

ASTR 380
The Origins of Life on Earth



The Origins of Life on Earth

The background of the slide is a composite image. In the upper left, a planet with a blue and white atmosphere is shown. In the upper right, a bright yellow sun is visible. The lower portion of the image shows a dark, rocky surface with a small crater, suggesting a planetary or lunar landscape.

Working back from today
The most basic components
How DNA and RNA work
Working forward from simple molecules
Bridging the gap

Debate: how easily does life arise?

Mid-term: October 13



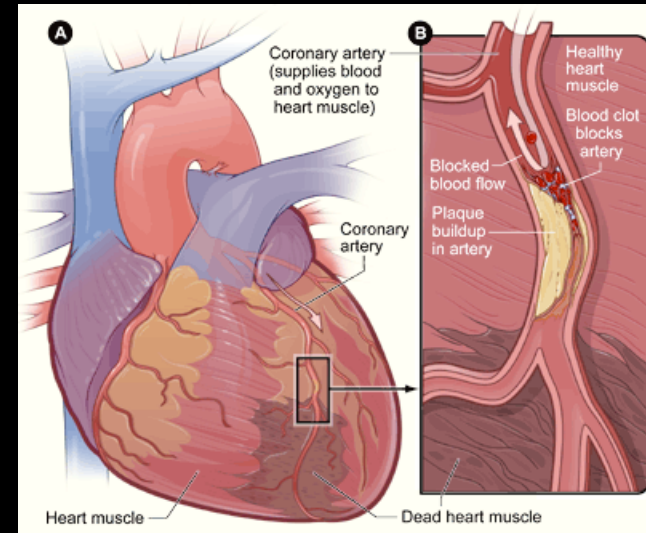
The Colonisation of Space.

Midterm

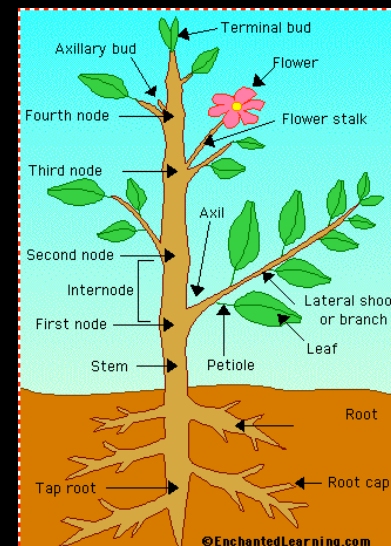
- In class, usual time
Closed-book, closed-notes
- Will cover everything thus far in class
Written notes
Slides and presentations/discussion in class
Reading from book
- Format will be similar to homeworks
Four short response questions
One question involving computation
Bring calculator, paper, extra pens!

Current Life: Animal, Plant

- Very complex
- Many organs, tissues with specialized functions
- What about their individual cells?



http://www.nhlbi.nih.gov/health/dci/images/heart_coronary_artery.gif



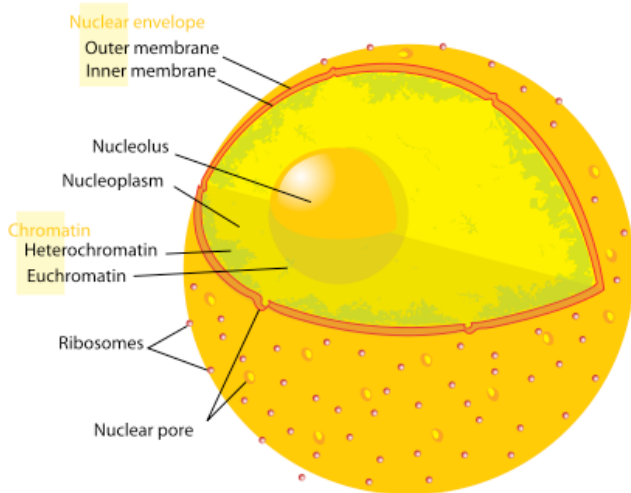
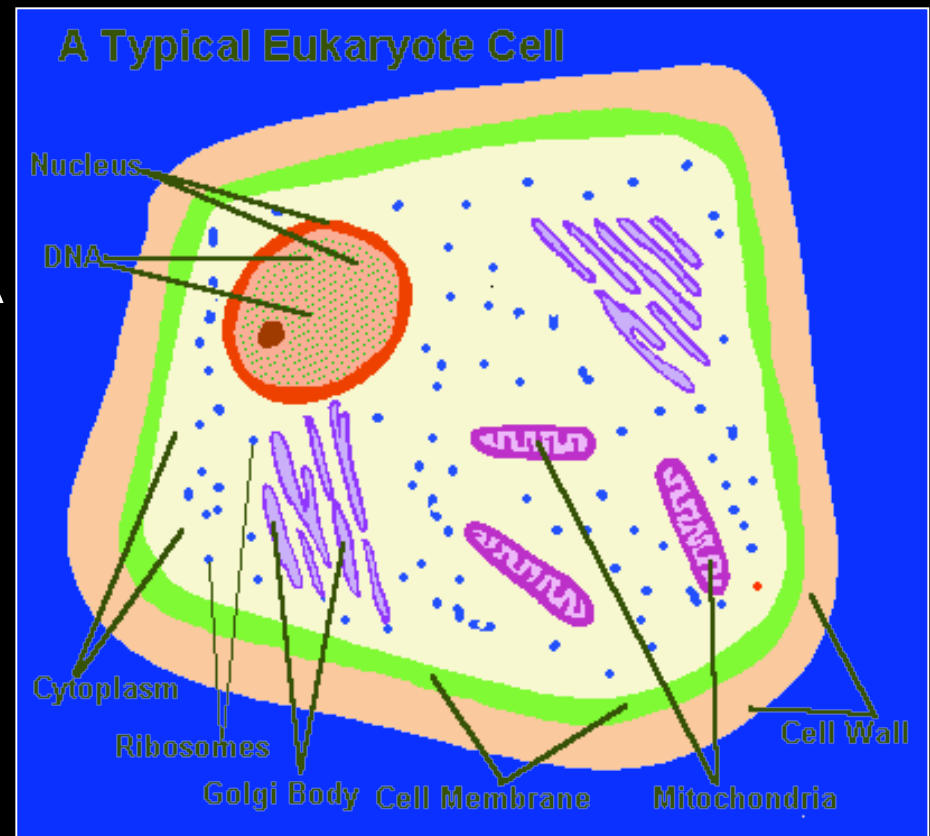
www.enchantedlearning.com

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What is the simplest form of life that exists today?

A eukaryote cell contains:

Nucleus – double walled cell within cell containing DNA
DNA – genetic material.
Blueprints for cell



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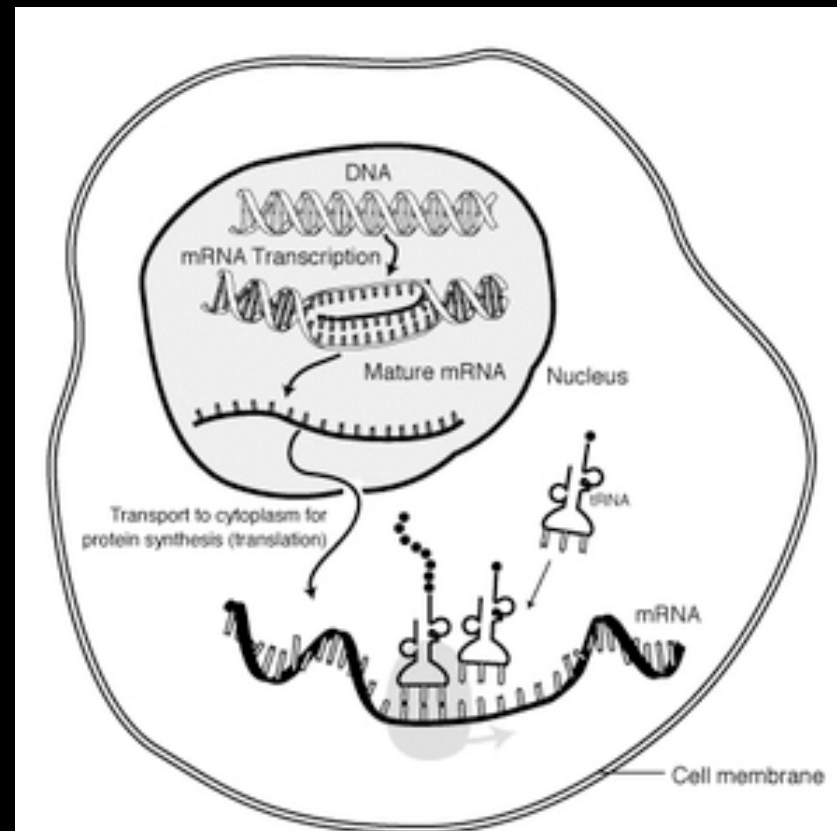
RNA world in eukaryote cell

mRNA – messenger RNA is copied from part of the DNA and contains the blueprint for a protein

tRNA – delivers amino acids to ribosomes for building proteins

rRNA – ribosome RNA which does the decoding of mRNA

Ribosomes – structures of RNA and proteins which build proteins from amino acids delivered by transfer RNA

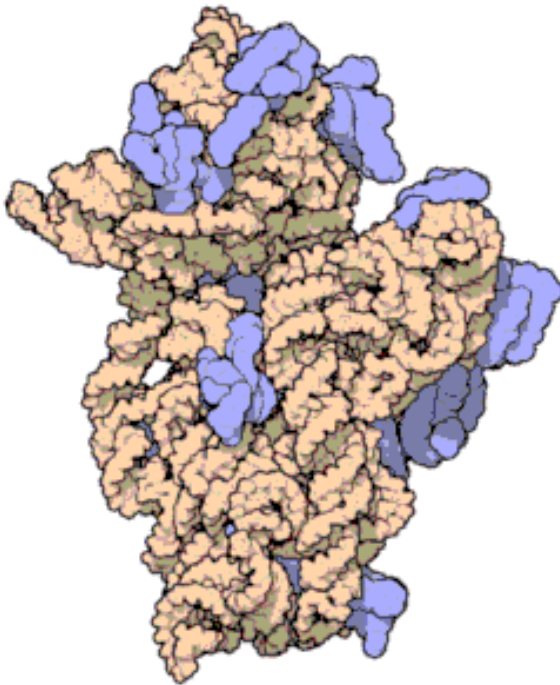


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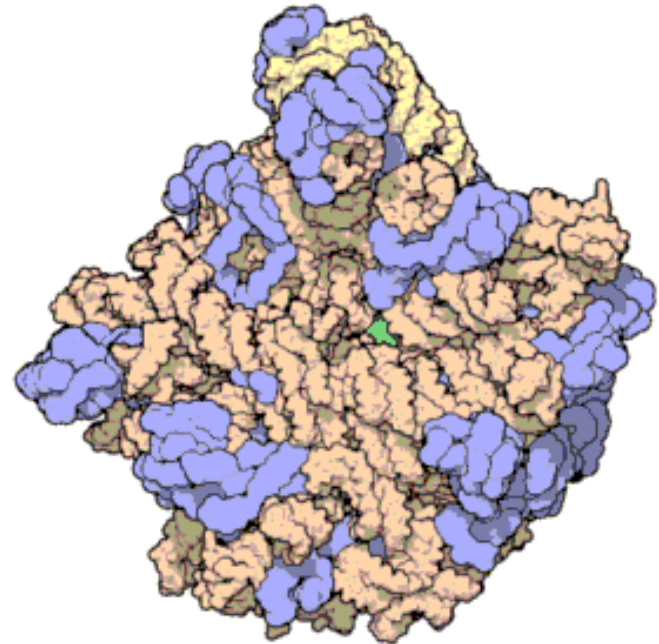
RNA world in eukaryote cell

Proteins are intertwined with RNA to create the correct structure.

Protein in blue



RNA in orange/yellow



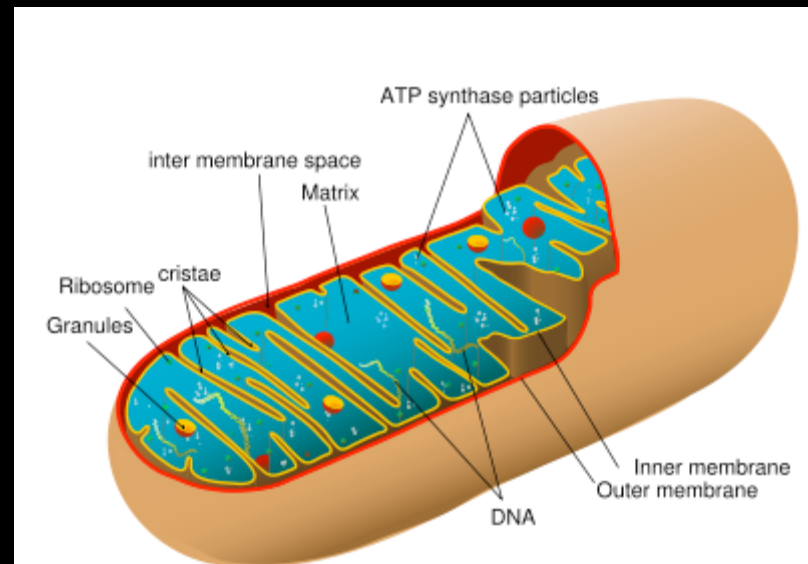
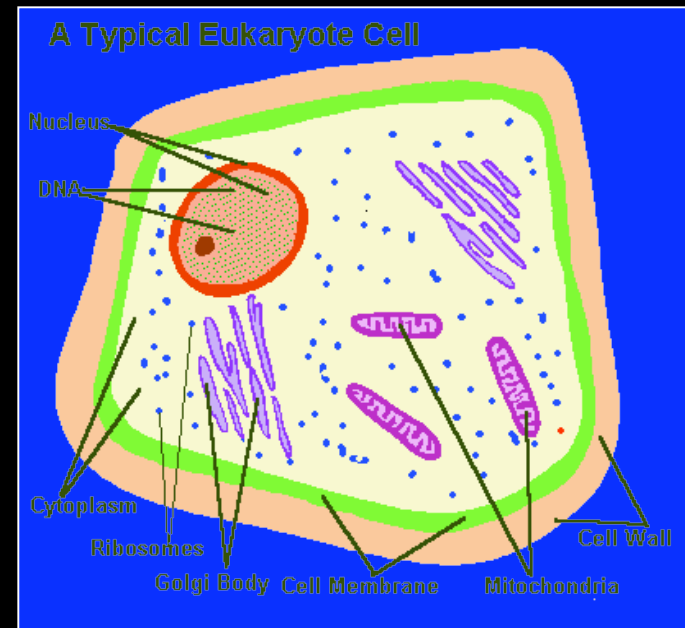
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A eukaryote cell contains:

Golgi body – packages proteins and lipids for use and delivers them around cell.

Mitochondria – separate cell which may be descendant of free living prokaryote with independent DNA.
Now the power supply.

Produces ATP from glucose and oxygen

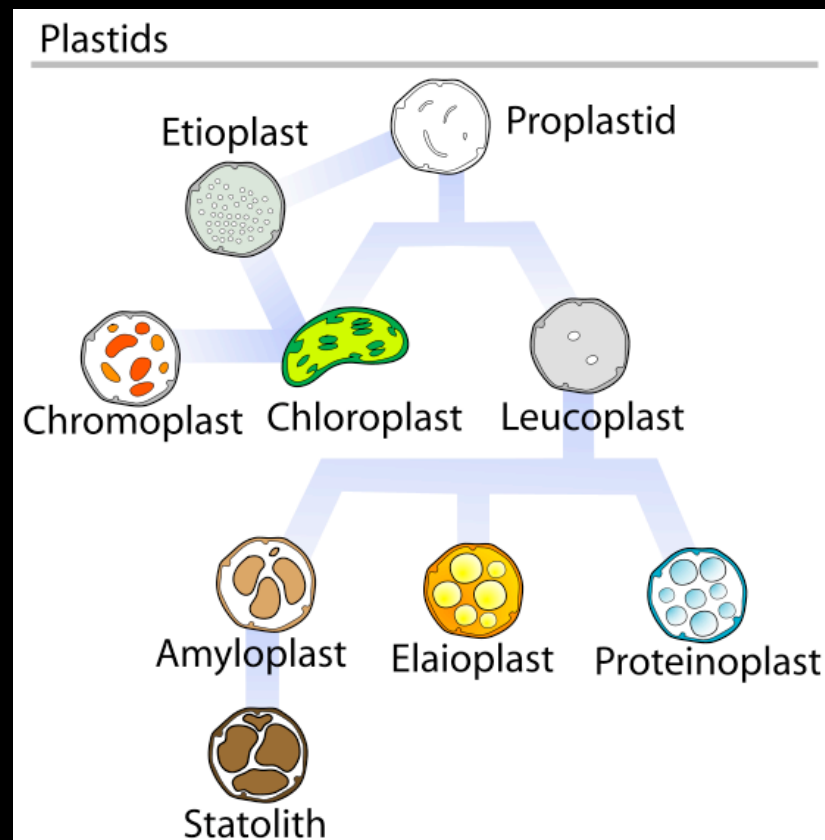


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A eukaryote cell contains:

Plastids – present in plants

do the photosynthesis and other essential tasks
separate DNA but dependent on cell DNA also

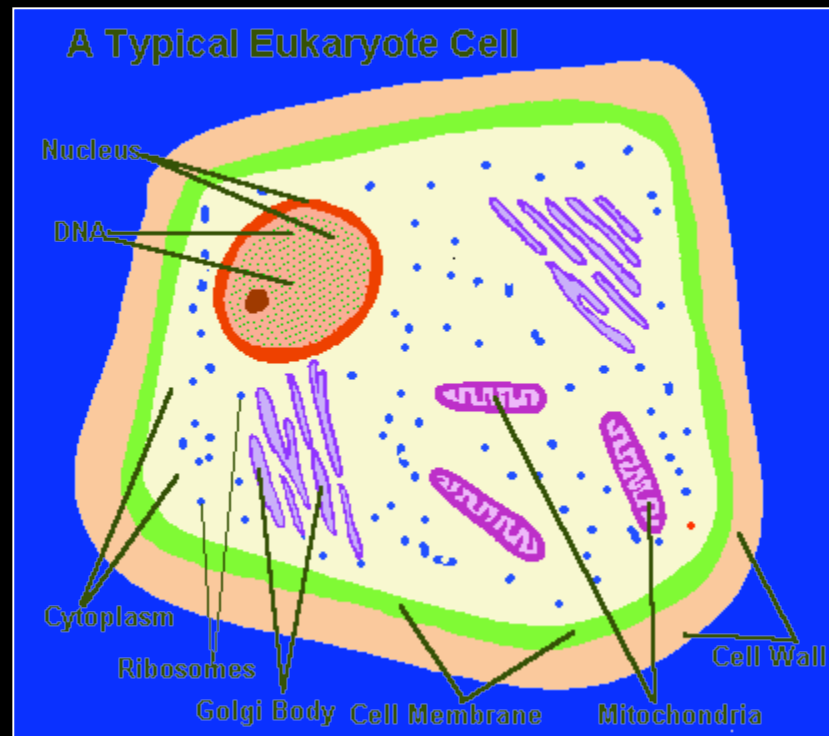


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A eukaryote cell is a complex of cells within cells.

Not a good place for life to start.

It rather looks like a chop-shop where all sorts of useful developments were brought together under one roof!

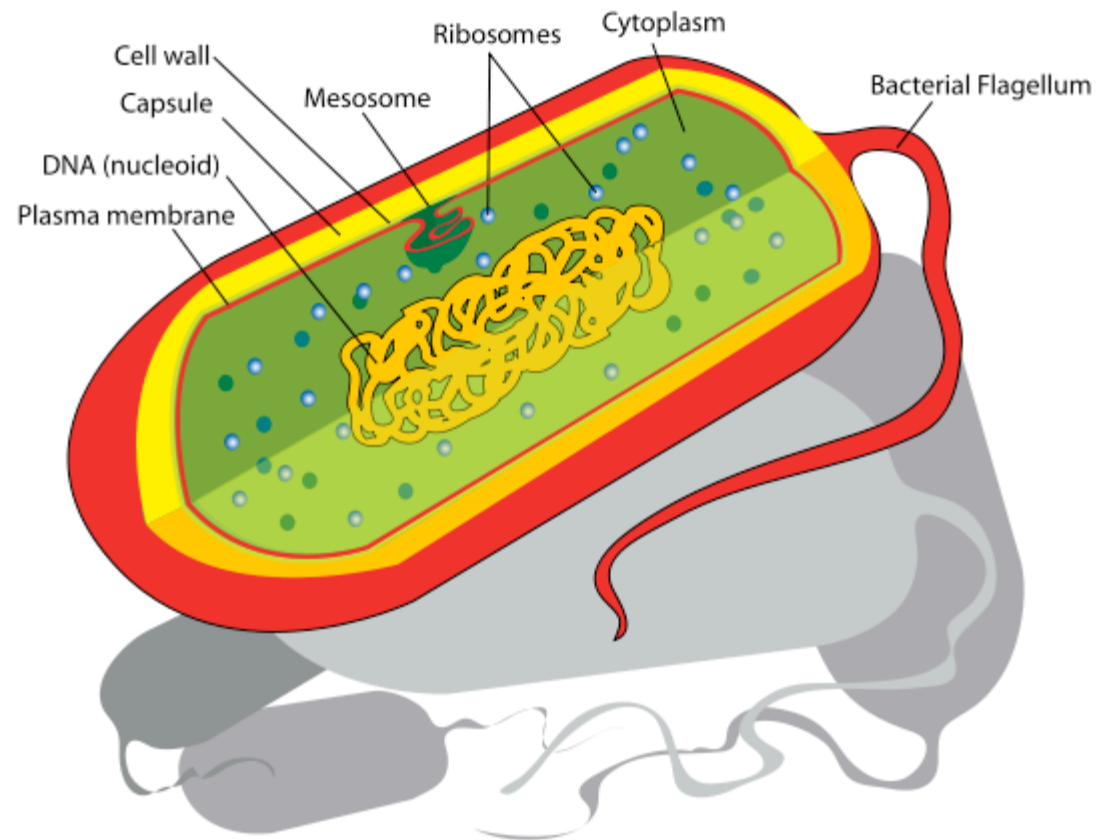


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A prokaryote cell contains:

DNA without a nucleus which is generally a single circular loop – with no wasted coding

Ribosomes and RNA
system to create
proteins



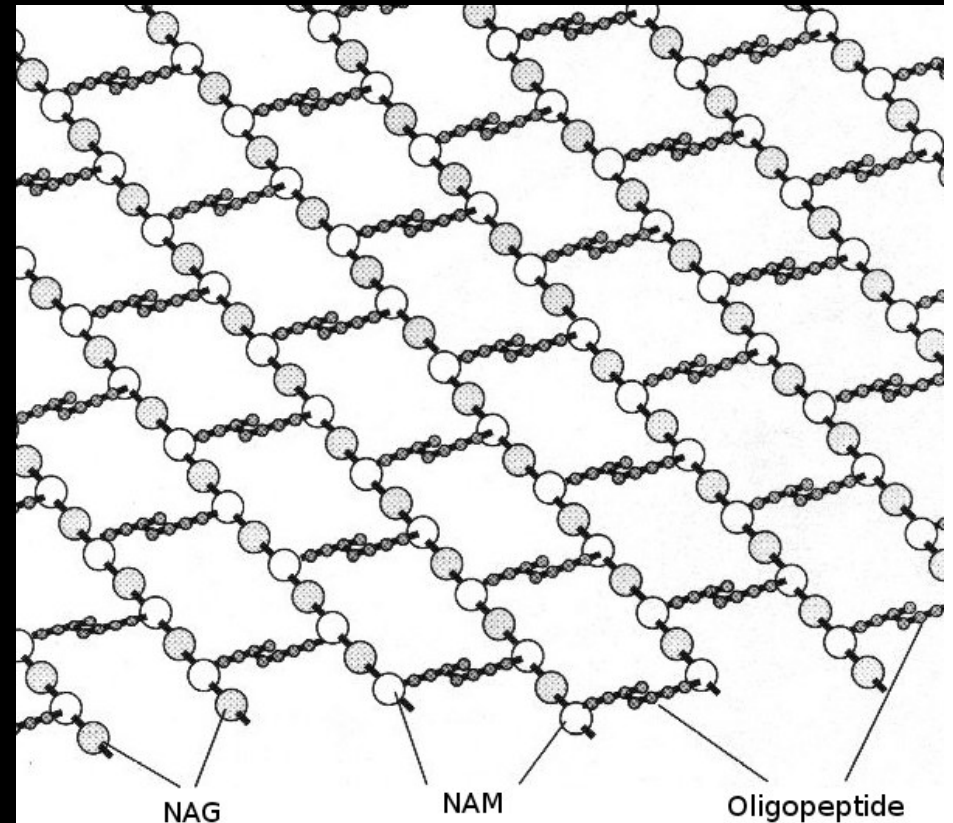
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A prokaryote cell:

Cell wall is a lattice structure of sugars and amino acids

The role of the Golgi body and the mitochondria occur at the cell wall.

Very clearly more primitive than eukaryote cells



Current Developments

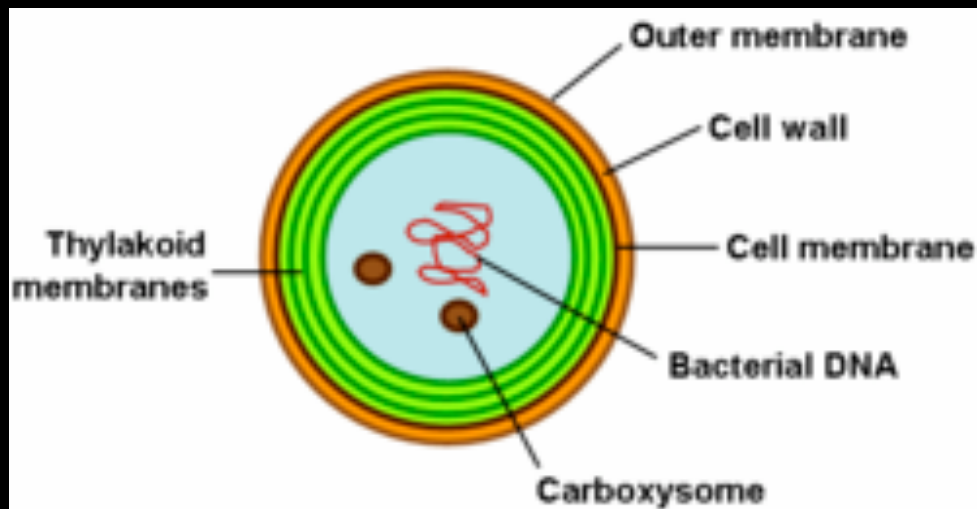
- Membrane-genetic coevolution?
- Jack Szostak and colleagues, 2009
- Basic idea:
 - Fatty acids naturally form double layers
 - Incorporate new fatty acids, divide
 - Small molecules can enter protocells
 - When combine to form larger molecules, cannot get out
- Nucleotides can assemble in this way

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Cyanobacteria are prokaryotes

Fossil evidence that they lived 3.8 billion years ago.

photosynthesis occurs within
Thylakoid structures – green
below

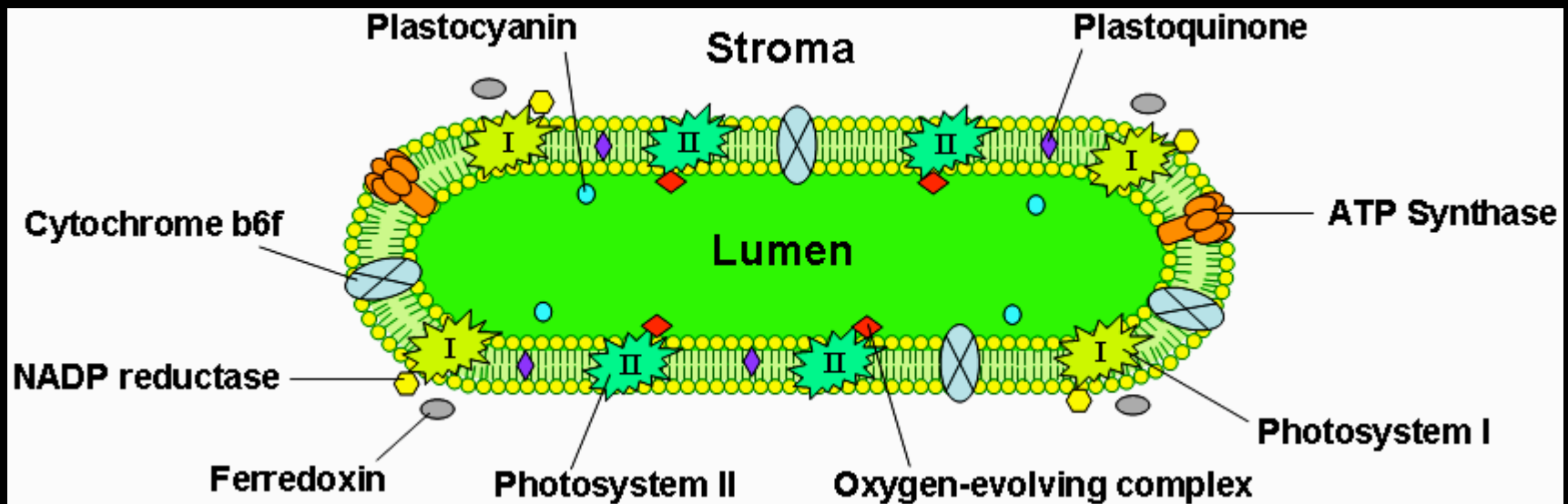


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Cyanobacteria

Thylakoid structure is a complex structure which contains at least 335 different proteins...

Simpler but not so simple....

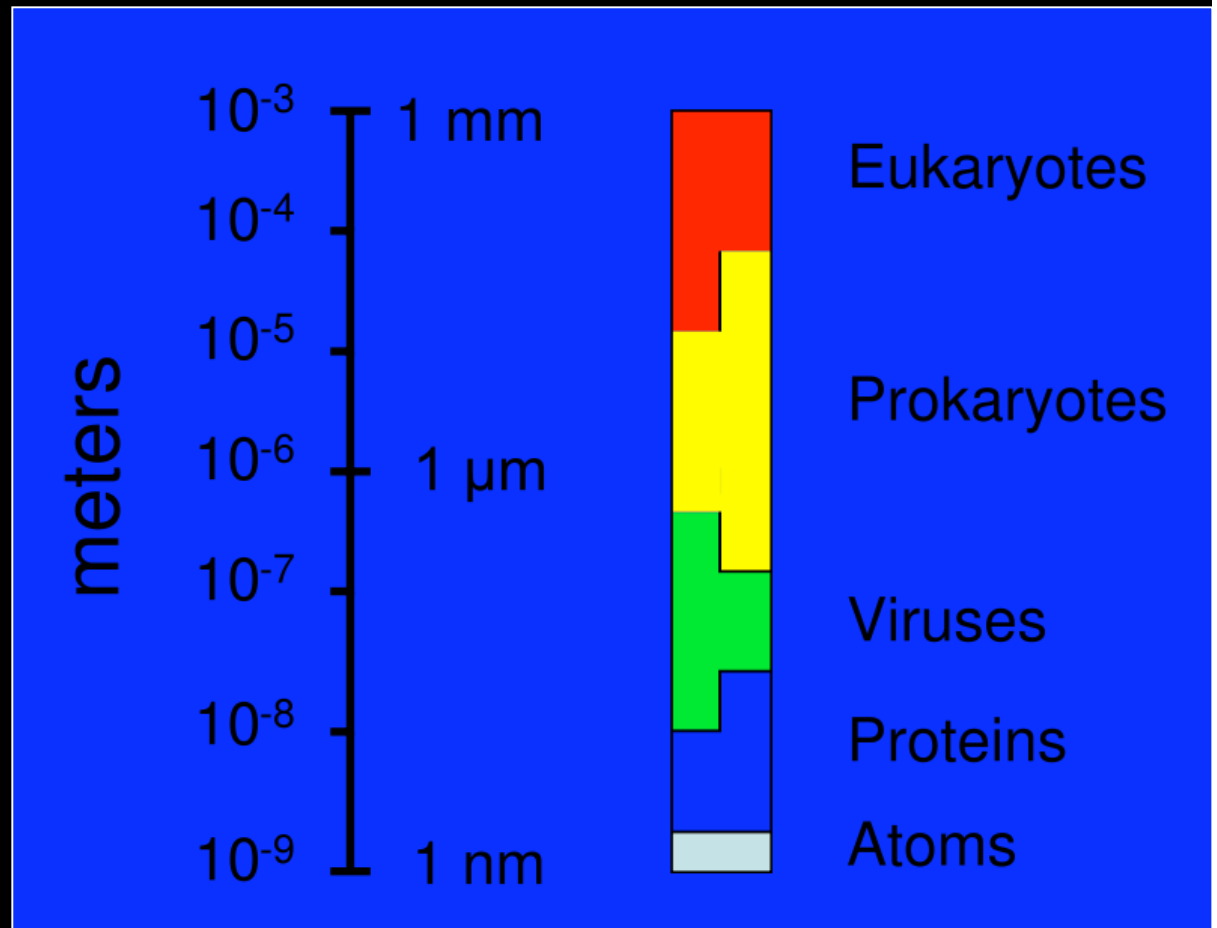
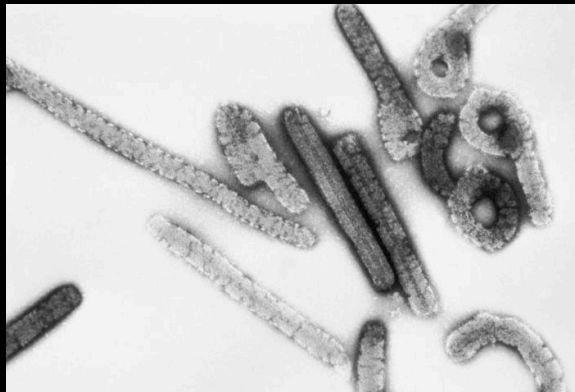
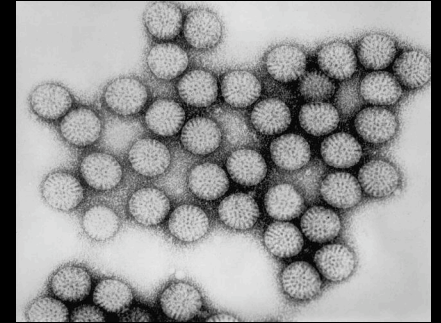


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What about viruses?

Smallest form of “life” – if considered life

Genetic material is
DNA or RNA



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What about viruses?

RNA – genetic material and blueprints for all parts

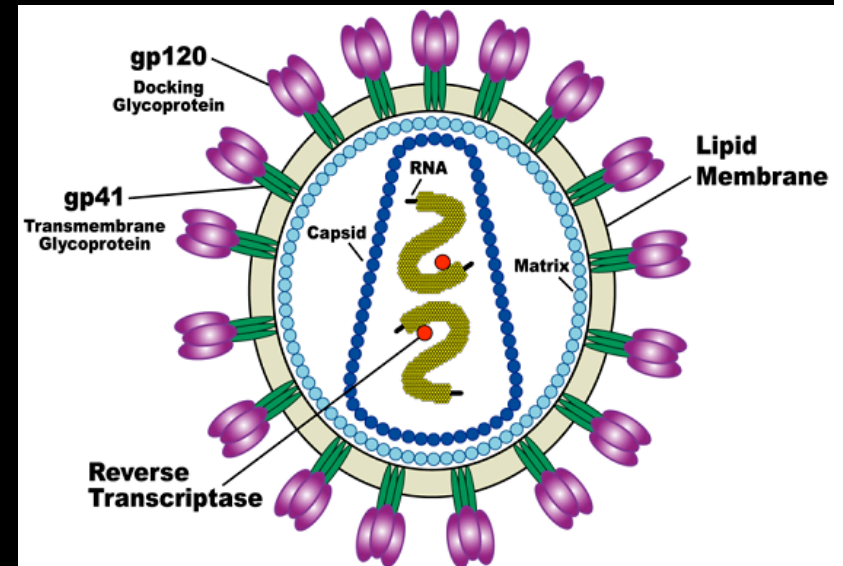
Reverse Transcriptase – enzyme which translates a single strand of RNA into DNA

Capsid – protein coating for RNA

Lipid membrane – bilayer of lipids that further protect virus serves as sites for receptor proteins

receptor proteins – proteins stuck on the surface to assist in cell entry

a wolf in sheep's clothing

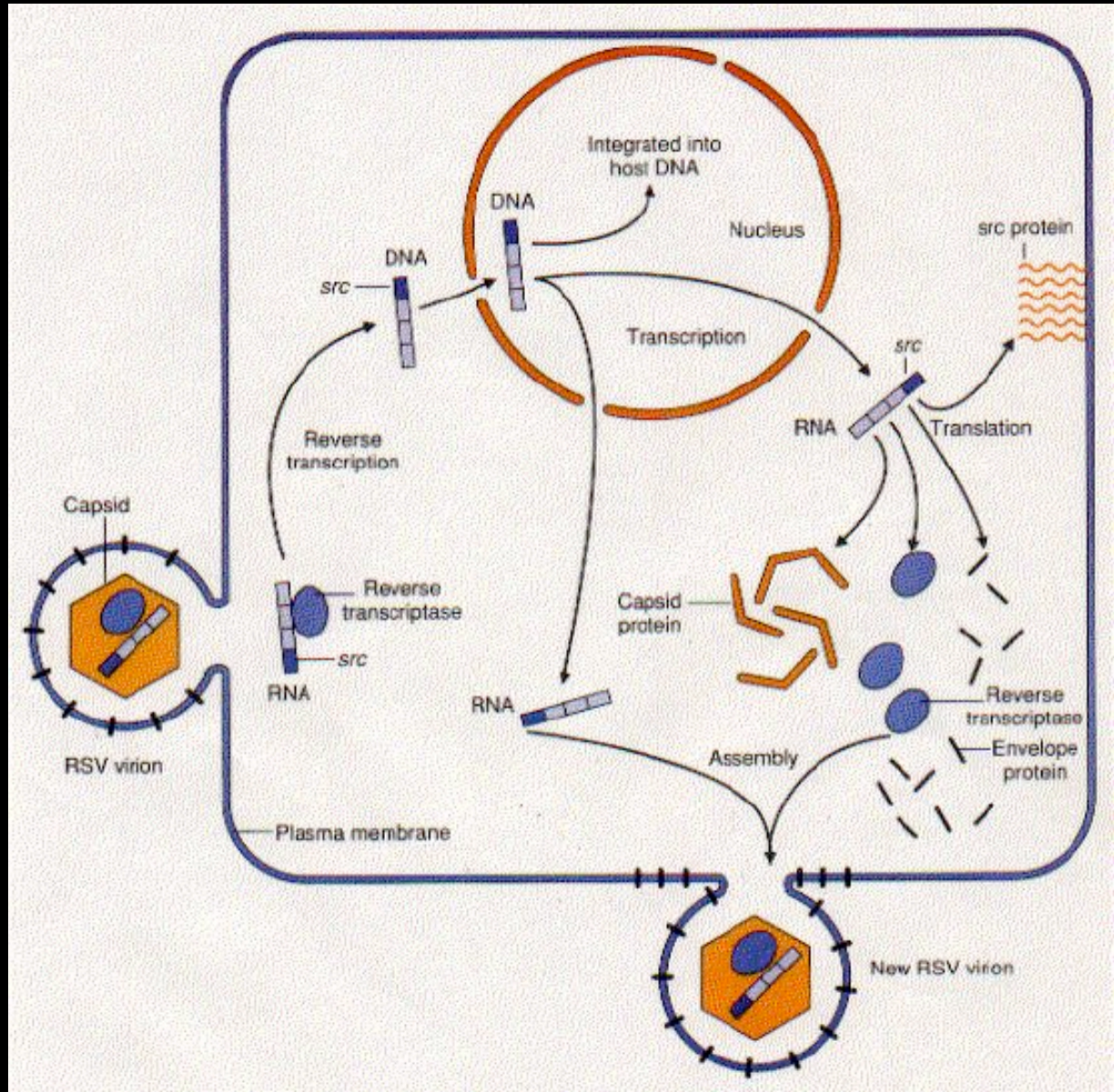


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Live Cycle of a Virus

And herein lies the rub.... A virus is dependent on hijacking the DNA of the host cell to reproduce..

Which is the chicken and which is the egg....



Prions and Viroids

- Even simpler than viruses (no protein coat)
- Prions were controversial once
- Cause mad cow disease
- Same problem: need other organisms to reproduce



Sizes of Organisms

- Smallest eukaryote: 10^{11} atoms
- Smallest prokaryote: 10^9 atoms
- Smallest virus: 10^6 atoms
- Smallest prion/viroid: 10^4 atoms
- Even smallest of these had to have smaller ancestors

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RNA World Hypothesis:

Hypothesis that RNA were the first self-reproducing molecules.

They were capable of making themselves and proteins

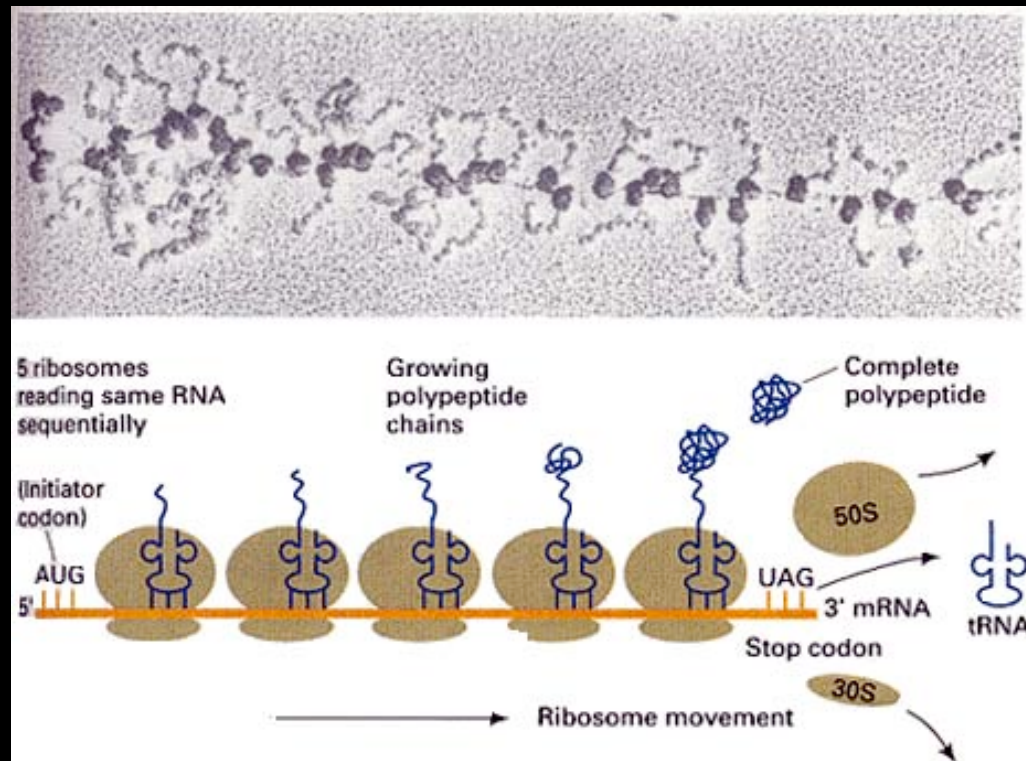
Later evolved to make DNA, and later evolved into DNA dominated world.

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RNA World Hypothesis:

In this hypothesis, ribosome RNA is considered the most primitive form.

Even though it now works on mRNA from the cell DNA

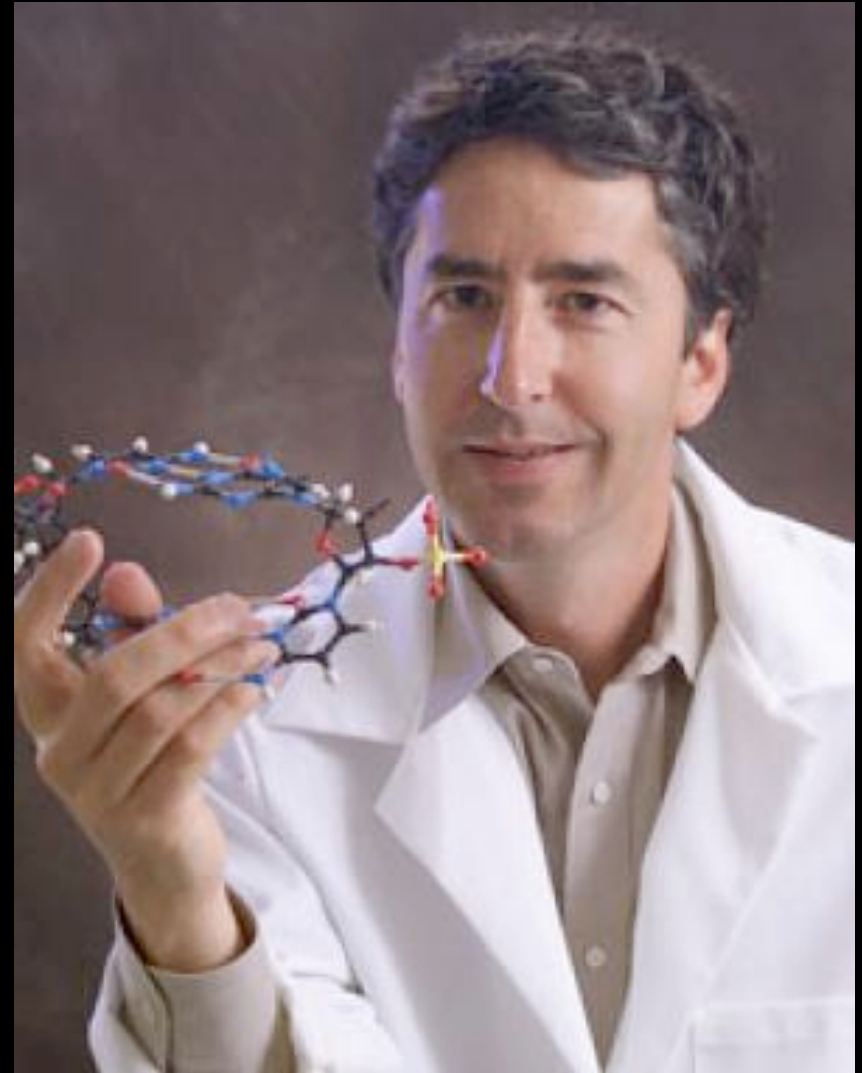


Current Developments

- Synthesizing nucleotides from prebiotic chemicals
- Consist of a sugar (e.g., ribose) joined to a base and a phosphate group
- But separate synthesis has been challenging
- John Sutherland, 2009
- Base and sugar can be built up as single unit

Gerald Joyce Lab

- Scripps, in CA
- Fitness of RNA, putting in only basic chemicals
- Lenski-like: let run, take out solution, put in fresh batch
- See clear improvement of fitness



Current Developments

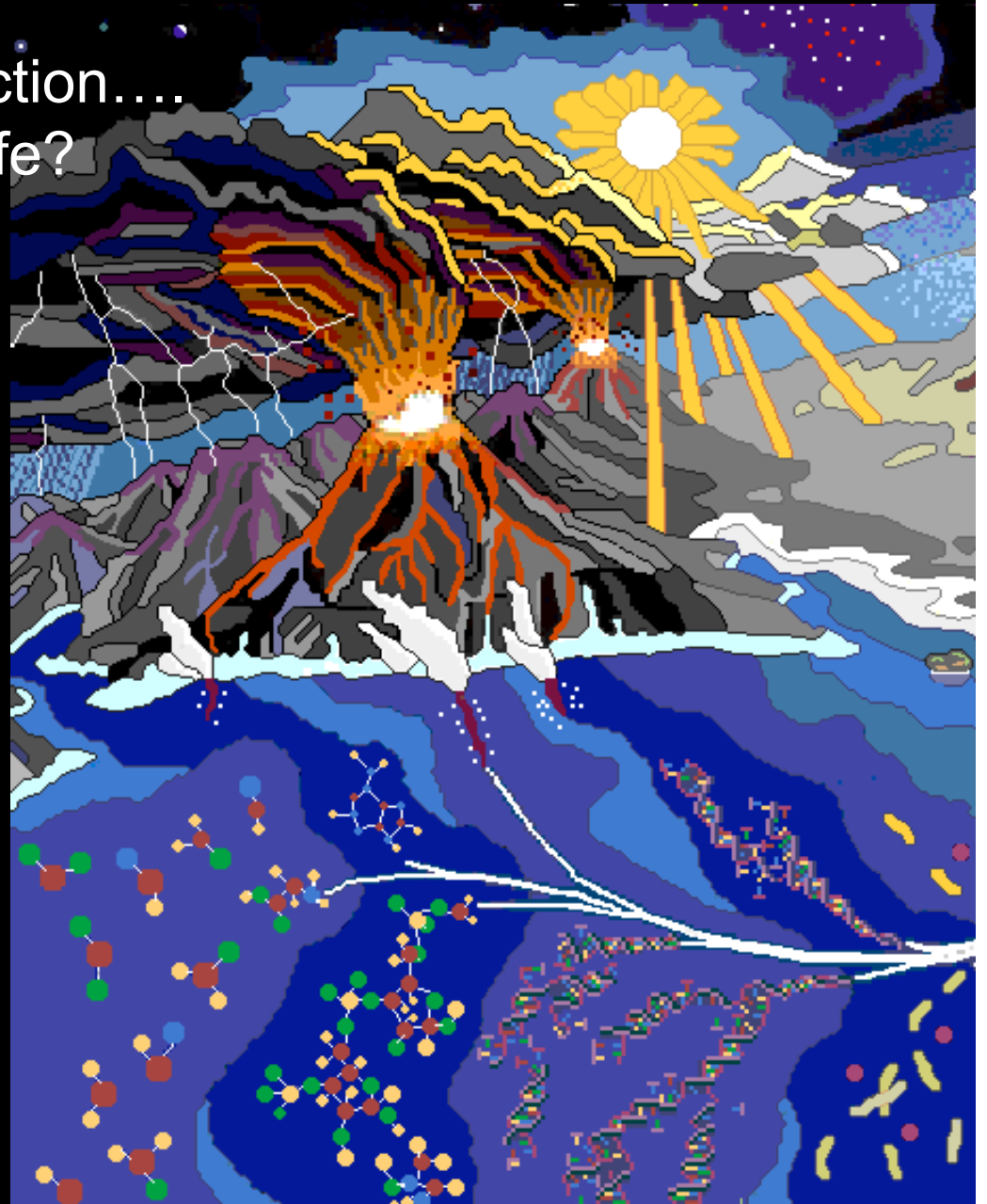
- Gerald Joyce and colleagues, 2009
- RNA can carry information and can also act as an enzyme to promote reactions
- Have developed two RNA molecules that can promote each other's synthesis
- Effectively, an immortal self-replicating system that can undergo evolution!

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Working in the forward direction....
From simple molecules to life?

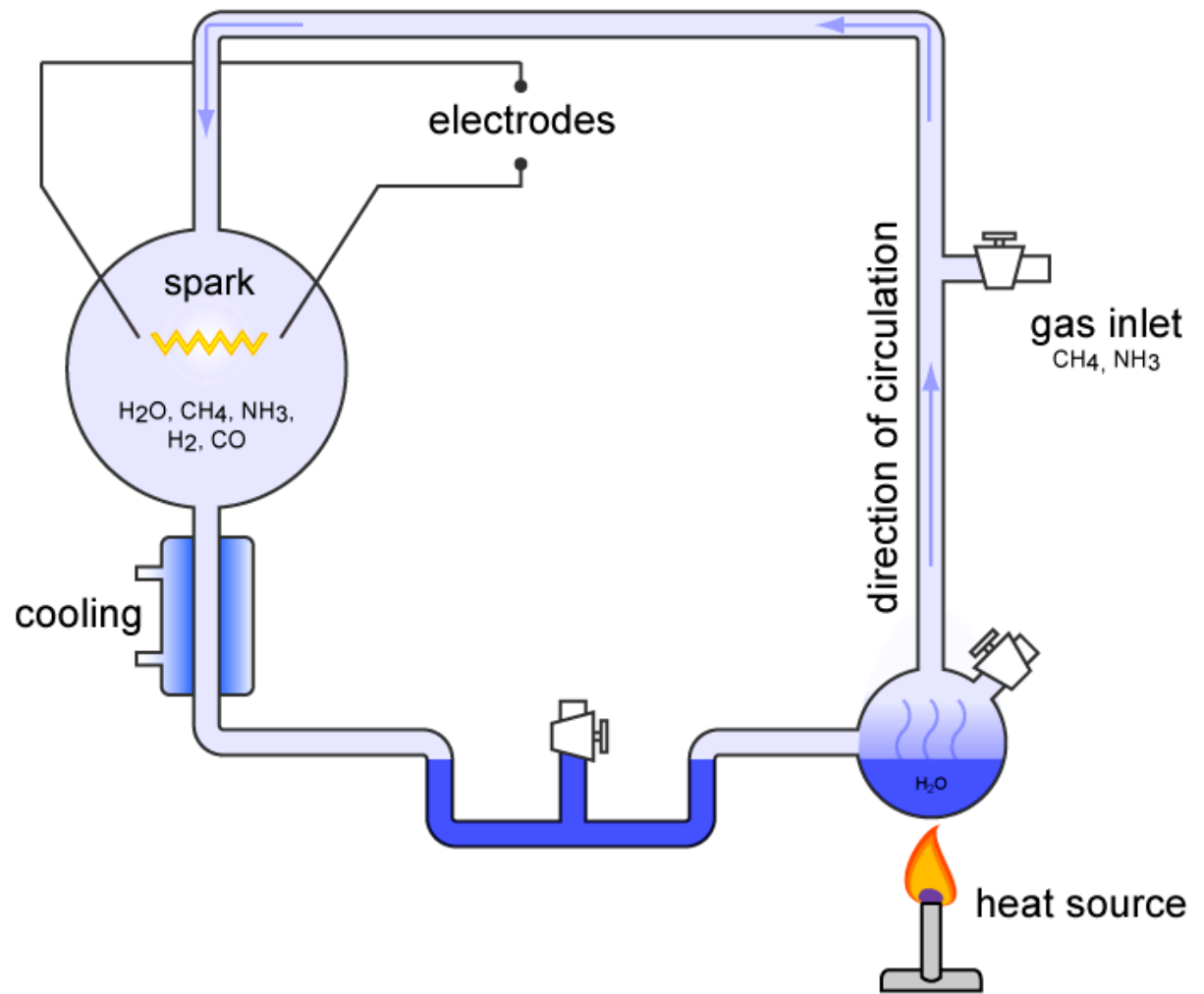
We know a lot about the
conditions on the Earth
4 Billion years ago.

liquid water
carbon dioxide
methane
ammonia
hydrogen
light
geothermal energy



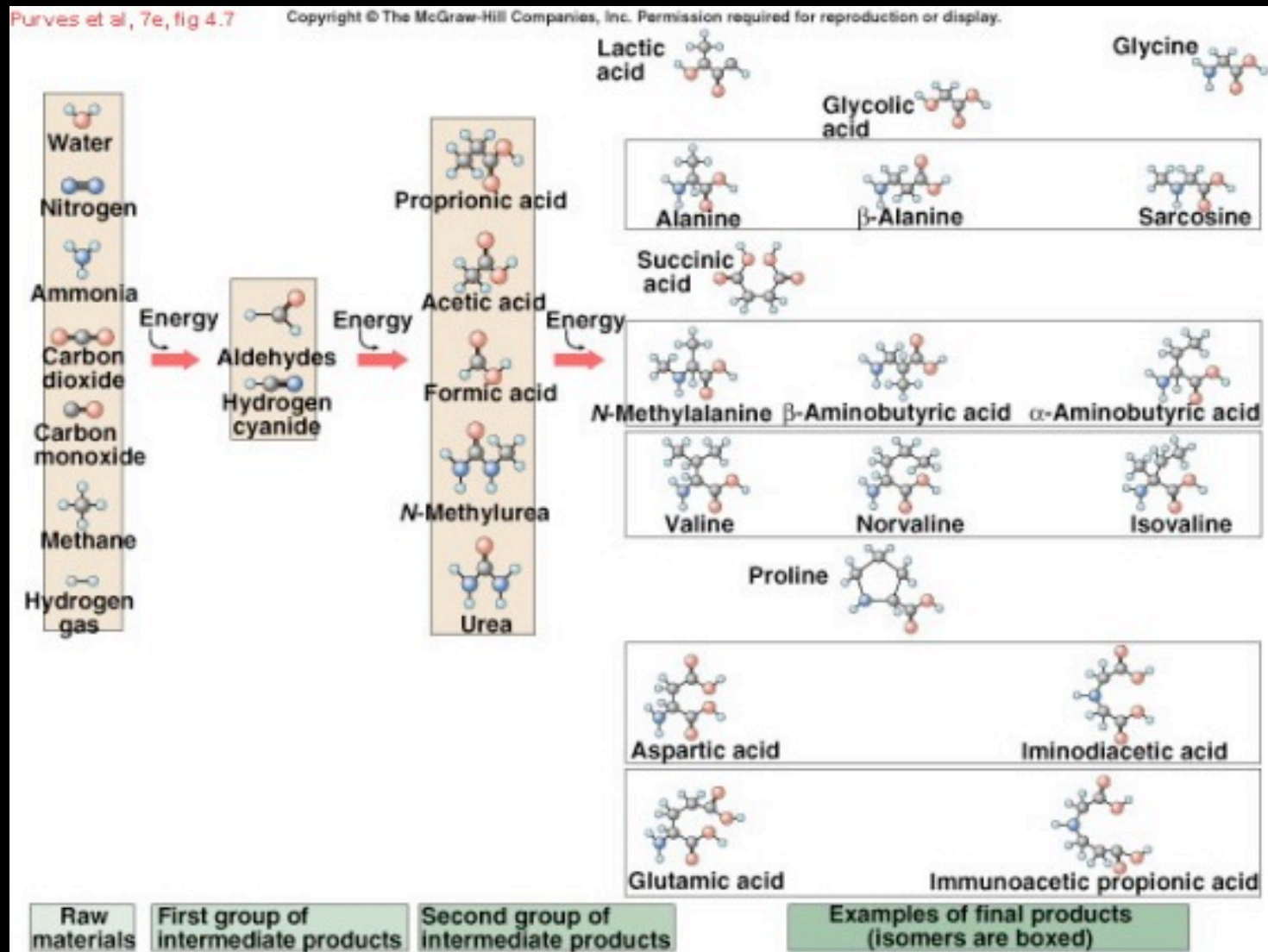
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Miller-Urey Experiment – showed that complex molecules can be made with simple chemical reactions



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Miller-Urey Experiment



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Continuing extensions of the experiments with best estimates of the early Earth's atmosphere continue at a modest level.

Experiments can produce amino acids, sugars.

No experiment to date has produced self-replicating molecules.

All of the chemistry is driven by the energy input in the form of "lightning" or light.

Biological and non-biological molecules (wrong-handed) are produced in these experiments.

Current Developments

- Handedness: biological amino acids are left-handed, sugars are right-handed
- Why? Strange asymmetry
- Donna Blackmond, 2009
- Even mixture converts to just one form by cycle of freezing and thawing
- Much distance to go, but far more understood about origins than a year ago

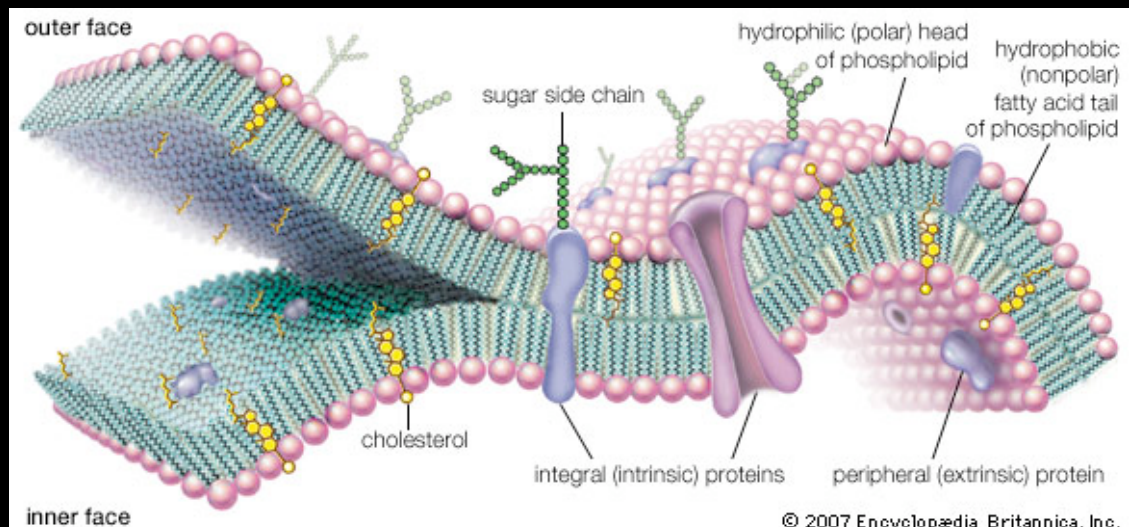
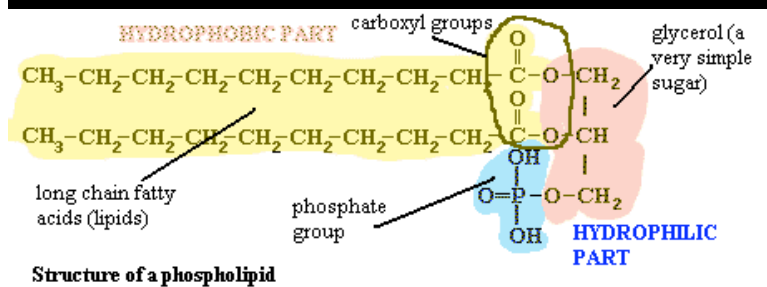
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What is the bare minimum for “life”?

RNA – some molecule complex enough to carry genetic blueprints for the organism.

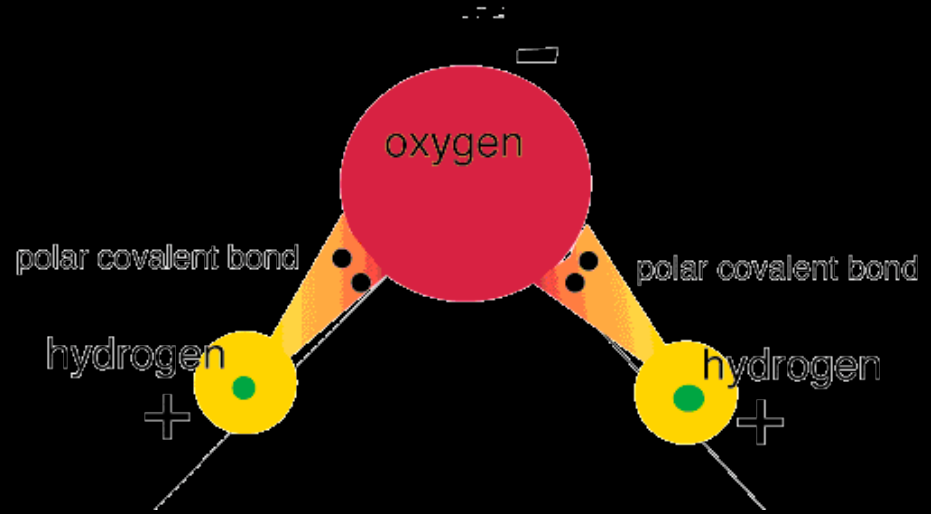
Cell wall – something to protect the RNA from the raw environment and contain replication

A rich organic soup of less complex molecules to “eat”

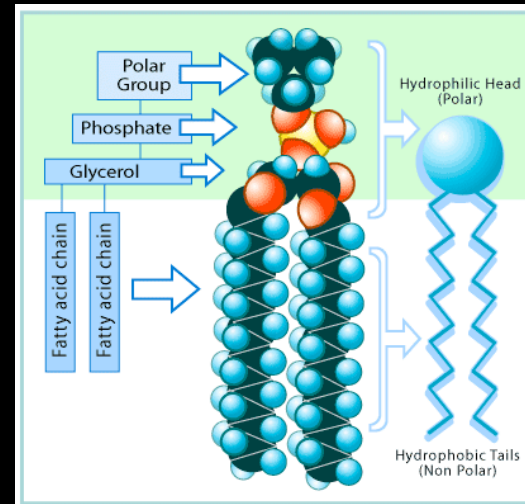


Nature of Cell Walls

- Water is a *polar* molecule
Negative on one side
Positive on the other
- Other polar molecules “like” water; nonpolar don’t
- Phospholipids: one water-liking side, one water-hating



<http://academic.brooklyn.cuny.edu/biology/bio4fv/page/image15.gif>



<http://www.bioteach.ubc.ca/Bio-industry/Inex/graphics/phospholipid.gif>

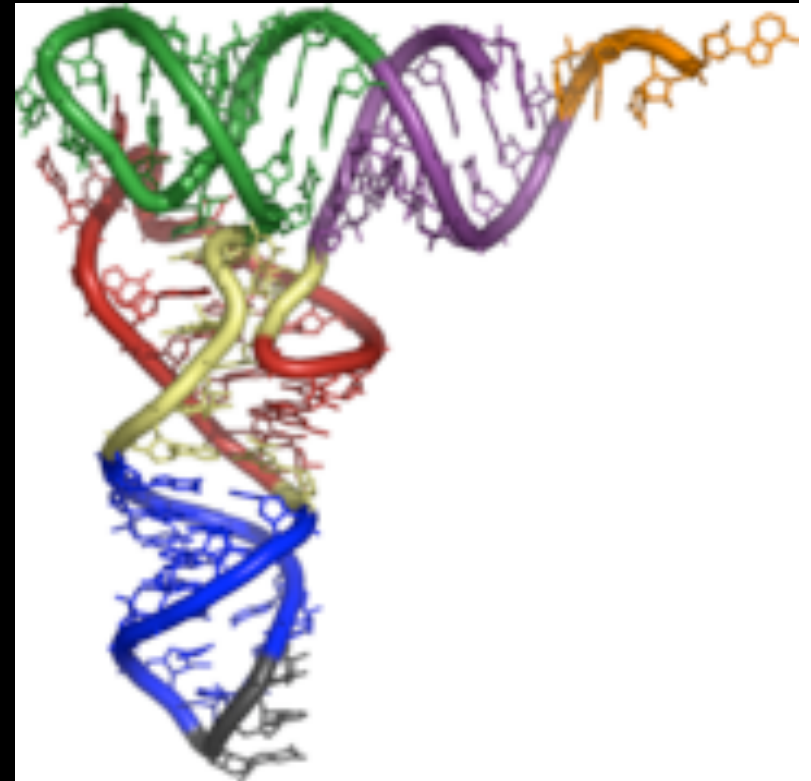
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What is the bare minimum for “life”?

Perhaps the first “life” included the concept of a cell....
The RNA reproduced when the soup was concentrated
enough... for whatever reason....

The step to RNA is huge.

We don't know how it happened!



Clay

- Suggested in 1985
- Crystals can grow, reproduce, mutate...
- Act like sources of transferable info
- Some types better for some environments
- Proto-organics catalyzed by surface properties?



http://www.motherjones.com/blue_marble_blog/clay.h4.jpg

An Intriguing Idea: Panspermia

- Suppose life is difficult to develop on a given planet
- If it lucked out somewhere, could microbes travel space?
- In this case, other life might be related to us!



http://ieti.org/graphics/dna_embr.jpg

Panspermia: Is There Enough Time?

Panspermia: Is There Enough Time?

- Have to do quick check
- Suppose a chunk of matter was kicked out at 30 km/s (1/10,000 of speed of light)
- Is there enough time for matter to get here?
- Milky Way: ~100,000 light years across
Would take 1 billion years
Easy: MW is 10 billion years old
- Keep this in mind when we think of how aliens could spread through galaxy

Other Checks on Panspermia?

If Not Panspermia, Where?

- Unresolved question
- Deep sea vents?
- “Warm little pond” a la Darwin?

Debate: Ease of Origin

- Given that we have conditions that could support life (liquid water, stable orbit, long-lived sun, etc.):

Will life arise easily and quickly?

Or did it require rare accidents in our case?

Summary

- Even simple life today is complicated by biochemical standards
Once it gets going, evolution does fine
- Experiments produce medium-complexity molecules from simple inputs
- RNA world may have been starter
- If first life came from elsewhere, eases some difficulties