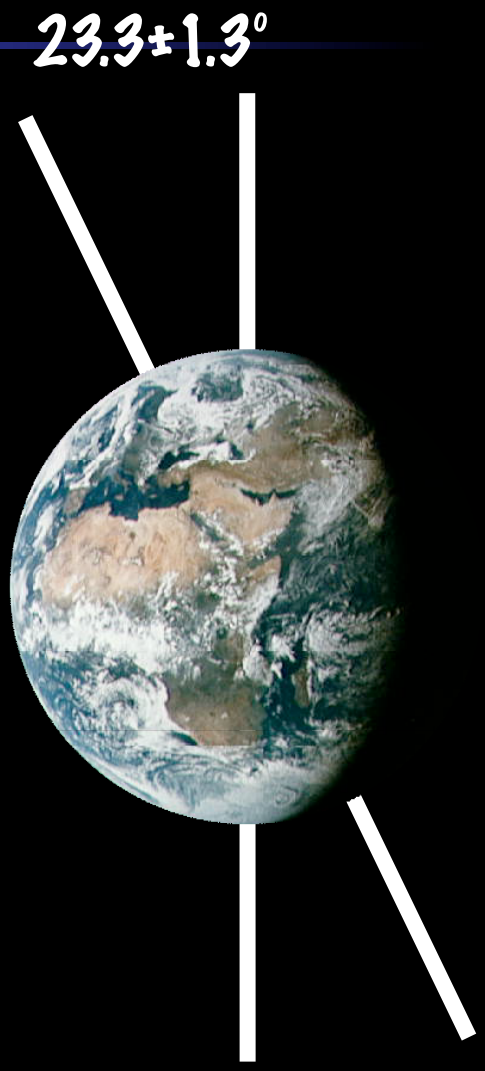
Problem with living on land is dessication. If winds higher, dessication would be worse.

Erosion high.

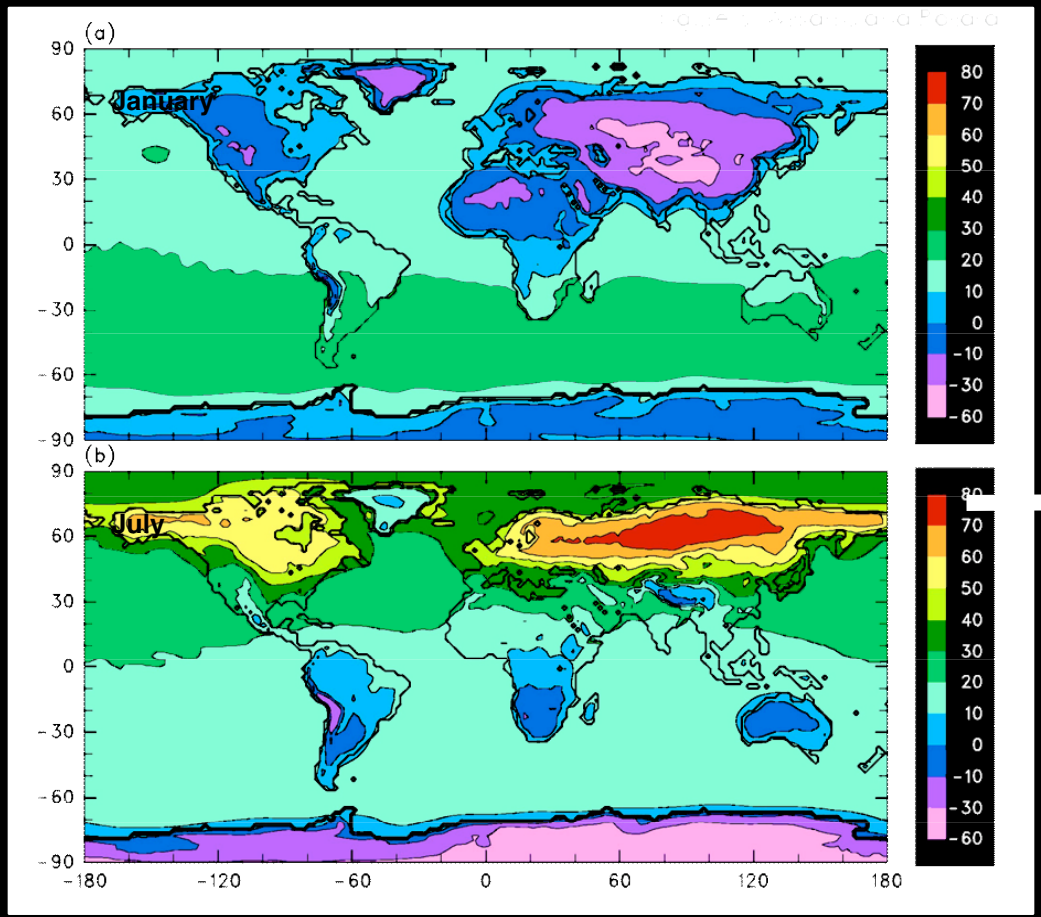
Upright posture difficult.

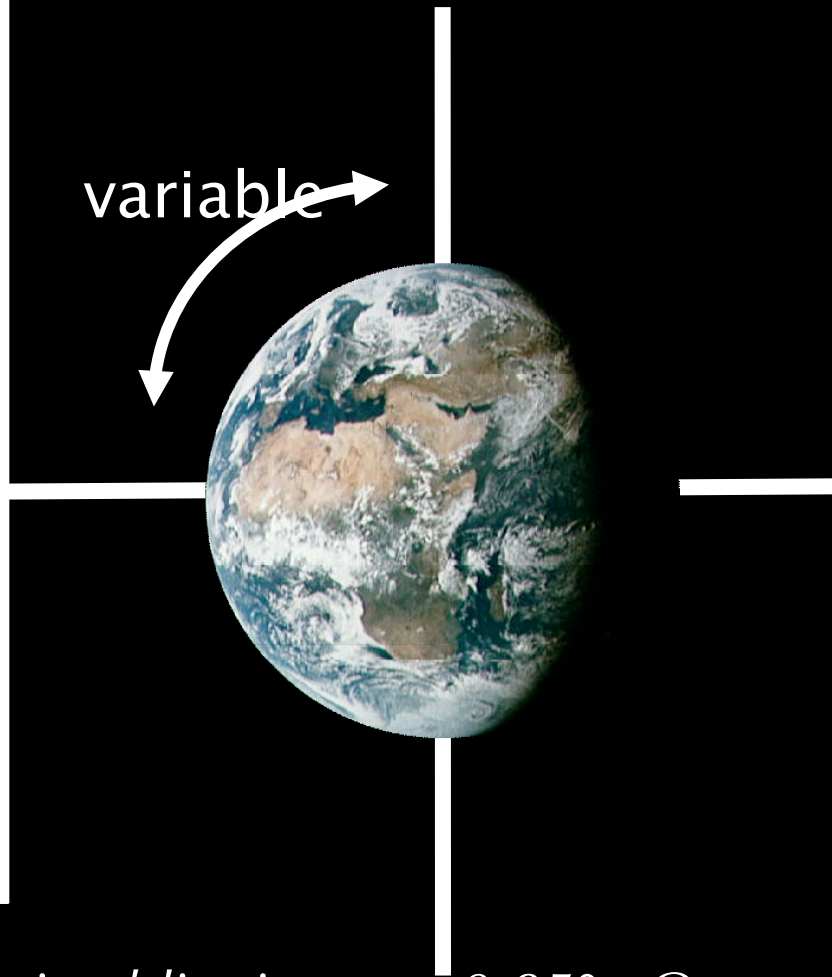
The moon stabilizes the obliquity of the Earth

- ✗ *Obliquity of the Earth is stabilized by moon, Sun, and other planets.*
- ✗ *Obliquity determines solar insolation, thus temperature etc.*
- ✗ *Without the moon, Earth's obliquity would oscillate more than that of Mars, which is ± 13°.*



What about a chaotic obliquity?





Without the moon we would have a chaotic obliquity - say 0-85°. On left is Williams and Pollard's model of climate on an Earth with an obliquity of 54°.

Ramifications of obliquity

Did shift in obliquity from 24.13 to 23.45° 9000 years ago force migration of humans from Sahara to Nile delta region?

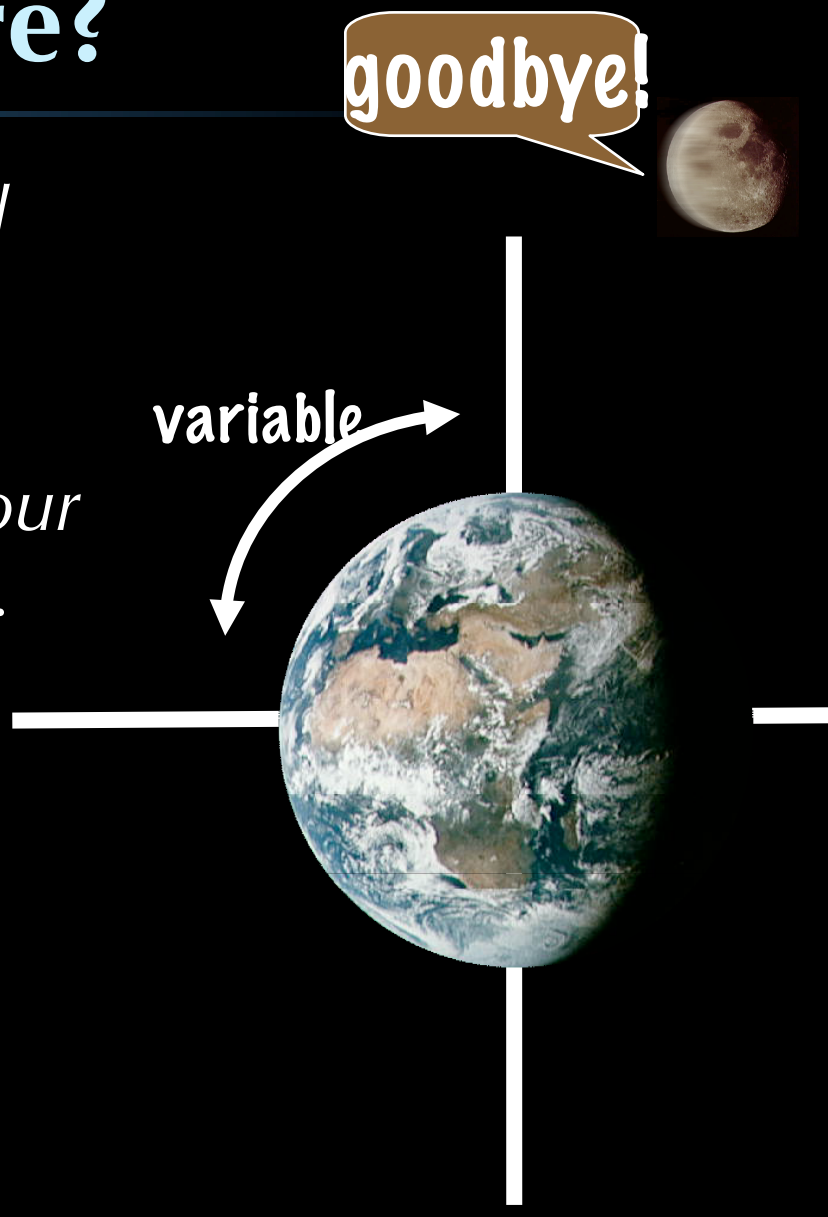
Would humans have evolved on a moonless earth?

Probably not.

Too little land, high wind issues, chaotic climate.

What about the future?

- *Without the moon we would have a chaotic obliquity.*
- *Bad news: we are going to lose the stabilizing effect of our moon in a billion or so years.*
- *What can we do about this?*
  - *Hang on to our moon (decrease tidal friction?)*
  - *Hijack new moon (Europa?)*
  - *Deal with it*



Astrobology and Space Exploration

"If We Had No Moon"

Discovery Channel

1999 York Television

all star cast *(ok, including me)*

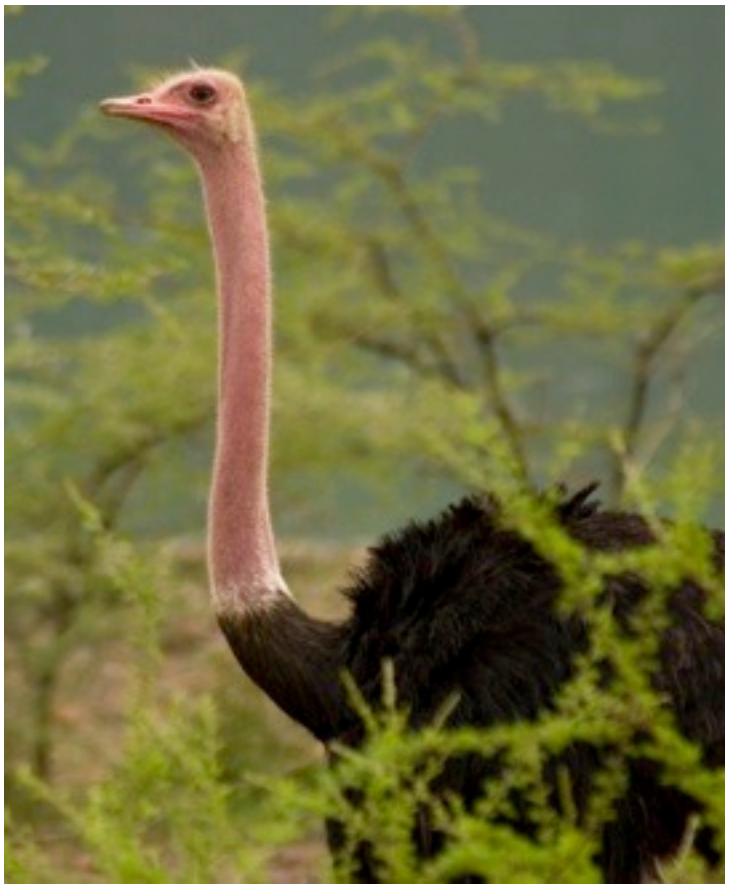
Lynn J. Rothschild
19 Jan 2010
Stanford

Why do we care what life is?

- Search for life
- Evolution of life
- It's our club!
- Moral & Legal reasons (e.g., determine beginning and end of life)


Life has a
vital principle
But the chemists showed there is none.

What is this thing we call



"life"

?


Approaches

Approaches

- What does life need?

Approaches

- What does life need?
- What is life made of?

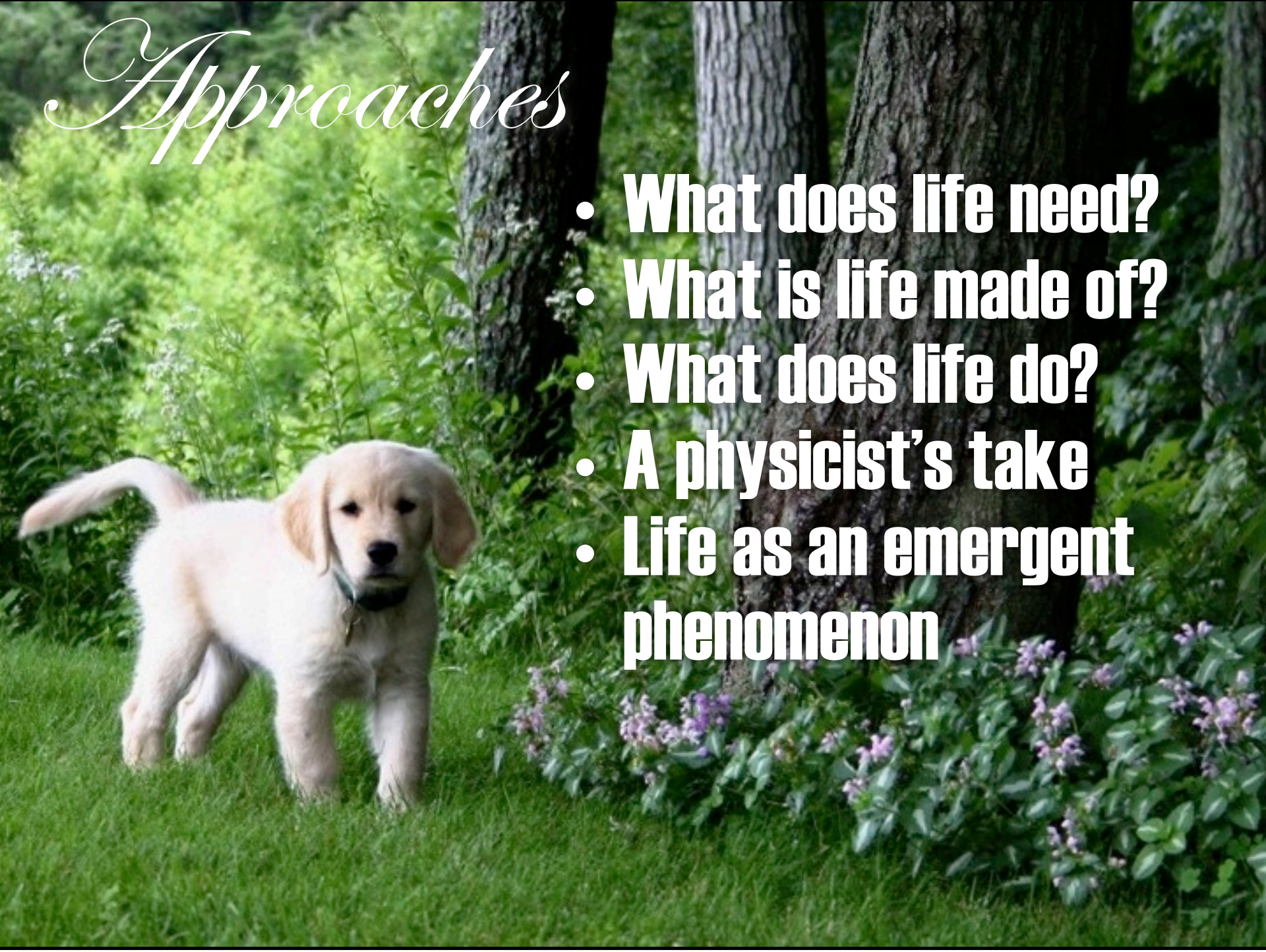
Approaches

- What does life need?
- What is life made of?
- What does life do?

Approaches

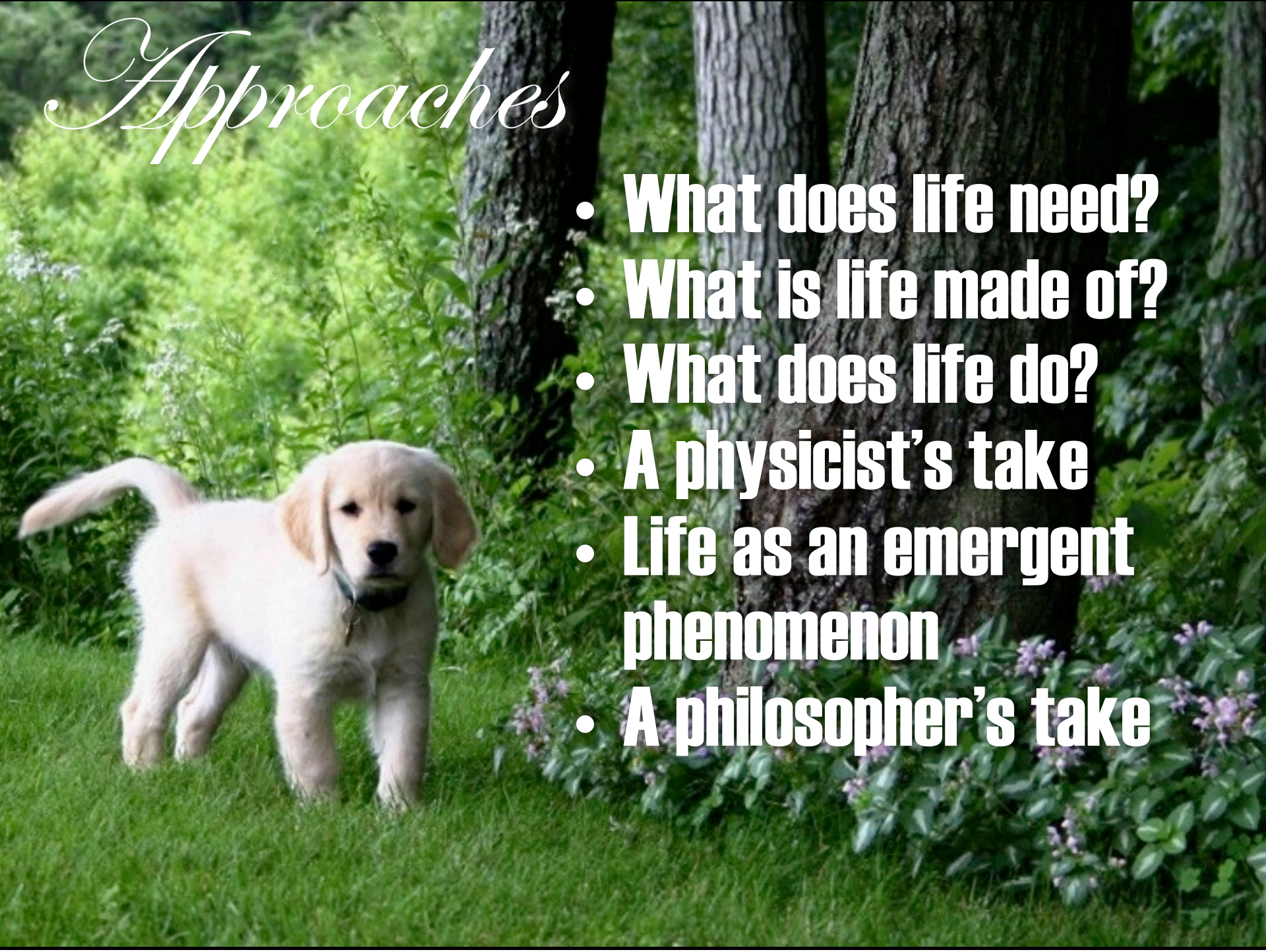
- What does life need?
- What is life made of?
- What does life do?
- A physicist's take

Approaches



- What does life need?
- What is life made of?
- What does life do?
- A physicist's take
- Life as an emergent phenomenon

Approaches



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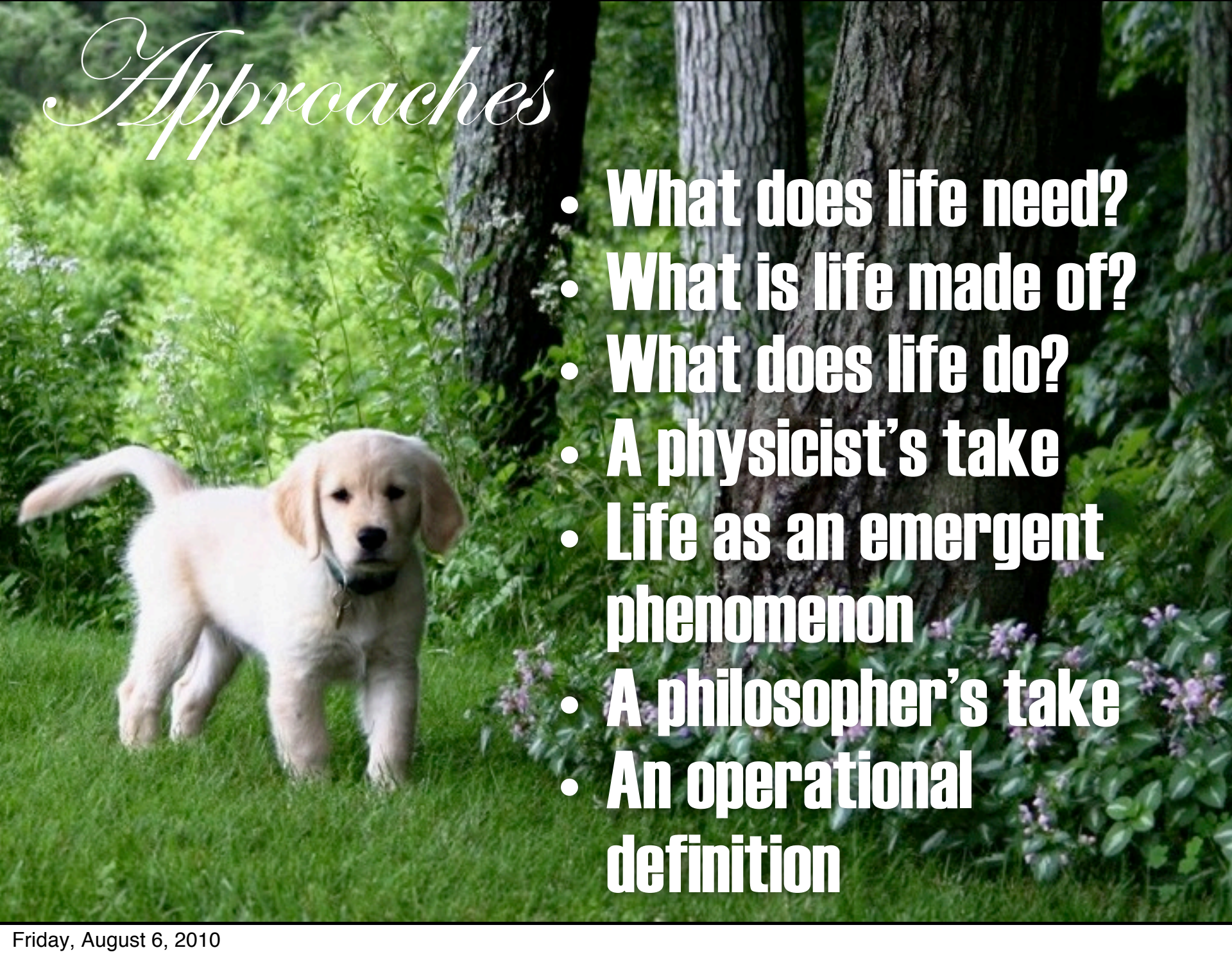
Approaches



- What does life need?
- What is life made of?
- What does life do?
- A physicist's take
- Life as an emergent phenomenon
- A philosopher's take
- An operational definition

What does **Life** *need?*

To be alive, organisms need

1. **A body.** The body is likely to be based on organic carbon. The top priority is to find or make organic carbon, and incorporate it.
2. **Survival.** Means dealing with a changing environment. Can do this with physiological, morphological, or genetic approaches.
3. **Leave offspring.** As the environment changes, need variability in offspring.
4. **Continuity!**

What do organisms need for life?

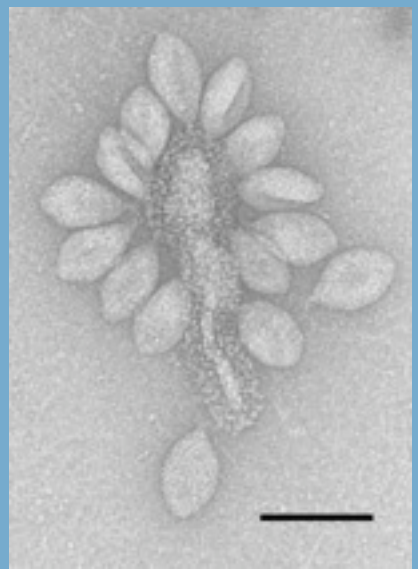
Problems.

1. **A body.** Does life have to have a body? Cellular slime molds, fruiting bodies, viruses.
2. **Survival.** How long does life need to survive to count?
3. **Leave offspring.** What about non-reproducing members?
4. **Continuity!** What if life arises de novo each generation but otherwise like current life - would that count?

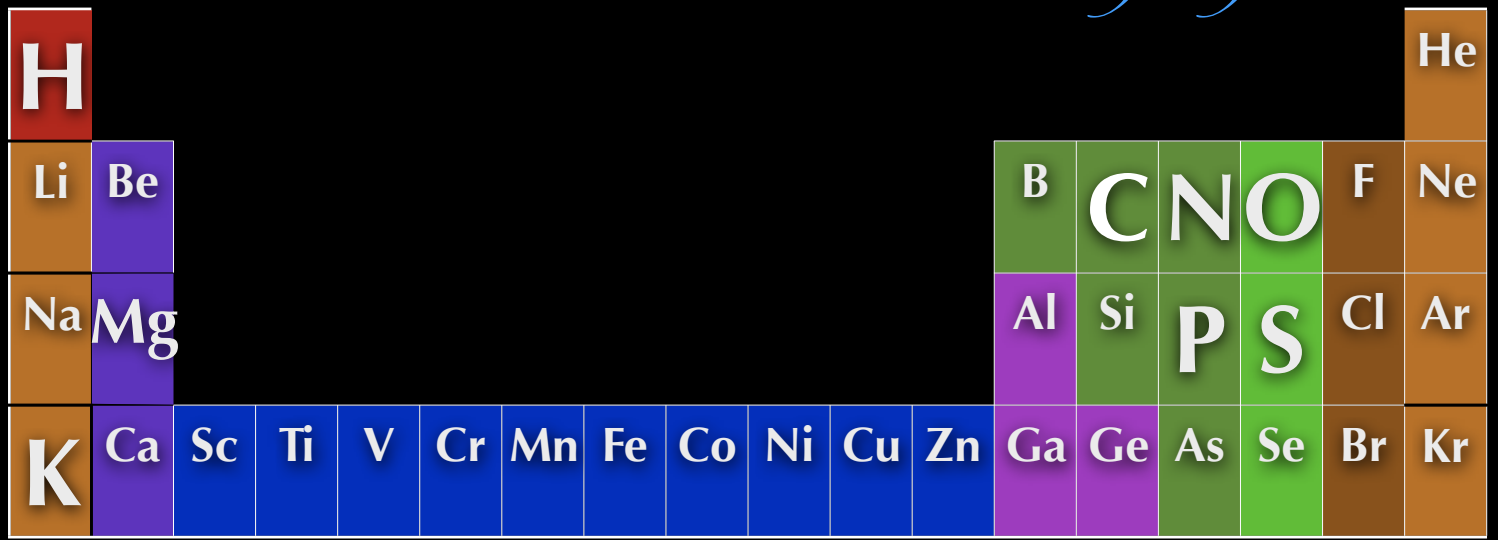
What about reproduction?

What if need others to accomplish reproduction, like a machine…or a virus?

What if use a set of instruction: Do you need to provide them or can someone/something else?



What are the elements of life?



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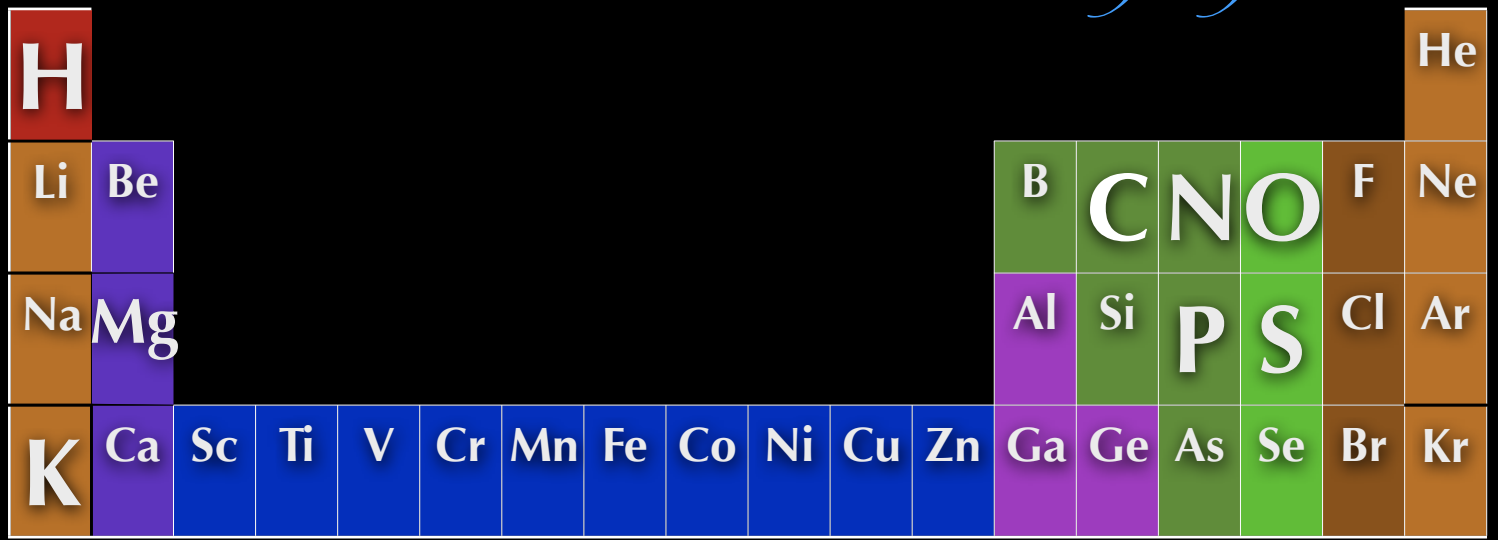

- Carbon – Main constituent of organic cellular material

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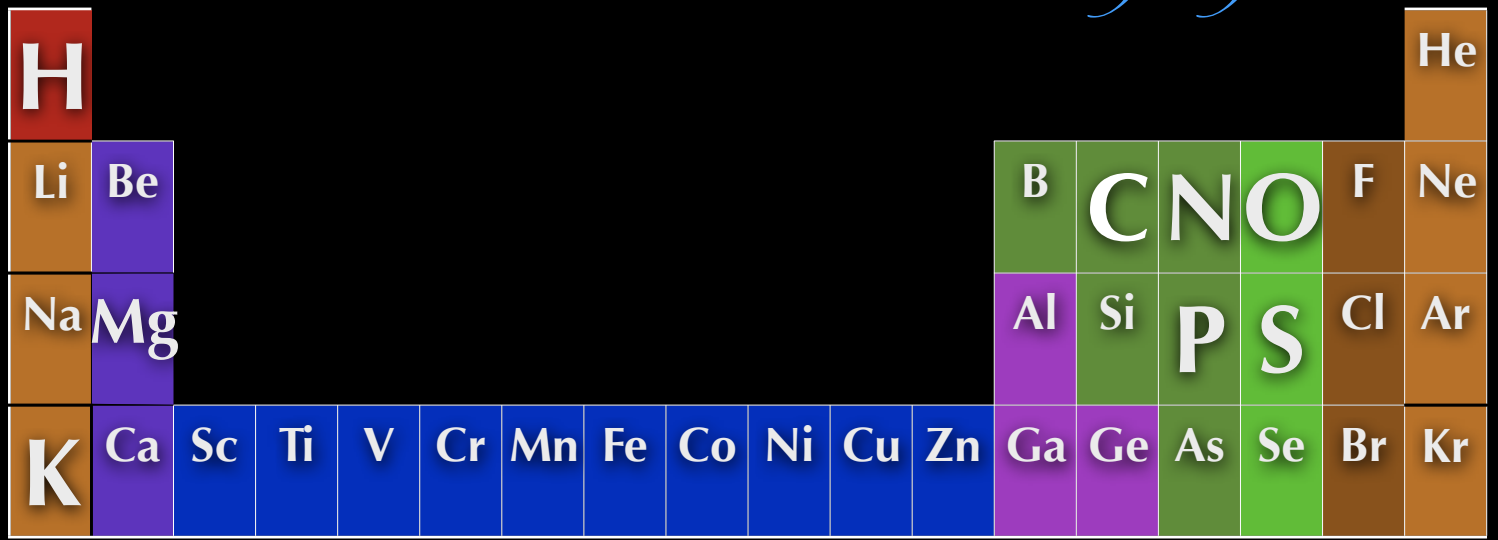

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- Nitrogen – Constituent of proteins, nucleic acids, and coenzymes

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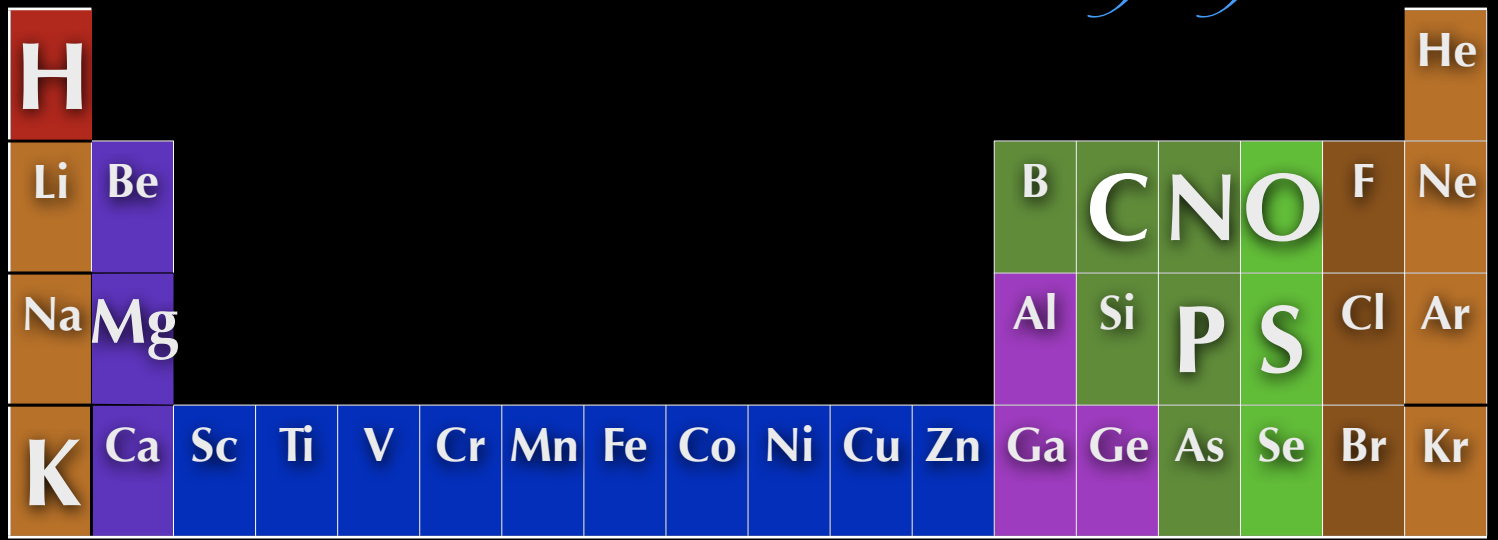

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- Hydrogen – Organic material and water

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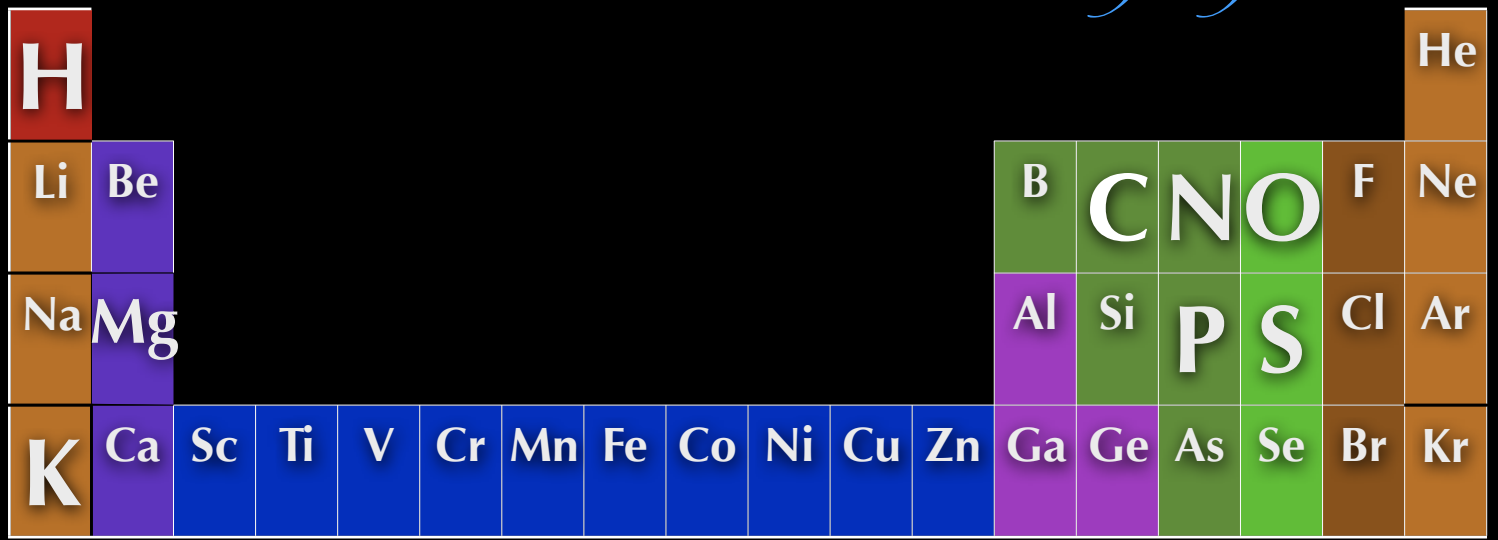

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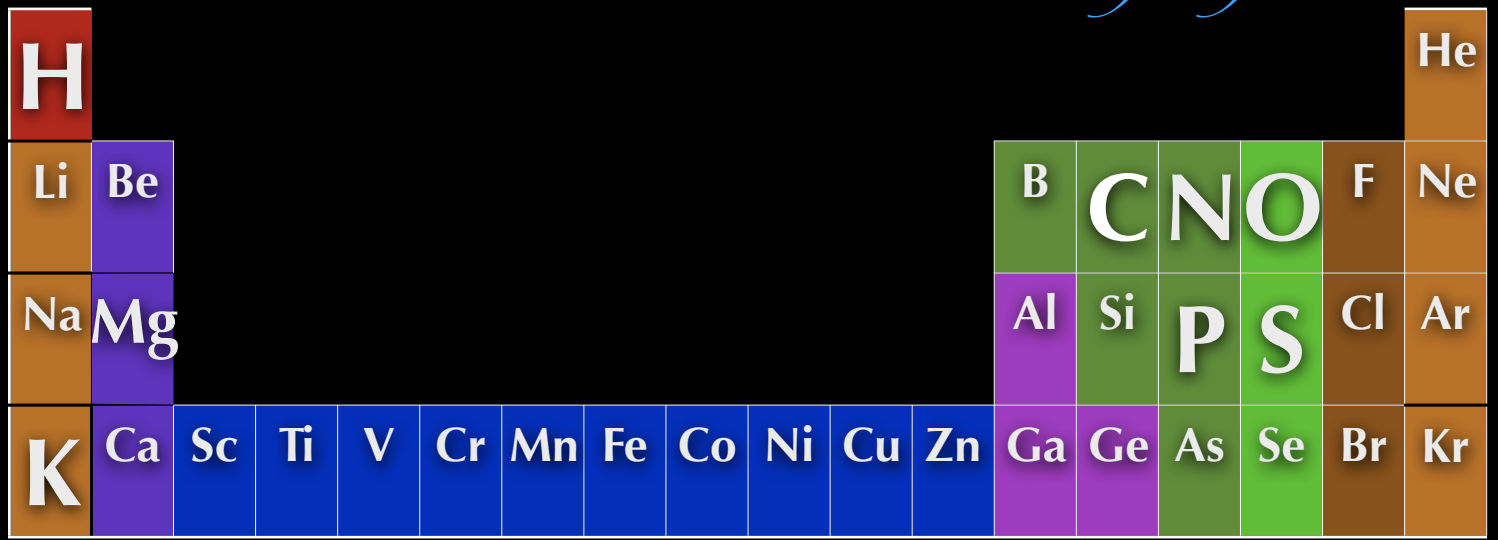

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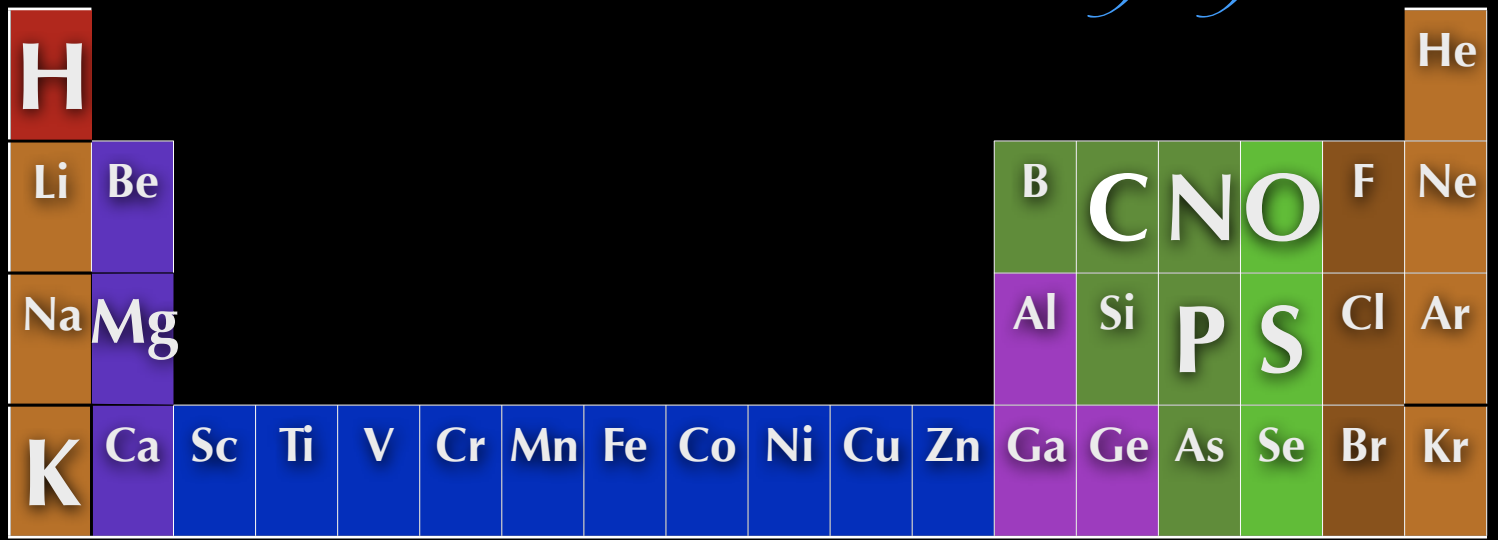

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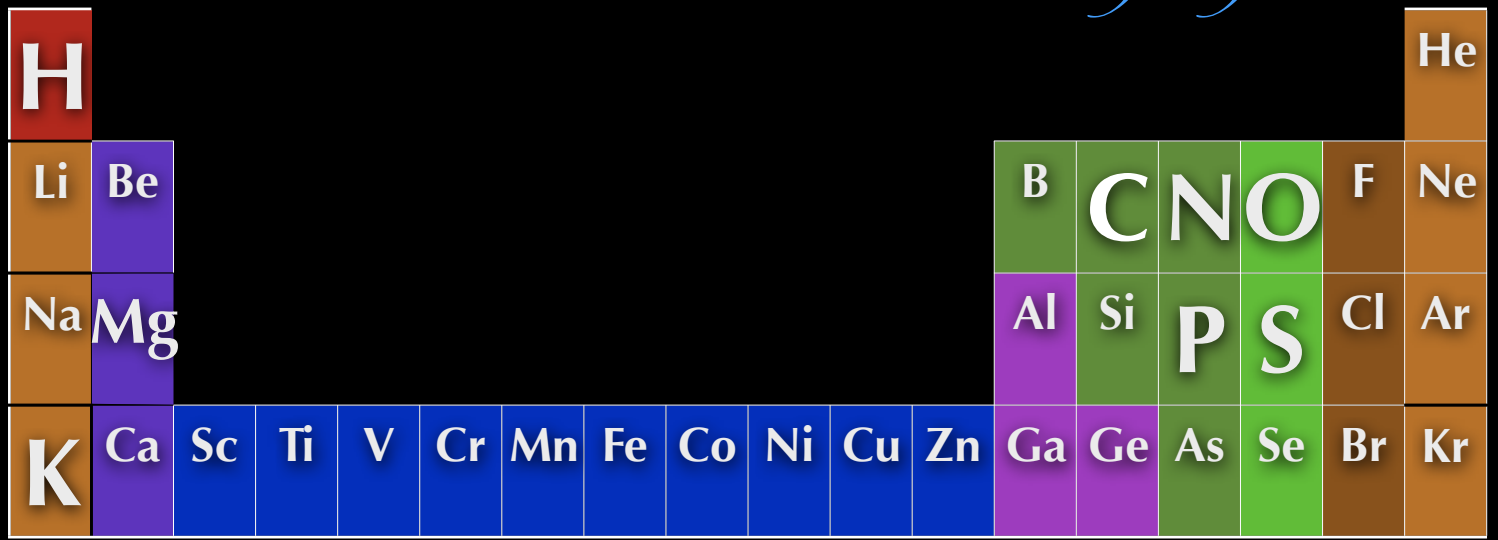

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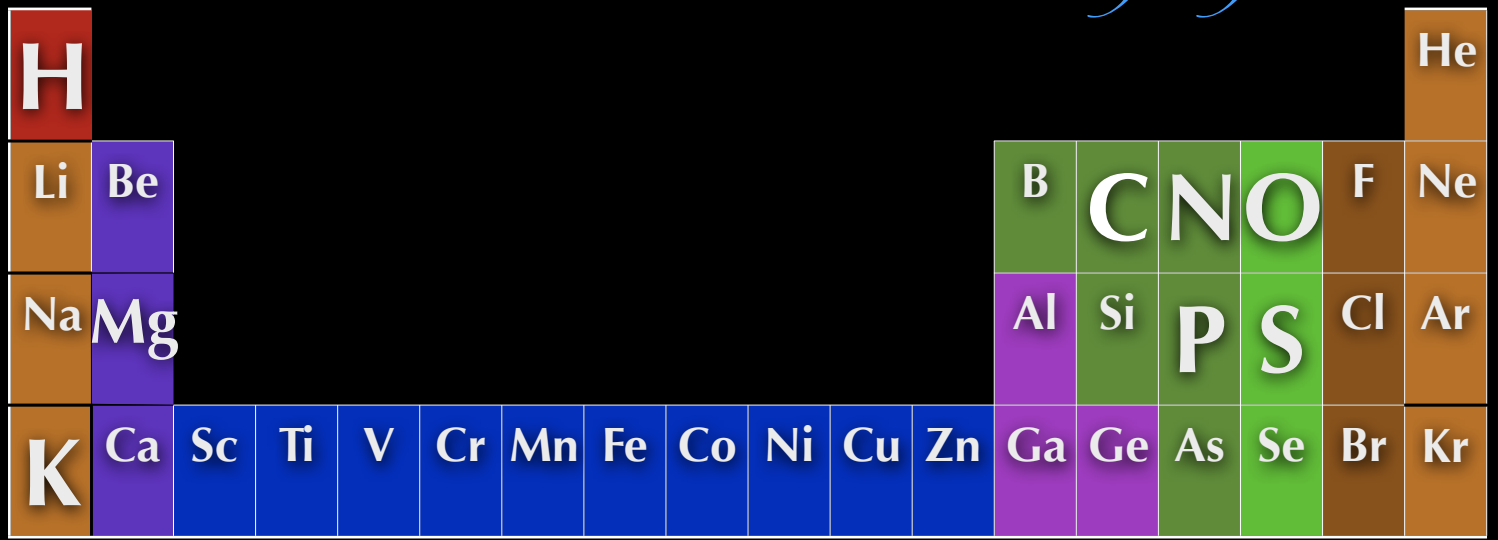

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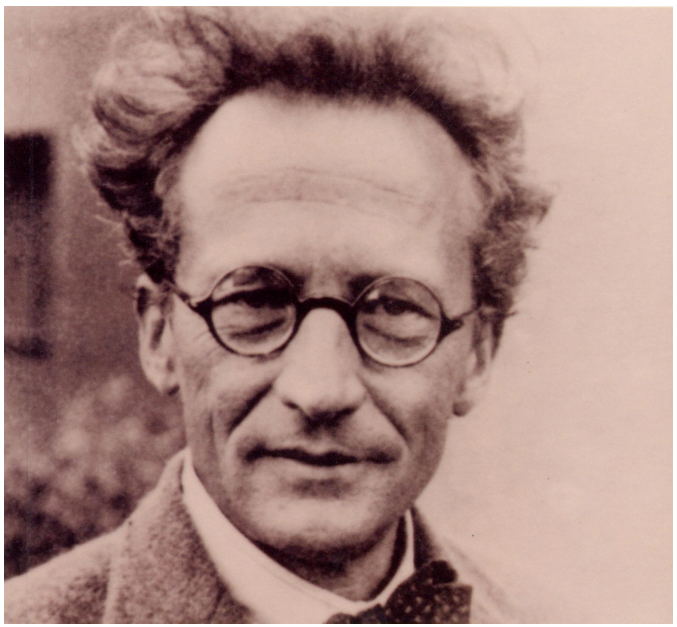
- Potassium – Principal inorganic cation in the cell and cofactor for some enzymes
- Magnesium – Cofactor for many enzymes and present in cell walls and membranes

a physicist's *approach*



Schrödinger, 1944

We can try a physicist's approach

When is a piece of matter said to be alive? When it goes on 'doing something', moving, exchanging material with its environment, and so forth, and that for a much longer period than we would expect an inanimate piece of matter to 'keep going' under similar circumstances. When a system that is not alive is isolated or placed in a uniform environment, all motion usually comes to a standstill very soon ... After that the whole system fades away into a dead, inert lump of matter. A permanent state is reached, in which no observable events occur. The physicist calls this the state of thermodynamical equilibrium, or of 'maximum entropy'. Practically, a state of this kind is usually reached very rapidly." Life feeds on "negative entropy".

What is life? Erwin Schrödinger, 1944

Does size matter?

Organisms must be so much larger than individual atoms that Brownian motion and other laws governing molecules become statistical. Example: Sinking fog. *In fact, life is statistical based on populations.

How does life circumvent this with DNA? Having it a solid (frozen) so less susceptible to Brownian motion. Think for a moment about multiple genomes.

What is the smallest size for life? There are living Bacteria and Archaea that have cell sizes from 0.02–400 μm^3. The smallest size for a free-living organism is suggested to be largely set by the catalytic efficiency of enzymes and protein synthetic machinery. Because of fluctuations in the environment, cells must maintain machinery to cope with various catastrophes; these mechanisms increase the minimum size of the cell.

What is life? *Erwin Shrödinger, 1944*
Koch, What size should a bacterium be? Annu. Rev. Microbiol. 1996. 50:317–48

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single droplet

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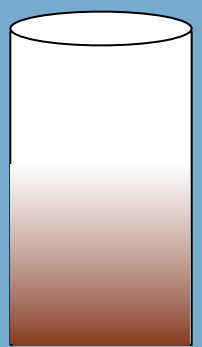

sinking fog

What is life? *Erwin Shrödinger, 1944*
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Create disequilibria

Negative entropy

Isotope fractionation

Atmospheric disequilibrium

What does life do?

What is life? Essential characteristics

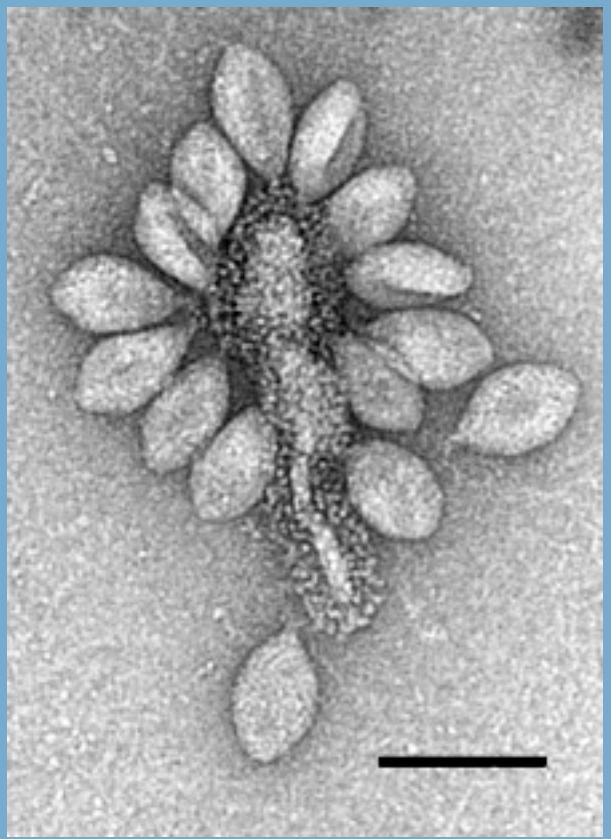
- Self-reproduction
- Mutation
- Metabolism

(Eigen, 1995)

But would a person without one of these characteristics still be "alive"? What if a whole species lacks the ability for self-reproduction (e.g., mule)? And so on. Does a fire "metabolize"?

Are viruses alive?

- Viruses need host to replicate.
- How did viruses arise?
  - Viruses arose from free-living organisms
  - Viruses arose from the host-cell genome
  - Viruses co-evolved with cellular life.



Mimivirus: an enormous DNA virus

- Isolated from amoebae growing in water tower.
- It has a 1.18 Mb genome, bigger than 20 cellular organisms from Archaea and Eubacteria.
- Most unexpected is the presence of numerous genes encoding central protein-translation components, as well as topoisomerases, DNA repair pathways, chaperonins, polysaccharide synthesis enzymes and one intron-containing gene.
- So, where is the boundary between viruses and parasites? Perhaps viruses arose at time of evolution of eukaryotes?

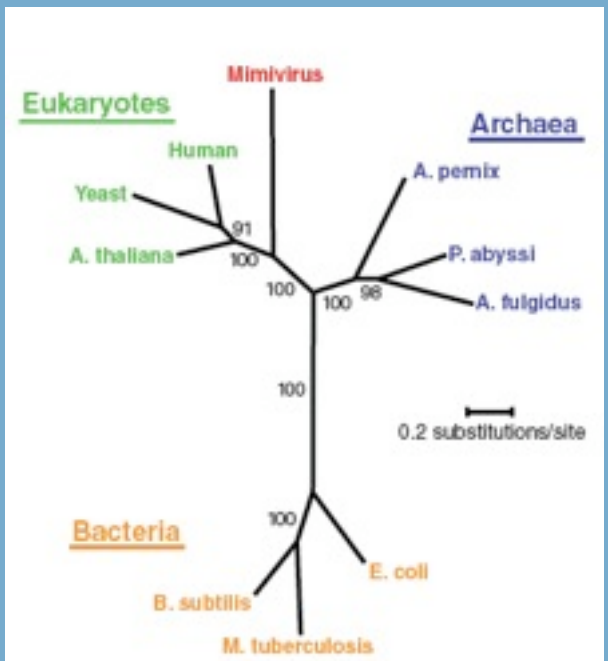
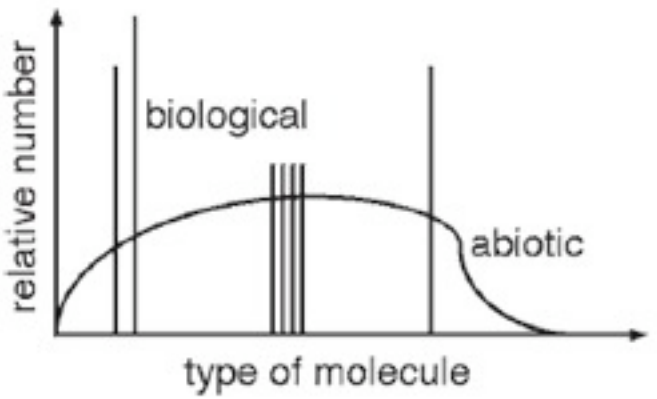


Fig. 3. A phylogenetic tree of species from the three domains of life (Eukaryota, Eubacteria, and Archaea) and Mimivirus. The tree was inferred with the use of a maximum likelihood method based on the concatenated sequences of seven universally conserved protein sequences:

The Lego Principle

Life uses a subset of all the possible molecules, thus a non-random distribution. Look for selection, e.g., L amino acids.



DOI: 10.1371/journal.pbio.0020302.g002

Figure 2. Comparison of Biogenic with Nonbiogenic Distributions of Organic Material

Nonbiological processes produce smooth distributions of organic material, illustrated here by the curve. Biology, in contrast selects and uses only a few distinct molecules, shown here as spikes (e.g., the 20 l-amino acids on Earth).

McKay, 2004, What is life and how do we search for it on other worlds? PLoS Biology Volume 2 | Issue 9 | e302

What is **Life** *like?*

We can describe its properties

1. A flexible, self-made bounding membrane…
2. Coordinated groups of specific catalysts (usually proteins)…
3. Molecular machinery to convert an external source of energy … into forms suitable to drive reactions within. the cell.
4. A hereditary system of information storage (DNA)
5. Each division must accurately provide each new cell with a full set of hereditary instruction
6. Interlocking control systems that regulate the varied functions to allow flexibility and adaptation to changing environments
7. Provision of means for defense

What is Life? A closer look", Engineering & Science/No. 3, 35-37, 1996, by Robert L. Sinsheimer

The seven pillars of life

1. Program
2. Improvisation
3. Compartmentalization
4. Energy
5. Regeneration
6. Adaptability
7. Seclusion

Koshland, Science 295: 2215 (2002)

Life *is an* emergent property

What is emergence?

In biology:

- The act or process of coming out, appearing, or coming about.
- The appearance of the adult form (imago) of an insect on the completion of the change (metamorphosis) from the larval stage.
- An outgrowth that lacks sap-conducting tissue for example, a thorn, coming from the body surface of a plant.

In philosophy: higher order phenomena cannot be predicted based on lower levels.

Examples of emergence in biology

Origin of self-replication

Origin of metabolic pathways

Origin of eukaryotic cell

Origin of multicellularity

Levels of selection (includes extinction)

Exaptation (e.g., origin of flight, radiation resistance, sex)

Emergent function

Emergent fitness

Implication.

Life is an emergent property

Is life an emergent state?

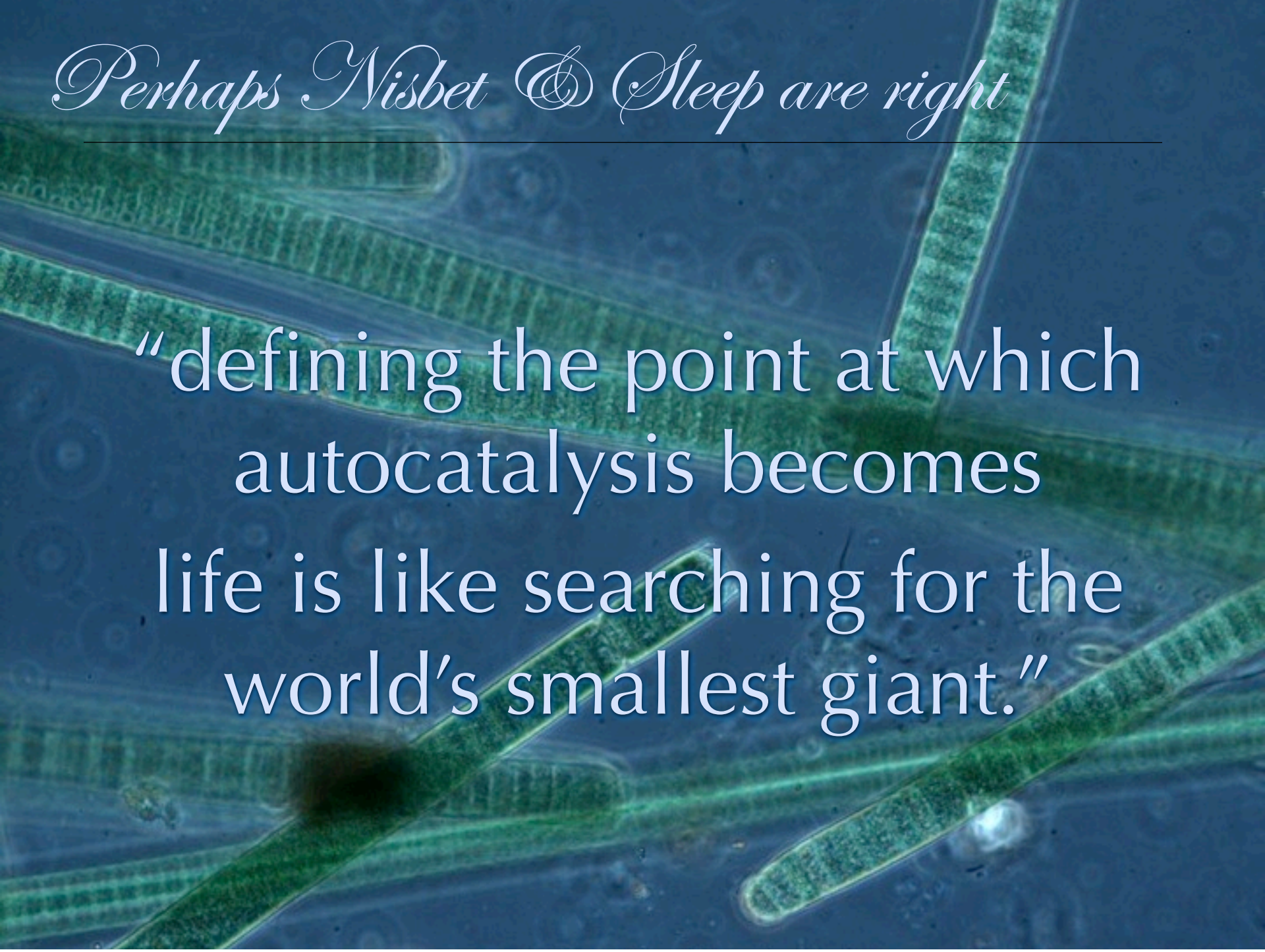
If you invert this, the result is, "IS REDUCTIONISM THE ANSWER?" That is, is life more than would be predicted by chemistry and physics?

If so, at one point did it emerge?

What if we start at the beginning

When did life begin?
That is, where is the line between pre-biotic and biotic?

Perhaps Nisbet & Sleep are right



"defining the point at which autocatalysis becomes life is like searching for the world's smallest giant."

Jack W. Szostak, David P. Bartel & P. Luigi Luisi

We can consider life as a property that emerges from the union of two fundamentally different kinds of replicating systems: the informational genome and the three dimensional structure in which it resides.

Synthesizing life, Nature Insight, 2001

a Philosopher's *approach*

The Nature of Definition

Carol Cleland & Chris Chyba (2002) *Origins of Life and Evolution of the Biosphere* **32**: 387–393.

Some Varieties of Definition

Ostensive and Operational definitions indicate the meanings of terms via representative examples (by directly indicating, in the former case, and by supplying tests, in the latter case), e.g.,'University' means Stanford University, Cambridge University. 'Acid' means anything that turns litmus paper red.

Ideal (full or complete) Definitions specify the meanings of terms by analyzing concepts and supplying a conjunction of predicates (or identifying description) that completely determines the extension of a general term by specifying necessary and sufficient conditions for falling into its extension, e.g., 'Bachelor' means unmarried, human male.

Why a definition of 'life' is unlikely to provide a satisfying answer to the question: What is life?

Natural Kind Terms

designate natural categories--categories that exist in nature independently of human interests and concerns, e.g., 'bird,' 'temperature'

Non-natural Kind Terms: designate categories that depend on human interests, concerns, and conventions, e.g., 'bachelor,' 'fortnight,' 'chair'.

Is LIFE a non-natural Kind Term?

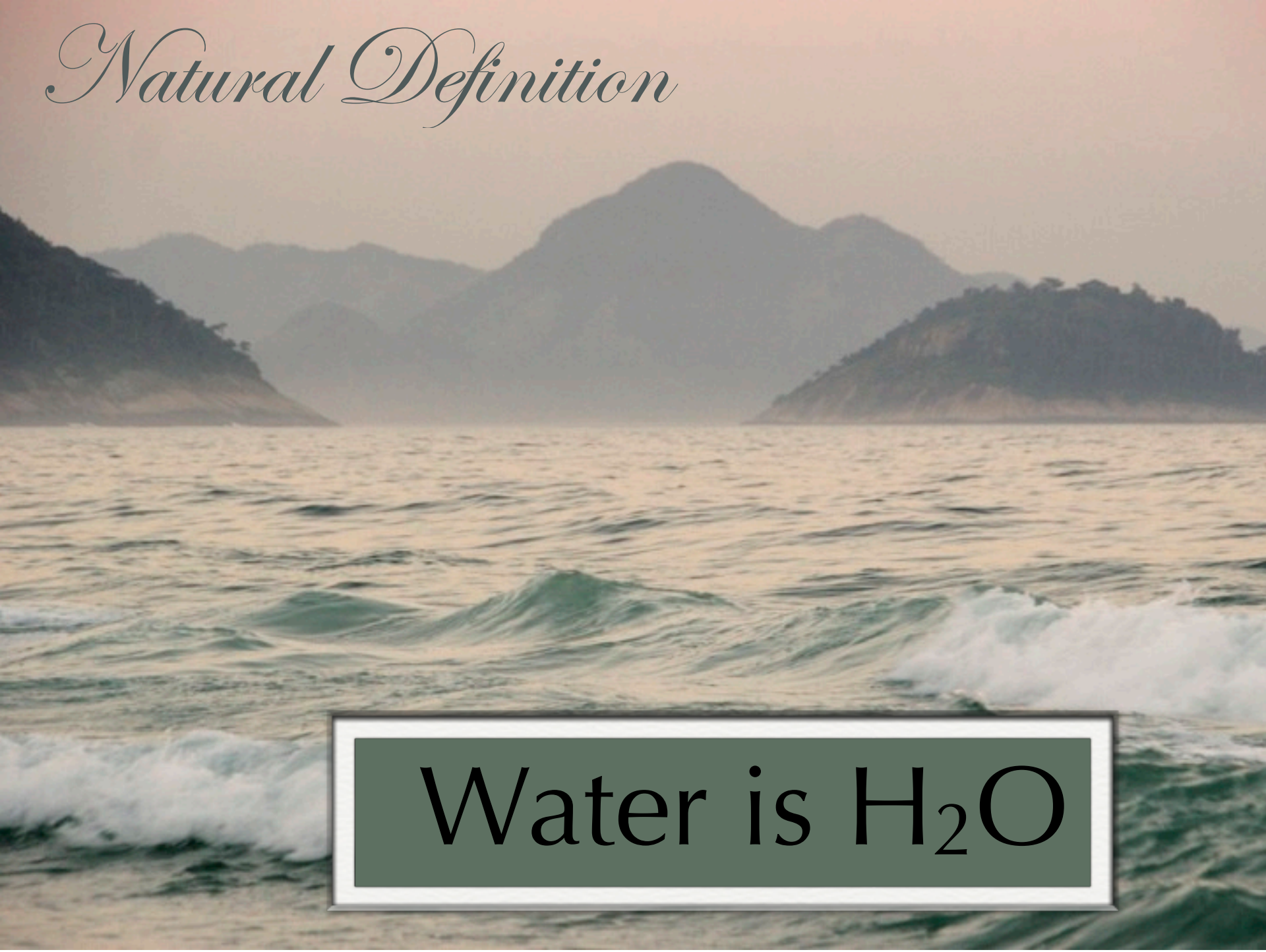
(Carol Cleland)

Non-natural definition

"Water is sometimes sharp and sometimes strong, sometimes acid and sometimes bitter, sometimes sweet and sometimes thick or thin, sometimes it is seen bringing hurt or pestilence, sometimes health-giving, sometimes poisonous. It suffers change into as many natures as are the different places through which it passes. And as the mirror changes with the colour of its subject, so it alters with the nature of the place, becoming noisome, laxative, astringent, sulfurous, salty, incarnadined, mournful, raging , angry, red, yellow, green, black, blue, greasy, fat or slim…." da Vinci, 1513

The Notebooks of Leonardo da Vinci, Vol II, 1513. Edward MacCurdy, trans. New York: Reynal and Hitchcock, 1938, pp. 97-98)

Natural Definition



A Dilemma for Defining Life:

Either life is a natural kind or not

If life is a natural kind, then attempts to define 'life' are currently impossible, for what we seek is not an explication of our current concept of life but an understanding of the inherent nature of life as something independent of human interests and concerns.

If life is not a natural kind, then attempts to define 'life' are not fundamental in a scientific sense because the term 'life' is not a natural category.

Thus, attempts to define 'life' are either currently impossible or not scientifically fundamental.

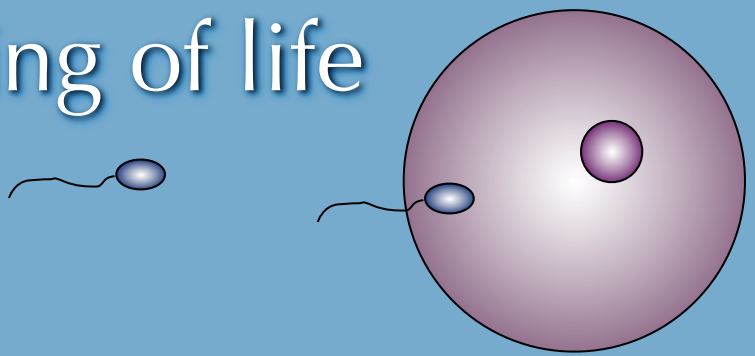
At least we need an

operational

definition

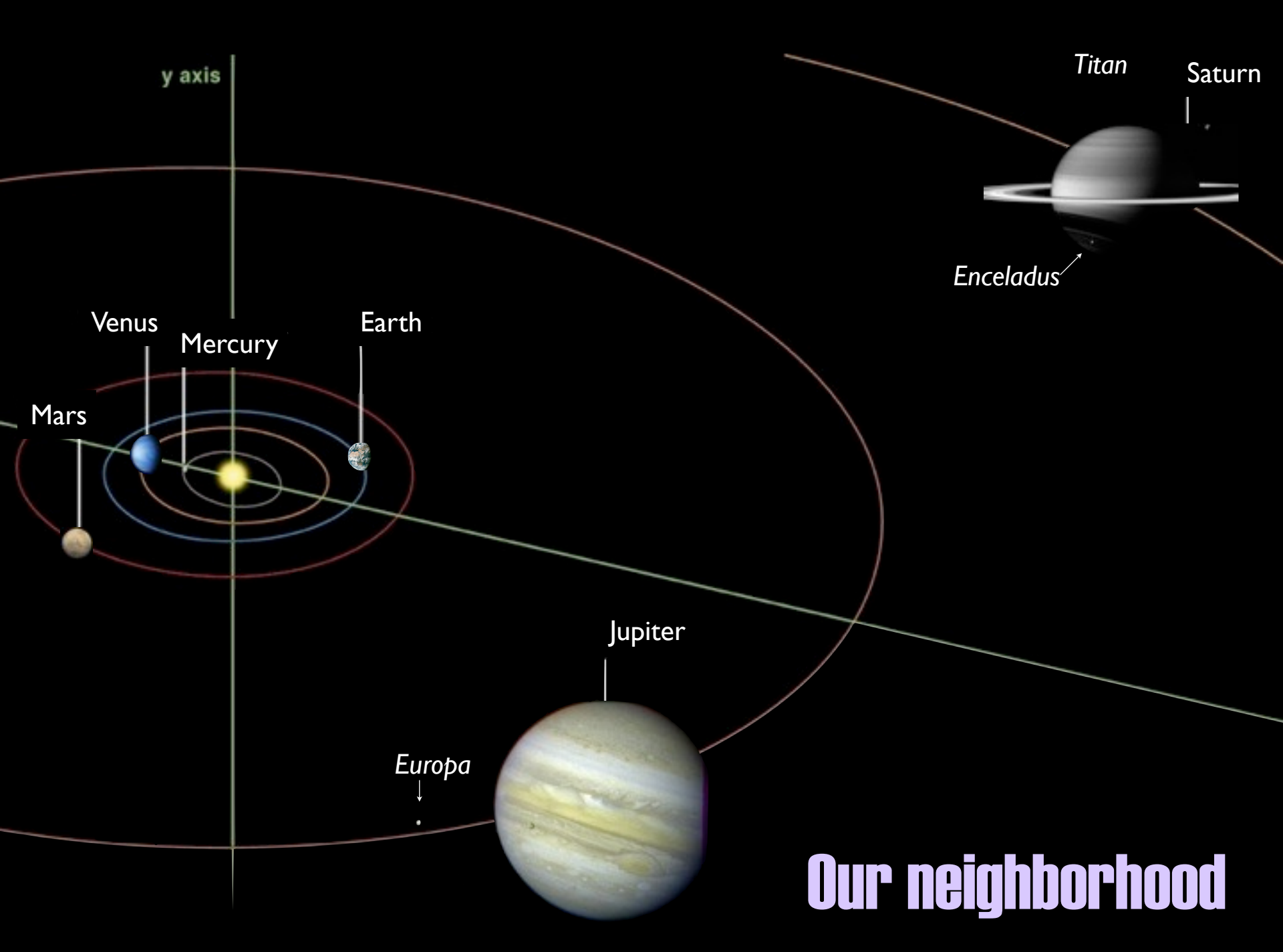
Or even a practical definition

Beginning of life



End of life

Synthetic life
Astrobiology


y axis
Titan
Saturn
Enceladus
Venus
Mercury
Earth
Mars
Jupiter
Europa
Our neighborhood


and beyond

Working definition

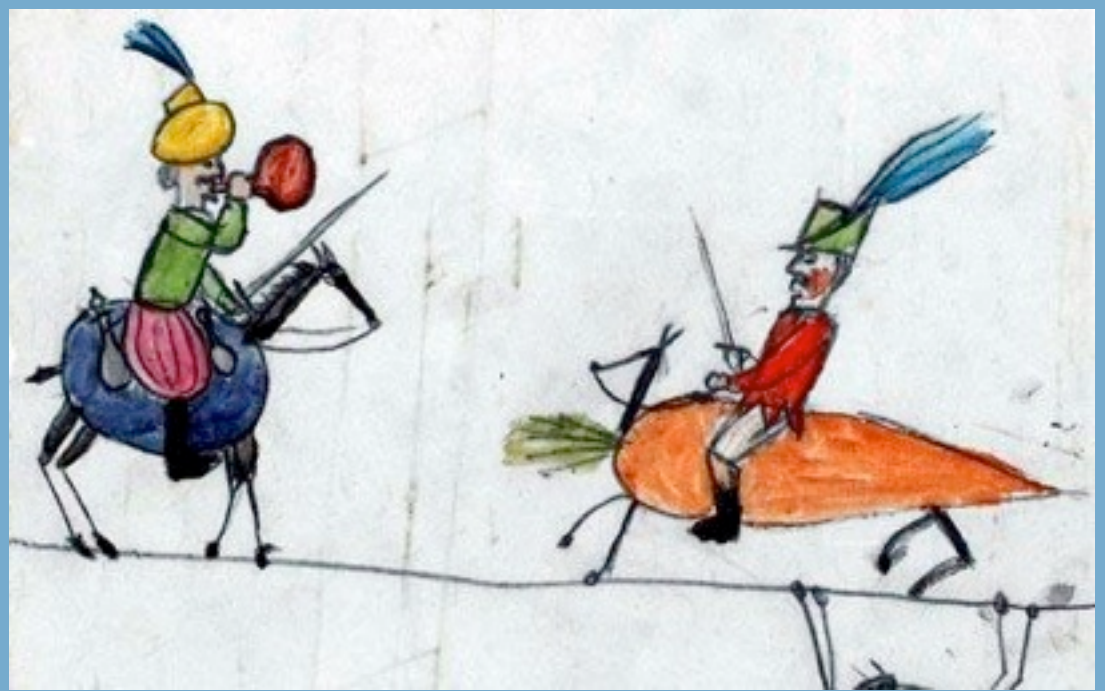
"Life is a self-sustained chemical system capable of undergoing Darwinian evolution."

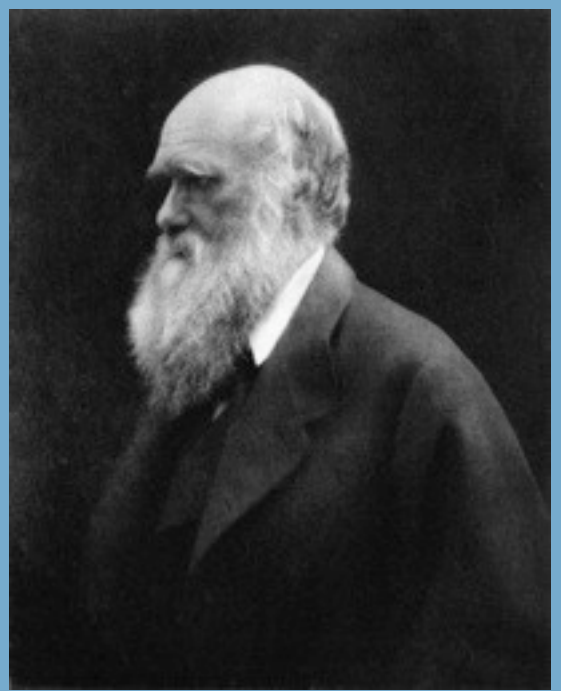
Joyce, G.F. 1994. Origins of Life: The Central Concepts. Deamer, D.W., Fleischaker, G.R., eds. Jones & Bartlett, Boston. pp. xi-xii.

versus

We'll know it when we see it.

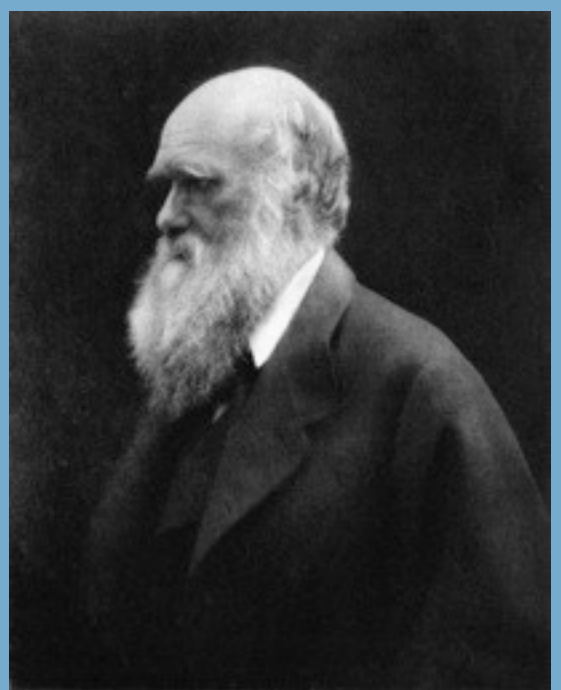
Is natural selection necessary?





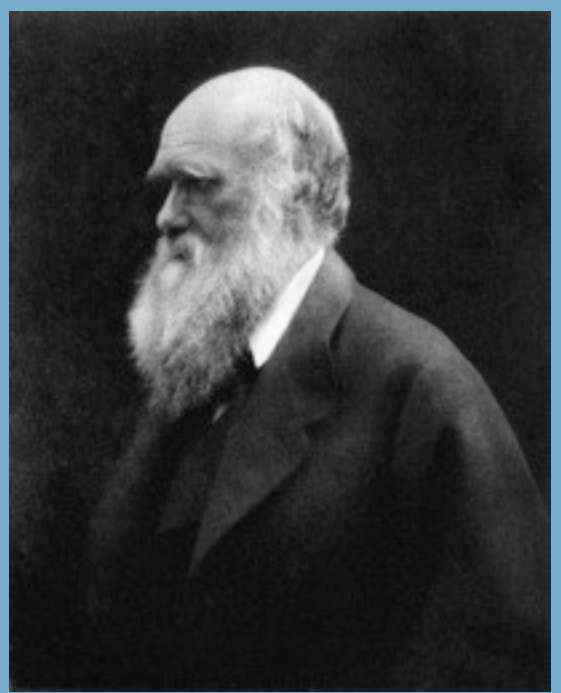
Is natural selection necessary?

- NASA includes natural selection



Is natural selection necessary?

- NASA includes natural selection
- But other mechanisms of evolution




Approaches

Approaches

- What does life need?

Approaches

- What does life need?
- What is life made of?

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- What does life need?
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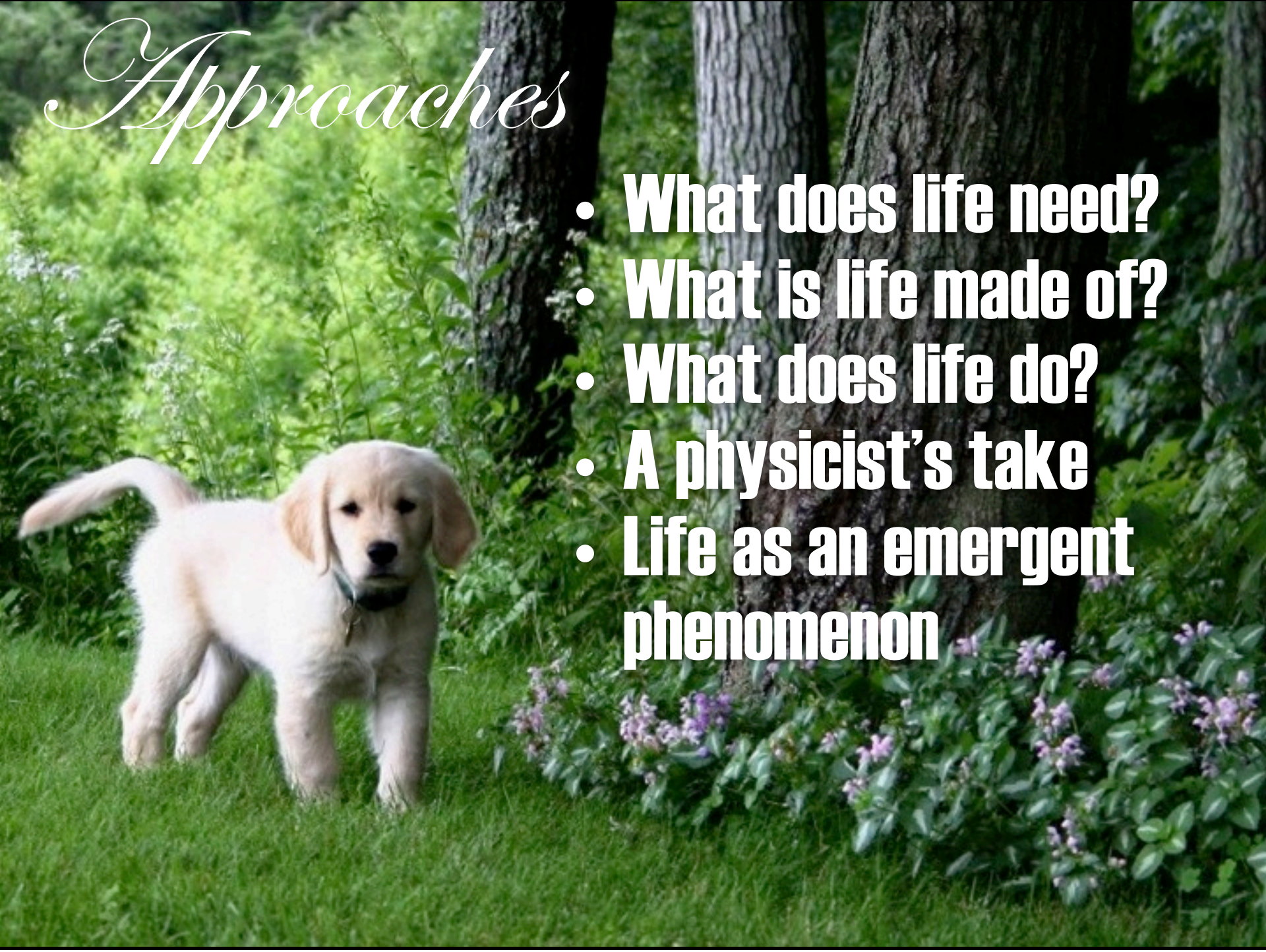
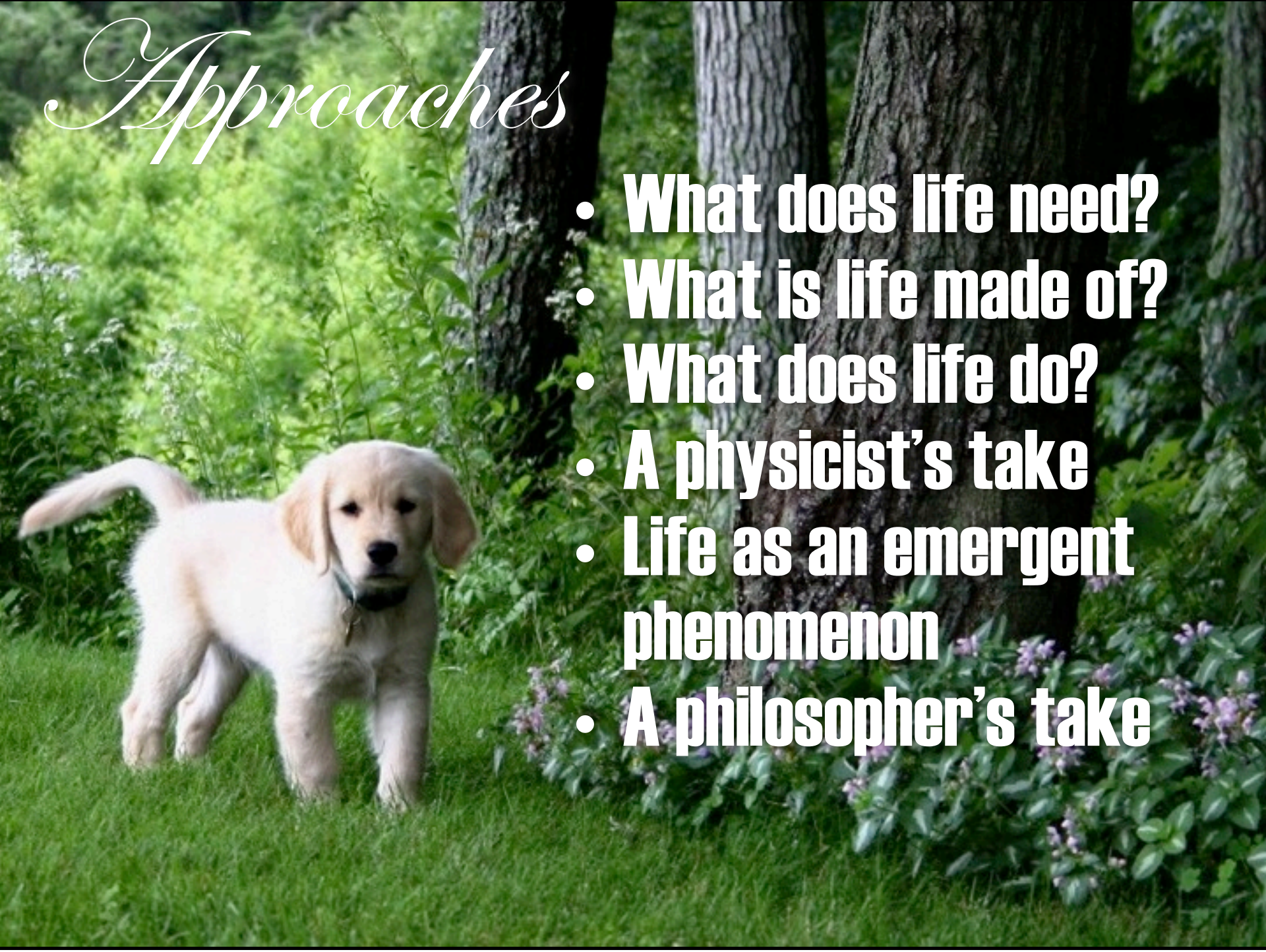
- A physicist's take

Approaches



- What does life need?
- What is life made of?
- What does life do?
- A physicist's take
- Life as an emergent phenomenon

Approaches



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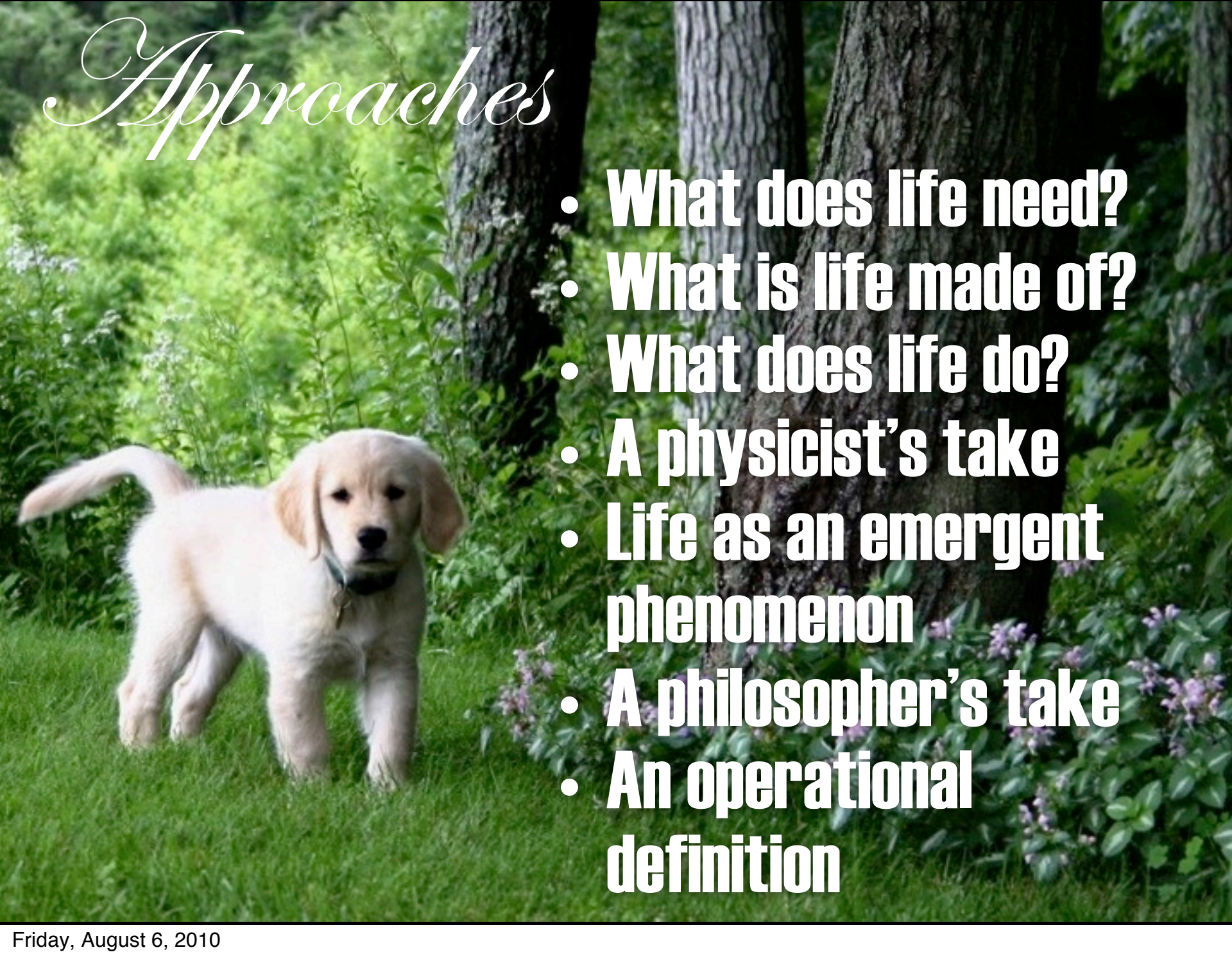
Approaches



- What does life need?
- What is life made of?
- What does life do?
- A physicist's take
- Life as an emergent phenomenon
- A philosopher's take
- An operational definition

What can we learn from Star Trek?

- Gene Rodenberry realized that if you can see eyes, easier to accept as life.
- What about sentience? Turing test: if you don't know if you are talking to a computer or person, it is alive. Next Generation, "The Measure of a Man". Is Data alive?
- Behavior. Creature in Deep Space 9 that behaved like a puppy although it was software. Original series – "Devil in the Dark". Rock that was silicon-based life form that was a mother trying to protect her young.
- What if they evolve? Next Generation, "Evolution". Nannites behave in collective manner and evolve.


What is life?

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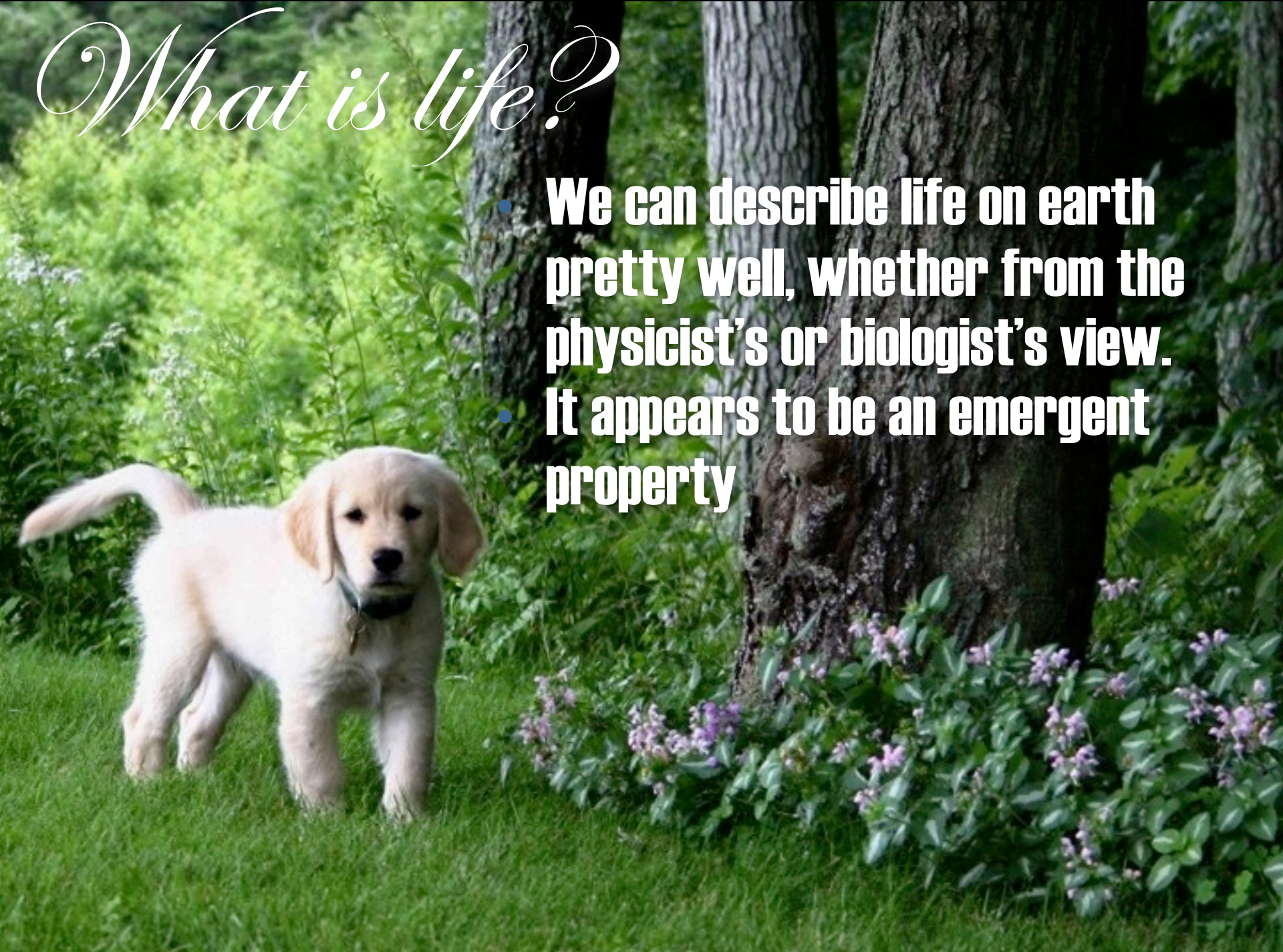
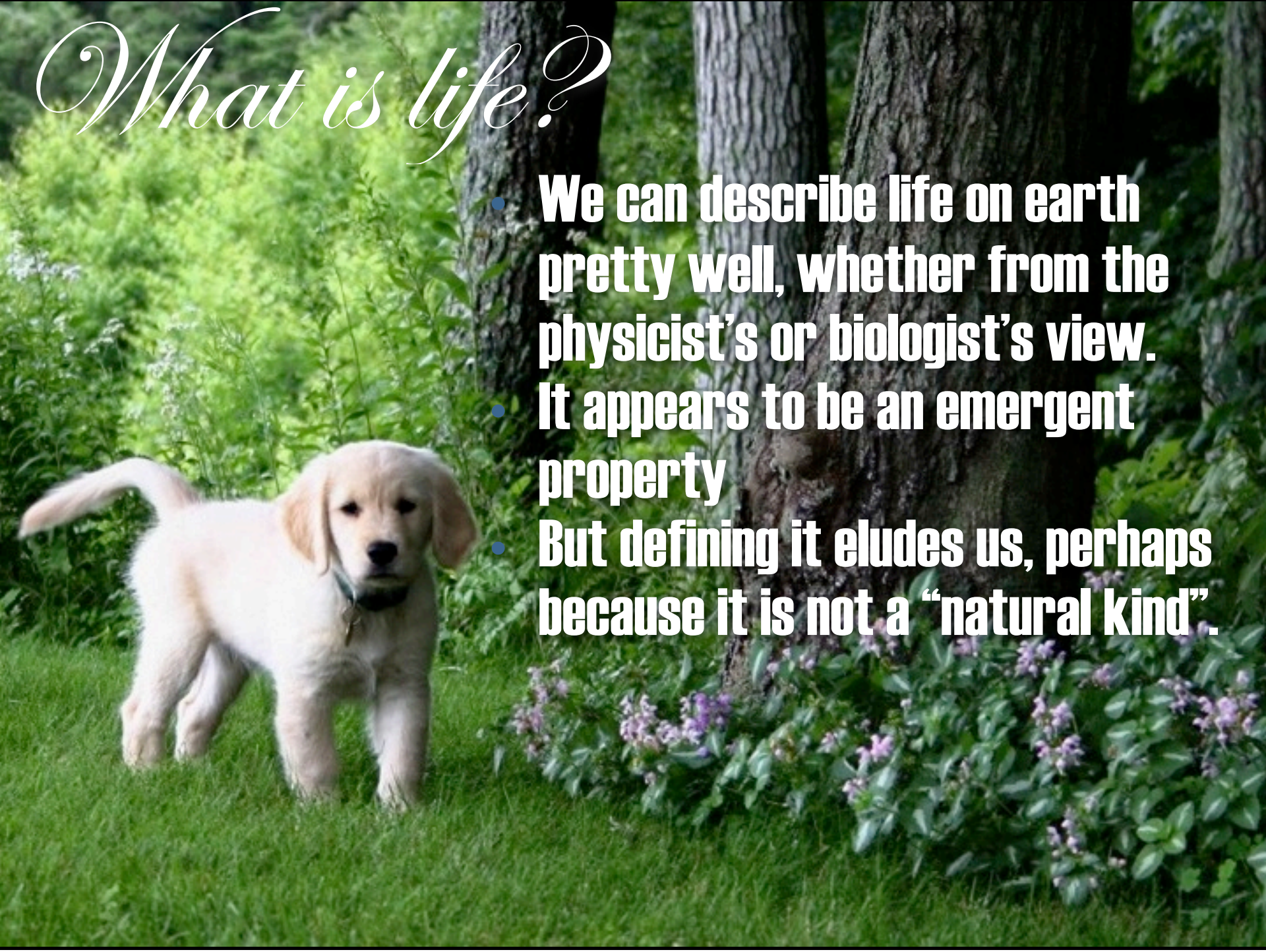


What is life?



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- But defining it eludes us, perhaps because it is not a "natural kind".

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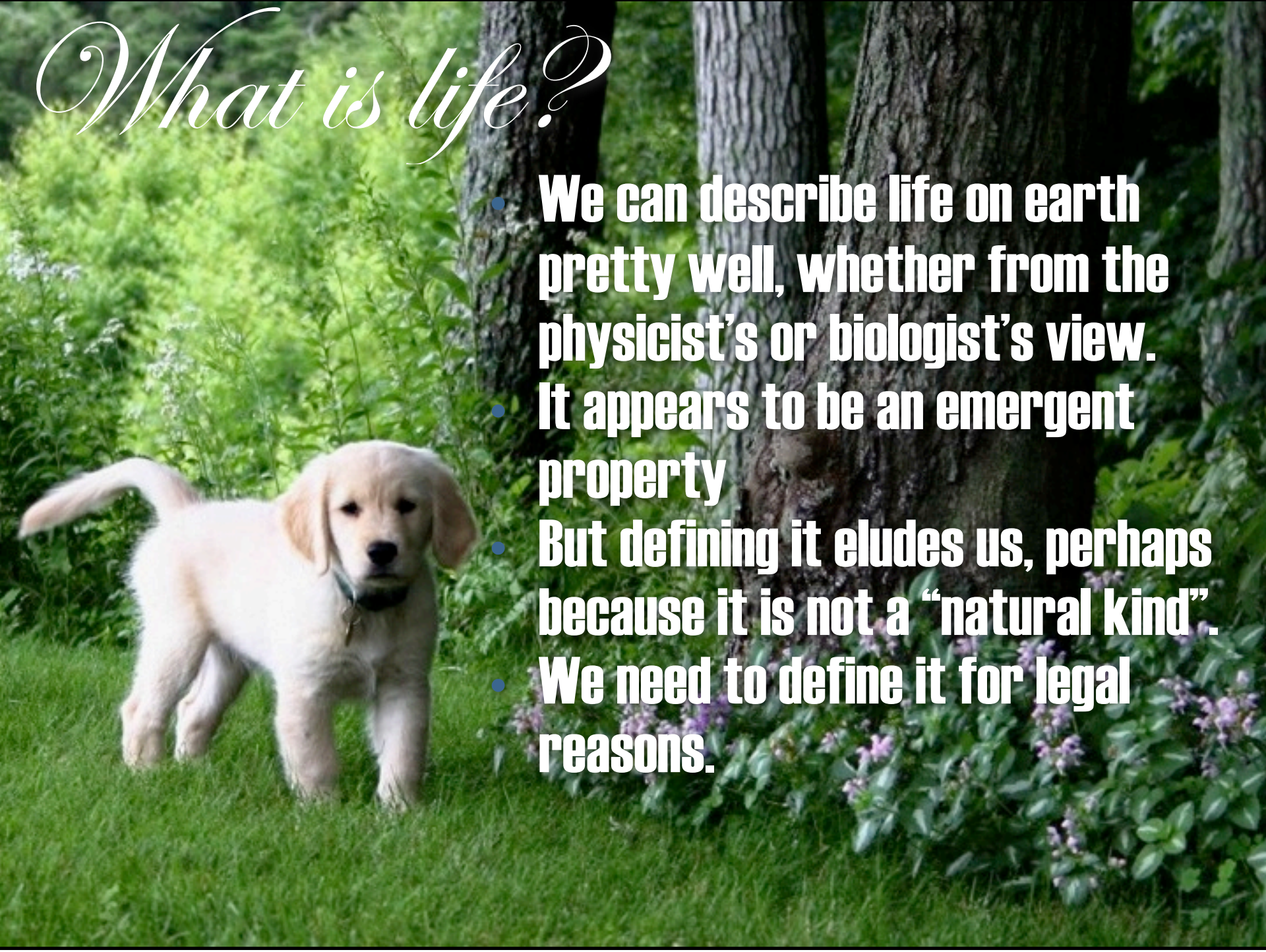

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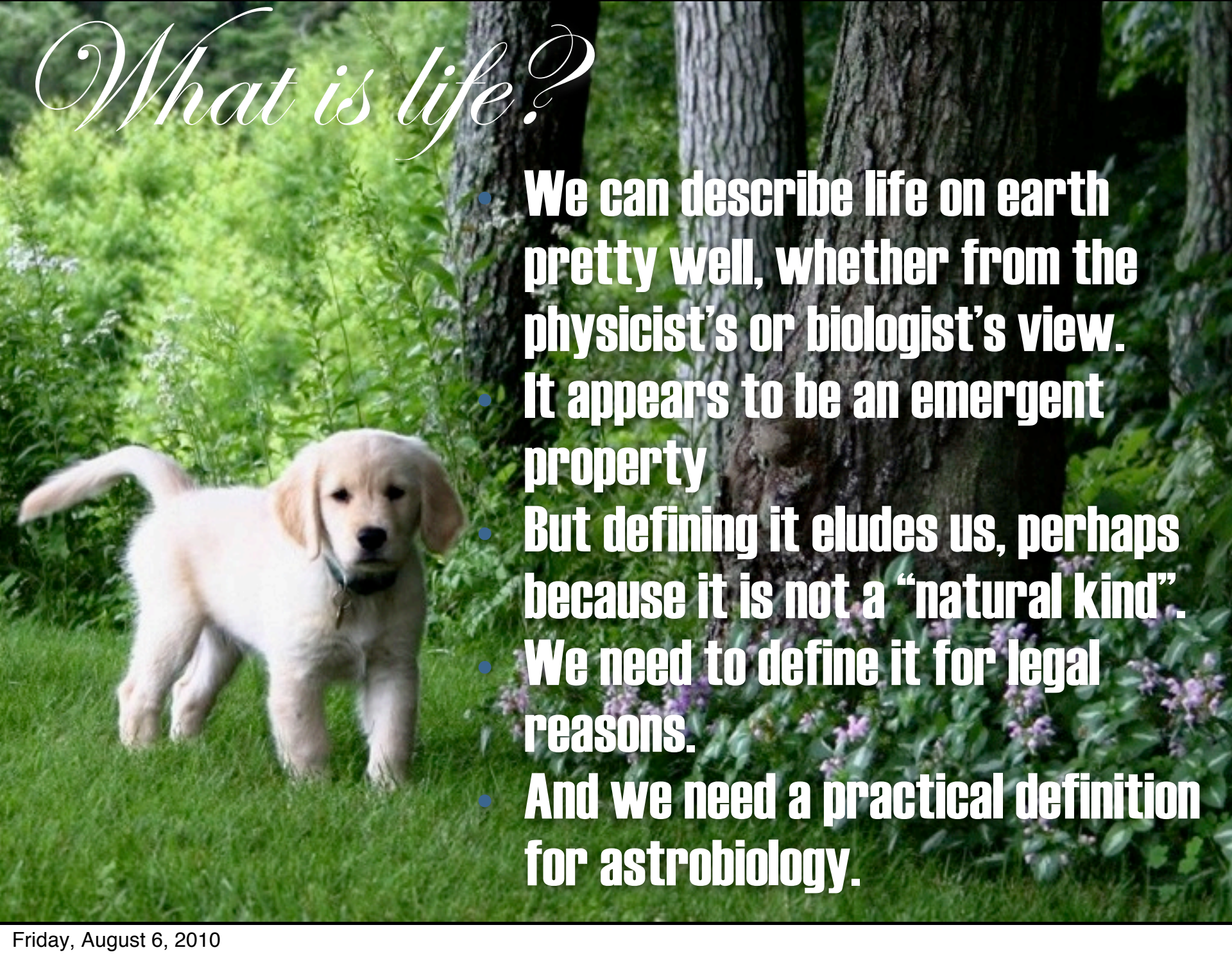

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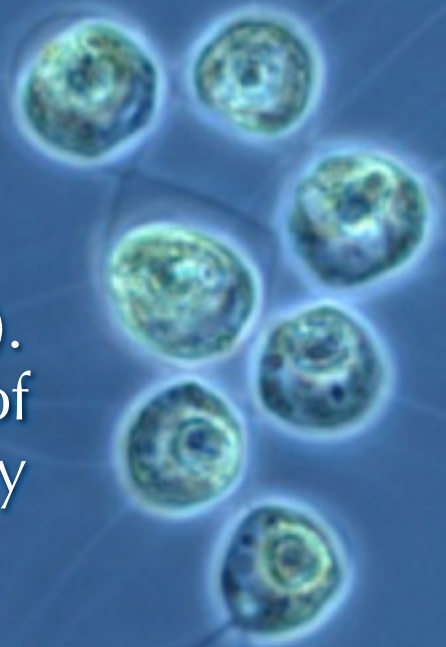
- It appears to be an emergent property
- But defining it eludes us, perhaps because it is not a "natural kind".
- We need to define it for legal reasons.
- And we need a practical definition for astrobiology.

What is Life? (Rothschild, 10/01)

- Life is historical. Normally molecules are interchangeable, individual organisms are not.
- Life as we know it must do everything possible to ensure survival of species. Life doesn't just do metabolism etc. Must self-heal, etc. In other words, must fight entropy. The penalty is extinction.
- However, the definition goes to the victors (us). We get to choose who we admit to the "club of life". If there are other sentient races, they may have a different definition, perhaps one that doesn't include us.
- This would suggest that "life" is a non-natural kind, at least we suspect so….



What is life?

- Perhaps it is only a matter of “taste”.