

TODAY

■ LIFE IN THE UNIVERSE

HOMEWORK #6 DUE NOW

**FINAL EXAM:
8:00 AM FRI DEC. 16**

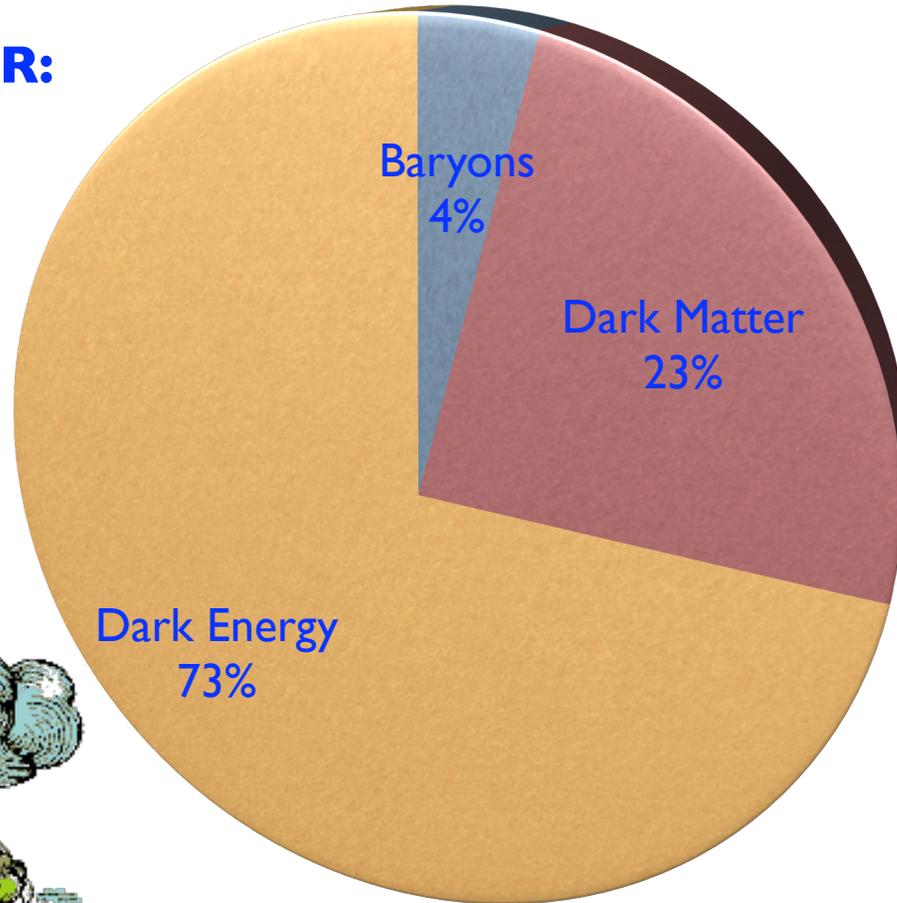
**REVIEW SESSION
6-8 PM TODAY
PHYS 1410**

COURSE EVALUATIONS OPEN



Contents of the Universe

THE ANSWER:



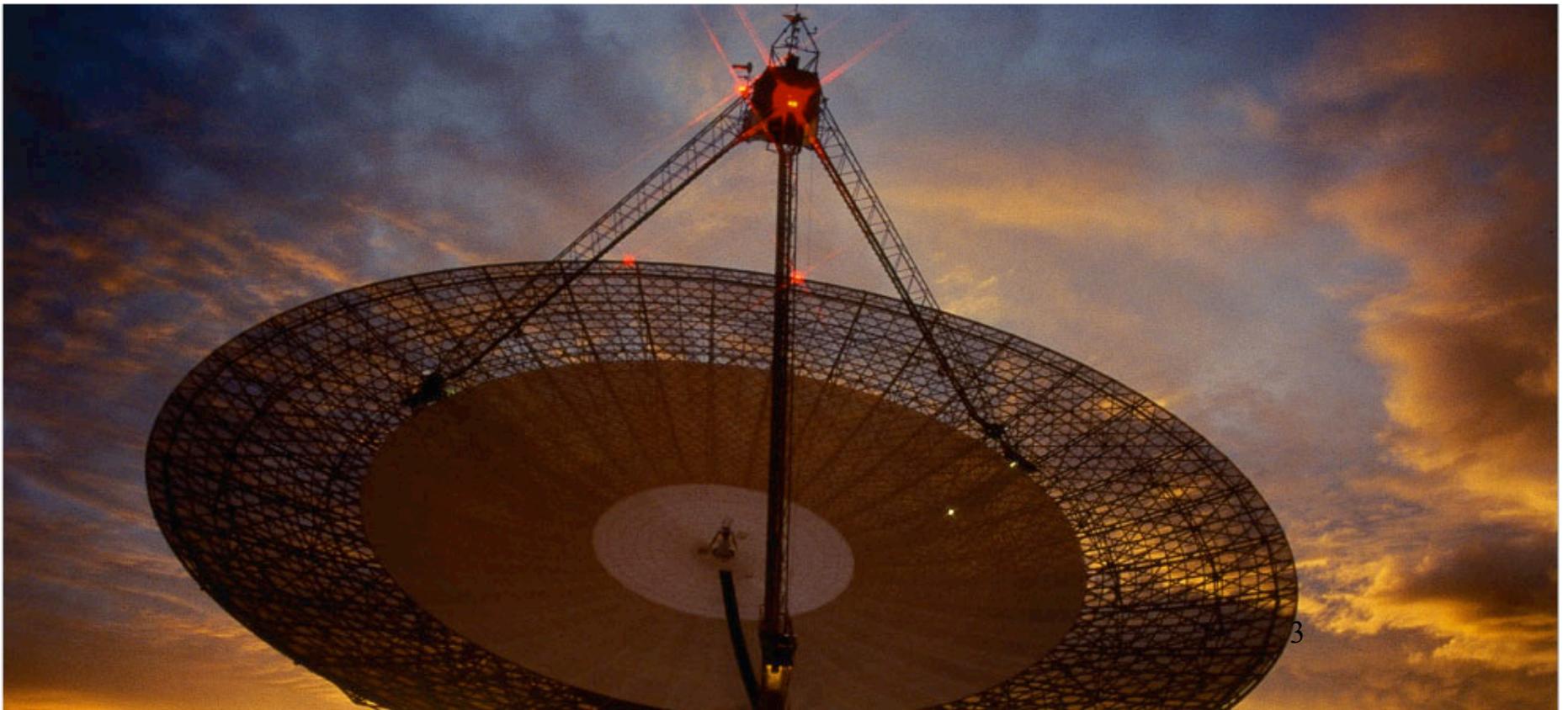
Hot Big Bang
+
Dark Energy
+
Dark Matter
is now called

“ Λ CDM”

Here there
be
dragons!



Life in the Universe



Evolution

- The unifying concept of biology
- Simple and general enough to work everywhere, so we'll discuss it

The Fact of Evolution

- Forms of life change over time, via descent with modification
- That's it!

The Theory of Evolution

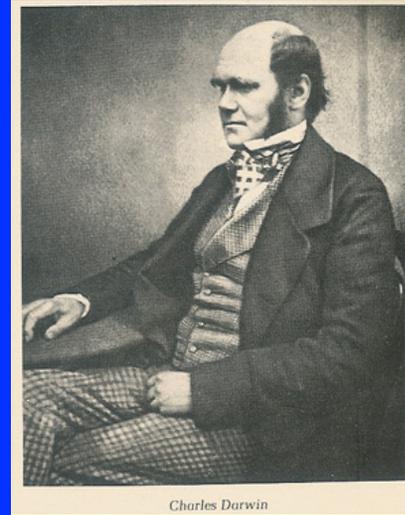
- Characteristics of population are most strongly influenced by individuals who leave the most viable offspring
Seems uncontroversial, even tautological!
- Variation: mutation, sex, horizontal gene transfer, neutral drift, incorporation of cells
- Selection: natural/sexual

Misconception: Evolution is Incompatible with Religion

- Question 1a: if I accept evolution, must I be an atheist?
- Question 1b: if we agree we are descended from animals, do we have no ethical guides?

Incompatible With Religion?

- No!
- Clergy letter project:
>11,000 ministers
signed in US alone
- Affirms evidence for
evolution; not at all in
conflict with personal
religious beliefs



Charles Darwin

<http://openparachute.files.wordpress.com/2008/02/charles-darwin.jpg>



http://www.clergyletterproject.net/clp140_160.gif

Must We Act Like Animals?

- No, how silly!
- Does gravity mean that you have to push people down stairs???
- Evolution is a description of what happened, not a guide
- Ethics comes from other sources

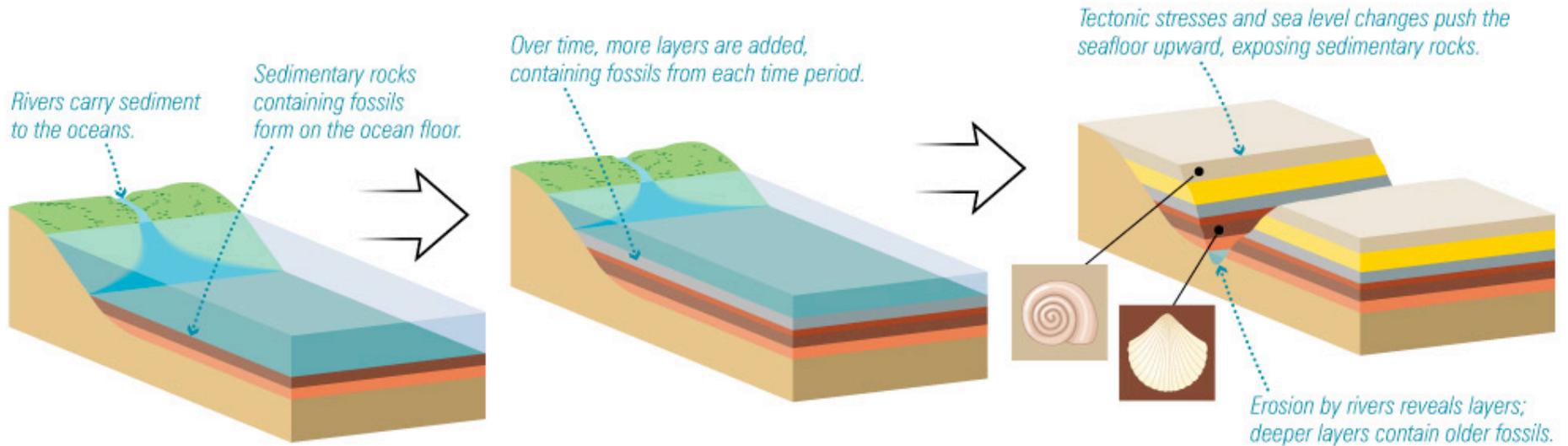


<http://www.looptvandfilm.com/blog/homerevolution.jpg>

Earliest Life Forms

- Life probably arose on Earth around 3.8 billion years ago, after the end of heavy bombardment.
- Evidence comes from fossils and carbon isotopes.

Fossils in Sedimentary Rock



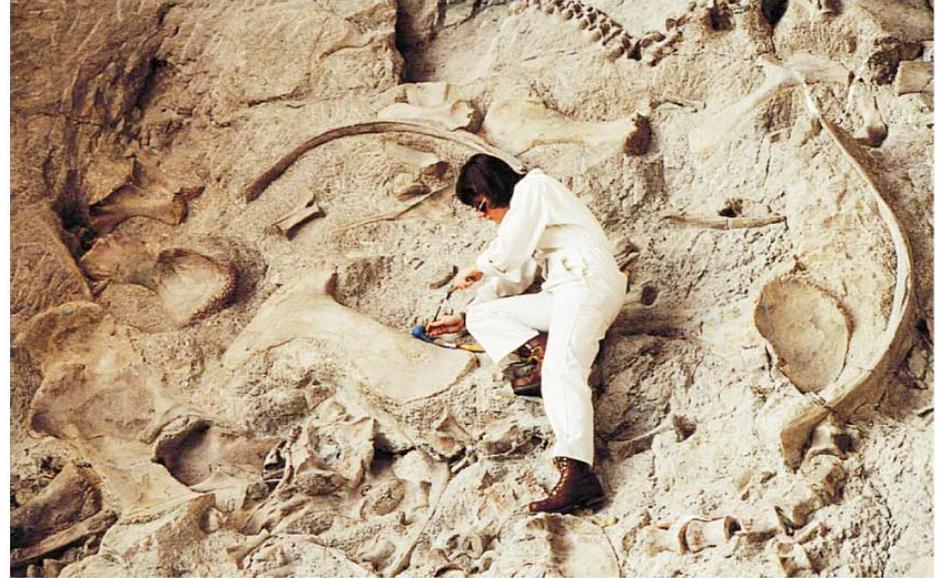
- relative ages: deeper layers formed earlier
- absolute ages: radiometric dating

White Cliffs of Dover



Chalk (a form of limestone) consist mainly of coccolith biomicrites formed from the skeletal elements of minute planktonic green algae, associated with varying proportions of larger microscopic fragments of bivalves, foraminifera and ostracods.

Fossils in Sedimentary Rock



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

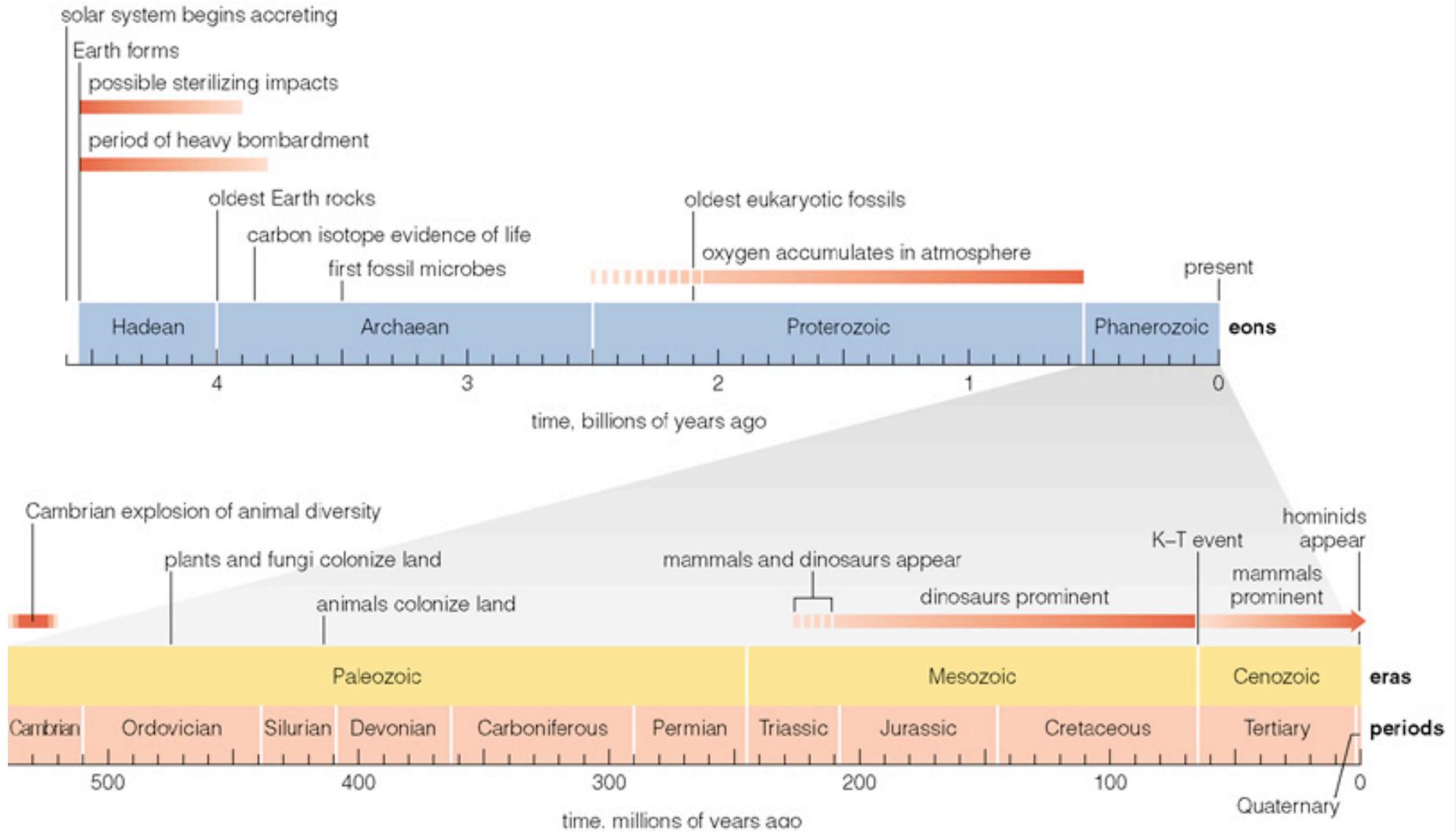
Earliest Fossils



Thrombolites in Lake Clifton, Western Australia. Also a less evolved organism at upper right

- The oldest fossils show that bacteria-like organisms were present over 3.5 billion years ago.
- Carbon isotope evidence pushes the origin of life to more than 3.85 billion years ago.

The Geological Time Scale

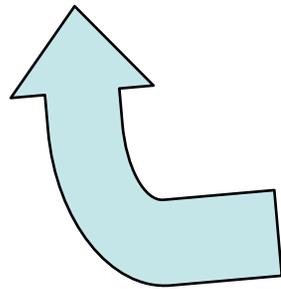


Brief History of Life

- 4.5 billion years — Earth forms
- 4.4 billion years — early oceans form
- 3.5 billion years — cyanobacteria start releasing oxygen
- 2.0 billion years — oxygen begins building up in atmosphere
- 540–500 million years — Cambrian Explosion
- 225–65 million years — dinosaurs and small mammals (dinosaurs ruled)
- Few million years — earliest hominids
- < 10,000 years — Our civilization

Necessities for Life

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



Hardest to find on
other planets

Necessities for Life

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

There is life *everywhere* on Earth where there is liquid water at least part of the time

Life Deep in Rock

- Probably most of the biomass on Earth!
- So far, record is almost three miles below the surface
- Also found miles below seafloor
- Live in rock cracks; can remain in stasis for many years (thousands? more?) until there is some water

Wild Speculation

- Depth limited by heat
Need liquid water
- Mars is smaller, has cooled off faster
- Probably much thicker part of crust that can harbor life
- Might there now be more living biomass on Mars than on Earth?



<http://www.windows.ucar.edu/mars/images/mars1.gif>³⁷

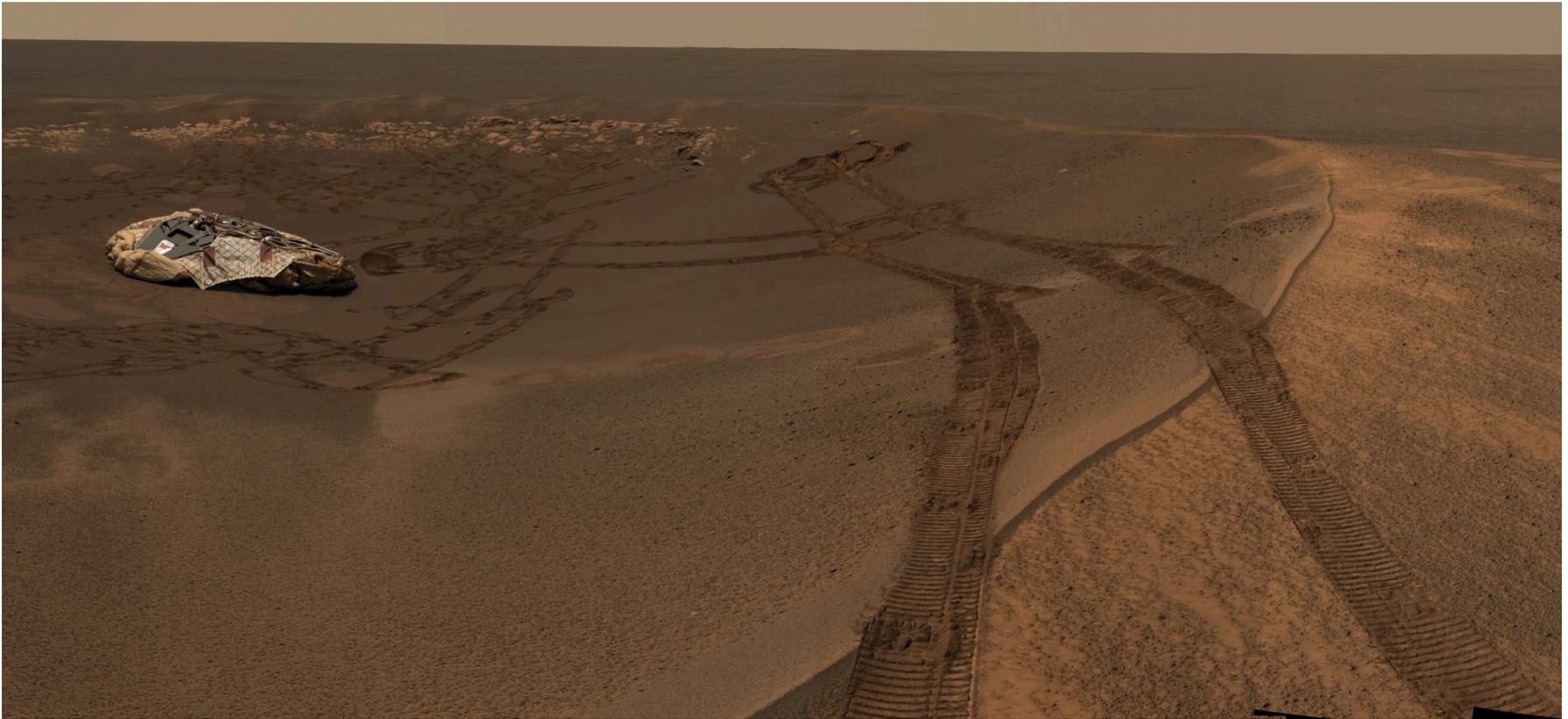
Undersea Thermal Vents

- Near volcanic vents
- Rich with minerals
- Bacteria/archaea use the nutrients
- Other things eat them
- Whole ecosystem!



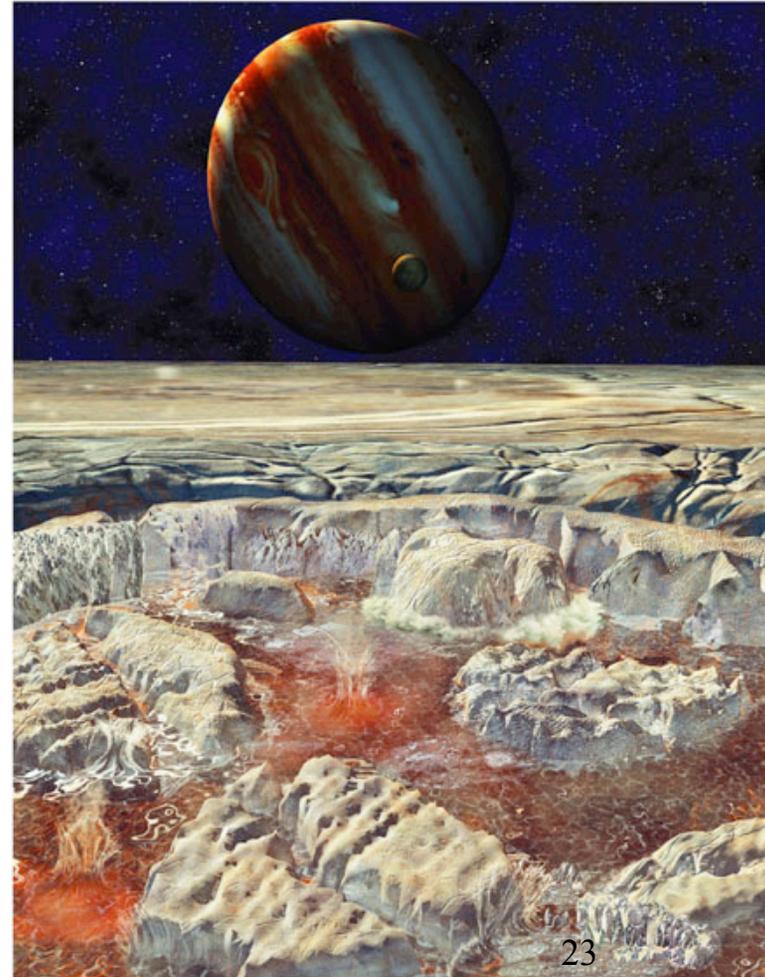
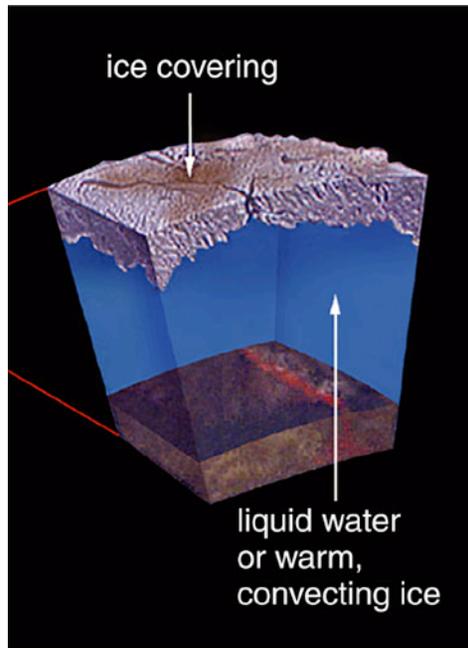
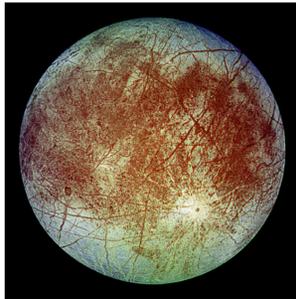
http://ocean-ridge.ldeo.columbia.edu/courses/subgeol/hot_springs/smokers.gif

Searches for Life on Mars

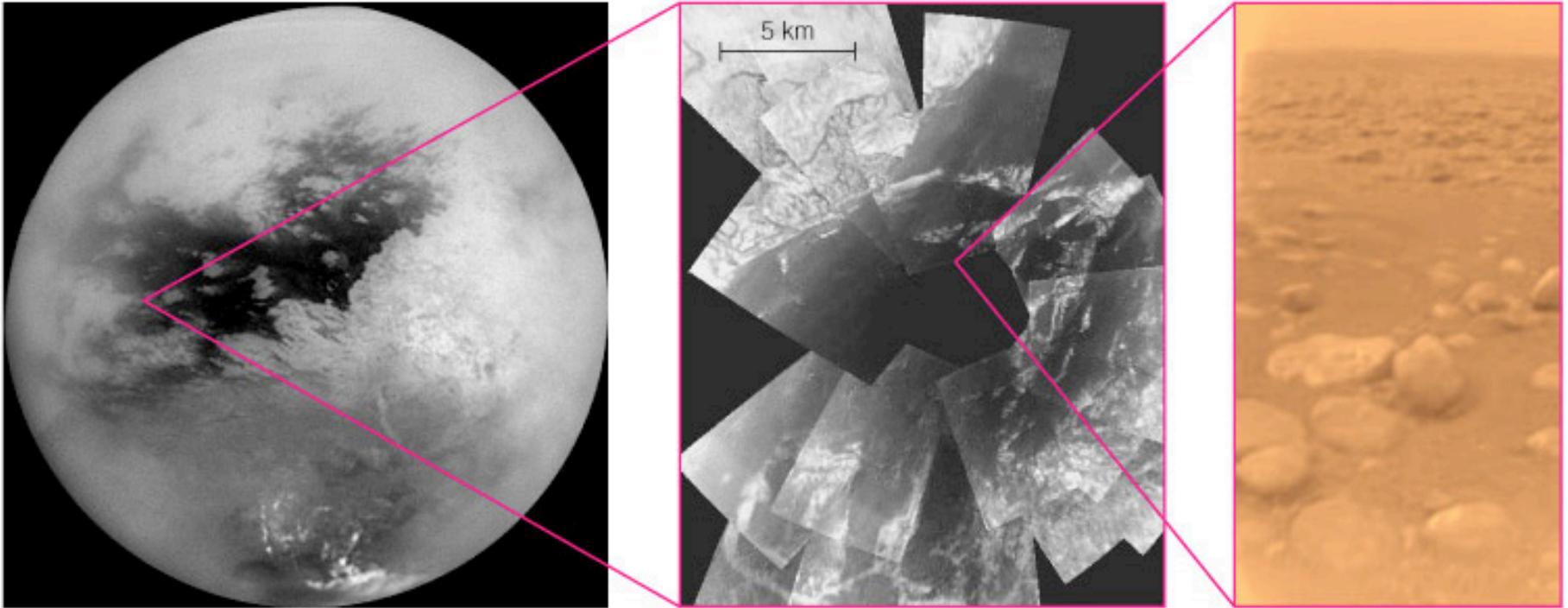


- Mars had liquid water in the distant past.
- Mars still has subsurface ice—possibly subsurface water near sources of volcanic heat.

Could there be life on Europa or other jovian moons?

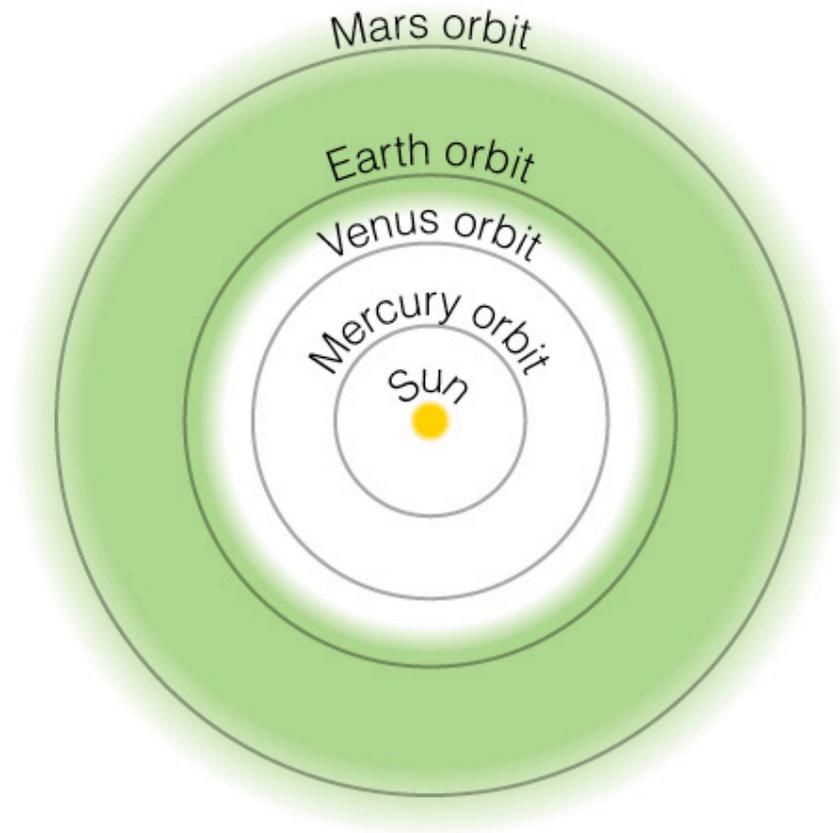


Titan

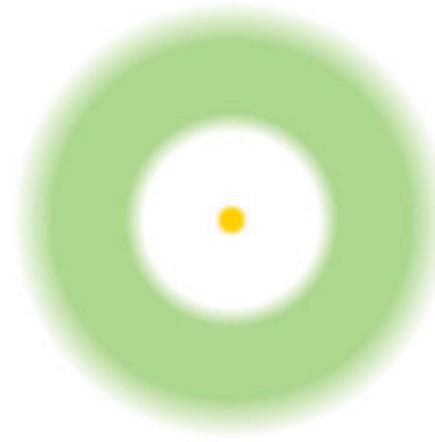


- Surface too cold for liquid water (but deep underground?)
- Liquid ethane/methane on surface

Habitable zone



Solar System



**Star with
mass $\frac{1}{2} M_{\text{Sun}}$**



**Star with
mass $\frac{1}{10} M_{\text{Sun}}$**

Habitable Planets

Definition:

A **habitable** world contains the basic necessities for life as we know it, including liquid water.

- It does *not* necessarily have life.

Constraints on star systems:

1. Old enough to allow time for evolution (rules out high-mass stars — 1%)
2. Need to have stable orbits (*might* rule out binary/multiple star systems — 50%)
3. Size of “habitable zone”: region in which a planet of the *right size* could have liquid water on its surface

Even so... billions of stars in the Milky Way seem at least to offer the possibility of habitable worlds.

The Bottom Line

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

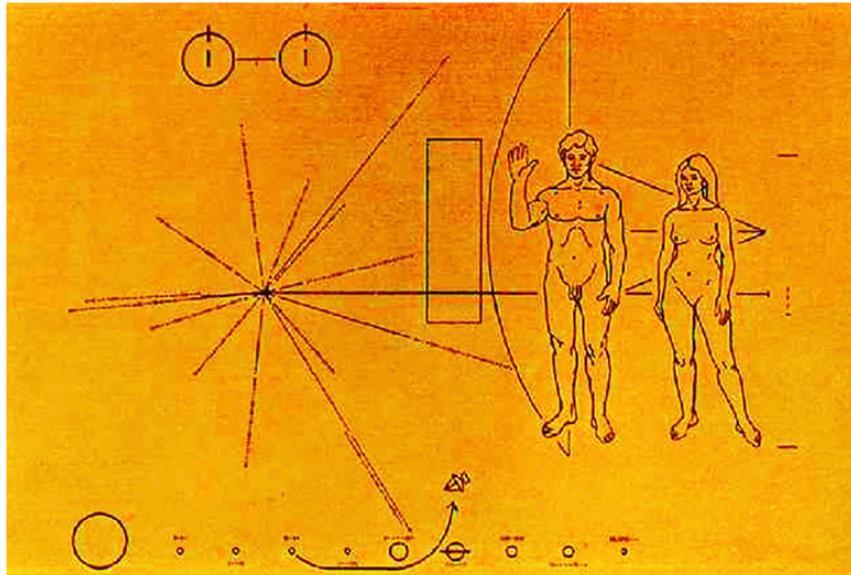
Interstellar travel (?)



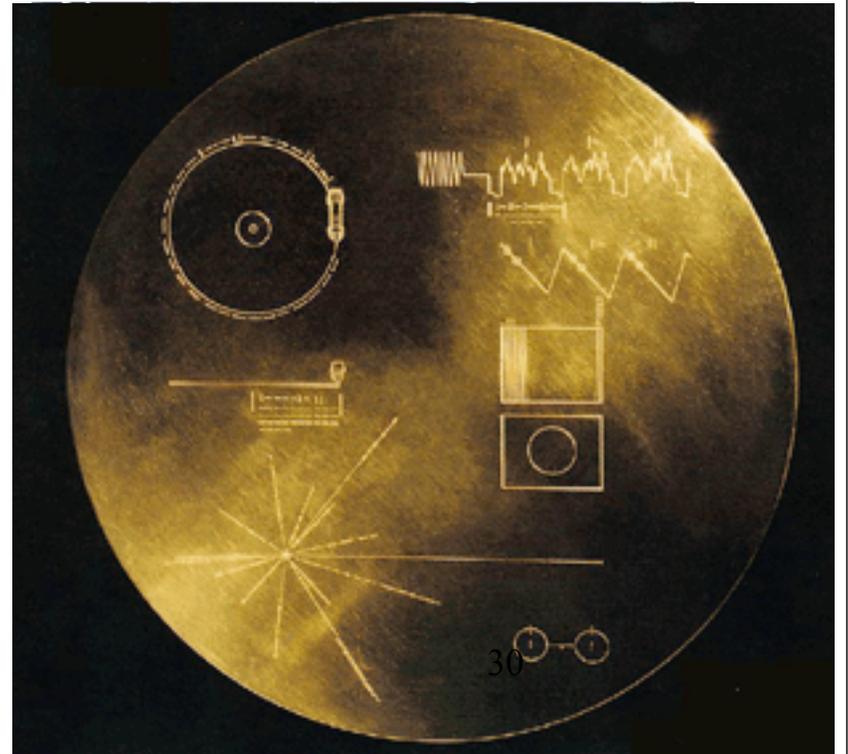
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Current Spacecraft

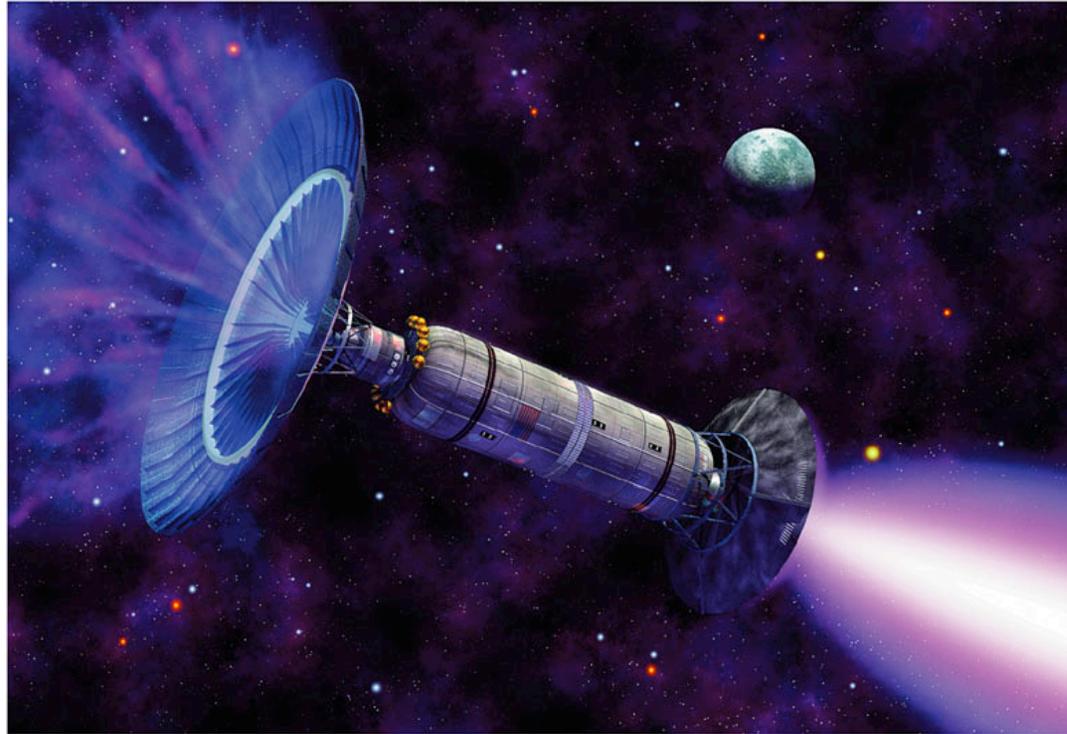
- Pioneers & Voyagers beyond Pluto now
- These spacecraft travel at $<1/10,000$ c;
100,000 years to the nearest stars



Pioneer plaque



Difficulties of Interstellar Travel



- Far more efficient engines are needed.
- Energy requirements are enormous.
- Ordinary interstellar particles become like cosmic rays.

Even at half light-speed...

- Takes 9 years to reach the nearest star
 - more with acceleration & deceleration
- Takes just as long to get back
- There are 32 stars within 12 light-years
- That's about all that can be explored in a human lifetime
 - 24 years to grow & train
 - 24 to get there, 24 to get back
 - you're 72 upon return

SO...

- The universe is **BIG**
- and really, really **OLD**

What are the chances that aliens are visiting us just now?

(Consider what you'd find if you had visited Earth at any random moment in its history.)



The Burden of Proof

- Suppose I claim to have seen an alien
- Is it up to you to disprove me?
- No!
- Carl Sagan: “Extraordinary claims require extraordinary proof”
- What does this mean in practice?

First Claim

- Suppose I told you that yesterday I saw a friend walking down the street
- Would you believe me? If not, what level of proof would you require?



Second Claim

- Now suppose I told you that the other day I saw a 100-foot tall cyclops walking down the street
- Would you believe me? If not, what level of proof would you require?



<http://bearah718.tripod.com/sitebuildercontent/sitebuilderpictures/cyclops.jpg>

Importance of Discovery

- Suppose visits by aliens were established beyond any question
- This would be the most important discovery in history
- As a result, we need to apply the highest standards of evidence to any alien claim
Must be absolutely indisputable
- ...and at this stage, no alien claim is even remotely indisputable

Alien life is likely

- LOTS of stars
- No reason to presume Earth is 100% unique

Visits from aliens very unlikely

- Distance between the stars is vast
- Nothing special about right now
 - If aliens did make it to earth, they only have a one in a million chance of arriving while we've been around