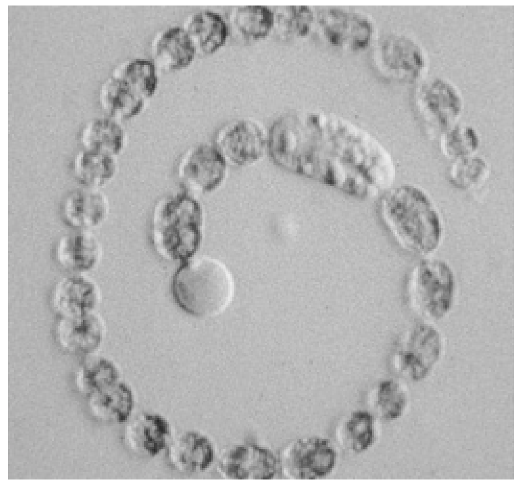
Lecture 16: Life in the Universe

Please remind me to take a break at 12:45 pm



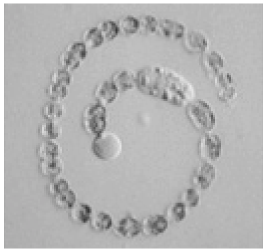
Claire Max

November 23rd, 2010

Astro 18: Planets and Planetary Systems

UC Santa Cruz

Schedule for project presentations next Tues and Thurs

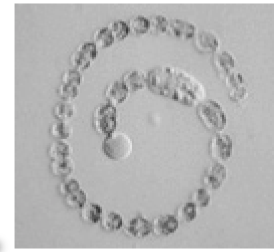


- **If you have some big constraint on which day your group needs to meet (e.g. somebody will be out of town Tues or Thurs), let us know at the break.**

- **We will have signup sheets for Tues and Thurs during the break. If there is an imbalance between Tues and Thurs, Jenn and I will move one or more groups to the other day**

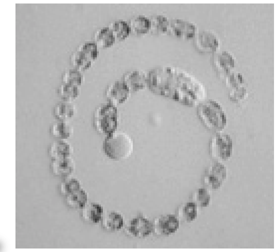
- **Check website late this afternoon to see which day your group will be speaking**

Very important: I need your advice about Pizza for next week!

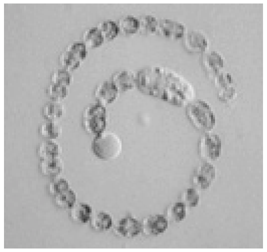


Suggestions about good pizza places that deliver?

Questions about what we expect for paper, presentations?



Practicalities: When to use quotes, citations, references



- **To avoid plagiarism, you must give credit whenever you use:**

  *** another person's idea, opinion, or theory;**

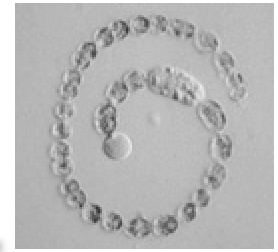
  *** any facts, statistics, graphs, drawings—any pieces of information—that are not common knowledge;**

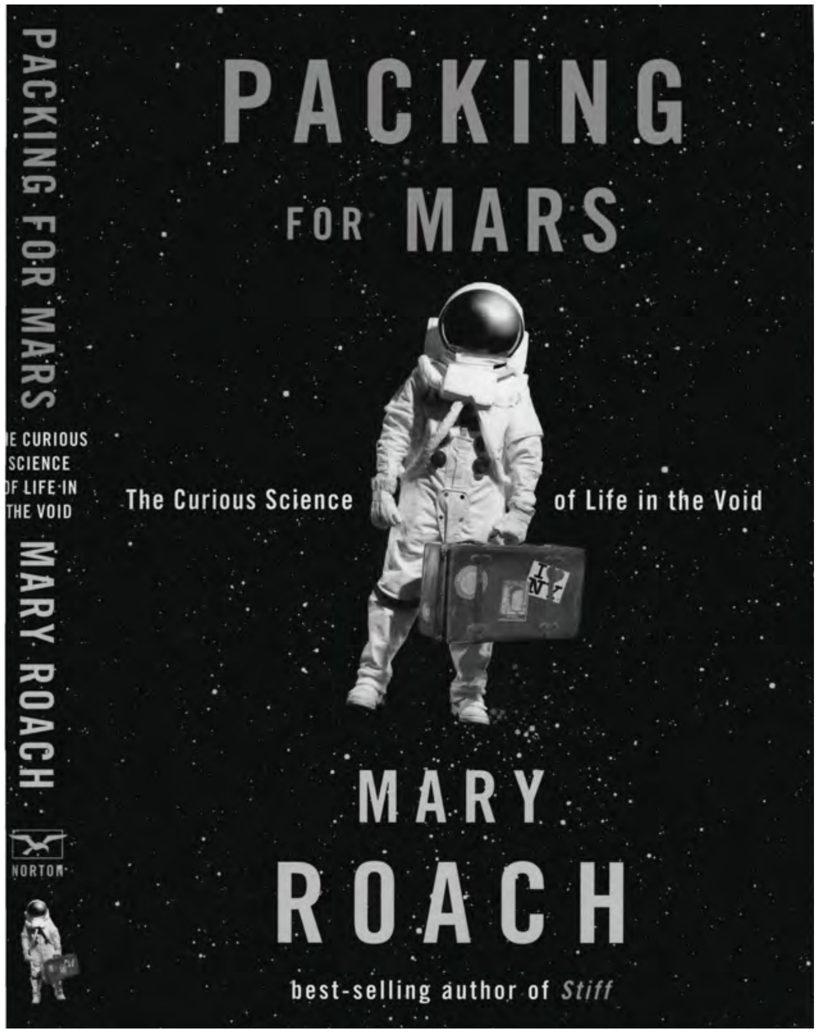
  *** quotations of another person's actual spoken or written words; or**

  *** paraphrase of another person's spoken or written words.**

- **See handout, from http://www.indiana.edu/~wts/pamphlets/plagiarism.shtml**

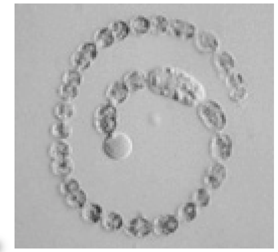
New book for groups discussing travel to other planets





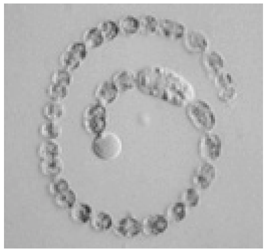
- **Just published**
- **Now on reserve in the Science and Engineering Library**
- **Very interesting: covers psychological issues as well as practical ones such as what to bring along**

Practicalities: Final Exam



- Tuesday December 7th, noon to 3pm
- In this classroom
- Bring scientific calculators (or borrow from us – sign up if you will need one so we won't run out)
- Review sessions in Sections next week; we will post a review sheet on class website

Practicalities: Final Exam info



- **Exam will consist of four parts:**

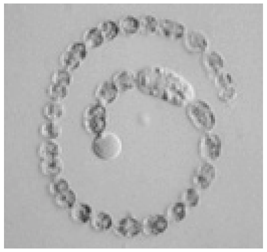
  Part 1: Multiple Choice Questions

  Part 2: Questions based on images of solar system objects and phenomena

  Part 3: Construct a concept map of your own (more details on next slide)

  Part 4: Short-Answer Questions

Exam question on concept maps: please prepare ahead of time!



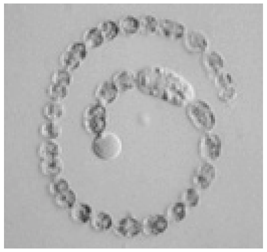
- In class we looked at concept maps that describe factors influencing planetary surface geology.

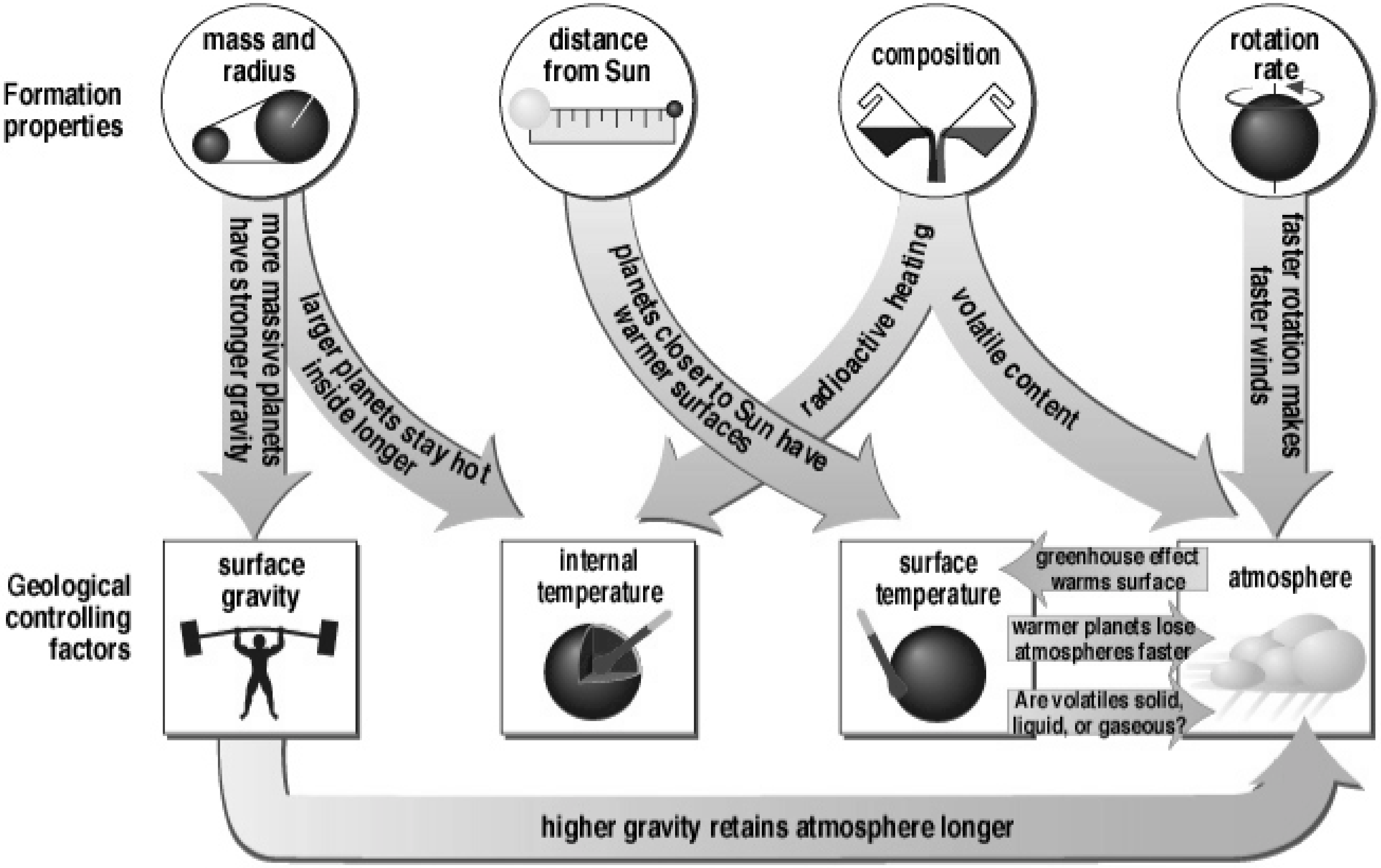
- Draw your own concept map describing factors influencing planetary atmospheres. Indicate with arrows and text labels how these factors interact with each other to determine the most important characteristics of the atmosphere.

- *Hint*: Factors you might include:

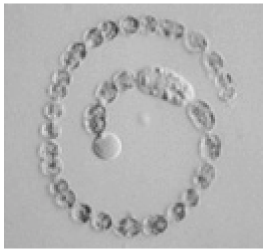
  – Planetary mass, surface gravity, rotation rate, distance from Sun, chemical composition, surface temperature, internal temperature, volcanism, greenhouse gases, cratering rate, temperature compared with the boiling or freezing point of water, presence of life.

Reminder: concept map for planetary geology



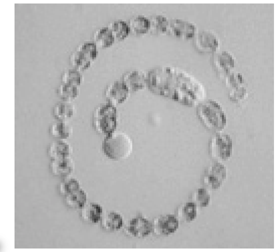


A loose end: How to remember order of planets?



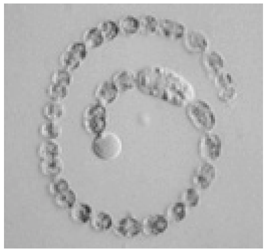
- Mercury Venus Earth Mars (Asteroids) Jupiter Saturn Uranus Neptune (not Pluto)
- Mnemonic: a sentence with same first letters of words. Helps remember a list.
- Example with Pluto: My very eager mother just sent us nine pizzas!
- Extra credit: Come up with a new mnemonic without Pluto.
  - Can start at either inside (Mercury) or outside (Neptune) of Solar System. (Starting at Neptune is worth a try….)
  - Nancy understood silly jokes after Mary explained very many
- Bring your candidates to the Final Exam

Outline of lecture



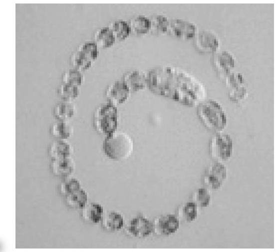
- **Life on Earth**
  - **How did it begin?**
  - **How did it change over time?**
- **Life elsewhere in the Solar System**
  - **Mars? Venus? in past?**
  - **Jovian moons? now?**
- **Life in other solar systems**
  - **Concept of a Habitable Zone**
- **Search for Extra-Terrestrial Intelligence (SETI)**

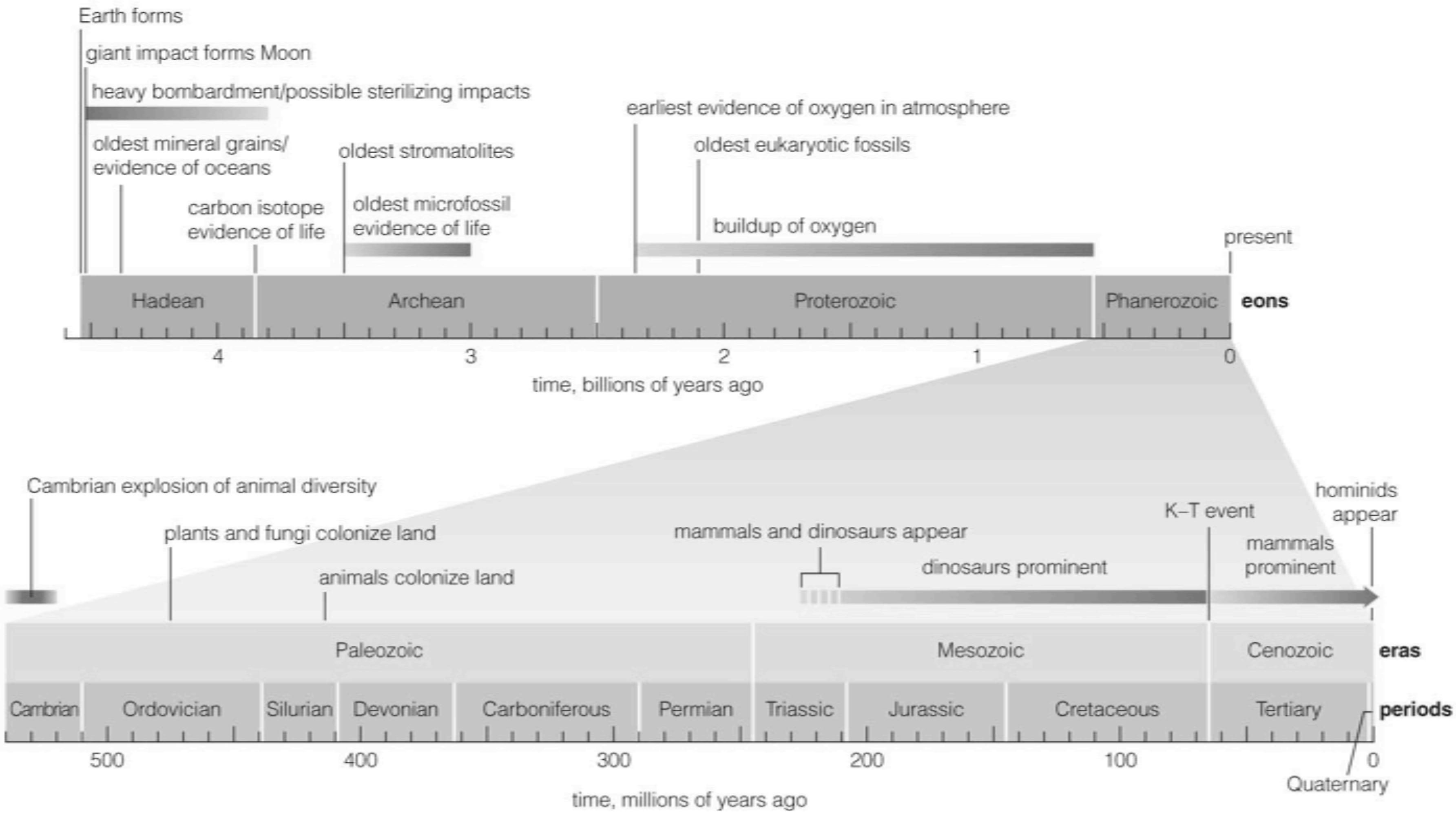
Life on Earth



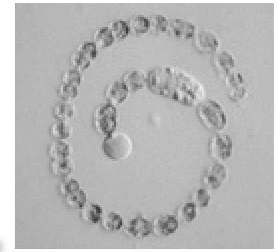
- **When did life arise on Earth?**
- **How did life arise on Earth?**
- **What are the necessities of life?**

When did life arise on Earth?



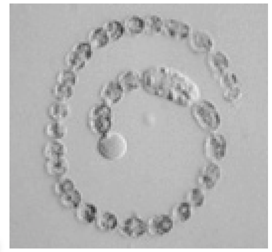


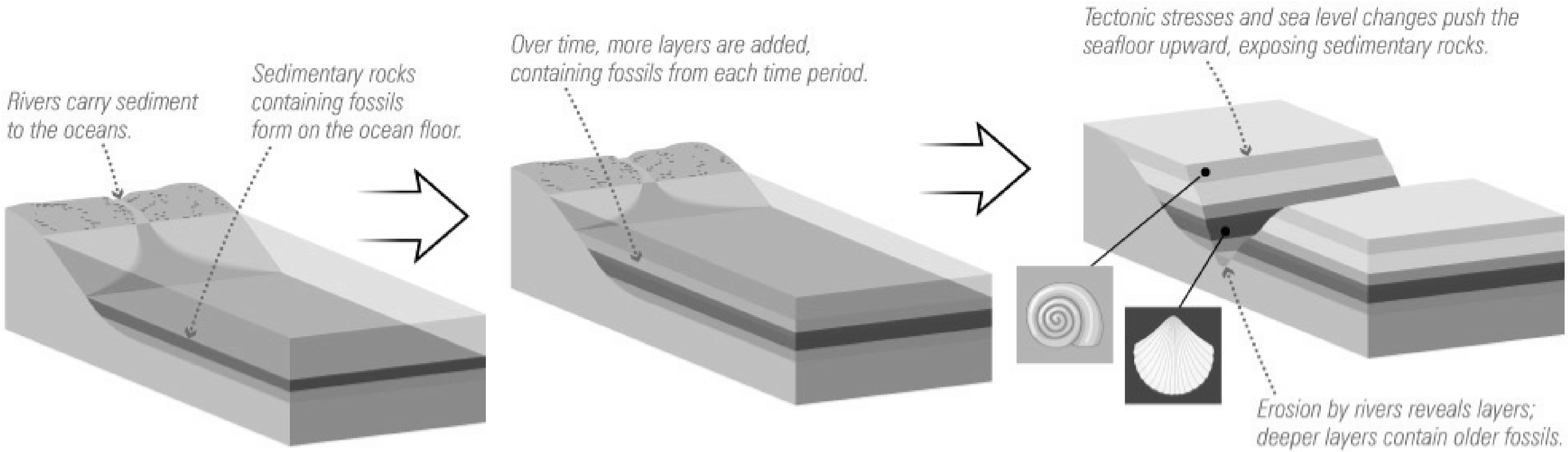
Earliest Life Forms



- **Life probably arose on Earth more than 3.85 billion years ago, shortly after the end of the late heavy bombardment**
- **Evidence comes from carbon isotopes**
- **There is still contraversy about age of earliest life on Earth**
  - **Hard to date the rock in which the carbon is embedded**

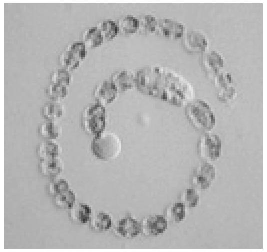
Earliest Fossils in Sedimentary Rock are from ~3.5 billion years ago





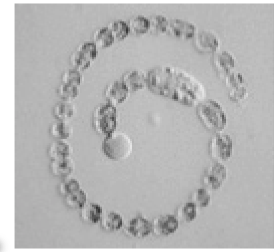
- **Relative ages: deeper layers formed earlier.**
- **Absolute ages: radiometric dating (isotope ratios)**

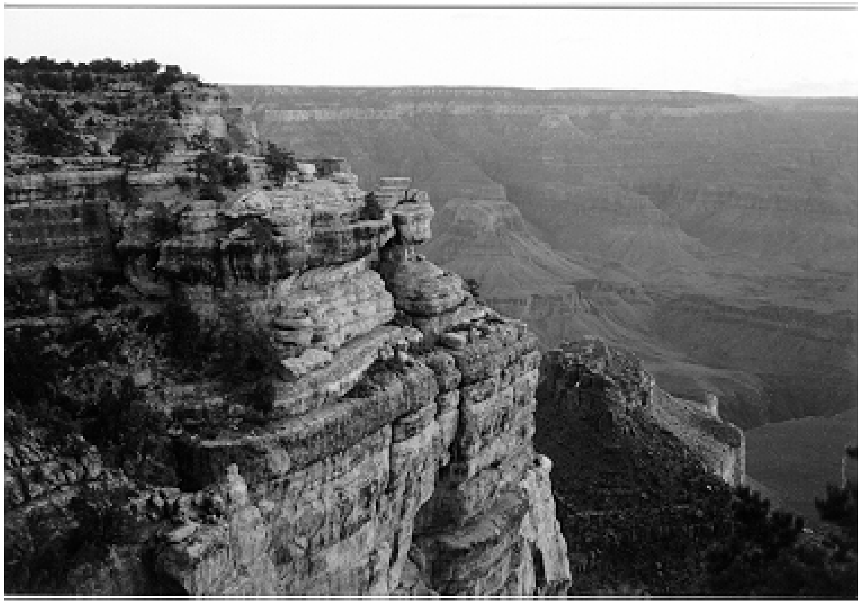
Use of Carbon isotope ratios to identify evidence of life in rocks

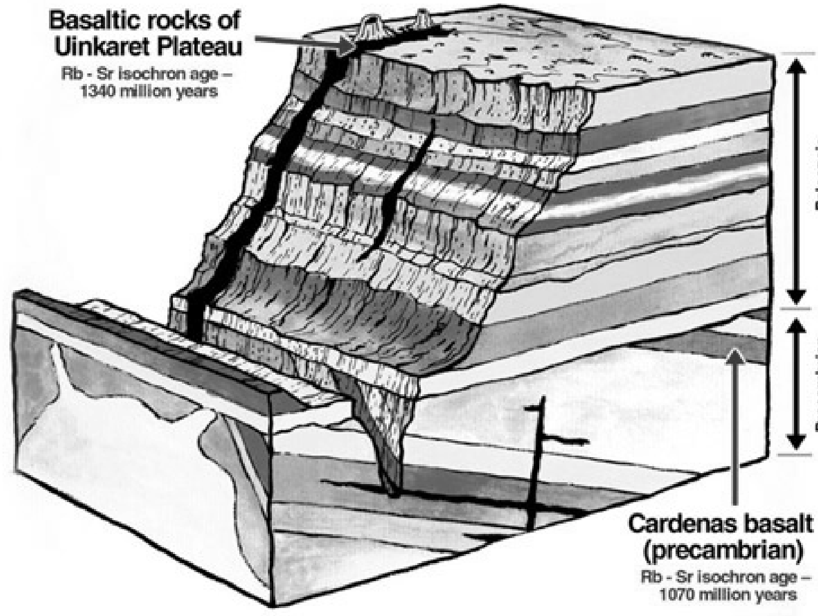


- **Isotopes: Atoms with the same number of protons in the nucleus (the same element), but different numbers of neutrons.**
- **Normally, carbon-13 (C-13, with atomic weight 13), is much rarer than C-12.**
- **Biological processes concentrate C-12, so when organic debris falls to the ocean floor, the C-12 to C-13 ratio rises still further in the sedimentary rock that forms.**
- **That ratio is preserved even in rocks so old that their fossils have been ground up and destroyed.**

Fossils in Sedimentary Rock

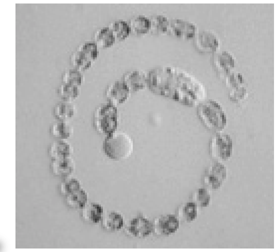




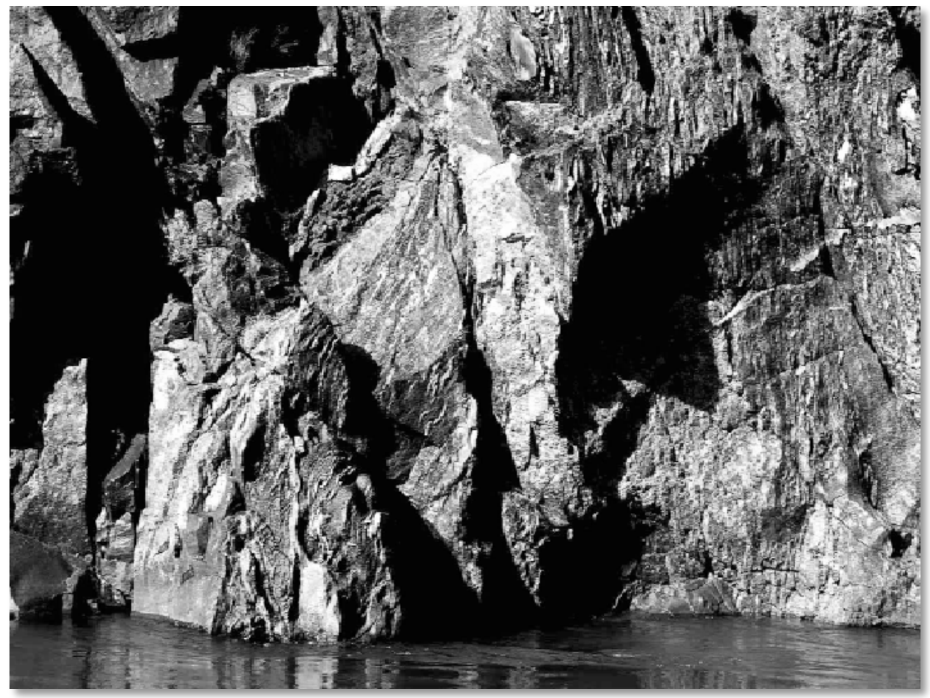


- **Rock layers of Grand Canyon record 2 billion years of Earth's history**

A Digression: Oldest Rocks in Grand Canyon



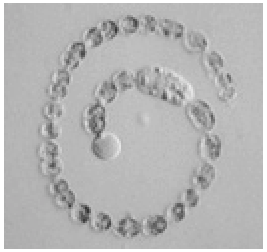
- **Vishnu Schist (about 2 billion years old)**



© Jerry Ginsburg 2004

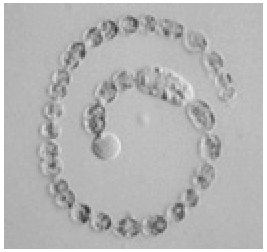
Vishnu Schist and Zoroaster Granite

Earliest Fossils



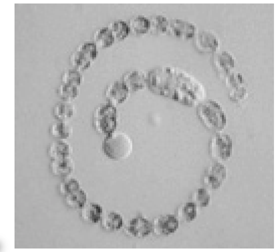
- **Oldest fossils show that bacteria-like organisms were present over 3.5 billion years ago**
- **Living cyanobacteria agglomorated together in big blobs called stromatolites**
- **Fossil stromatolytes show first evidence of cyanobacteria**

Origin of Life on Earth



- Did it come from somewhere else?
  - Panspermia
- Or did it form here on Earth
  - Chemical reactions to create building blocks of life

Could life have migrated to Earth? Theory called Panspermia.



- **Venus, Earth, Mars have exchanged tons of rock (blasted into orbit by impacts)**
- **Some microbes can survive many years in space...**
- **Theory that life came from beyond Earth is called "Panspermia" - "life everywhere"**

ORGANIC COMPOUNDS IN THE MURCHISON CHONDRITE

Class	Concentration (ppm)	Compounds Identified
Monocarboxylic Acids	**>300**	**20**
Polar Hydrocarbons	100-120	10+
Amino Acids	**60**	**74**
Amides	55-70	49+
Aliphatic Hydrocarbons	**>35**	**140**
Dicarboxylic Acids	>30	38
Aldehydes & Ketones	**27**	**9**
Aromatic Hydrocarbons	>15-28	87+
Hydroxy Acids	**15**	**51**
Alcohols	11	8
Amines	**8**	**10**
Basic N-Heterocycles	7	32
Purines and Pyrimidines	**1**	**5**
Sulfonic Acids	71	8
Phosphonic Acids	**2**	**4**

Credit:
Pawel Artymowicz

Over 14,000 chemical compounds have been identified in the Murchison Meteorite

Geochemical (mineralogic) map
of Murchison (CM) Chondrite
(carbonate shown in purple)

Credit: Arizona State Univ.

Comets: Dirty Snowballs with lots of organic compounds

- **Not yet clear whether there would have been enough organic compounds to "seed" life on Earth**

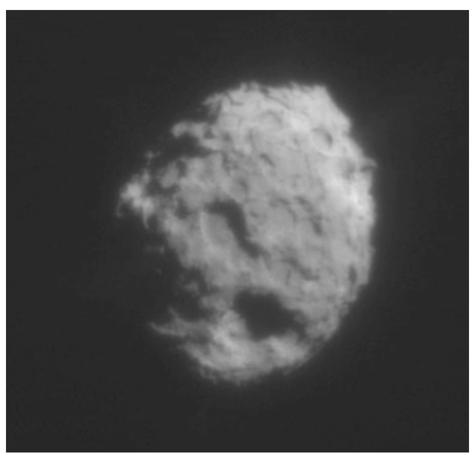
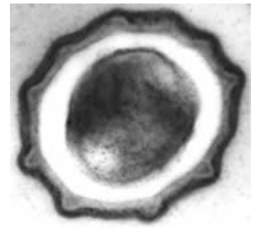
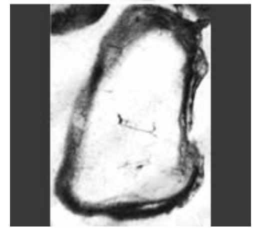


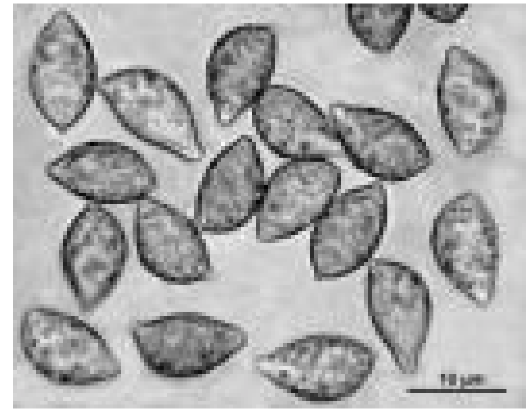
Table 1. Organic compounds in comets*

Molecule	Relative abundance
H_2O	100
CO	23
CO_2	6
CH_4	0.6
C_2H_2	0.1
C_2H_6	0.3
CH_3OH	2.4
H_2CO	1.1
HCOOH	0.1
CH_3CHO	0.02
$HCOOCH_3$	0.08
NH_2CHO	0.02
NH_3	0.7
HCN	0.25
HNC	0.04
HNCO	0.1
CH_3CN	0.02
HC_3N	0.02
H_2S	1.5
CS_2	0.2
CS	0.2
SO_2	0.2
SO	0.3
OCS	0.4
H_2CS	0.02
NS	0.02

Bacterial spores







A highly resistant, resting phase displayed by some types of bacteria.

Spores are formed in response to adverse changes in the environment.

Original cell replicates its genetic material. One copy grows a tough coating. Outer cell disintegrates, releasing spore which is now protected against a variety of traumas, including extremes of heat and cold, and an absence of nutrients, water, or air.

Credit: Pawel Artymowicz

Panspermia, continued

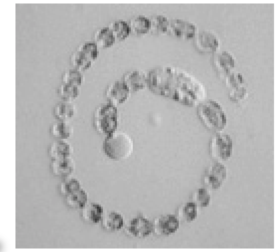
Unmanned probe Surveyor 3 soft-landed on Moon in 1967. In 1969, 2.5 yrs later, Apollo12 astronauts recovered the camera from Surveyor 3 and brought it back to Earth. The insulation covering its circuit boards contained 50 to 100 viable specimens of Streptococcus mitis, a harmless bacterium commonly found in the human nose, mouth, and throat.

(NASA Johnson Space Center)

Pete Conrad later commented: "I always thought the most significant thing that we ever found on the whole Moon was that little bacteria who came back and living and nobody ever said anything about it."

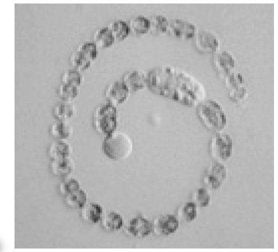
Credit: Pawel Artymowicz

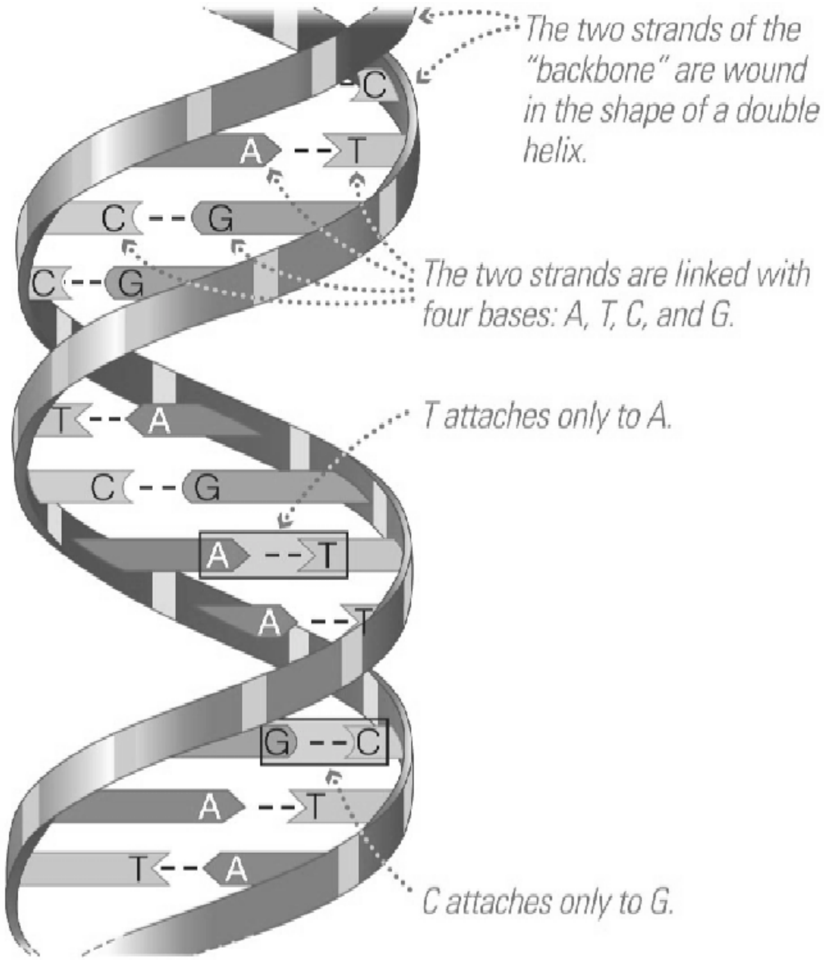
Alternative to Panspermia



- The in situ formation of life here on Earth
- Predominant theory, presently

The Theory of Evolution

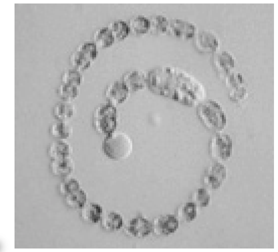




DNA encodes our genetics

- **Fossil record shows that changes in species have occurred through time.**
- **Darwin's theory tells us how evolution occurs: through natural selection.**
- **Theory strongly supported by discovery of DNA: present in each cell nucleus, encodes our genetics.**
- **Evolution proceeds through mutations of DNA.**
  - **Mutations induced by many factors: UV light, oxidants, ...**

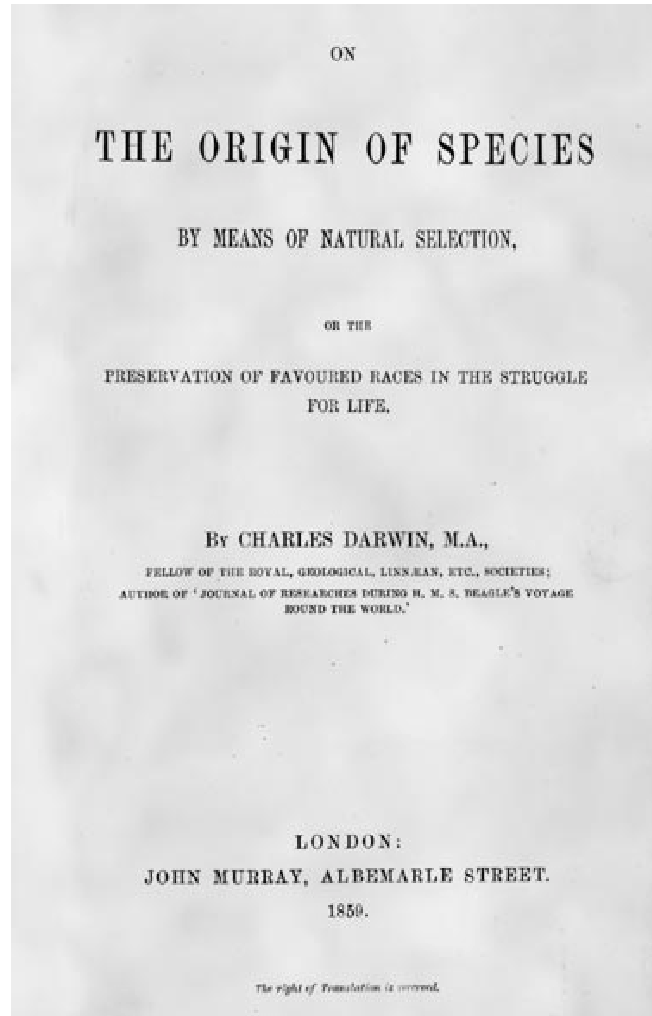
Elements of Evolution: Definitions



- **Evolution:**
  the change over time of the genetic composition of populations

- **Natural selection:**
  populations of organisms can change over the generations if individuals having certain heritable traits leave more offspring than others

- **Evolutionary adaptations:**
  a prevalence of inherited characteristics that enhance organisms' survival and reproduction



ON

THE ORIGIN OF SPECIES

BY MEANS OF NATURAL SELECTION,

OR THE

PRESERVATION OF FAVOURED RACES IN THE STRUGGLE FOR LIFE.

BY CHARLES DARWIN, M.A.,

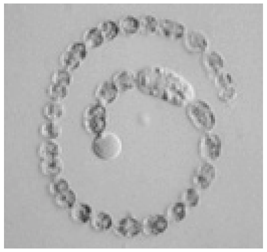
FELLOW OF THE ROYAL, GEOLOGICAL, LINNÆAN, ETC., SOCIETIES;
AUTHOR OF 'JOURNAL OF RESEARCHES DURING H. M. S. BEAGLE'S VOYAGE ROUND THE WORLD.'

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1859.

The right of Translation is reserved.

November 24, 1859

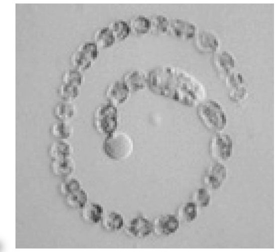
Natural Selection



- **Process itself is not random**
  - **Response to environmental conditions, especially if a species faces environmental threats**
- **Changes to DNA is random**
  - **Mutation: changes to DNA**
    - » **Occasionally cause beneficial changes in traits**
    - » **Increased reproductive success**
    - » **Trait endures through subsequent generations**

Credit: Amer. Association for the Advancement of Science

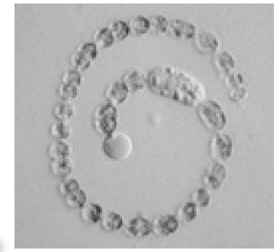
Other Evolutionary Mechanisms



- **Sexual selection**
  - **Females prefer to mate with most impressive male**
- **Genetic drift**
  - **The genetic structure of a population changes randomly over time.**

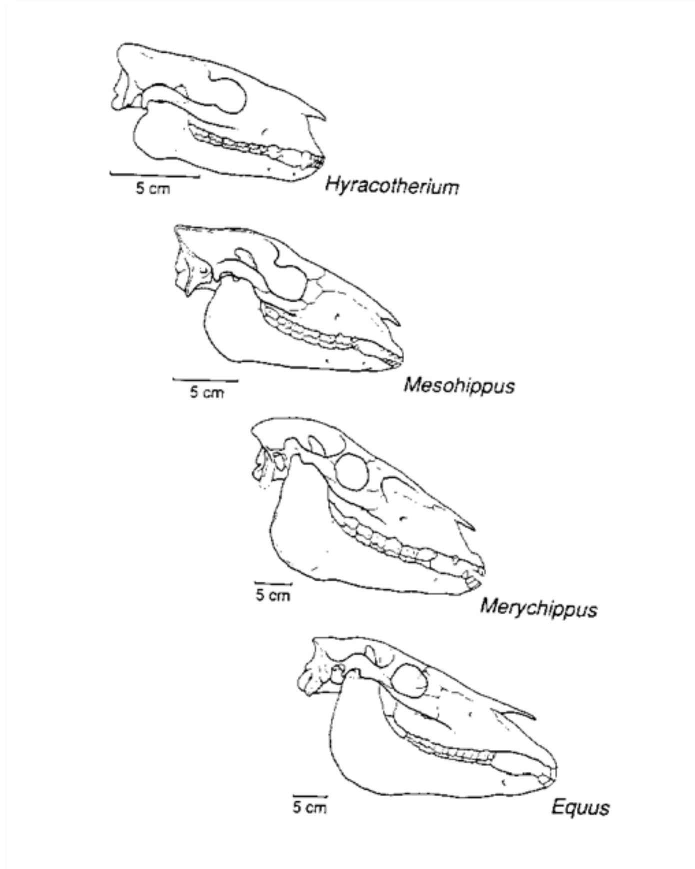
Credit: Amer. Association for the Advancement of Science

Evolution Evidence: The Fossil Record



The fossil record:

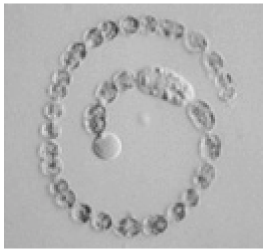
- provides direct evidence of evolution
- shows that lineages change and diversify through time
- gives information about the *process* of evolution
- gives information on the *rate* of evolution

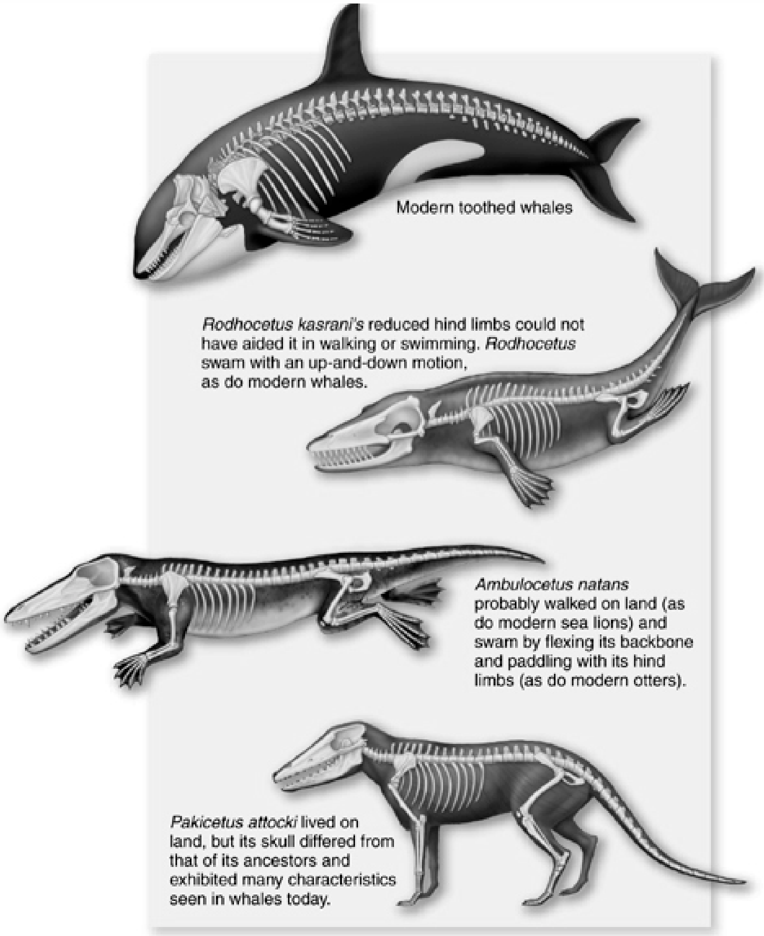


Evolution of horse head from browsing (top) to grazing (bottom)

From MacFadden [1992] Cambridge Univ. Press

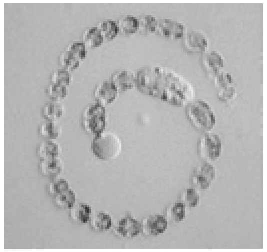
Fossil Evidence of Evolution: Whale "Missing Links"

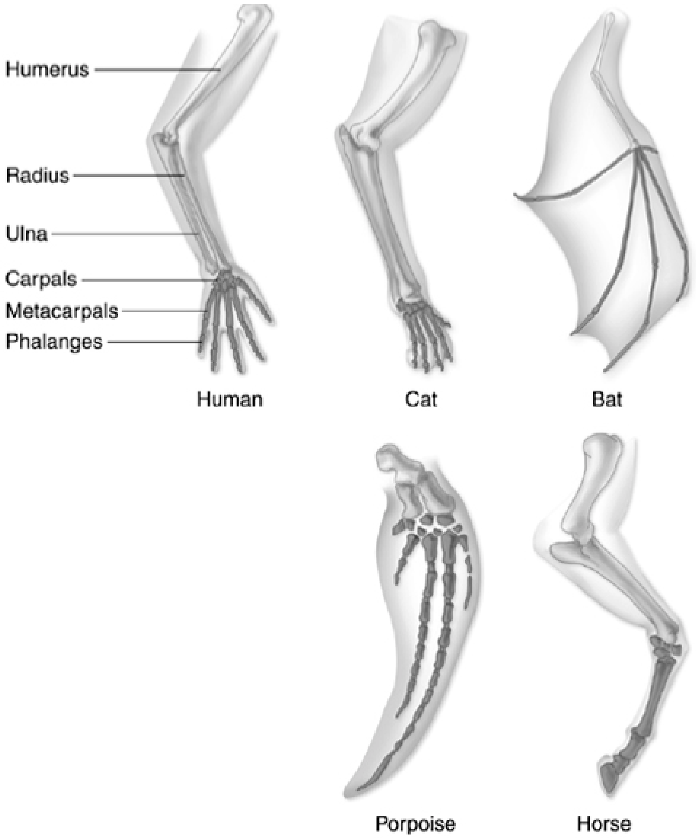




Credit: Tom De Lany, Kilgore College

Anatomical Evidence for Evolution: Homologous Structures



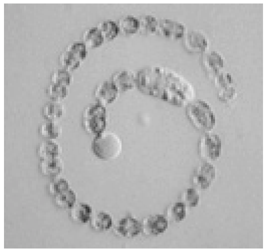


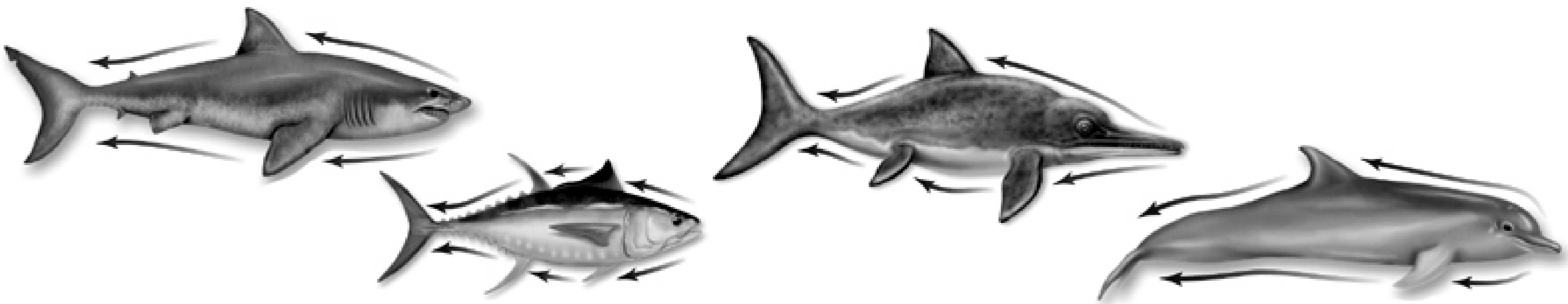
Homology of the bones of the forelimb of mammals

Homologous structures: structures with different appearances and functions that all derived from the same body part in a common ancestor

Credit: Tom De Lany, Kilgore College

Convergent Evolution

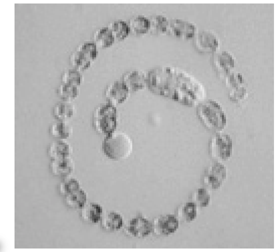




Convergence among fast-swimming predators

Credit: Tom De Lany, Kilgore College

Evolution Evidence: Molecular Biology

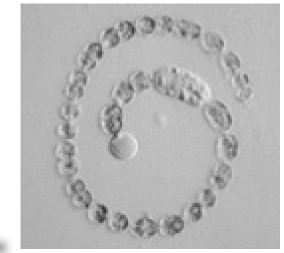


- **Similarities in DNA, proteins, genes, and gene products between species**
- **Common genetic code**
- **Reconstruct sequence of slow genetic changes over time**
- **Extremely compelling evidence for evolution**

Table 22.1 Molecular Data and the Evolutionary Relationships of Vertebrates

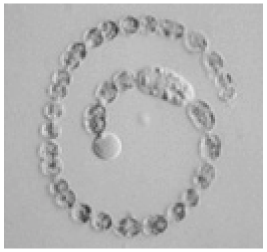
Species	Number of Amino Acids That Differ from a Human Hemoglobin Polypeptide (Total Chain Length = 146 Amino Acids)
Human	0
Rhesus monkey	8
Mouse	27
Chicken	45
Frog	67
Lamprey	125

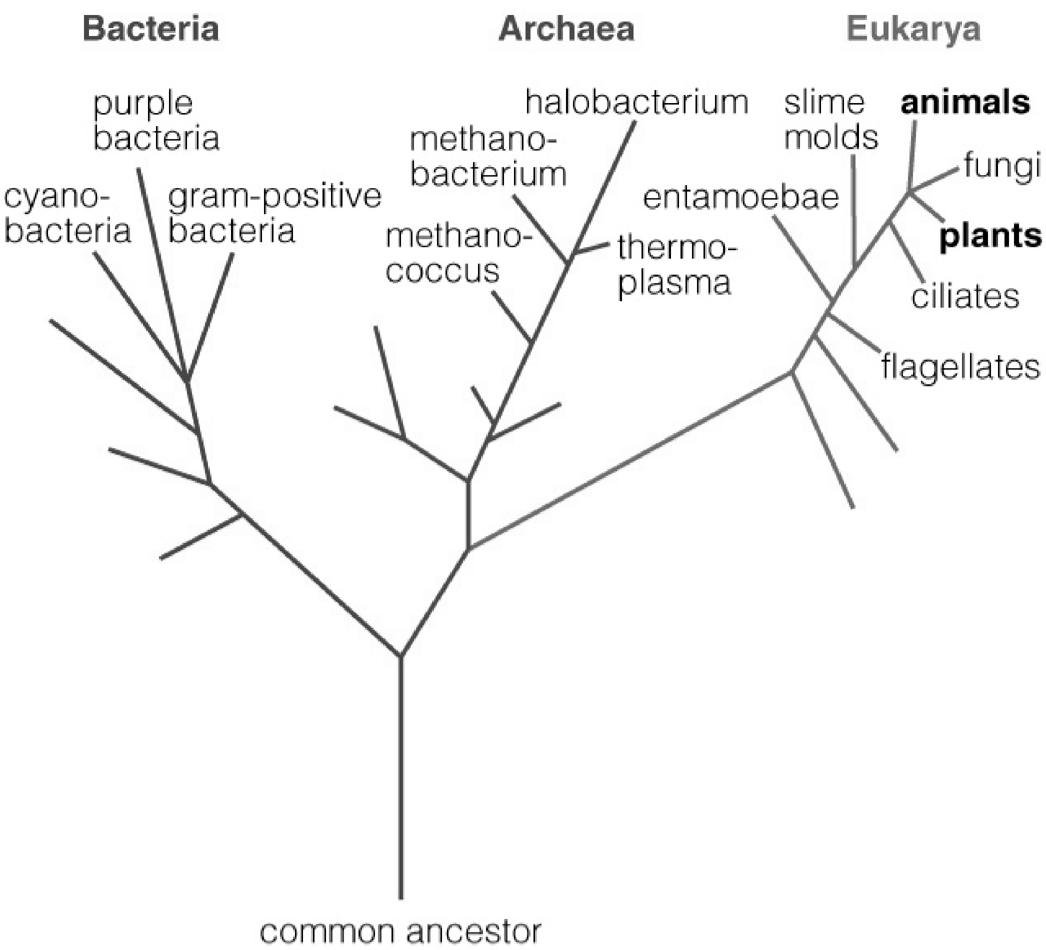
Brief History of Life



- 4.4 billion years - early oceans form (no free oxygen)
- First life 3.8 - 3.5 million yrs ago
- 3.5 billion years - cyanobacteria start releasing oxygen
  - Initially deposited on surfaces of rocks, not in the air
- 2.0 billion years - oxygen begins building up in atmosphere (before that it was oxidizing surface rocks)
- 540-500 million years - Cambrian Explosion - many new species
- 225-65 million years - dinosaurs and small mammals (dinosaurs ruled)
- Few million years - earliest hominids

Tree of Life





- **Mapping genetic relationships has led biologists to discover this new "tree of life."**
- **Adjacent branches have very similar DNA**
- **Plants and animals are a small part of the tree.**
- **Suggests likely characteristics of common "ancestor".**
- **What was it?**

- **Genetic studies suggest that earliest life on Earth resembled bacteria today found near deep ocean volcanic vents (black smokers) and geothermal hot springs. Energy from chemicals, not photosynthesis.**

Deep-ocean vent

A hot-spring in Yellowstone. Different bacteria (colors) inhabit water at different temperatures.

Life in hydrothermal vents sustained by chemosynthesis

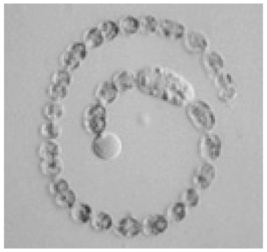
- Survival of *Riftia* (and other vent species) depends on a symbiotic relationship with the billions of bacteria that live inside these worms.

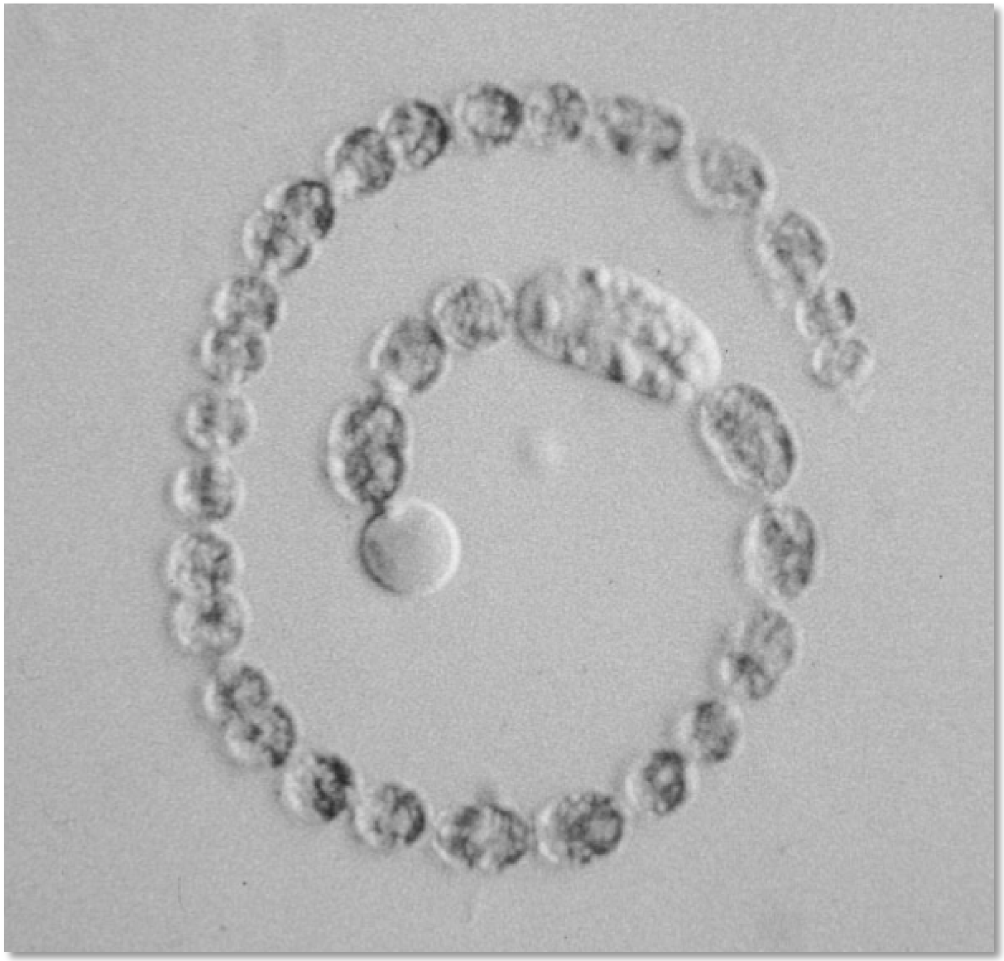
- These bacteria convert chemicals that shoot out of the hydrothermal vents into food for the worm.

- This chemical- based food-making process is chemosynthesis, $2\,H_2S + CO_2 \Rightarrow S_2 + CH_2O + H_2O$

Credit: David Webb, Univ. of Hawaii

Origin of Free Oxygen in Atmosphere



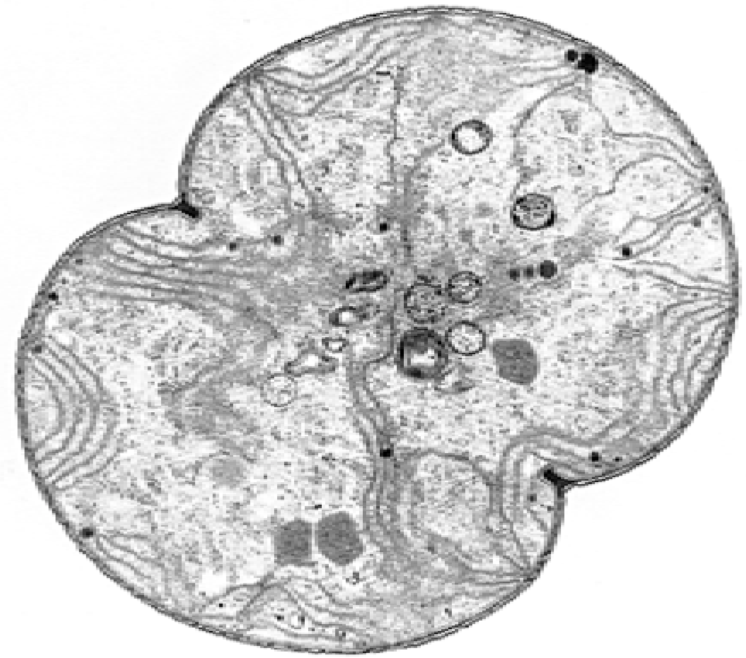


- **Cyanobacteria paved the way for more complicated life forms by releasing oxygen into atmosphere via photosynthesis**

Division Cyanophyta

Bacteria that are:

- Photosynthetic (convert light energy to food)
- Produce O_2 as a byproduct of photosynthesis
- Some produce toxins
- Some have capacity to fix N_2 into NH_4
- Some have formed millions of years old stromatolites as living structures

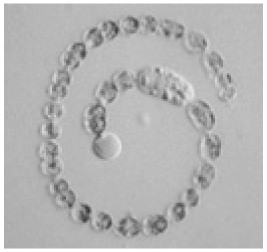


TEM of dividing cell

Cyanophytes have changed the path of evolution on earth

Credit: David Webb, Univ. of Hawaii

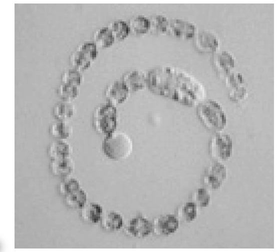
Thought Question



You have a time machine with a dial that you can spin to send you randomly to any time in Earth's history. If you spin the dial, travel through time, and walk out, what is most likely to happen to you?

A. You'll be eaten by dinosaurs.
B. You'll suffocate because you'll be unable to breathe the air.
C. You'll be consumed by toxic bacteria.
D. Nothing. You'll probably be just fine.

Necessities for Life



- **Nutrient source**
- **Energy (sunlight, chemical reactions, internal heat)**
- **Liquid water (or possibly some other liquid)**

Hardest to find on other planets

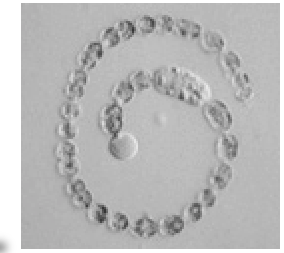
David Grinspoon, Denver

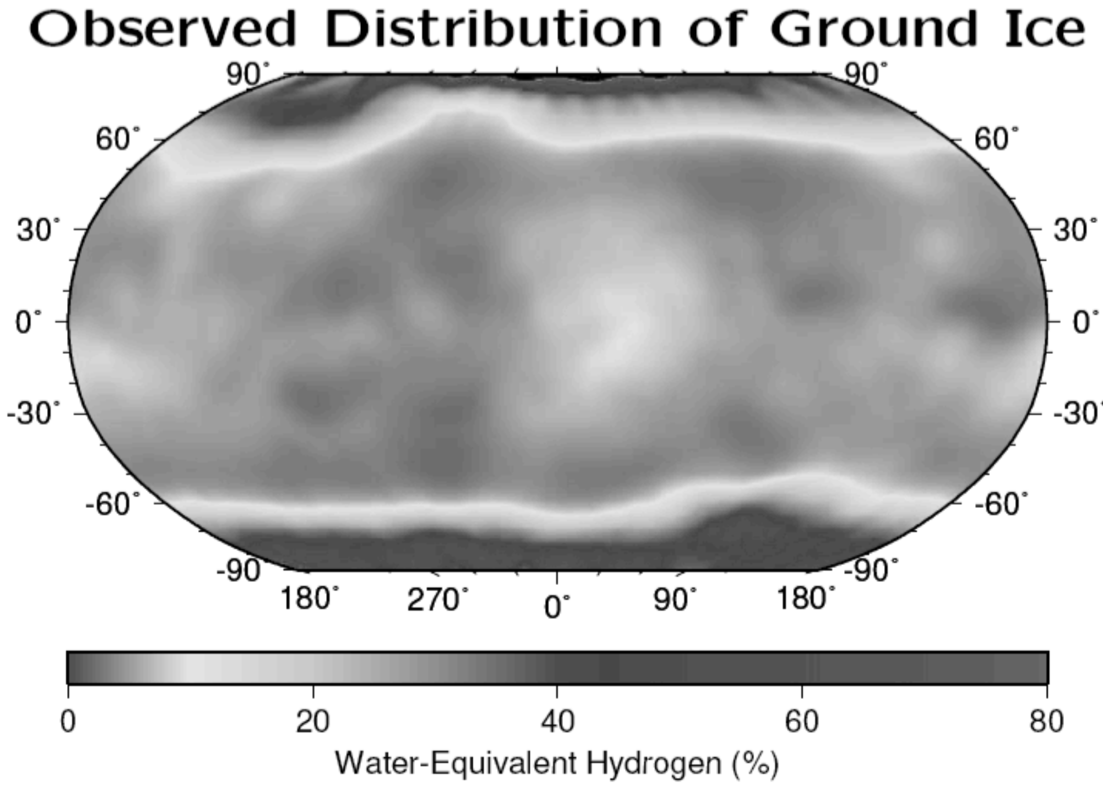
History of Venus: A Unified Scenario

- ≈ 2 Gy Loss of surface water, subduction of hydrated sediments ceases.
- Mantle becomes desiccated.
- Lack of water makes lithosphere thicker & more difficult to break.
- Loss of asthenosphere -> lithosphere is tightly coupled to mantle.
- Crustal recycling is inhibited.
- ≈ 1 Gy Plate tectonics ceases, Venus becomes a “1 plate planet”
- ≈ 700 My, global resurfacing rate declines precipitiously.
- 700 My to present: localized volcanism and tectonism, conductive heat release, production population of craters.

  – Tessera are remnants of more vigorous past tectonics. (continents?)
  – Plains record “global resurfacing”, or at least an epoch of much higher resurfacing rates that ended “suddenly” enough to allow very few craters modified by plains volcanism.
  – Venus may have been a habitable planet (with an oxygenated atmosphere) for much of Solar System history.

Mars had liquid water in past; did it (does it) have life?

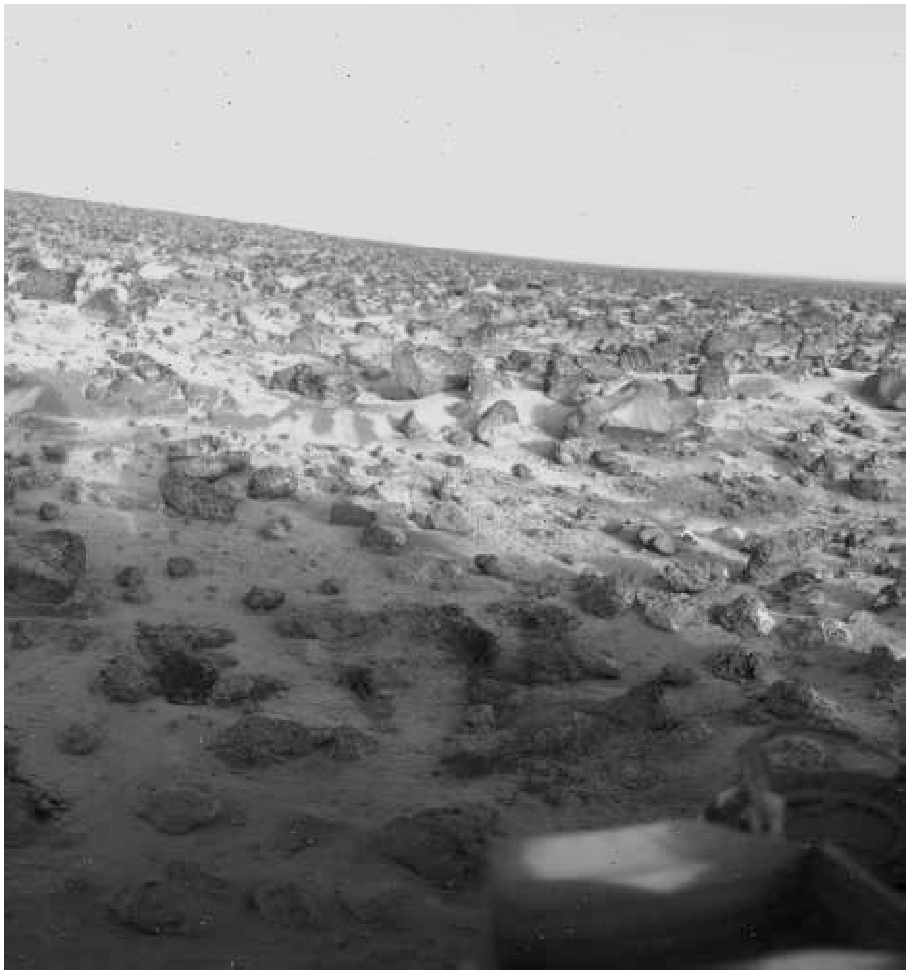




H_2O-equivalent mass fraction in the upper ~1 meter of the surface from epithermal neutrons (Feldman et al., 2004).

Norbert Schorghofer, U. Hawaii

Seasonal Frost at Viking 2 Lander Site

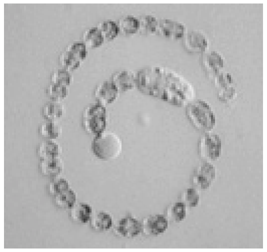


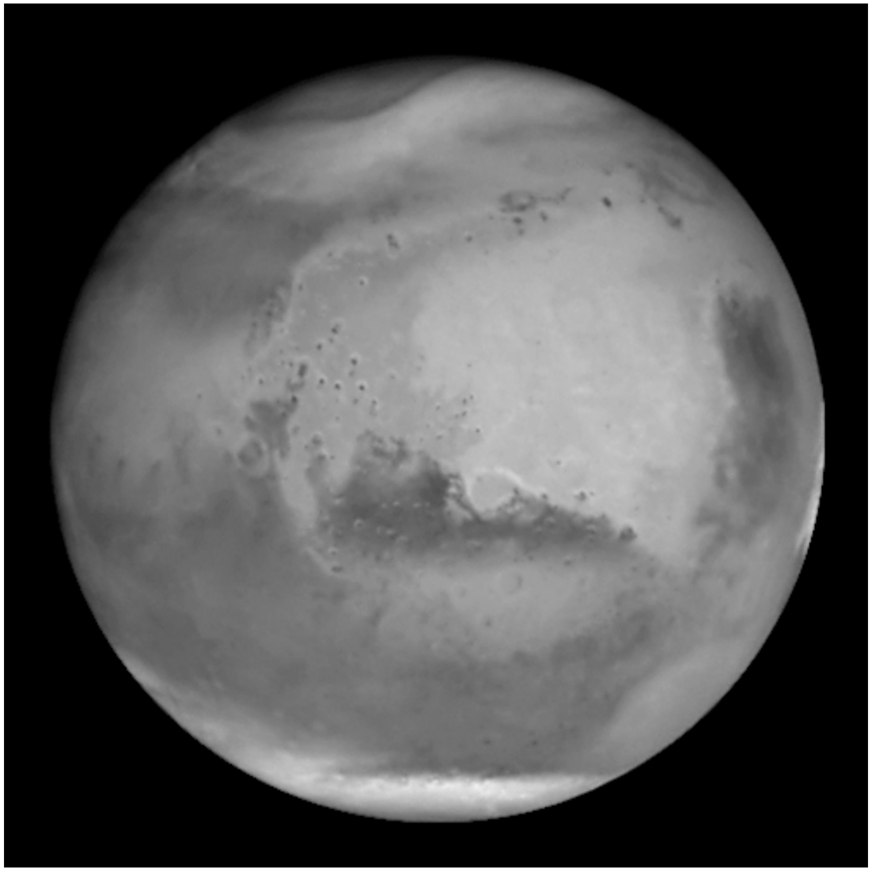
- Latitude 48°N
- probably H_2O rather than CO_2 frost
- vapor may be supplied from beneath

(Wall 1981;
Hart & Jakosky 1986;
Svitek & Murray 1990)

Norbert Schorghofer, U. Hawaii

In our Solar System, Mars is best candidate for finding life

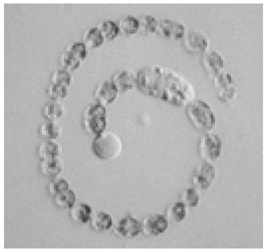




Mars at 2001 opposition
Hubble Space Telescope image

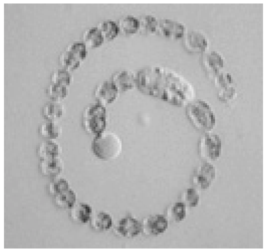
- Exploration of Solar System has revealed…
  - no sign of large life forms
  - we must search for <u>microbial</u> life
- Mars is best candidate:
  - Mars was apparently warm & wet in its distant past
  - it had the chemical ingredients for life
  - it has significant amounts of water ice
  - pockets of underground liquid water *might* exist if there is still volcanic heat
- Will we find life underground?

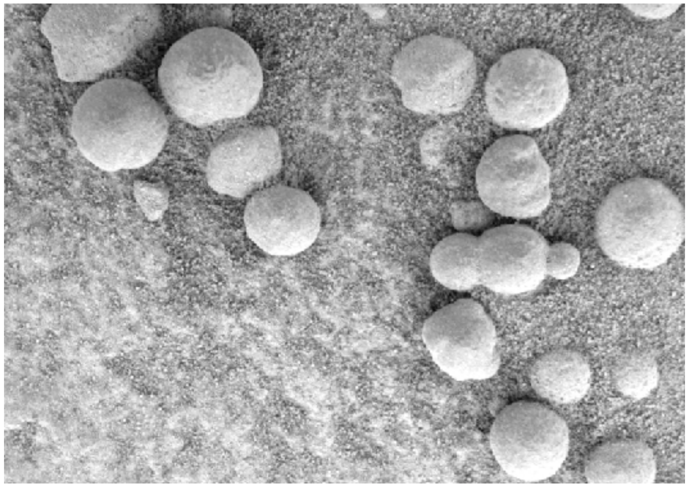
Phoenix Lander on Mars



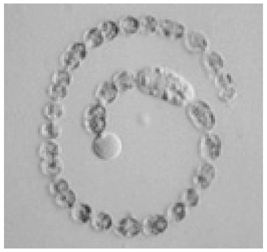
- Scratched surface, uncovered ice
- Evaporated (sublimed) when Sunlight had shown on it for a while

Mars rovers found more signs of water on Mars

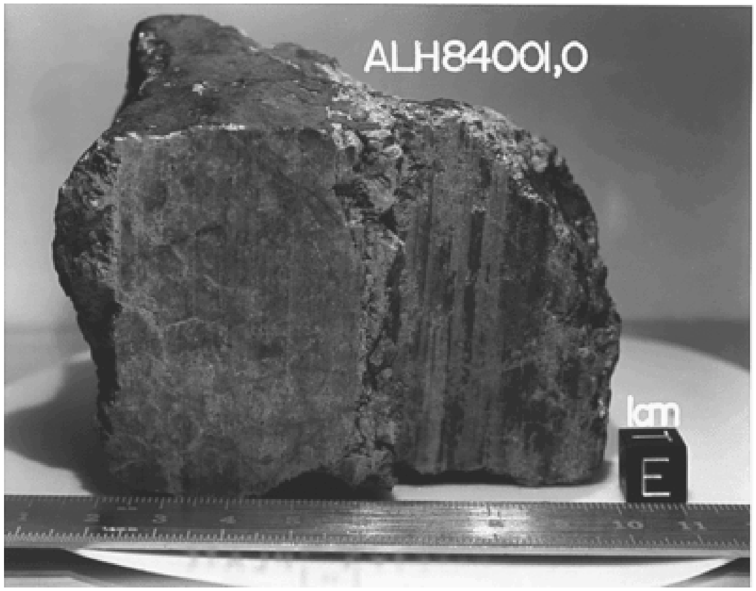




- In 2004, NASA Spirit and Opportunity Rovers sent home new mineral evidence of past liquid water on Mars.
- "Blueberry" spheres are thought to have formed by the precipitation of iron-bearing minerals when groundwater rose up through layers of sediment.



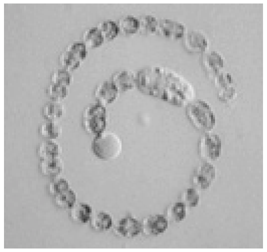
The Martian Meteorite debate

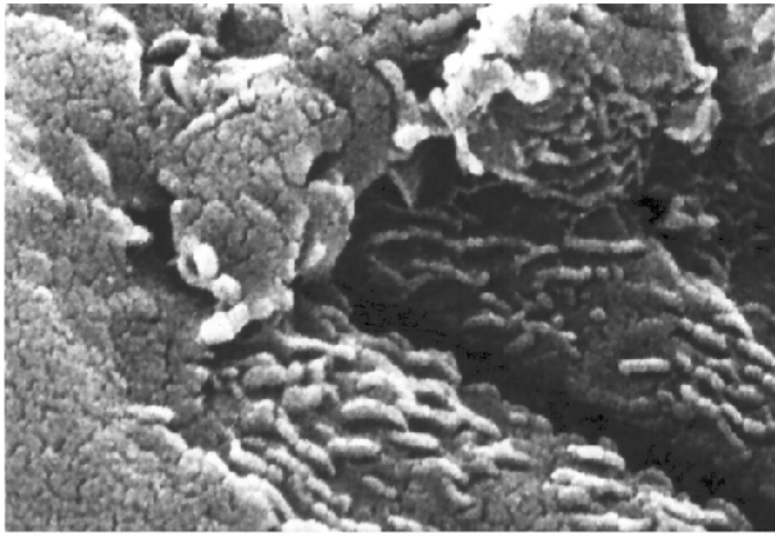


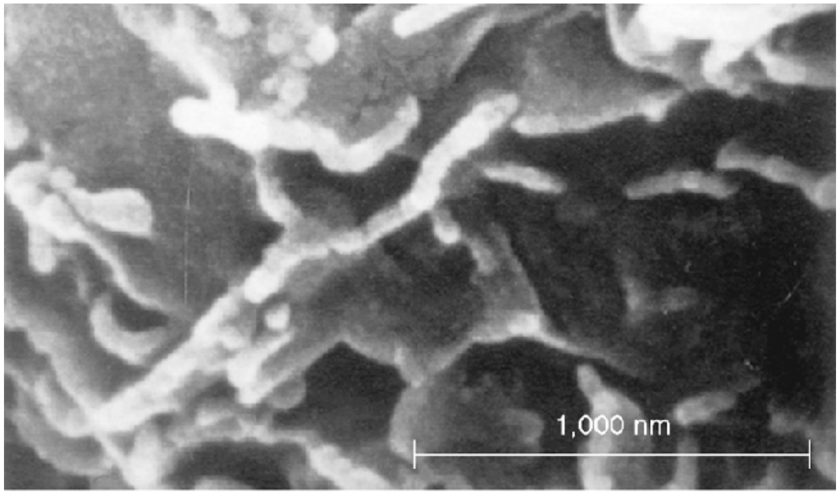
Composition indicates origin on Mars.

- **1984: meteorite ALH84001 found in Antarctica**
- **13,000 years ago: fell to Earth in Antarctica**
- **16 million years ago: blasted from surface of Mars**
- **4.5 billion years ago: rock formed on Mars**

Does the meteorite contain fossil evidence of life on Mars?

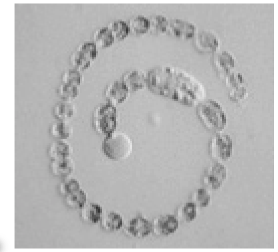


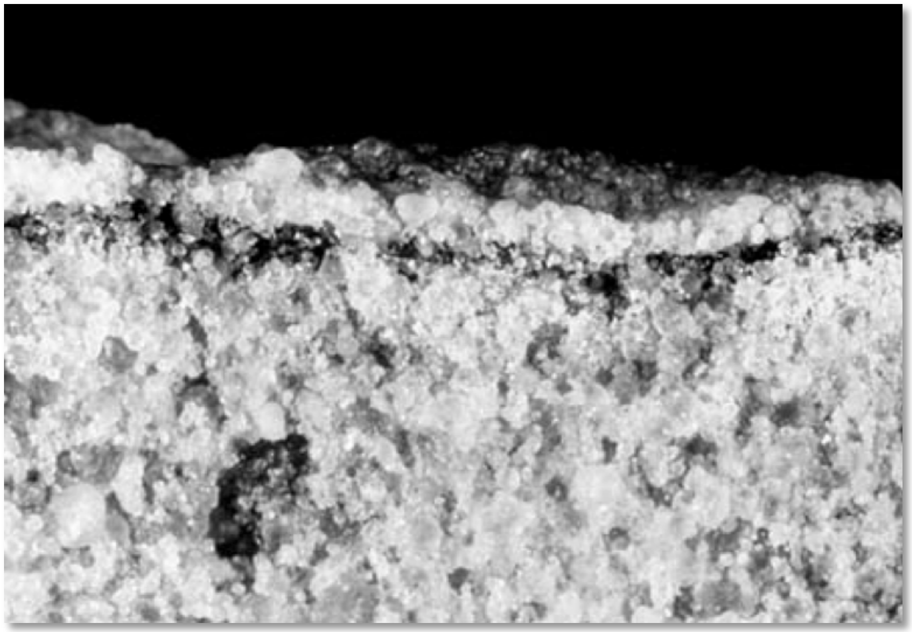




… most scientists not convinced

Looking for life in rocks has good precedent on Earth

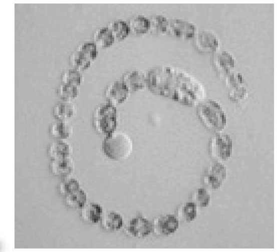


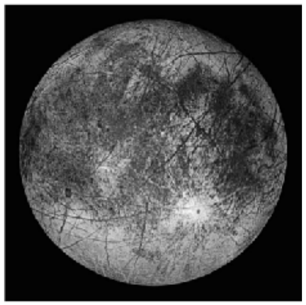


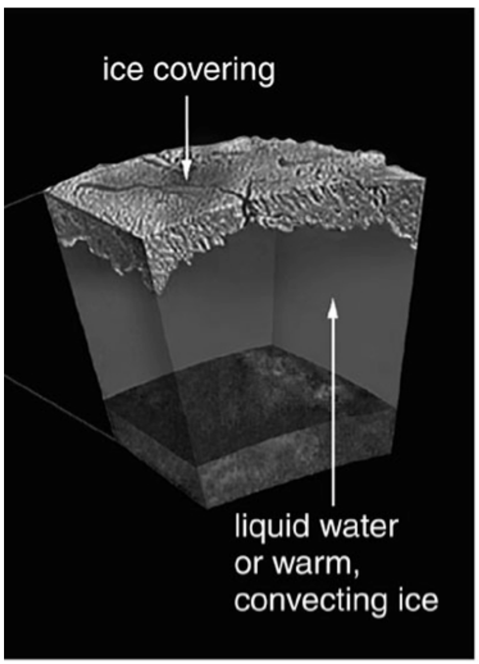
Outer few sixteenths of an inch of a rock in the cold desert of the McMurdo Dry Valleys create microclimates with just enough above-freezing days per year and just enough moisture that minute spaces between grains are home to organisms. Organisms are active enough to contribute to weathering of rock surface, but appear to be on the limit of their capability and are dormant most of the year.

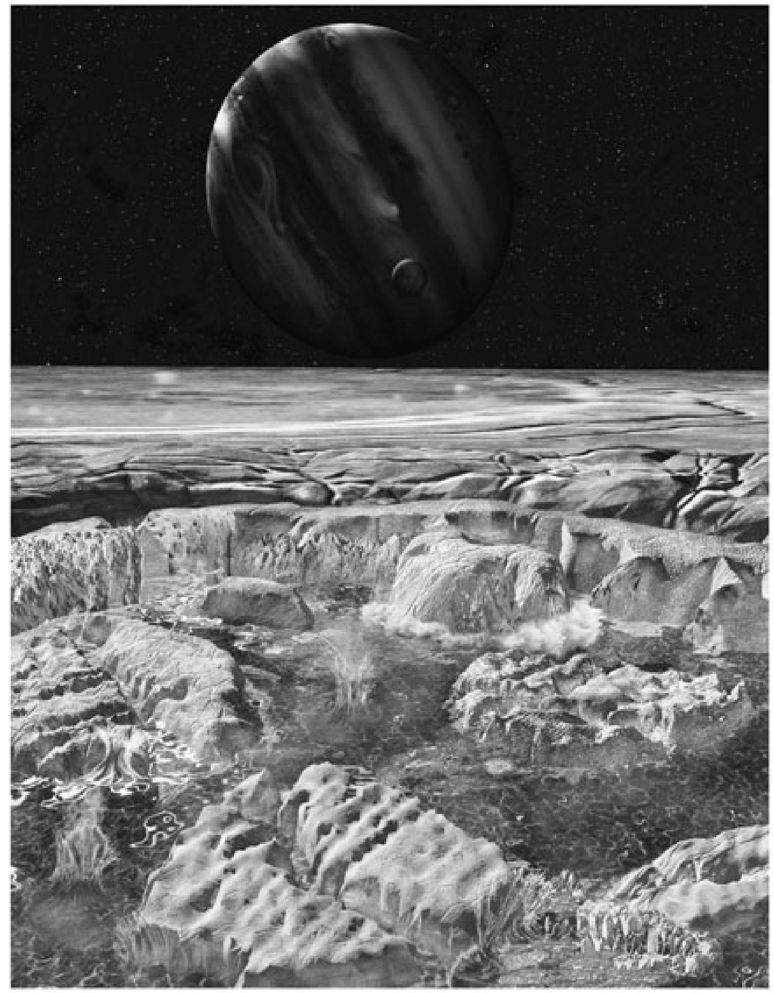
(photo courtesy E. Imre Friedman, Florida State)

Could there be life on Europa or other jovian moons?

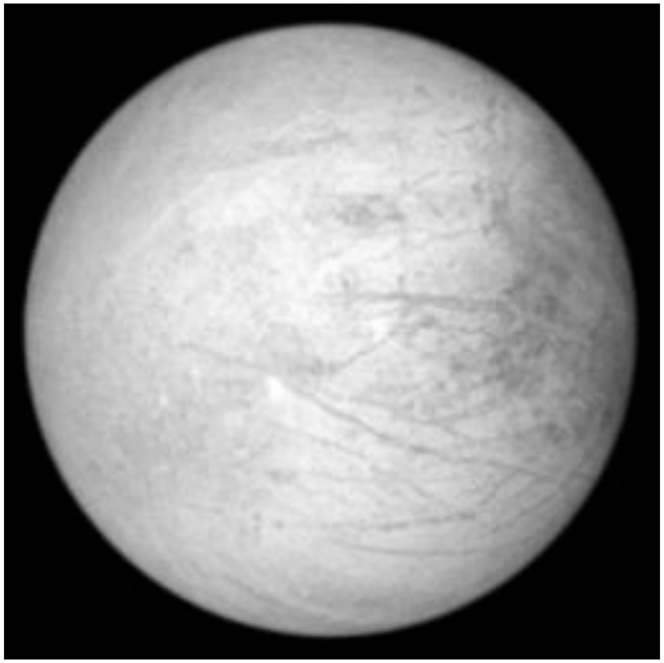




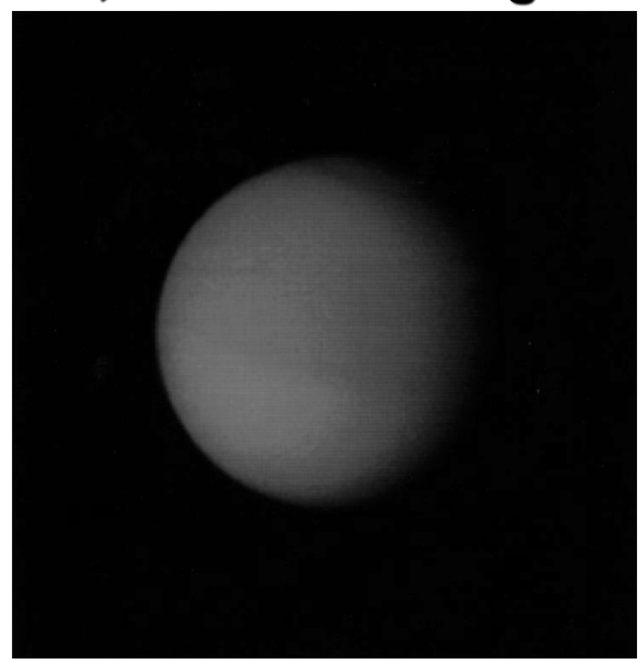




Possible Life on Jovian Moons

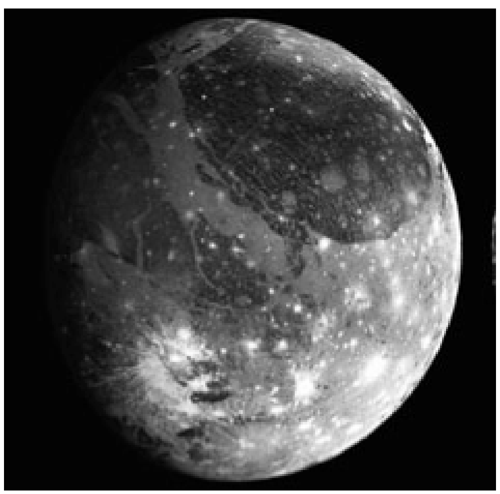


- **Beneath its icy surface, Europa may have an ocean of liquid water.**
  - **tidal heating keeps it warm**
  - **possibly with volcanic vents**
  - **conditions may be similar to how Earth life arose**
- **Ganymede & Callisto may also have subsurface oceans, but tidal heating is weaker.**



- **Titan has a thick atmosphere and oceans of methane & ethane.**
  - **water is frozen**
  - **perhaps life can exist in liquids other than water (??)**
- **Pockets of liquid water might exist deep underground.**

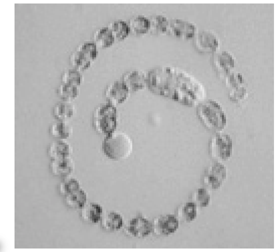
- **Ganymede, Callisto also show some evidence for subsurface oceans.**
- **Relatively little energy available for life, but still…**
- **Intriguing prospect of THREE potential homes for life around Jupiter alone…**

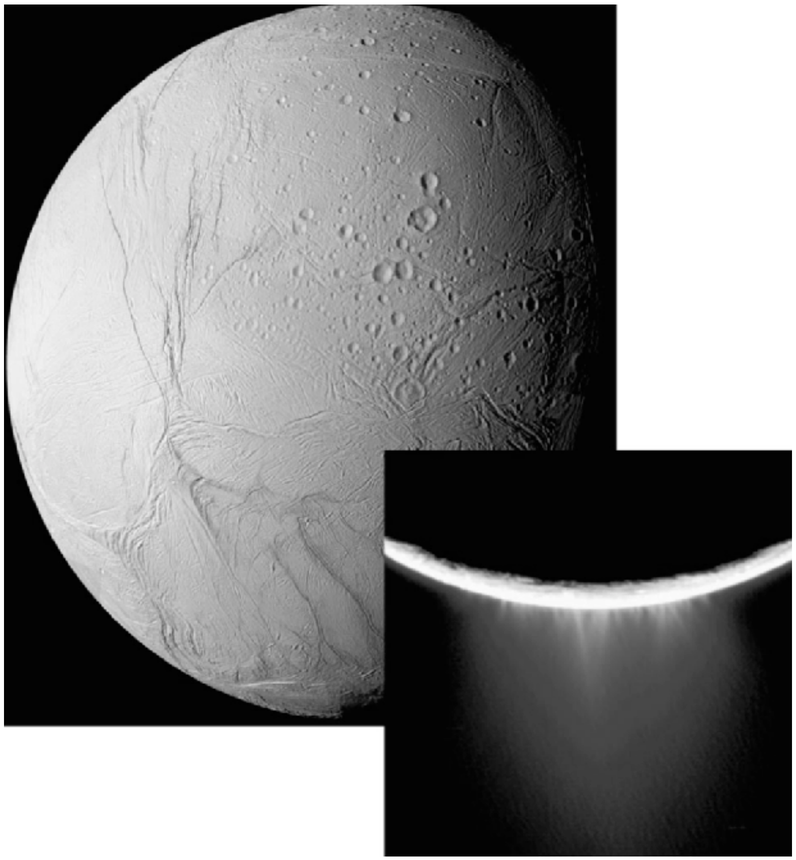


Ganymede

Callisto

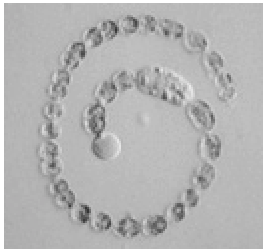
Enceladus





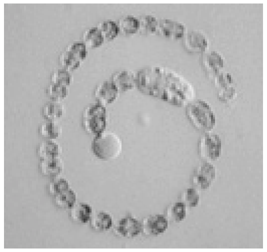
- Ice fountains suggest that Enceladus may have a subsurface ocean.

Are We Alone?



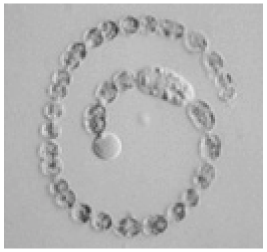
- Humans have speculated throughout history about life on other worlds
  - It was assumed by many thinkers of the 17th & 18th Centuries
  - Widely accepted by the public in the early 20th Century
  - Scientists became more skeptical once we began to explore the planets in our own Solar System

What is "life" ?

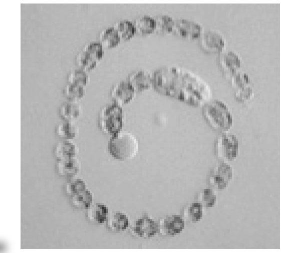


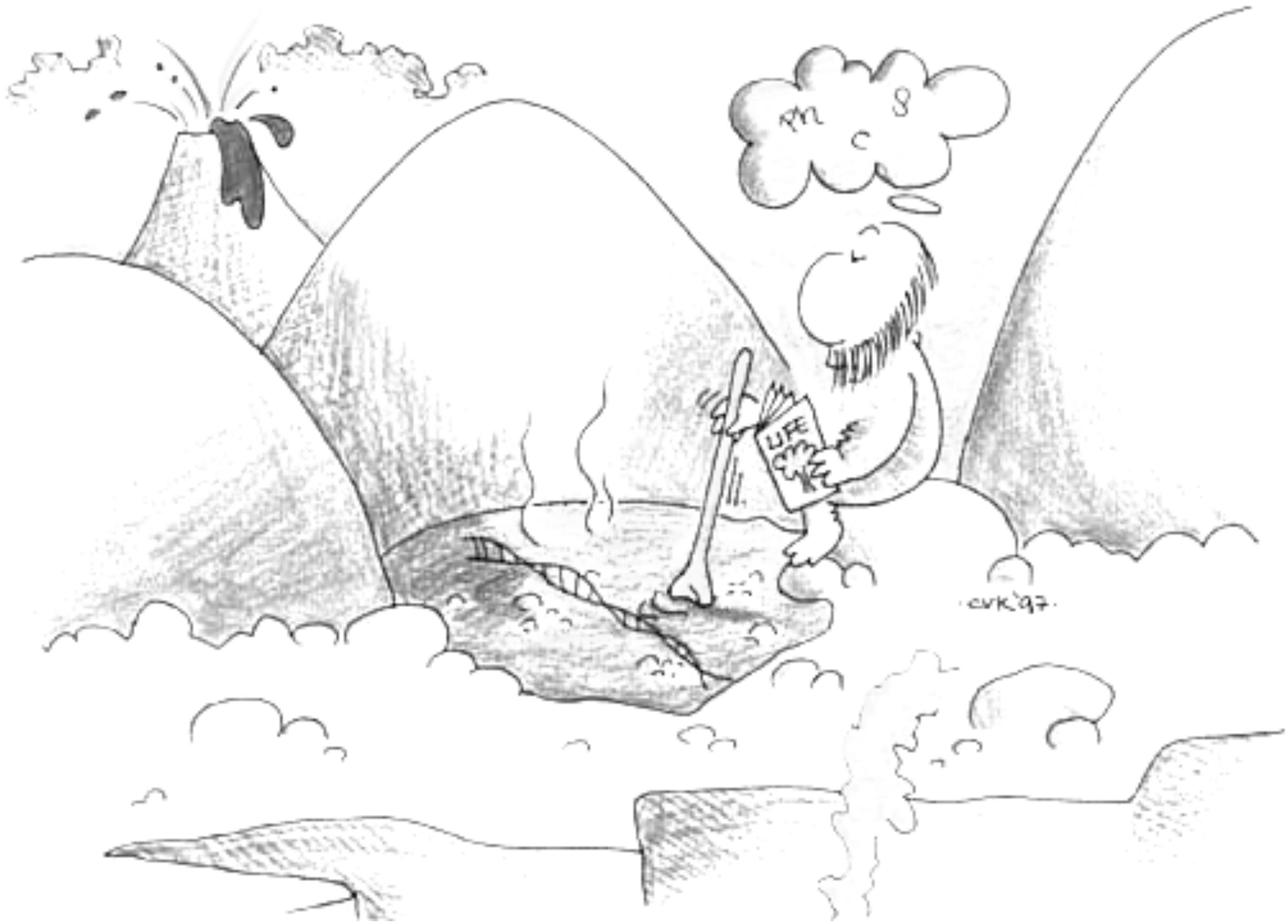
- **Surprisingly hard to define, if we want to avoid saying that all life must be like us**
- **Reasonable defining characteristics: (not unique set)**
  - **Ability to take energy from environment and change it from one form to another**
  - **Highly organized. Chemicals found within bodies are synthesized through metabolic processes into structures with defined purposes.**
  - **Regulate body and internal structures to certain normal parameters (e.g. temperature, acidity)**
  - **Respond to stimuli**
  - **Self-replicating by making copies of themselves**
  - **Grow and develop**

Where did "building blocks of life" come from?



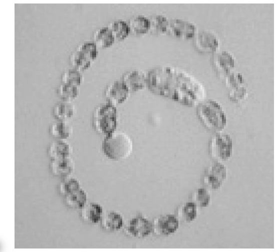
- **Building blocks of life**
  - **Amino acids, nucleic acid bases, sugars, phosphoric acid**
- **Origins of the building blocks?**
  - **Abiotic synthesis:**
    - » **Lab experiments in "reducing atmosphere" (little oxygen)**
    - » **Ingredients from volcanoes, sparked with electricity (as in lightning), rapidly formed amino acids and nucleic acids**
  - **Extraterrestrial origins:**
    - » **Carbonaceous chondrites (meteorites) carry amino acids**
    - » **Lab experiments: mixture of ices (water, carbon dioxide, carbon monoxide, methanol) was cooled to ten degrees above absolute zero. Ice mixture was then exposed to strong ultraviolet radiation. Formed amino acids and nucleic acids.**

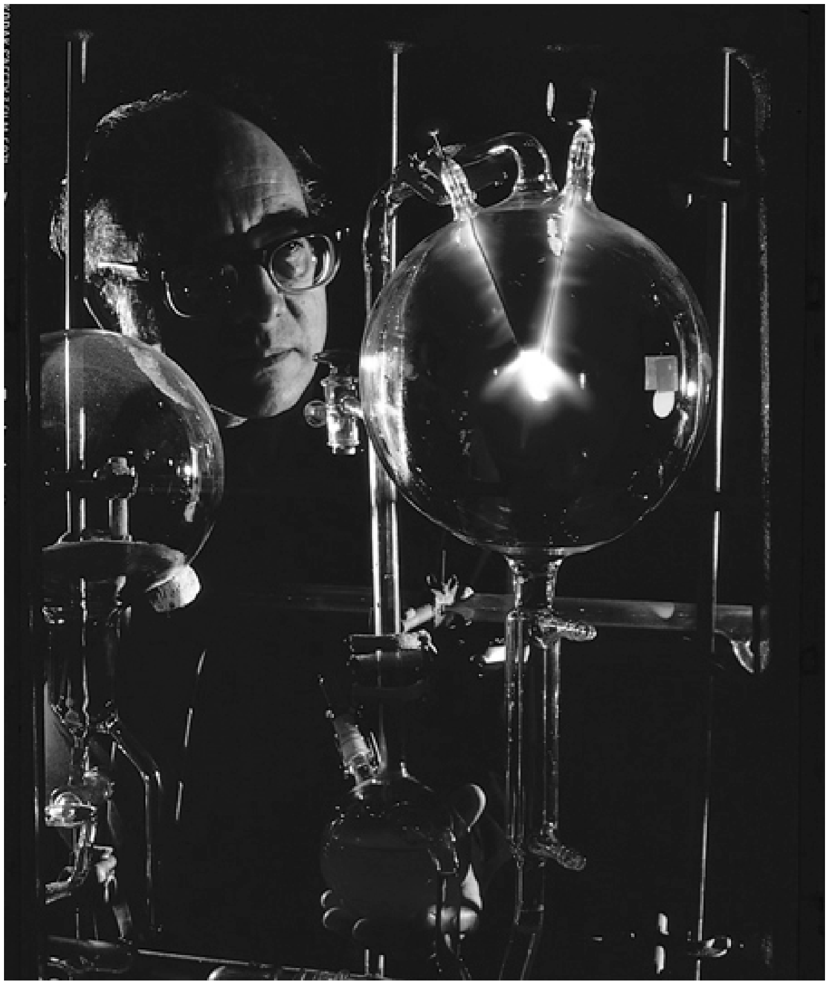




LIFE
cvk'97

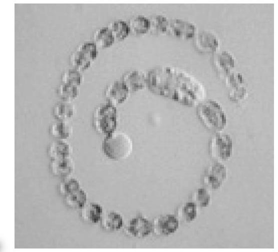
Laboratory Experiments



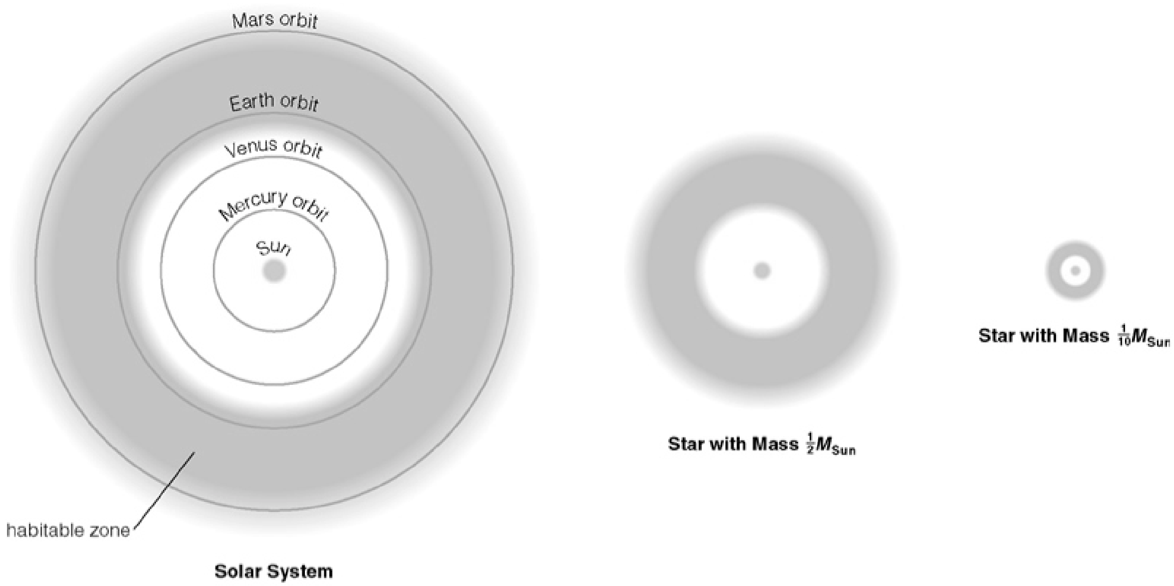


- Miller-Urey experiment (and more recent experiments) show that building blocks of life can form spontaneously under conditions of early Earth.

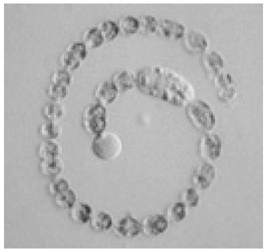
Which stars are most likely to have planets harboring life?

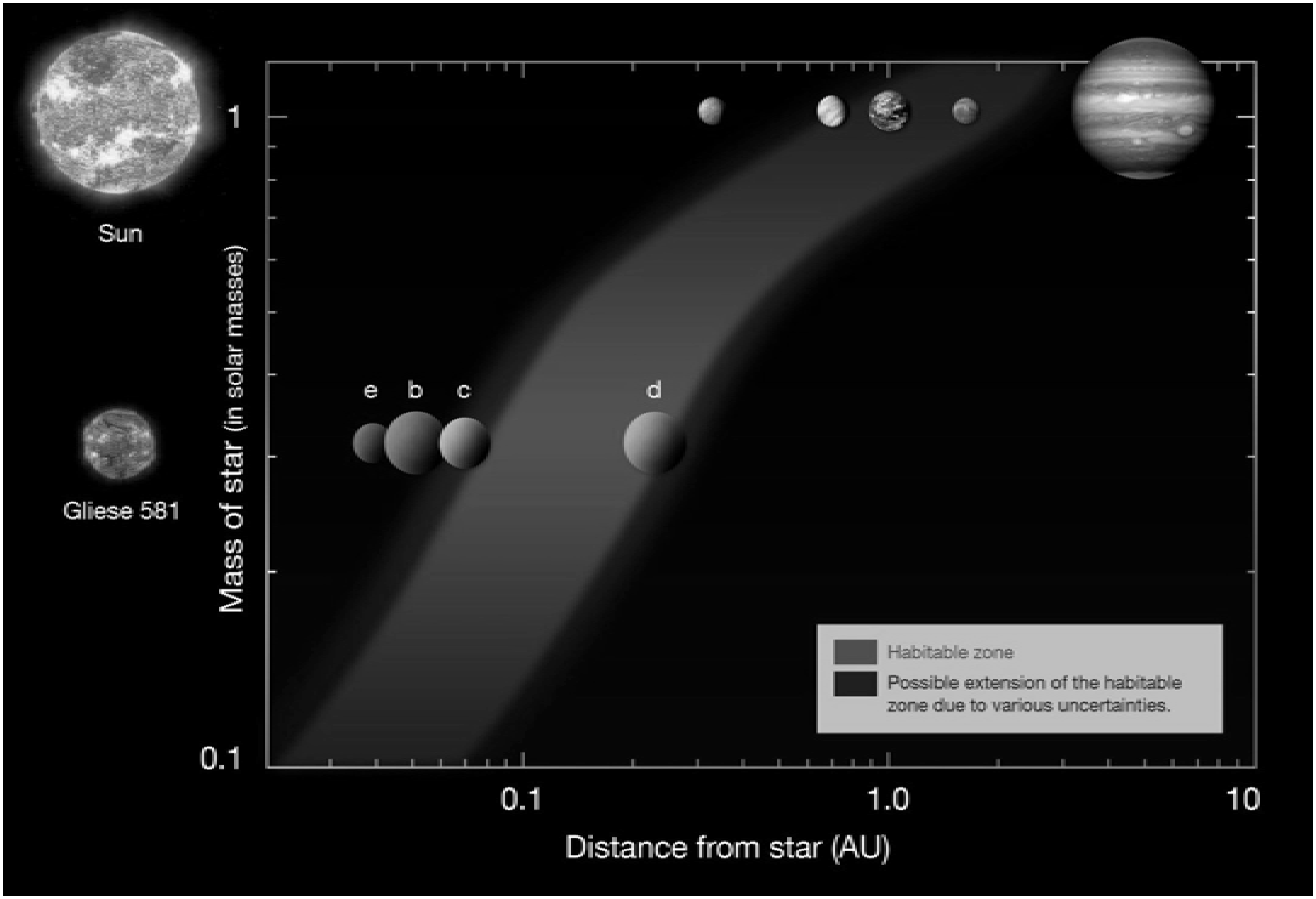


- **Must be old enough that life could arise**
  - **More than a few x 10^8 years old, so not high-mass stars**
- **They must allow for stable planetary orbits**
  - **Probably rules out binary and multiple star systems**
- **They must have relatively large** habitable zones
  - **Surface temperature that allows water to exist as a liquid**

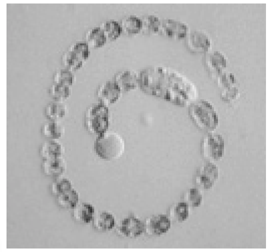


Planets in habitable zones

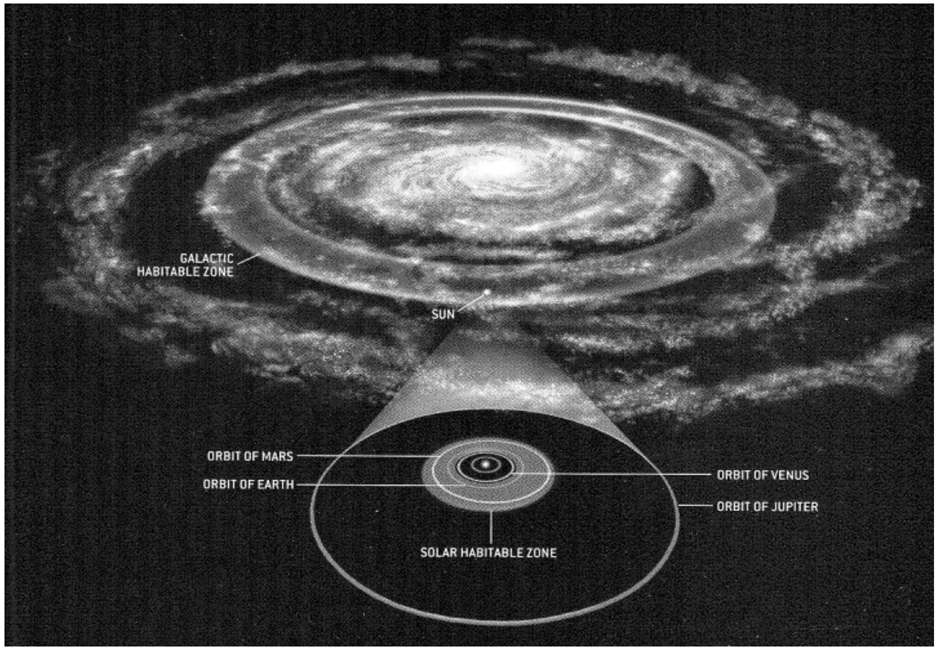


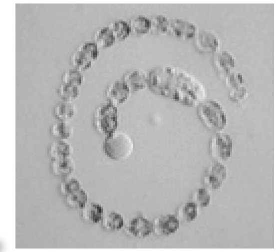


There may be a Habitable Zone in our Galaxy as well



- Too far out in the Galaxy, not enough elements heavier than H and He.
- Too close to center, too high a density of stars & too many supernovae, dangerous to life.
- But this is not a settled question. For example if planet has atmosphere and B field, can protect against supernova radiation.





The Washington Post

First 'habitable zone' planet found outside solar system

By Marc Kaufman
Washington Post Staff Writer
Wednesday, September 29, 2010; 11:00 PM

For the first time, astronomers have detected a rocky planet in another solar system that has the most basic and essential conditions needed to support extraterrestrial life.

THIS STORY
- Earth contains a vast amount of water, but scientists are unsure of its origins
- » First 'habitable zone' planet found outside solar system
- Finding a planet that's like our own

VIDEO

Video: New planet has potential for life
Astronomers have spotted a planet so similar to earth that they believe the conditions for life are "just right." Erica Hill reports.
» LAUNCH VIDEO PLAYER

The presence of Earth-like exoplanets in what is called the "habitable zone" has been predicted for some time, but actually identifying and measuring one was referred to Wednesday as the beginning of a new era in the search for life beyond Earth.

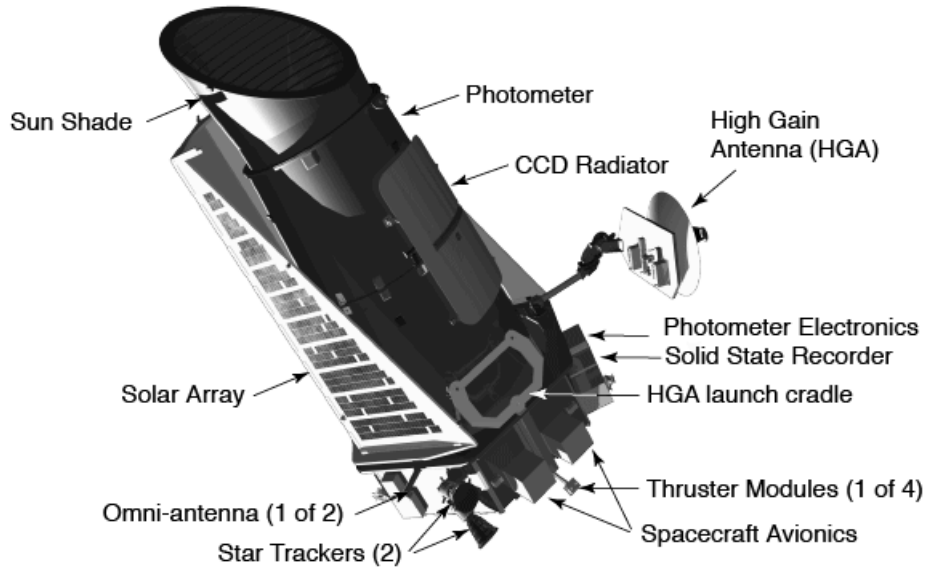
"This is our first Goldilocks planet - just the right size and the right distance from its sun," said astronomer and "planet-hunter" Paul Butler with the Carnegie Institution of Washington. "A threshold has been crossed."

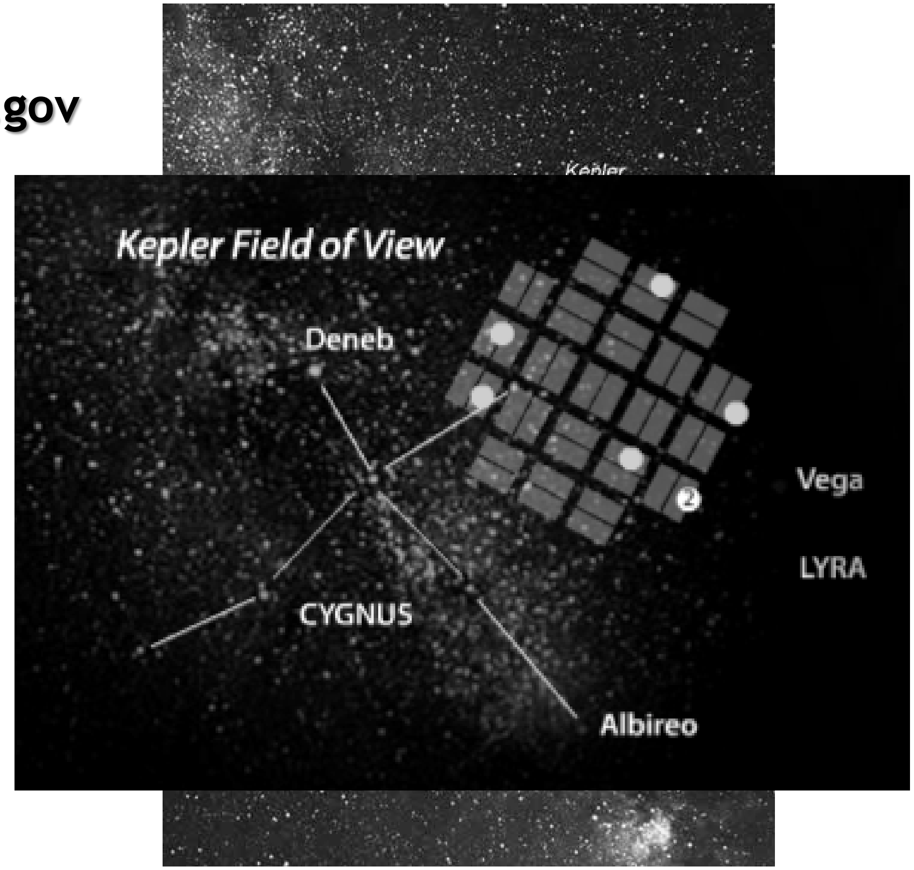
The planet, called Gliese 581G, is quite close at 20 light years

Kepler space mission will find many more!

Kepler

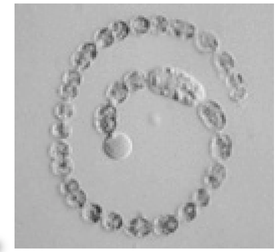
http://kepler.nasa.gov



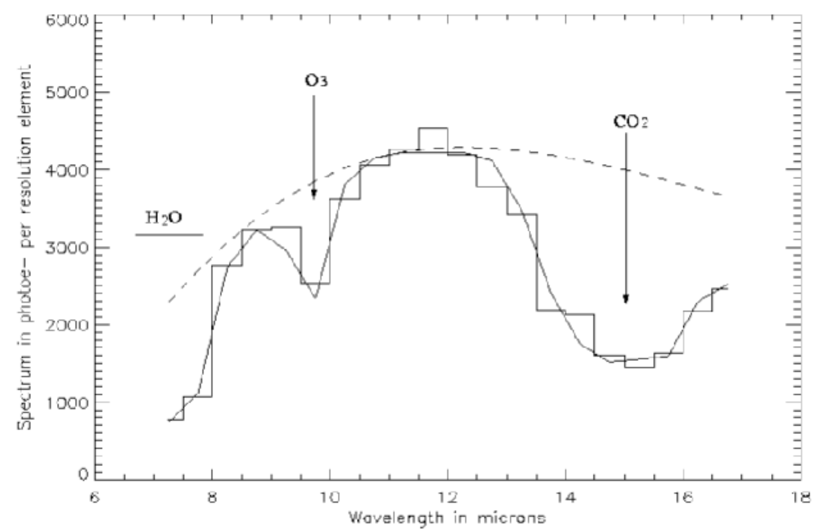


- **Search for and monitor transits around 100,000 stars for 4 years: frequency of Earth-size planets, semi-major axes of their orbits**
- **As of June 2010: 706 stars from 1st data set have exoplanet candidates with sizes from as small as Earth to larger than Jupiter**
- **Big data release in February 2011 (many more planets)**

Signs of life

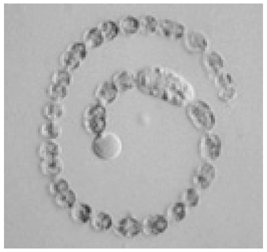


- **Oxygen is highly reactive**
  - **Not stable in Earth's atmosphere: maintained by plants**
  - **Earliest fossils were already photosynthesizing**
    - » **oxygen in atmosphere good indicator of life even in early stages**
  - **Spectroscopic detection possible**
    - » **in infra-red to reduce background from star**
    - » **good for 3-atom molecules**
    - » **detect CO_2 (atmosphere), H_2O (oceans), O_3 (life)**



Simulated spectrum from DARWIN homepage

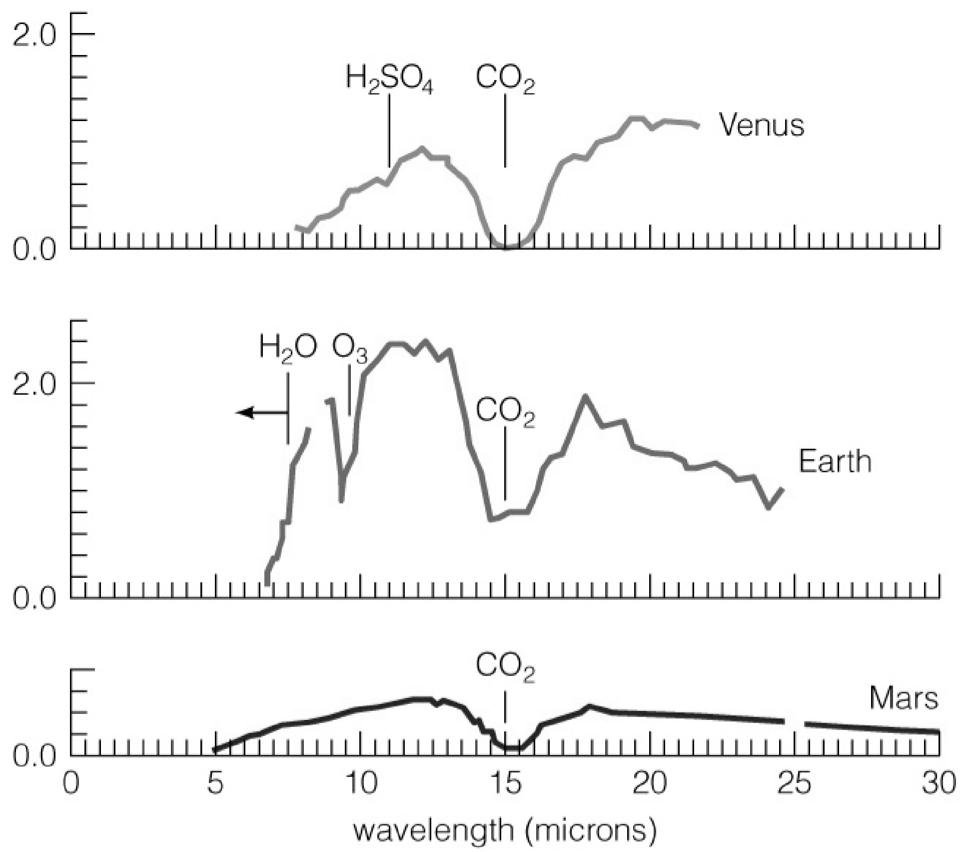
Specific Spectral Signatures of Life



Venus

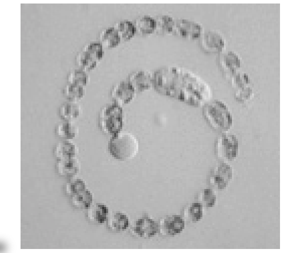
Earth

Mars



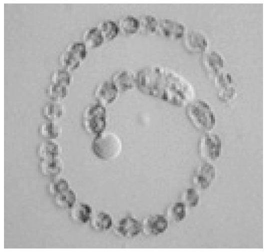
oxygen/ozone

Renewed interest in "Astrobiology"



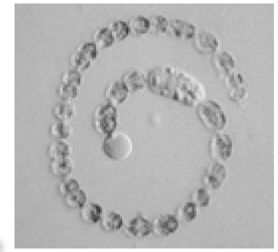
- **Reasons:**
  - **discovery of extrasolar planets indicate that planetary systems are common**
  - **organic molecules are found throughout the Solar System and Galaxy**
  - **geological evidence suggests life on Earth arose as soon as it was possible**
  - **discovery that living organisms can survive in the most extreme conditions on Earth**

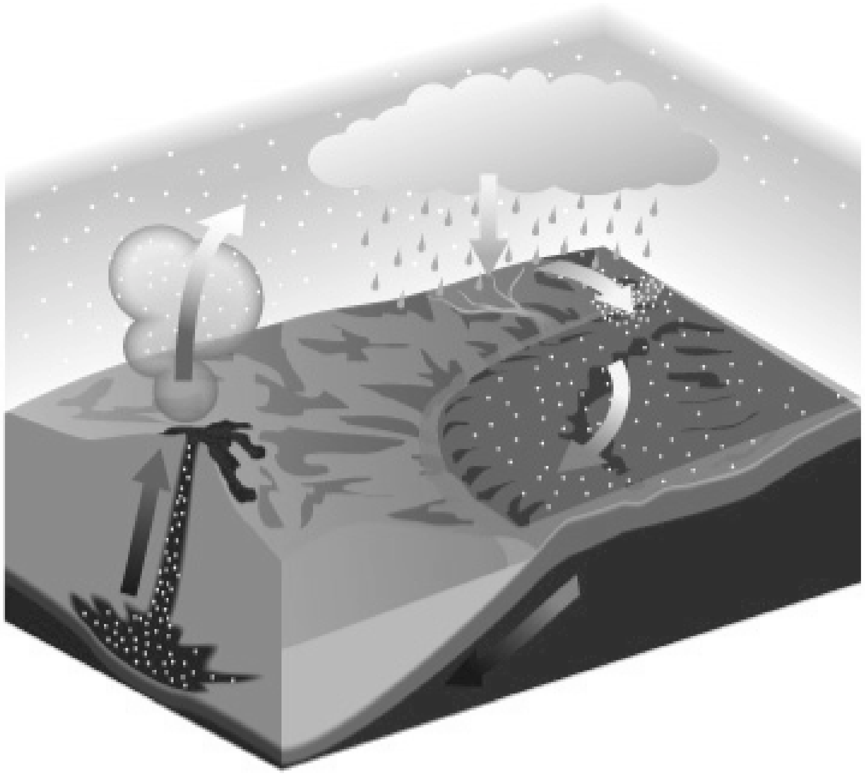
Impacts and Habitability



- Some scientists argue that Jupiter-like planets are necessary to reduce rate of impacts on the terrestrial planets
- If so, then Earth-like planets may be restricted to star systems with Jupiter-like planets

Climate and Habitability

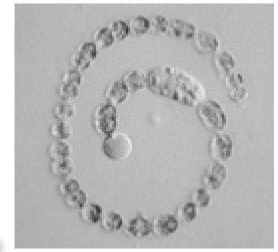




- Some scientists argue that plate tectonics and/or a large Moon are necessary to keep the climate of an Earth-like planet stable enough for life
- Would make habitable planets more rare

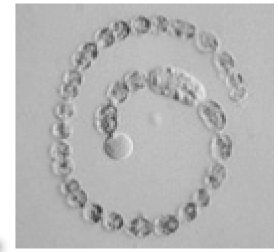
We don’t yet know how important or negligible these concerns are.

Life beyond microbes: Rare or Common?



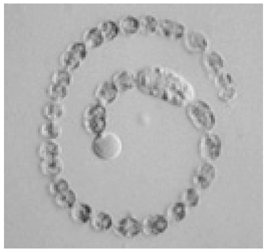
- **Why animal life may be common:**
  - billions of stars in Galaxy have medium-size habitable zones
  - planet formation theory: easy to form terrestrial planets
  - life on Earth began as soon as conditions allowed
- **But some scientists propose "rare Earth hypothesis"**
  - terrestrial planets may only form around stars with high abundances of heavy elements
  - the presence of our Jupiter deflects comets and asteroids from impacting Earth, so animal life can evolve from microbes
  - hence must have a Jupiter that did not migrate in towards the sun
  - Earth has plate tectonics which allows the CO_2 cycle to stabilize climate, so animal life can evolve
  - Moon, result of chance impact, keeps tilt of Earth's axis stable
- **We will not know the answer until were have more data on other planets in the Galaxy**

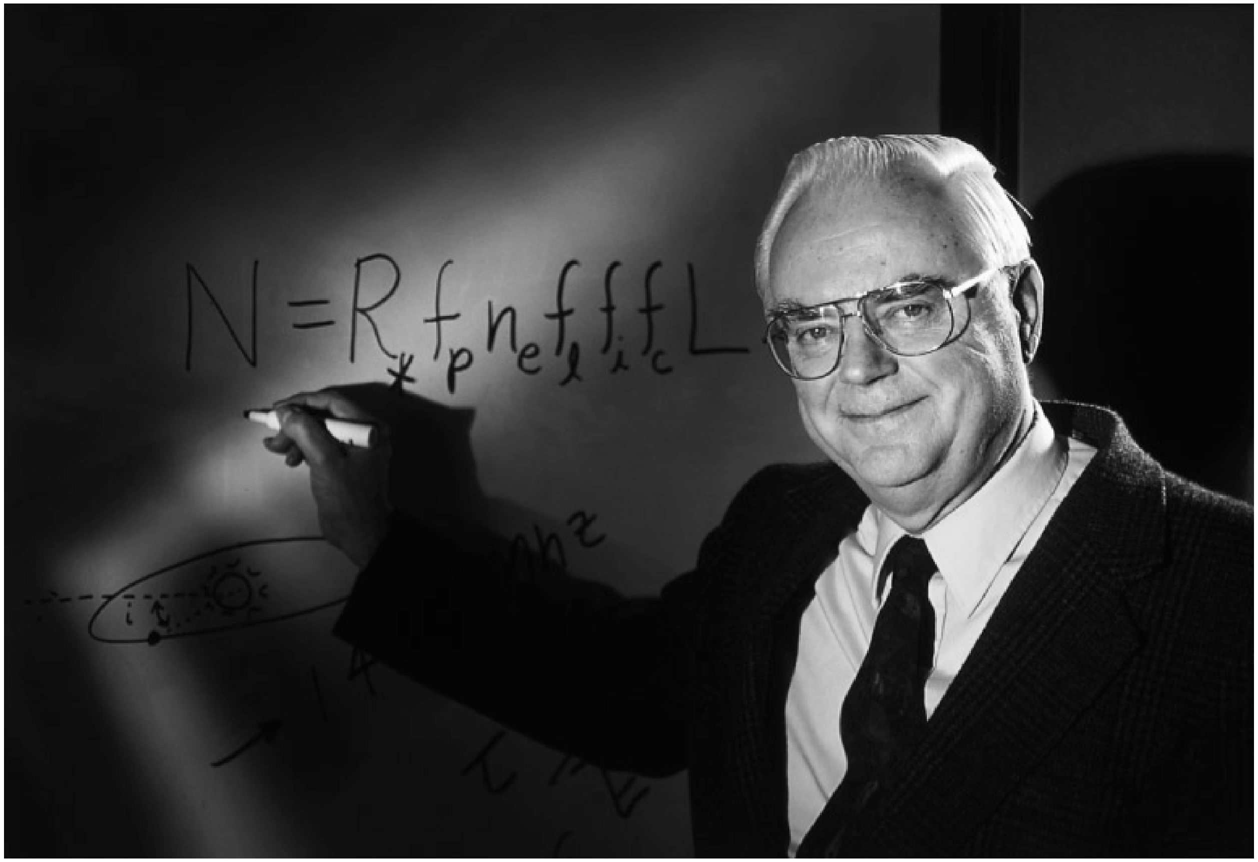
The Search for Extraterrestrial Intelligence



- **What is the Drake equation and how is it useful?**
- **What is SETI?**

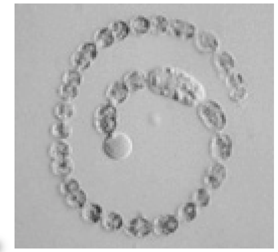
How many civilizations are out there?





Professor Frank Drake, UCSC (retired)

How many civilizations exist in our Galaxy with whom we could make contact?



N_{HP} = number of habitable planets in the Galaxy

f_{life} = fraction of habitable planets which actually contain life

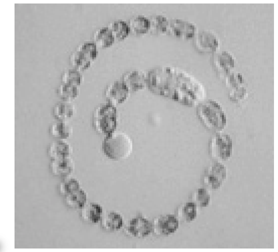
f_{civ} = fraction of life-bearing planets where a civilization has *at some time* arisen

f_{now} = fraction of civilizations which exist *now*

$$\text{Number of civilizations} = N_{HP} \times f_{life} \times f_{civ} \times f_{now}$$

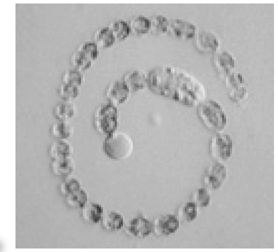
- **This simple formula is a variation on an equation first expressed in 1961 astronomer Frank Drake (UCSC)**
- **It is known as the** Drake equation.

How many civilizations exist in our Galaxy with whom we could make contact?



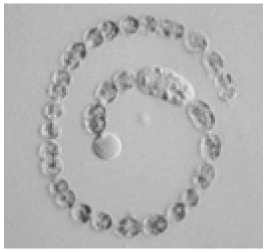
- **Values of the terms in Drake Equation are unknown**
- **The term we can best estimate is N_{HP}**
  - **including single stars whose mass < few $M_{\odot}$ AND…**
  - **assuming 1 habitable planet per star, N_{HP} ~ 100 billion**
  - **unless the "rare Earth" ideas are true**
- **Life arose rapidly on Earth, but it is our only example**
  - **f_{life} could be close to 1 or close to 0**
- **Life flourished on Earth for 4 billion yrs before civilization arose**
  - **value of f_{civ} depends on whether this was typical, fast, or slow**
- **We have been capable of interstellar communication for 50 years out of the 10 billion-year age of the Galaxy**
  - **f_{now} depends on whether civilizations survive longer than this**

How does SETI work?



SETI experiments look for *deliberate* signals from E.T.

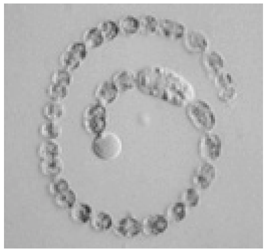
Search for ExtraTerrestrial Intelligence



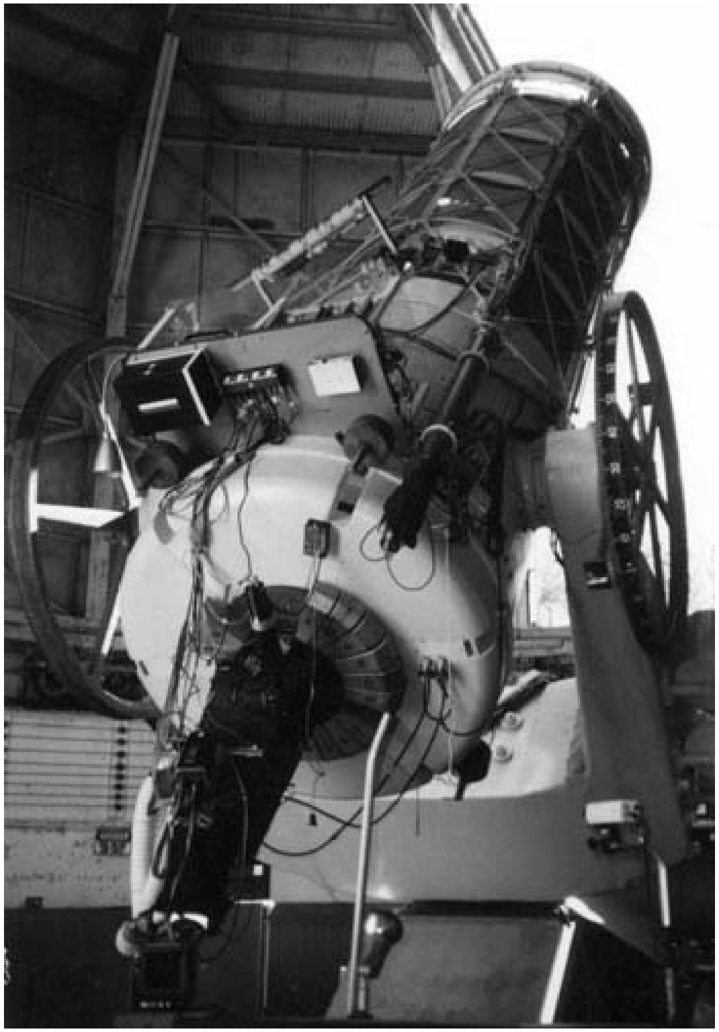
- IF we are typical of intelligent species and…
- IF there are many intelligent species out there…
  - then some of them might also be interested in making contact!
- That is the idea behind the SETI program.

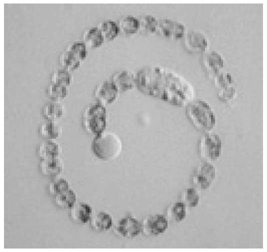
- Radio telescopes listen for encoded signals.
  - strategies to decide which stars to observe
  - scan millions of frequencies at once
- We sent a powerful signal once in 1974 to the globular cluster M13
  - now we just listen
- SETI is privately funded
  - NASA dropped funding when a senator made fun of SETI

Also "Optical SETI" - search for spectral lines typical of common lasers



- A search for intense short laser pulses, transmitted deliberately in our direction by another civilization.
- Harvard
- Lick Observatory
- Princeton
- Columbus Ohio

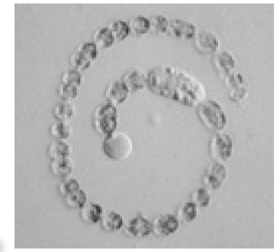




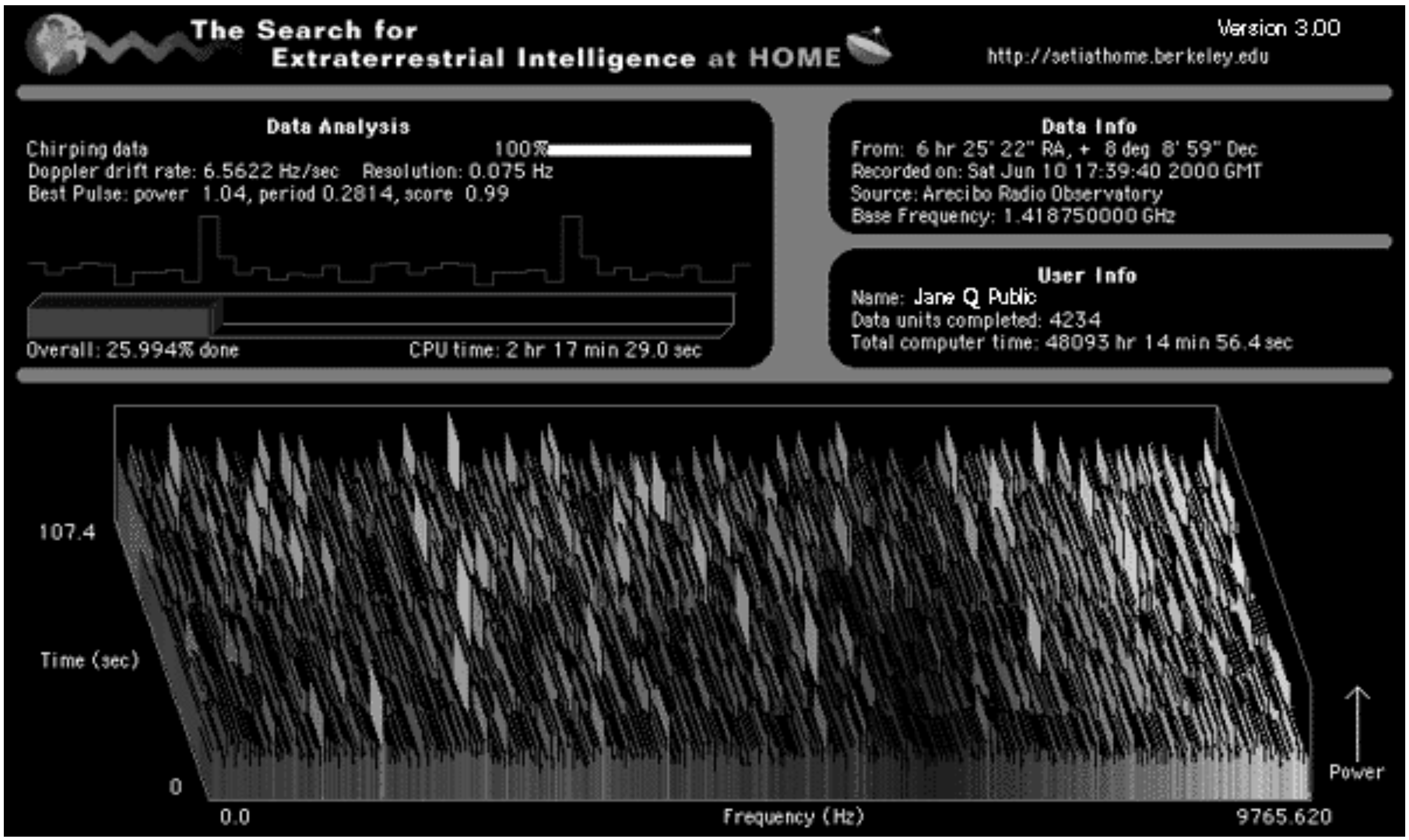
We've even sent a few signals ourselves…

Earth to globular cluster M13: Hoping we'll hear back in about 42,000 years!

You can participate in SETI@home



- **Screensaver that analyzes results from Arecibo radio telescope, sends back results to SETI**



http://setiathome.ssl.berkeley.edu/

Participate in SETI@home | The Search for Extra Terrestrial Intelligence at UC Berkeley

http://seti.berkeley.edu/setiathome/participate

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The Search for Extra Terrestrial Intelligence at UC Berkeley

Home

"From Ozma to the Starship Enterprise"

Check out Photos from the Conference!

"A Conversation about the Next 50 Years of SETI at the National Radio Astronomy Observatory" SETI-people from all over the country met up over three days to discuss the last 50 years of SETI science.

Webcasts of the September 12-15 workshop in West Virgina will be available soon!

Read and take part in the workshop's online discussion

The Great Debate! - Are We Alone?

tweets

Participate in SETI@home

System requirements

- There is an initial download of about 10 MB.
- You'll need about 20 MB of free disk space and 64 MB of RAM.
- with a typical computer (such as a 2 GHz Pentium 4), you'll need to let SETI@home run for at least 2 hours per week (slower computers are fine but they'll have to run proportionally more).

Rules and policies

The rules for participating in SETI@home - read this first.

Download

Download and install the BOINC software used by SETI@home.

Help

Get help installing or running SETI@home.

Tell a friend

Like SETI@home? Email your friends about it.

Porting and optimization

Compile SETI@home for other platforms or with processor-specific optimizations.

Add-on software

Check out add-on software developed by other participants.

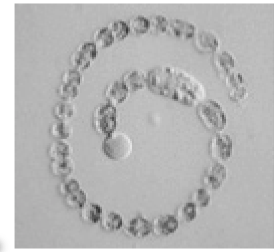
Applications

See the latest versions of applications.

Customize graphics

Learn how to change the appearance of SETI@home graphics.

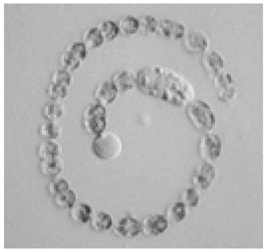
Interstellar Travel and Its Implications for our Civilization



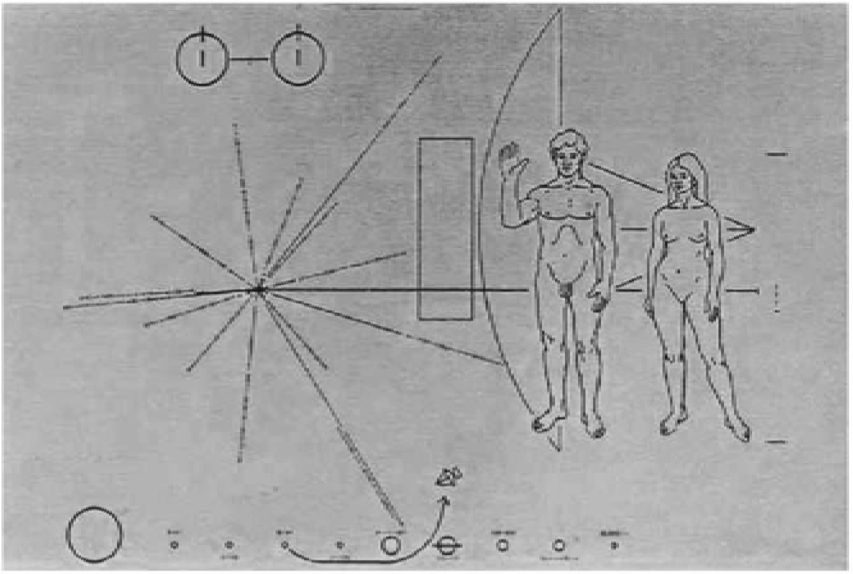
Goals for learning:

- **How difficult is interstellar travel?**
- **Where are the aliens?**

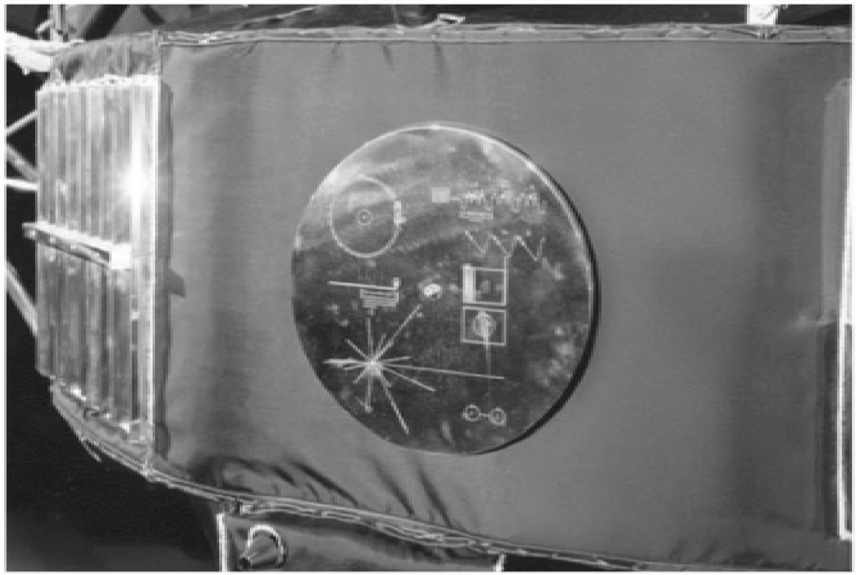
Current Spacecraft are WAY too slow



- **Current spacecraft travel at <1/10,000*c*; 100,000 years to the nearest stars**

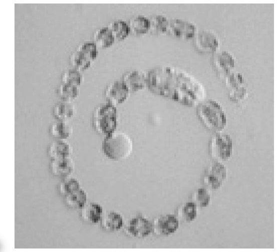


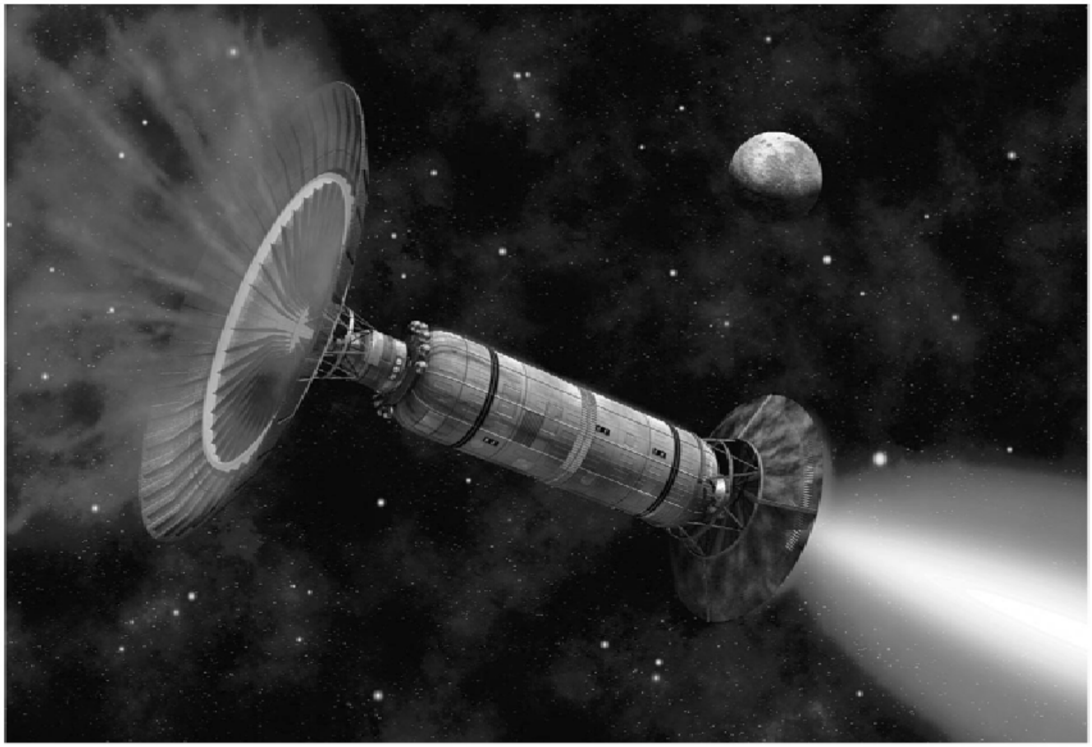
Pioneer plaque



Voyager record

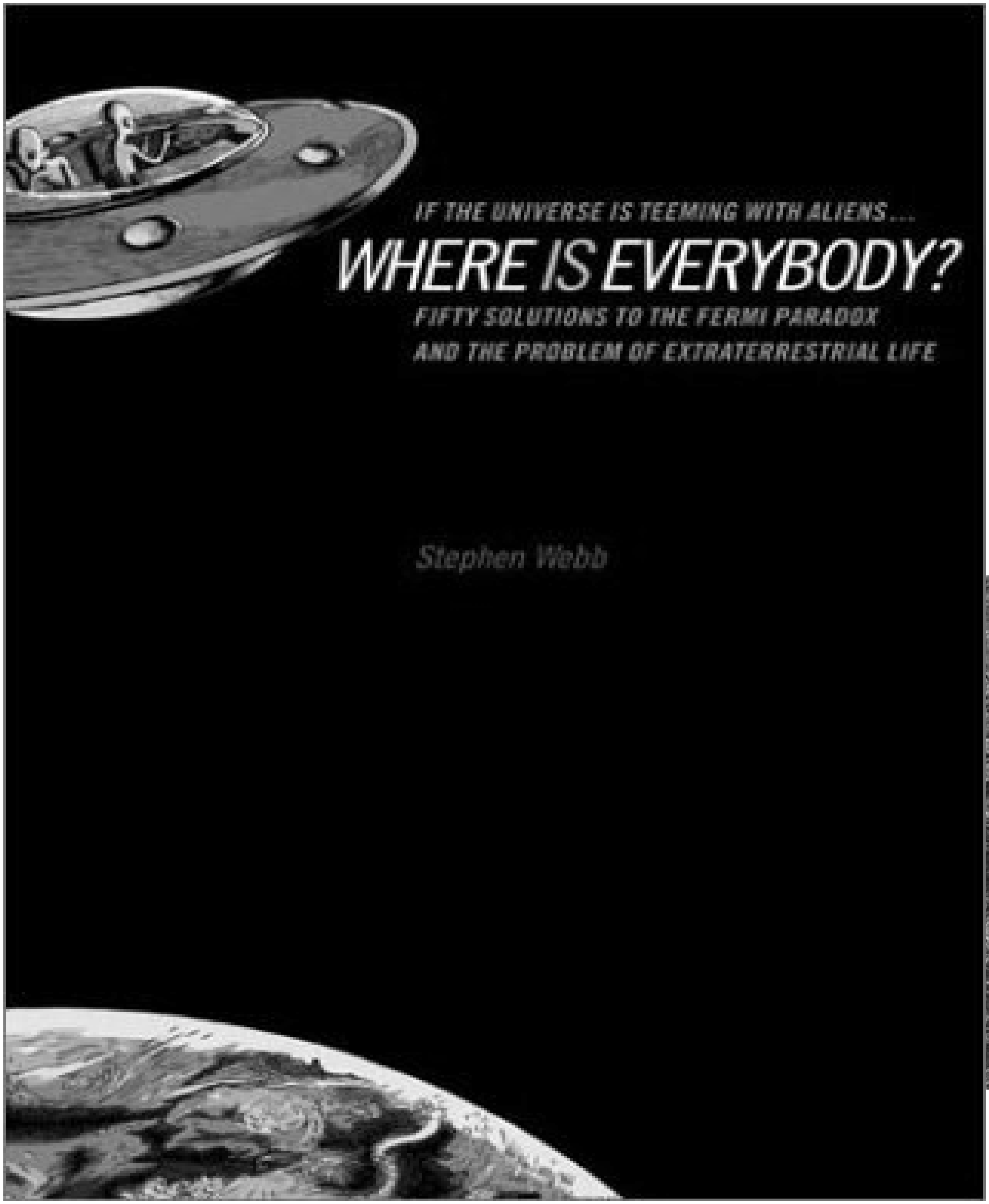
Difficulties of Interstellar Travel

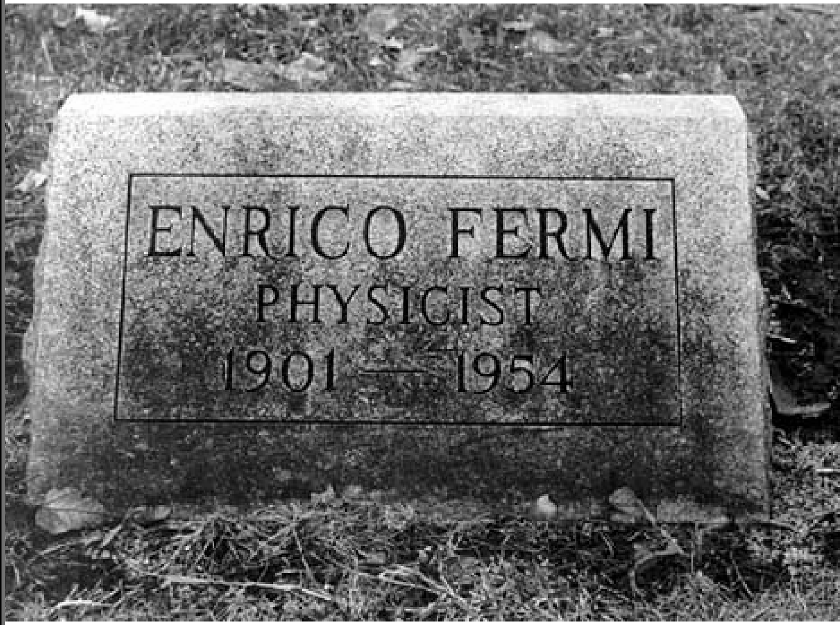




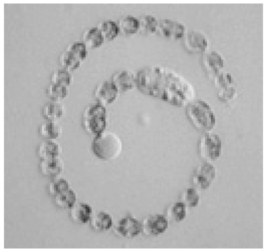
- **Far more efficient engines are needed.**
- **Ordinary interstellar particles become like cosmic rays.**
- **Social complications of time dilation.**

Energy: to accelerate a single spacecraft the size of Starship Enterprise to half the speed of light would require 2,000 times the total annual energy use of the whole world today


IF THE UNIVERSE IS TEEMING WITH ALIENS . . .
WHERE IS EVERYBODY?
FIFTY SOLUTIONS TO THE FERMI PARADOX
AND THE PROBLEM OF EXTRATERRESTRIAL LIFE
Stephen Webb

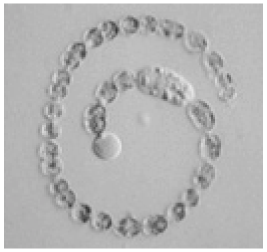

ENRICO FERMI
PHYSICIST
1901 — 1954

Where are the Aliens? Fermi's paradox



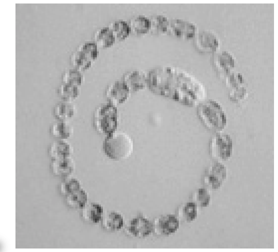
- **With current technology it is plausible that…**
  - **within a few centuries, we could colonize nearby stars**
  - **in 10,000 years, we could spread out to 100s of light years**
  - **in a few million years, human outposts throughout the Galaxy**
- **Assume most civilizations take 5 billion yrs to arise:**
  - **the Galaxy is 10 billion yrs old, 5 billion yrs older than Earth**
  - **IF there are other civilizations, the first could have arisen as early as 5 billion yrs ago**
  - **there should be many civilizations which are millions or billions of years ahead of us**
  - **they have had plenty of time to colonize the Galaxy**
- **So…where is everybody? Why haven't they visited us?**

Possible Solutions to Fermi's Paradox



- **We are really alone**
  - civilizations are extremely rare and we are the first one to arise
  - then we are unique, the first part of the Universe to attain self-awareness
- **Civilizations are common, but have not colonized**
  - interstellar travel is even harder or costlier than we imagine
  - most civilizations have no desire to travel or colonize
  - most civilizations have destroyed themselves before they could
- **There *is* a Galactic civilization**
  – it has deliberately concealed itself from us
- **We may know which solution is correct within your generation!**

Main Points



- **Life elsewhere in the universe:**
  - **None discovered yet**
  - **Building blocks seen throughout interstellar space**
  - **Microbial life seems VERY resilient here on Earth**
  - **Promising other sites for life in our Solar System**
  - **Kepler spacecraft is searching for Earth-like planets: big announcement in February!**
- **Big unknowns: are conditions for animal-type life common, or rare?**