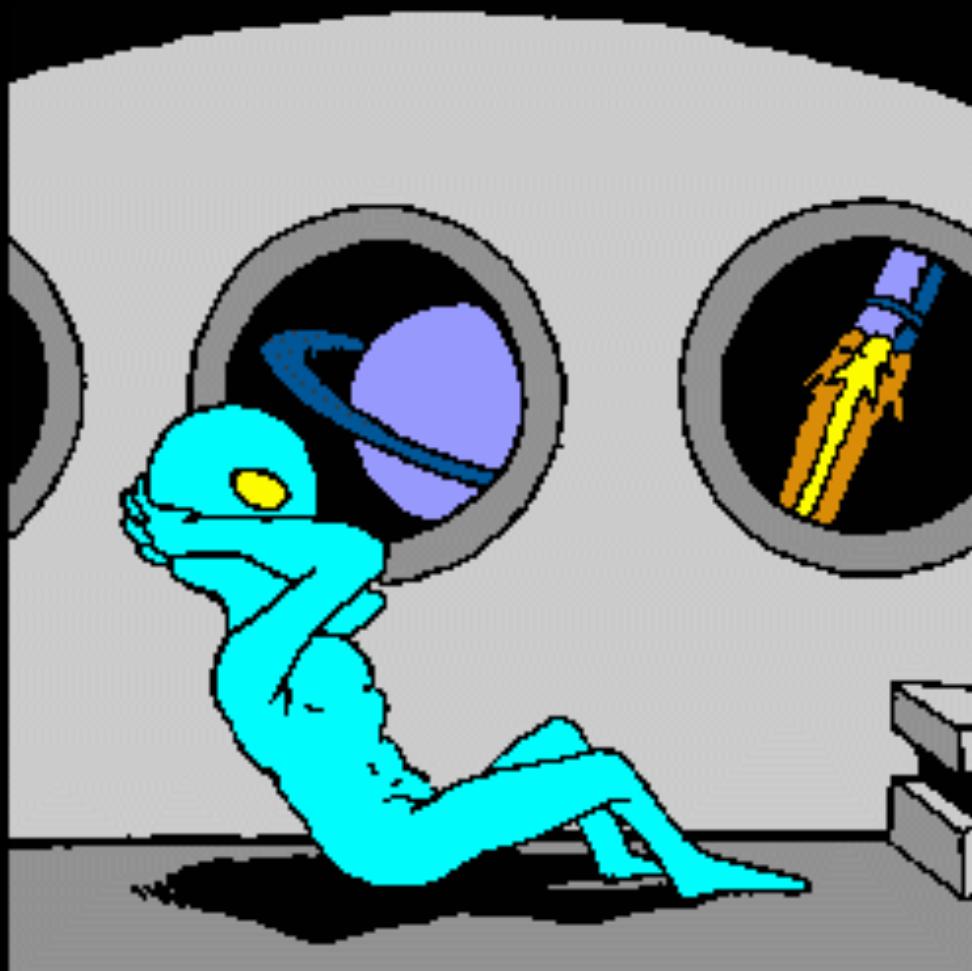
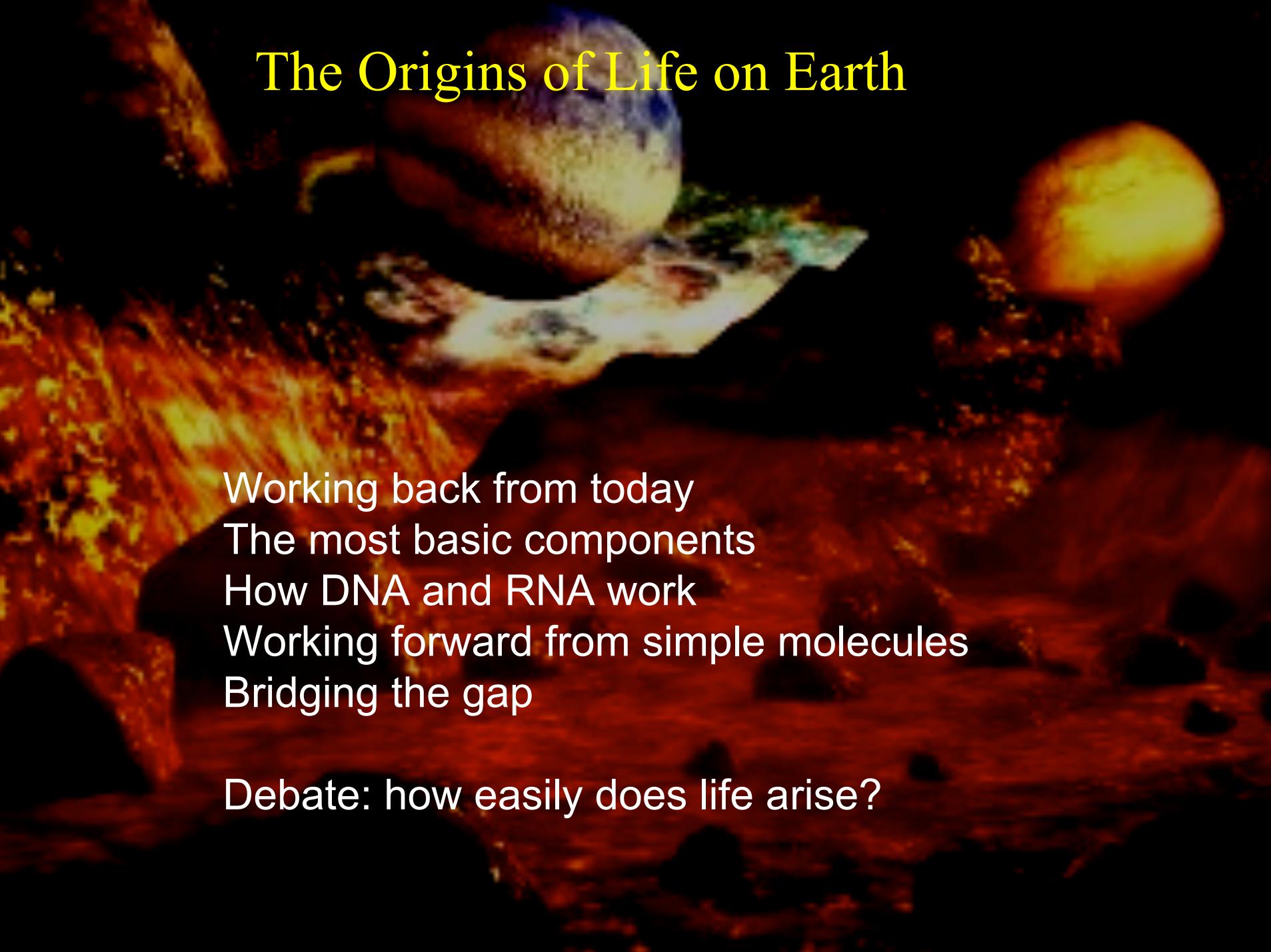


ASTR 380  
The Origins of Life on Earth



**ALIEN ABDUCTION**

# The Origins of Life on Earth



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



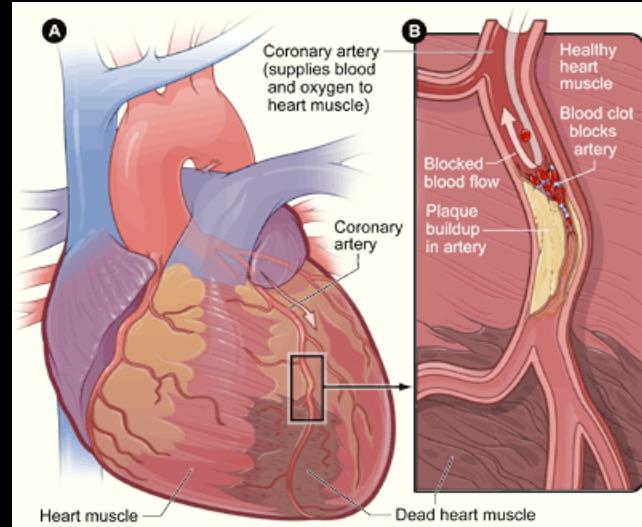
The Colinisation of Space.

# Midterm

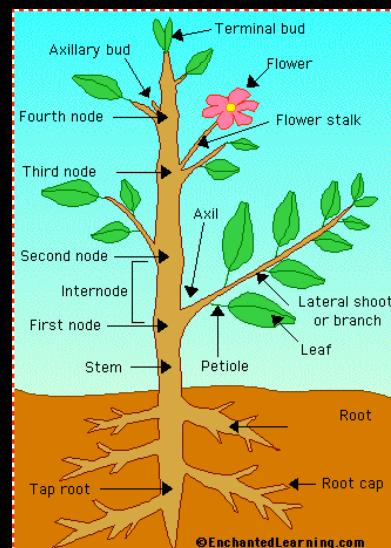
- In class, usual time  
Closed-book, closed-notes
- Will cover everything thus far in class  
Written notes  
Slides and presentations/discussion in class  
Reading from book
- Format will be similar to homeworks  
Four short response questions  
One question involving computation  
Bring calculator, 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](http://www.nhlbi.nih.gov/health/dci/images/heart_coronary_artery.gif)



[www.enchantedlearning.com](http://www.enchantedlearning.com)

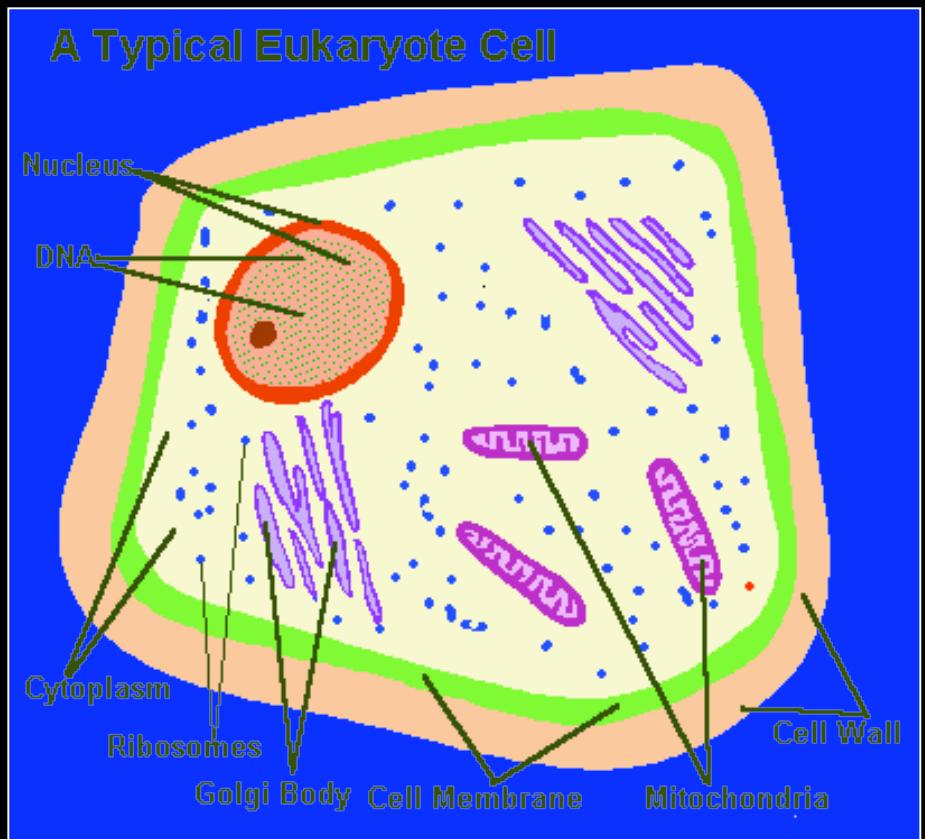
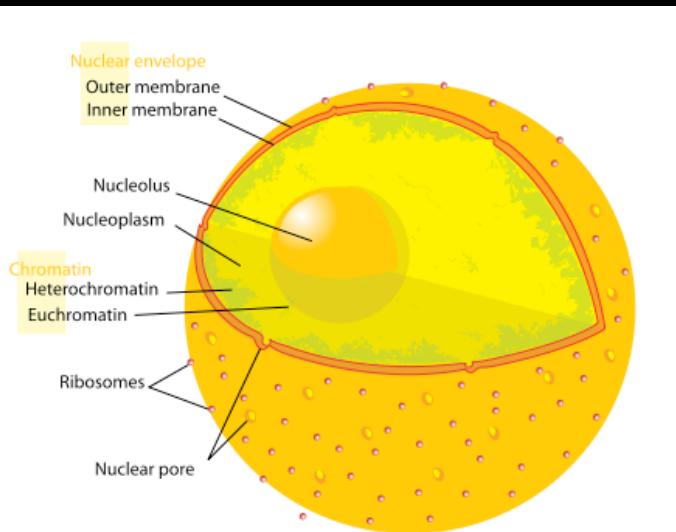
# The Origins of Life on Earth

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



# The Origins of Life on Earth

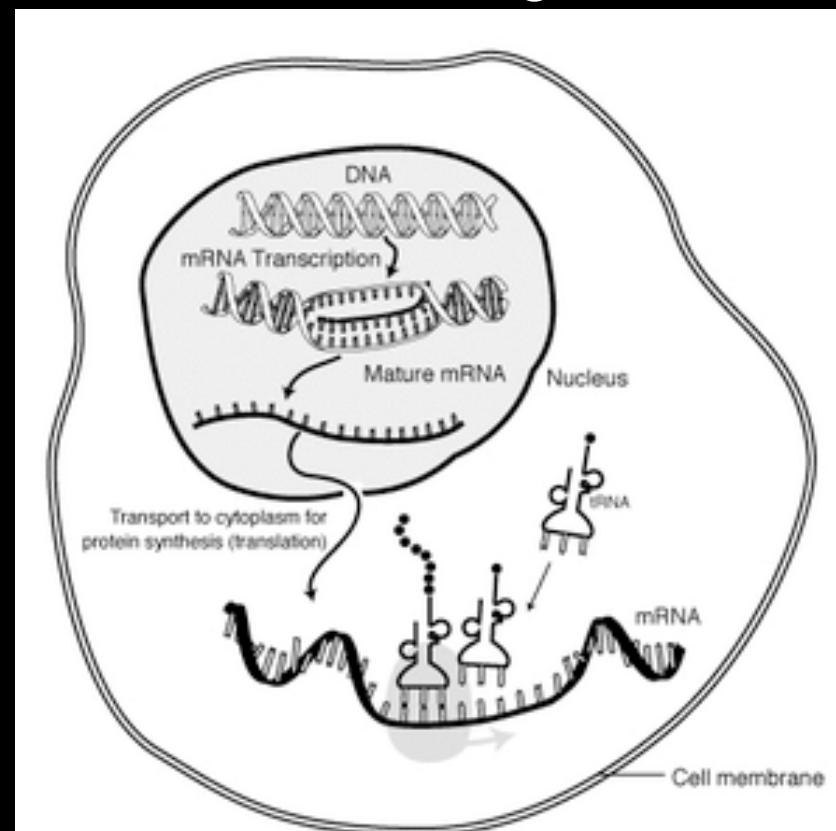
RNA world in eukaryote cell

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

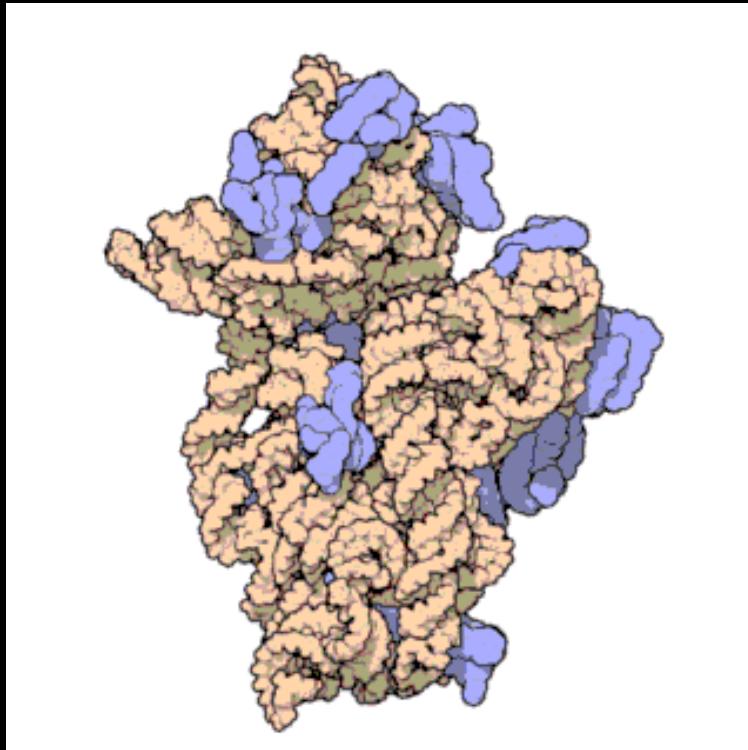


# The Origins of Life on Earth

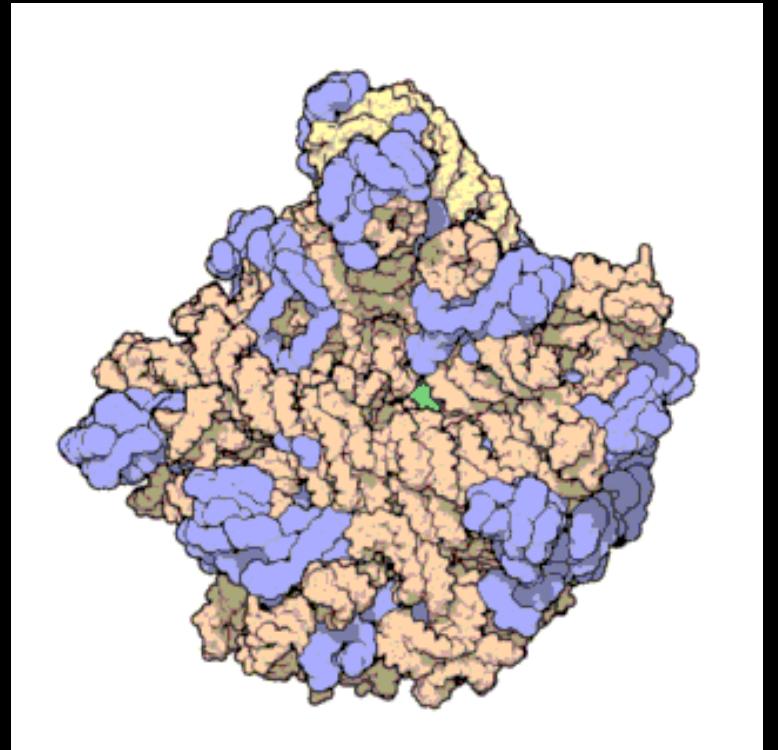
RNA world in eukaryote cell

Proteins are intertwined with RNA to create the correct structure.

Protein in blue



RNA in orange/yellow



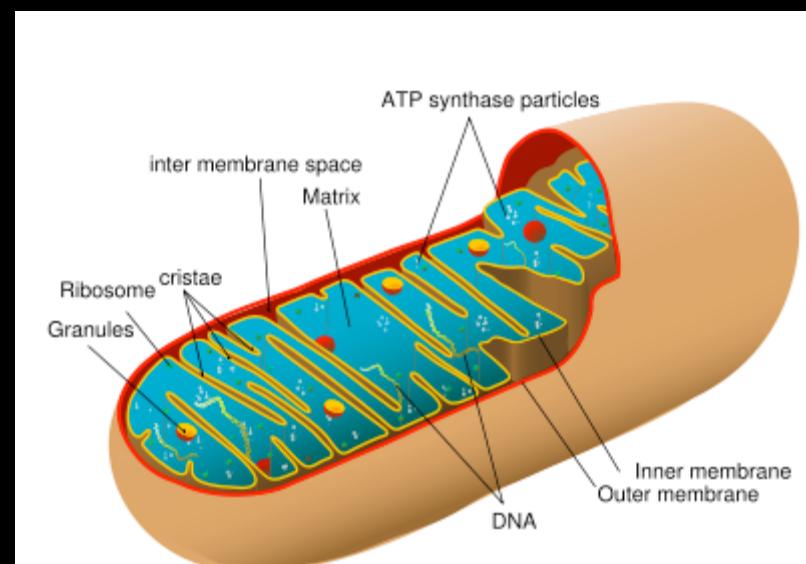
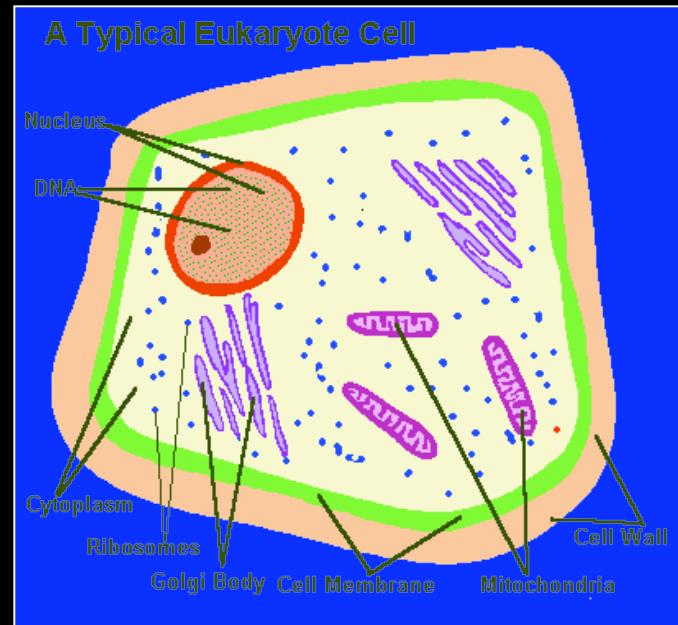
# The Origins of Life on Earth

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

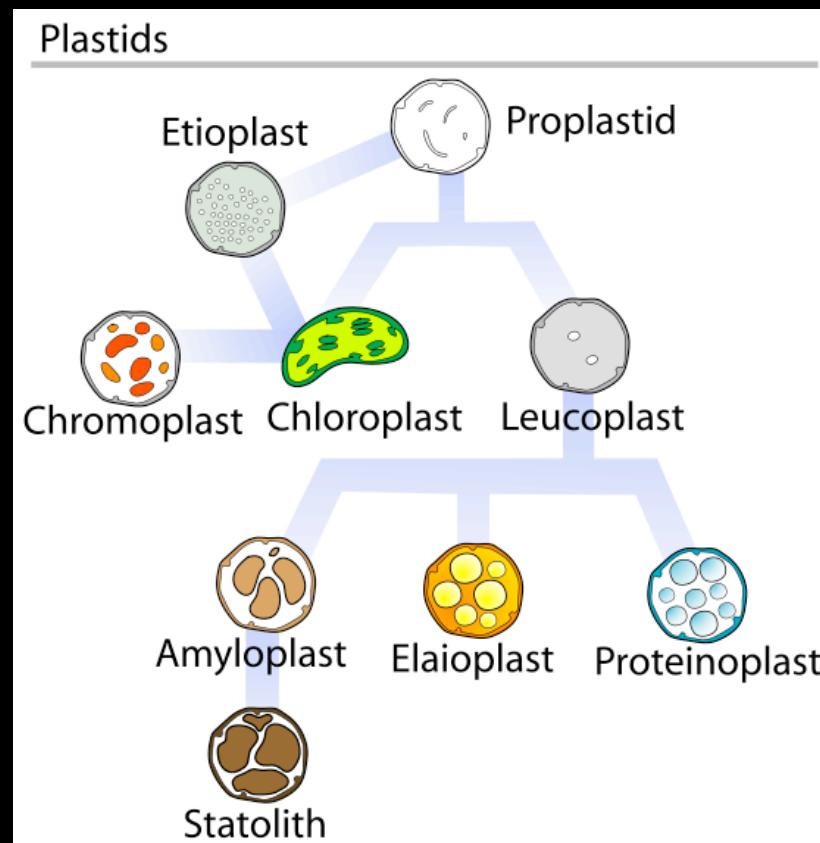


# The Origins of Life on Earth

A eukaryote cell contains:

Plastids – present in plants

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

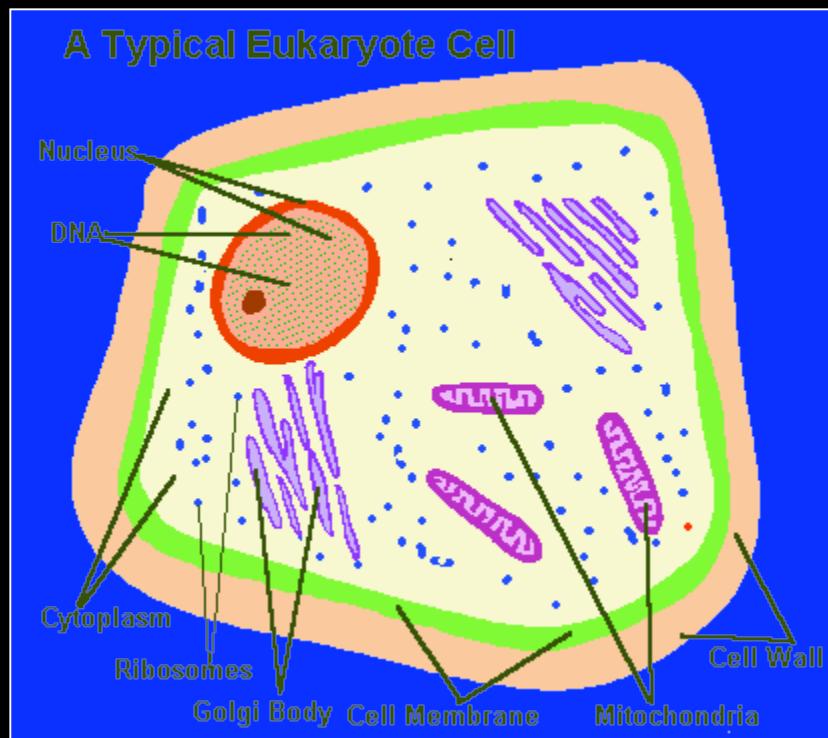


# The Origins of Life on Earth

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!

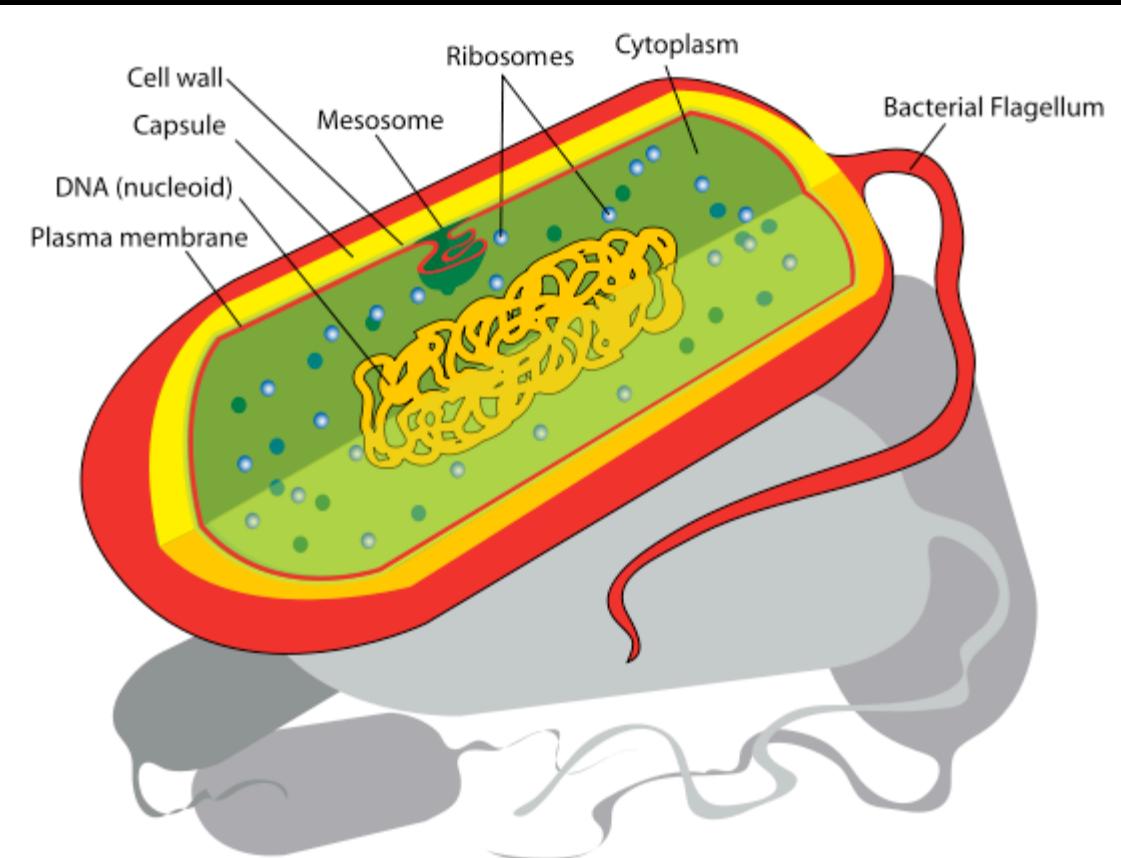


# The Origins of Life on Earth

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



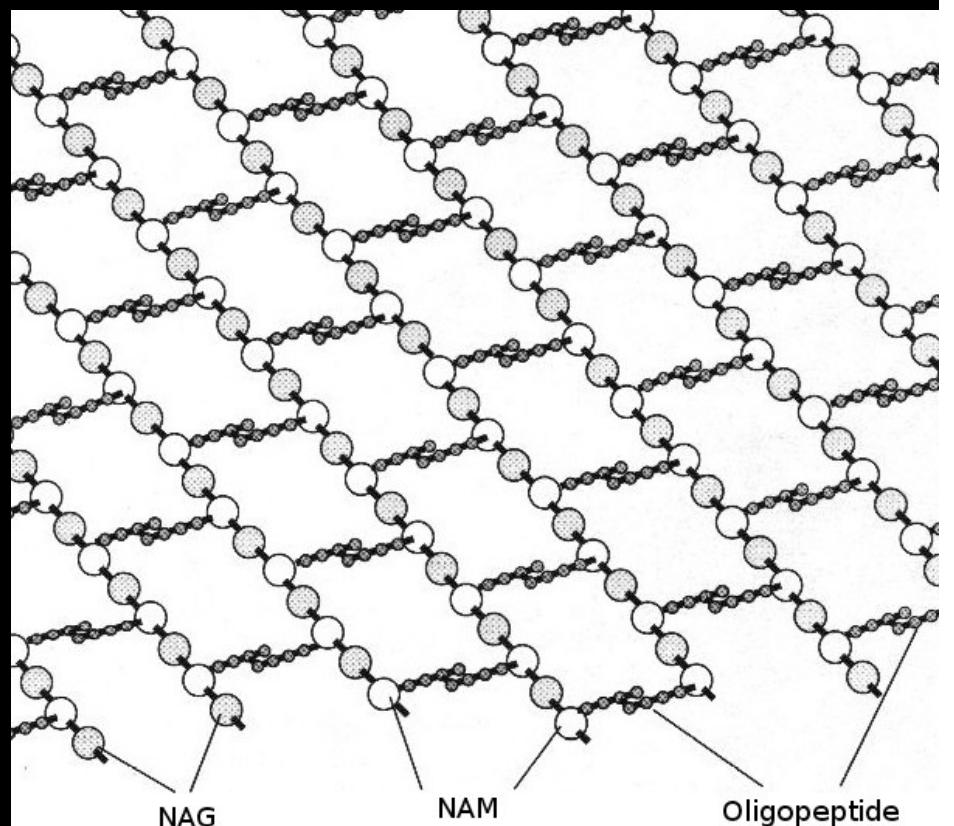
# The Origins of Life on Earth

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

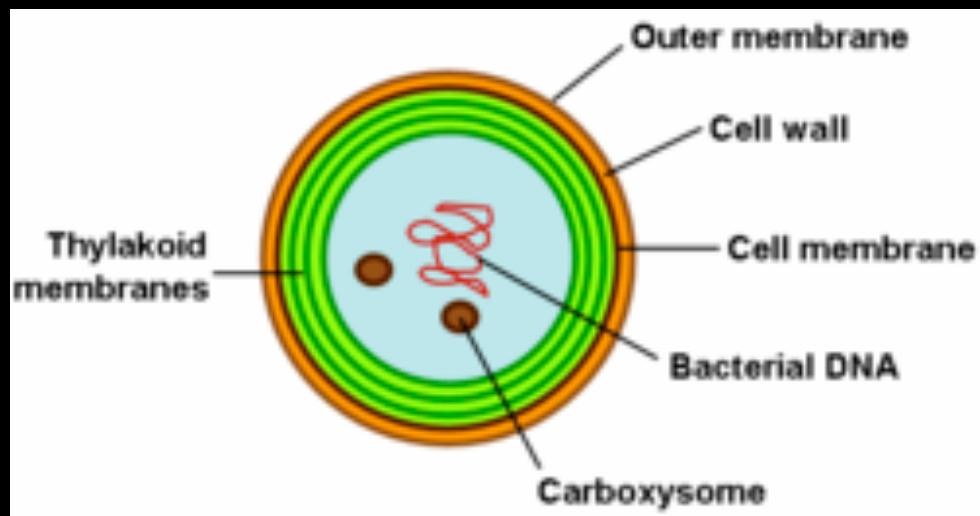
- Membrane-genetic coevolution?
- Jack Szostak and colleagues, 2009
- Basic idea:
  - Fatty acids naturally form double layers
  - Incorporate new fatty acids, divide
  - Small molecules can enter protocells
  - When combine to form larger molecules, cannot get out
- Nucleotides can assemble in this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

# The Origins of Life on Earth

Cyanobacteria are prokaryotes

Fossil evidence that they lived 3.8 billion years ago.

photosynthesis occurs within Thylakoid structures – green below

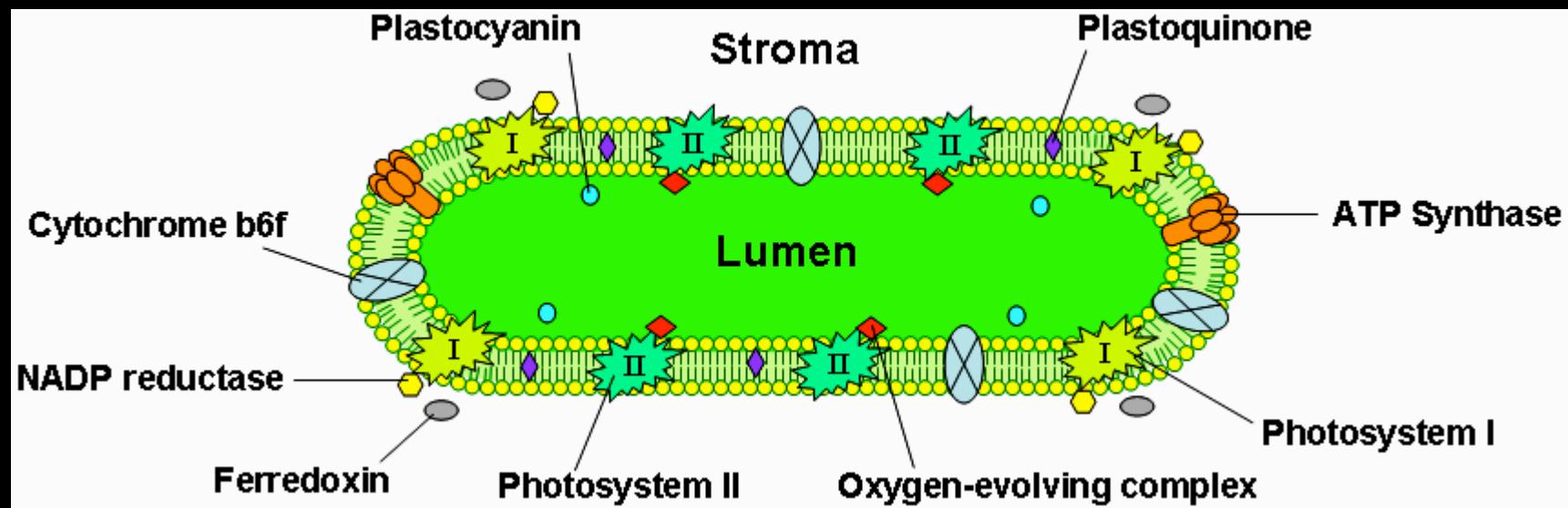


# The Origins of Life on Earth

## Cyanobacteria

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

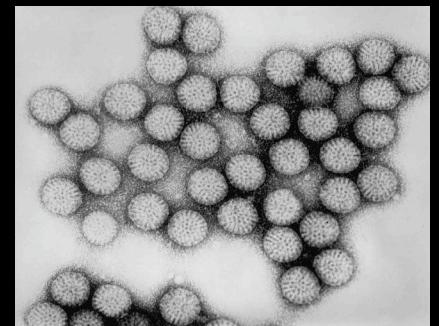
Simpler but not so simple....



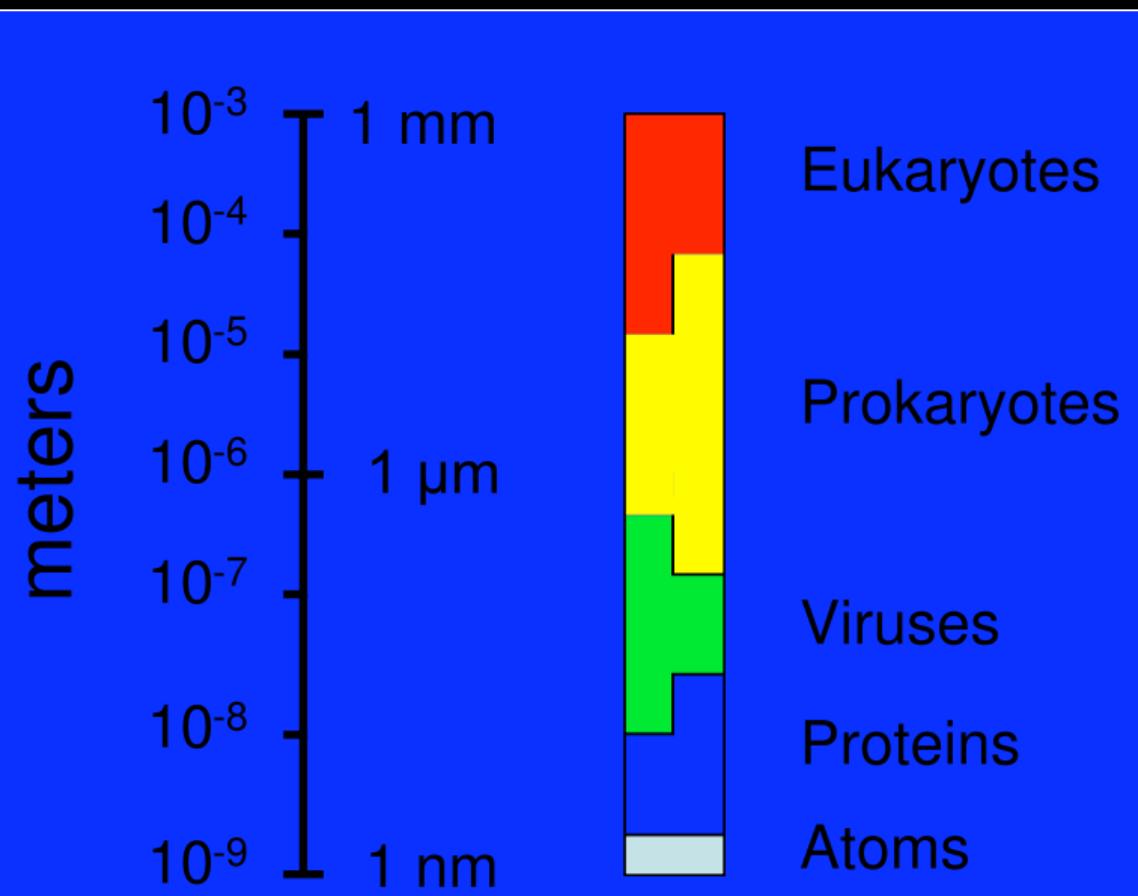
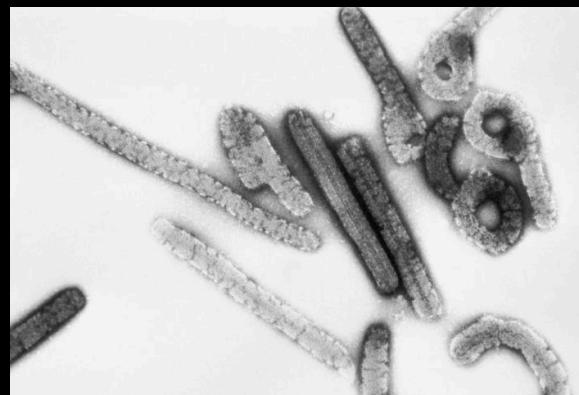
# The Origins of Life on Earth

What about viruses?

Smallest form of “life” – if considered life



Genetic material is  
DNA or RNA



# The Origins of Life on Earth

What about viruses?

RNA – genetic material and blueprints for all parts

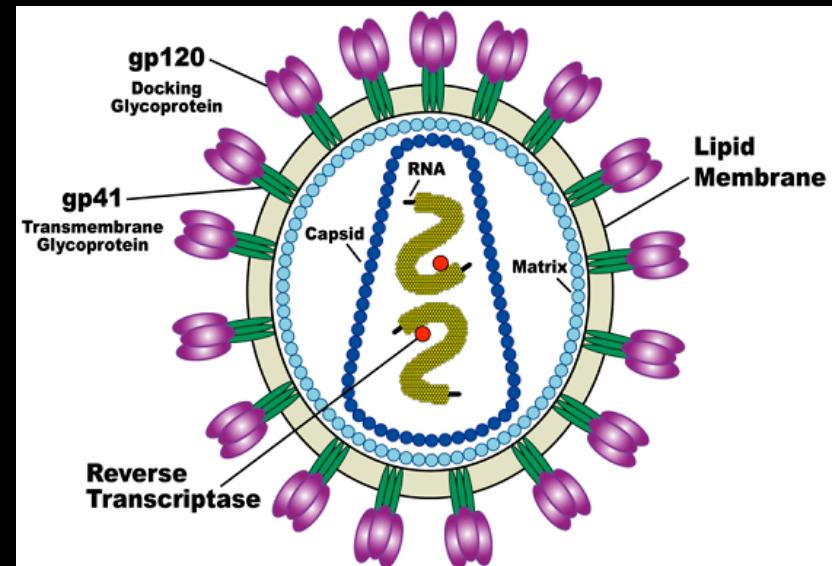
Reverse Transcriptase – enzyme which translates a single strand of RNA into DNA

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

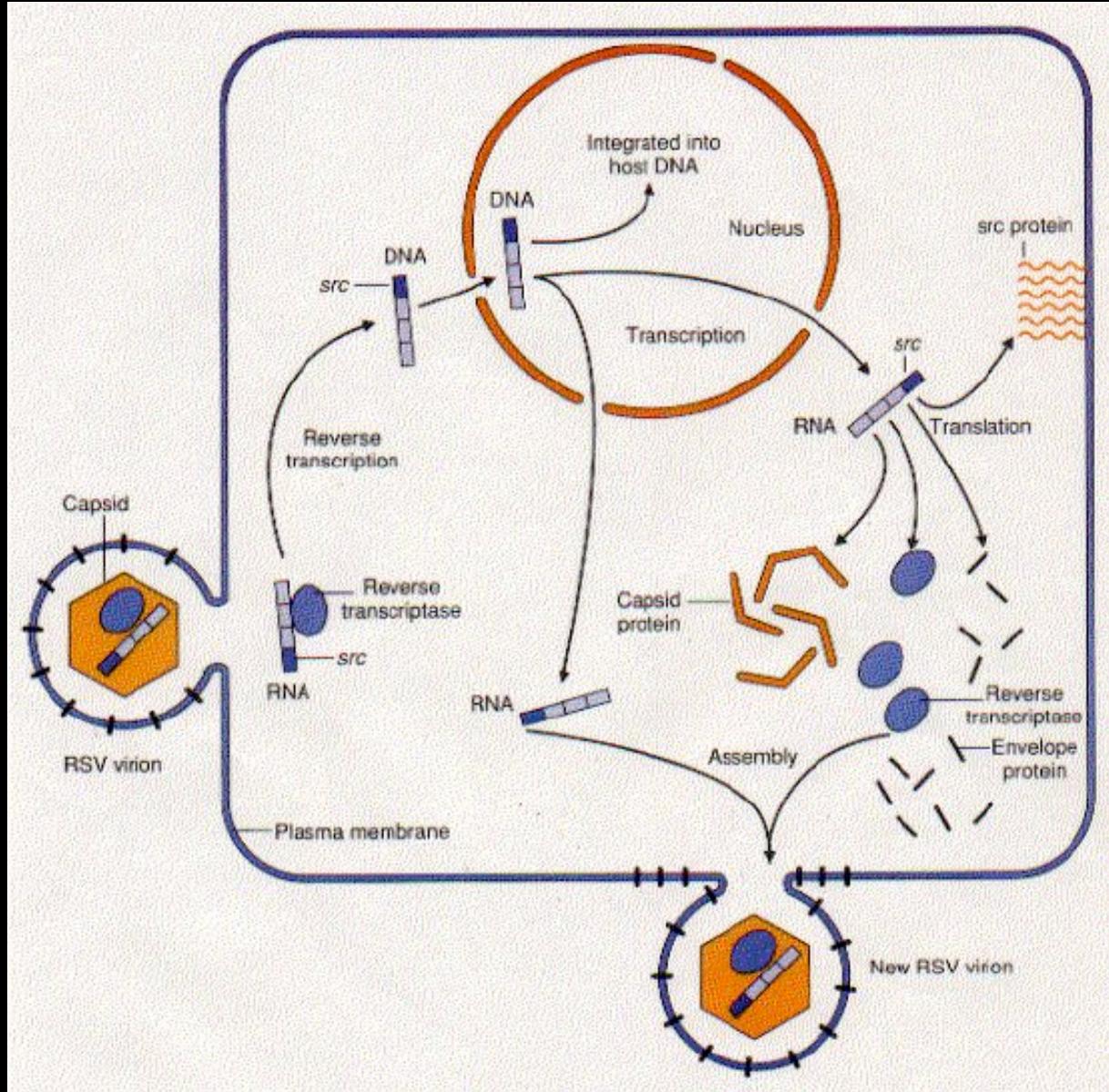


# The Origins of Life on Earth

## 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



<http://student.biology.arizona.edu/honors2005/group13/prion.gif>

# 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

# The Origins of Life on Earth

RNA World Hypothesis:

Hypothesis that RNA were the first self-reproducing molecules.

They were capable of making themselves and proteins

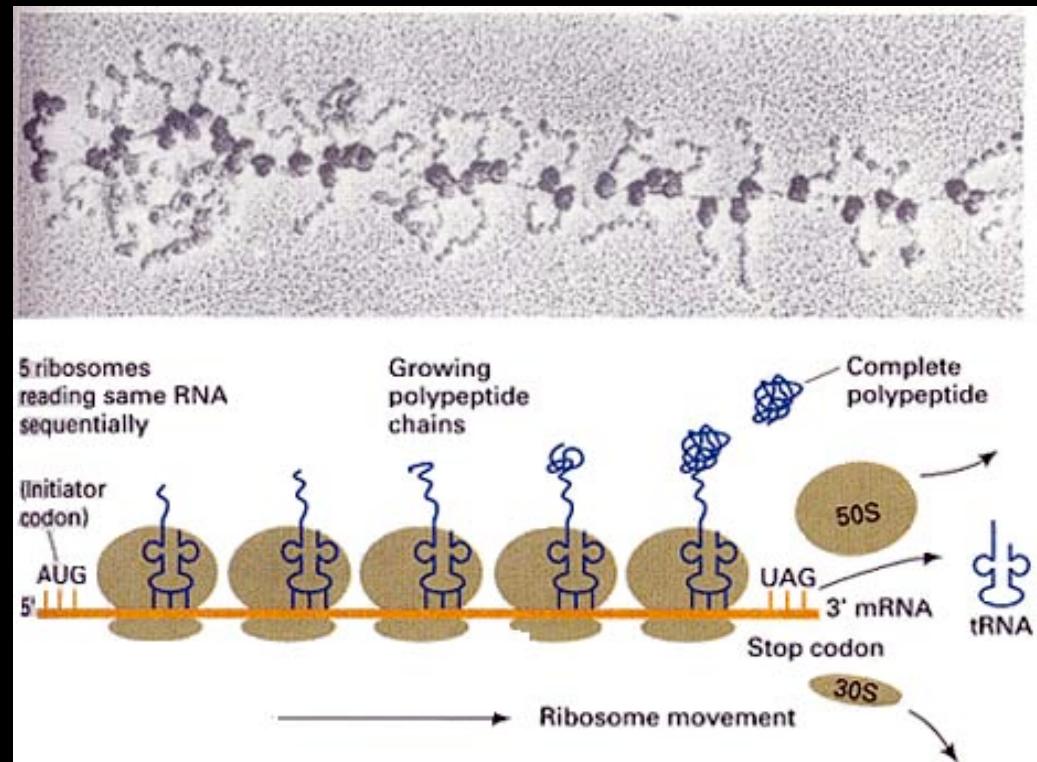
Later evolved to make DNA, and later evolved into DNA dominated world.

# The Origins of Life on Earth

## 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

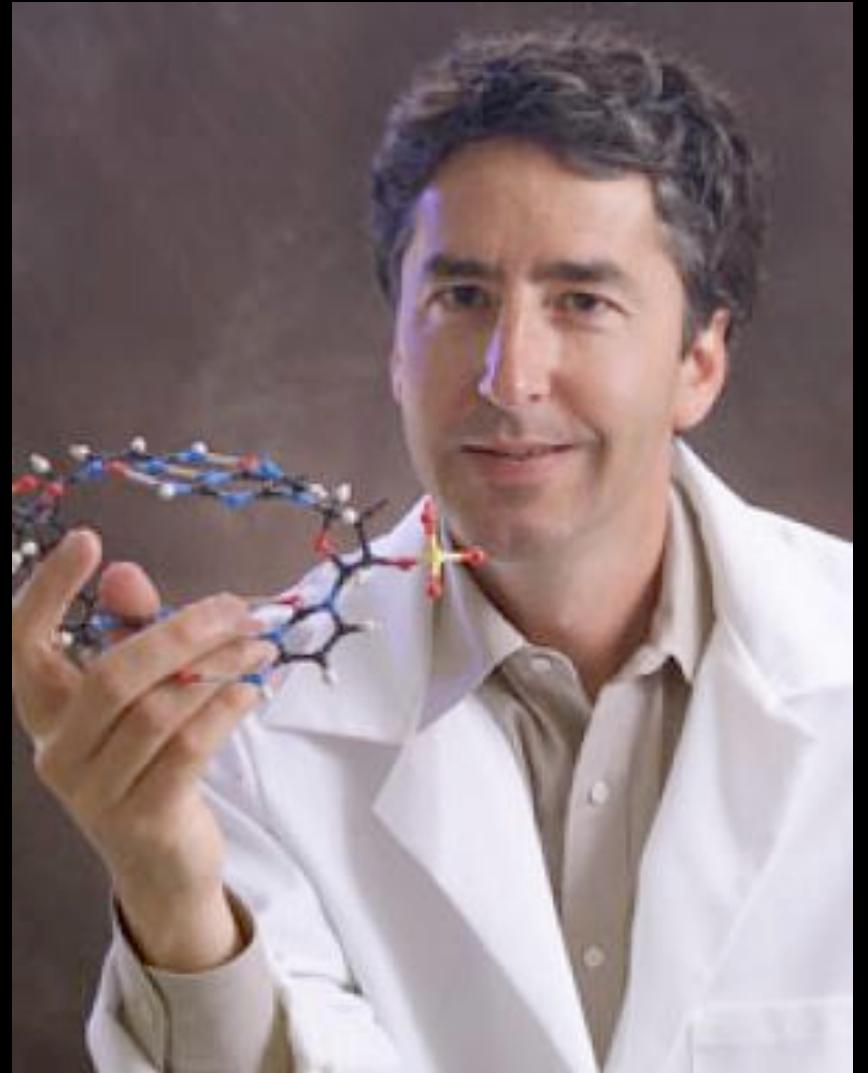


# Current Developments

- 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



<http://www.sciencedaily.com/images/2006/03/060327083737.jpg>

# Current Developments

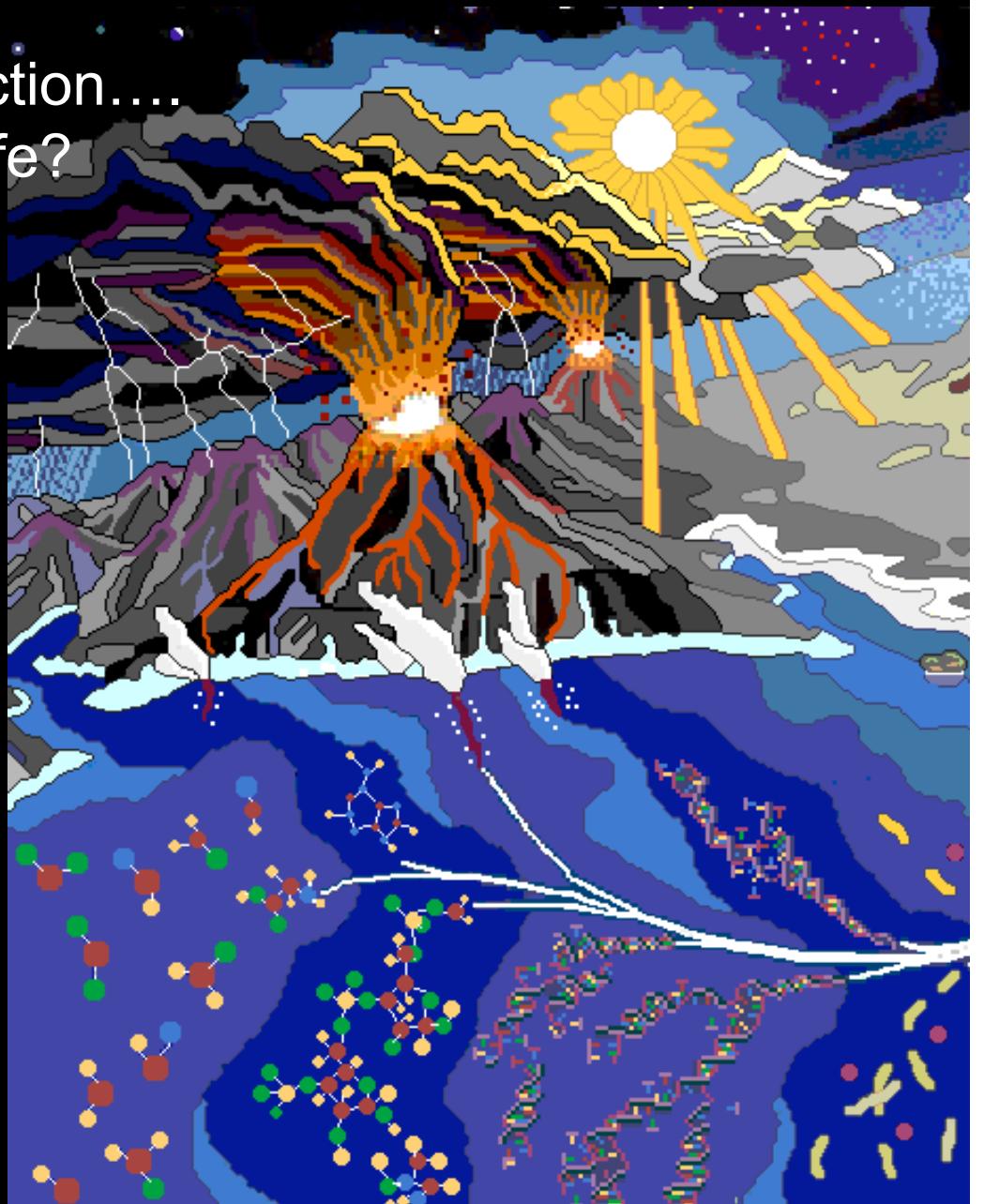
- Gerald Joyce and colleagues, 2009
- RNA can carry information and can also act as an enzyme to promote reactions
- Have developed two RNA molecules that can promote each other's synthesis
- Effectively, an immortal self-replicating system that can undergo evolution!

# The Origins of Life on Earth

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

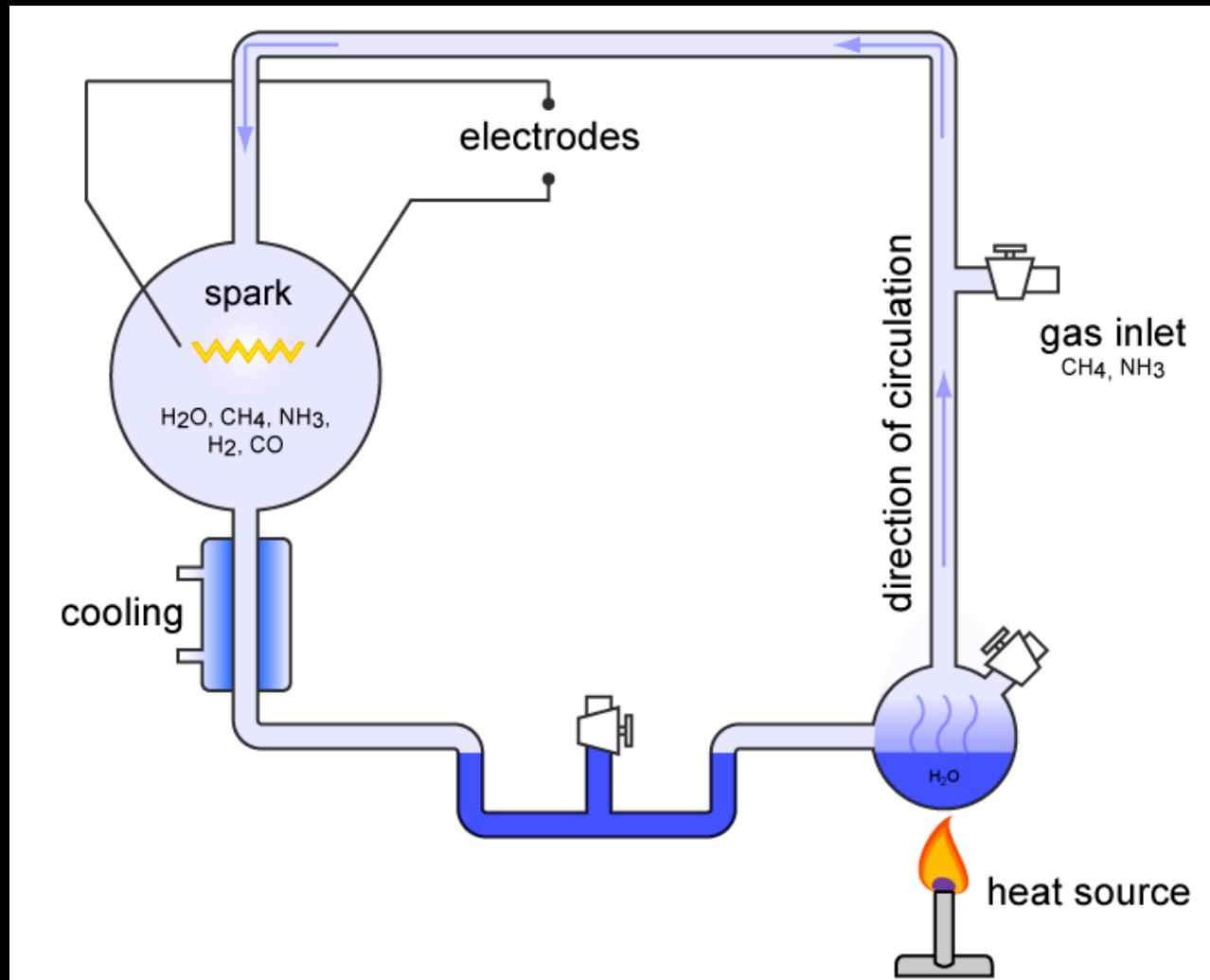
We know a lot about the  
conditions on the Earth  
4 Billion years ago.

- liquid water
- carbon dioxide
- methane
- ammonia
- hydrogen
- light
- geothermal energy



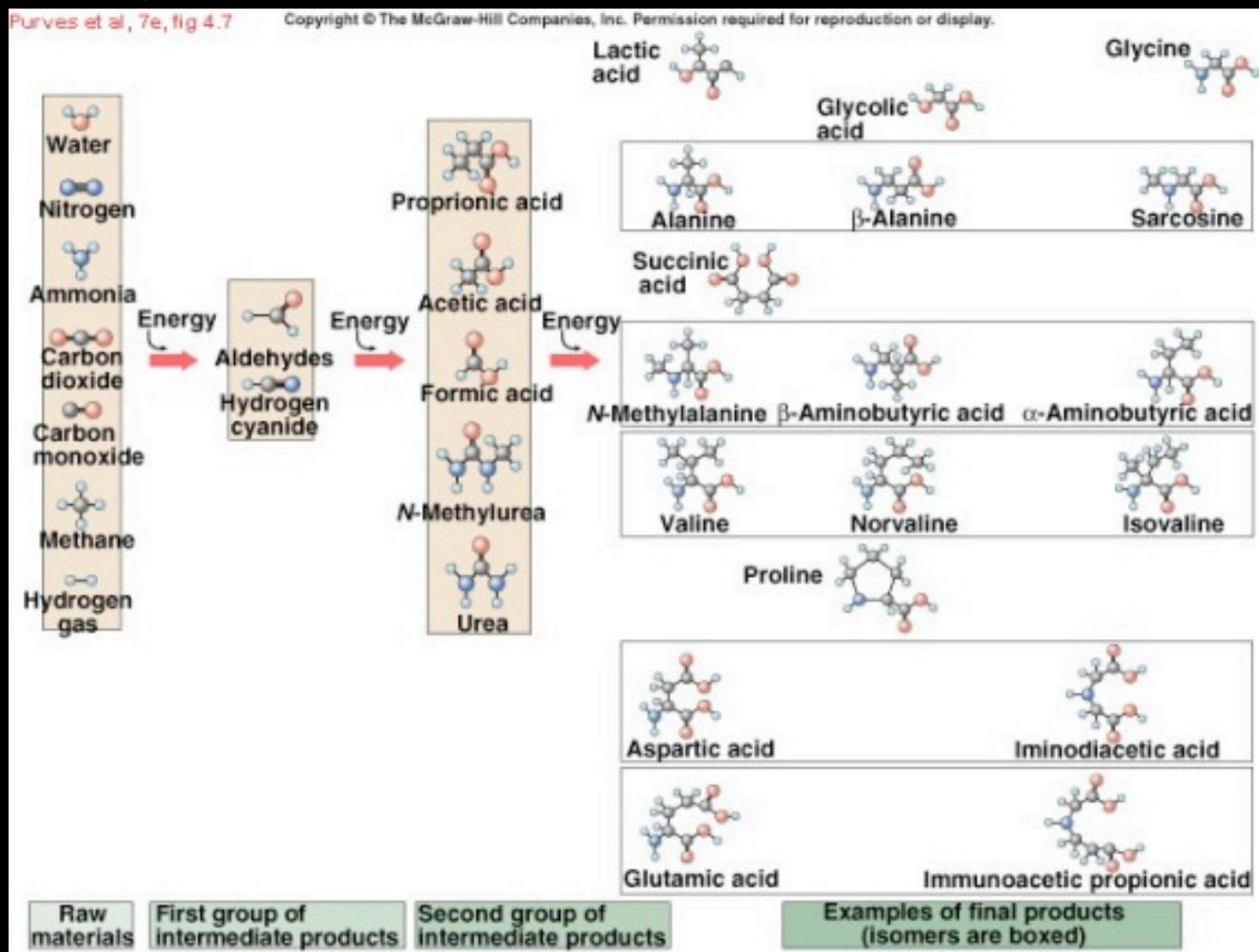
# The Origins of Life on Earth

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



# The Origins of Life on Earth

## Miller-Urey Experiment



# The Origins of Life on Earth

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

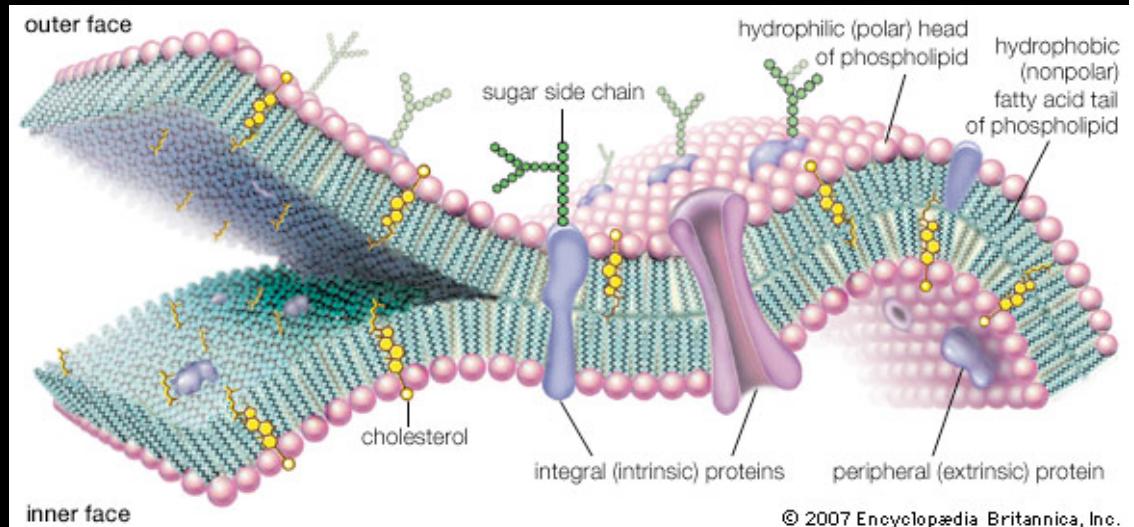
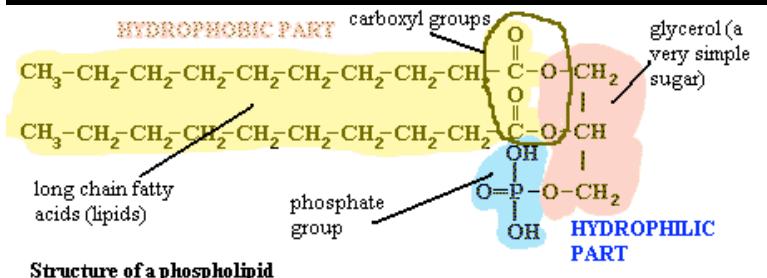
# The Origins of Life on Earth

# What is the bare minimum for “life”?

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

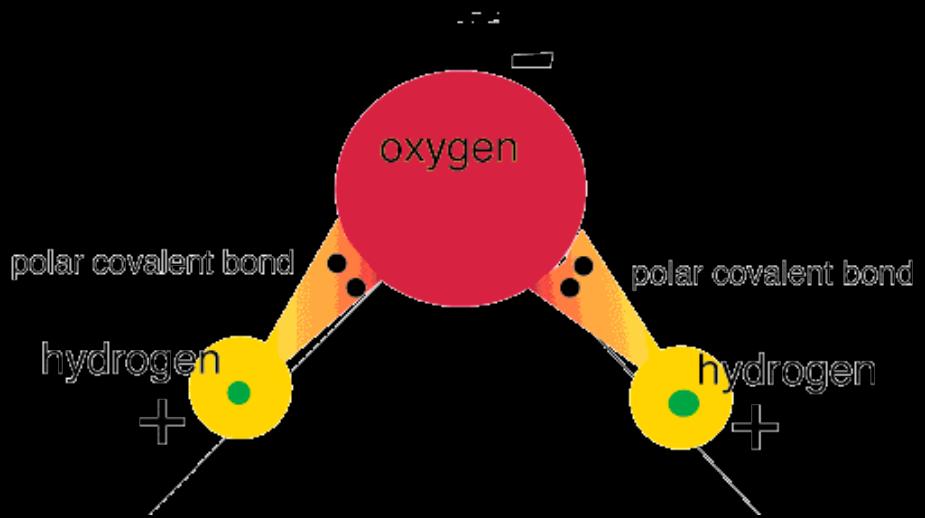
Cell wall – something to protect the RNA from the raw environment and contain replication

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

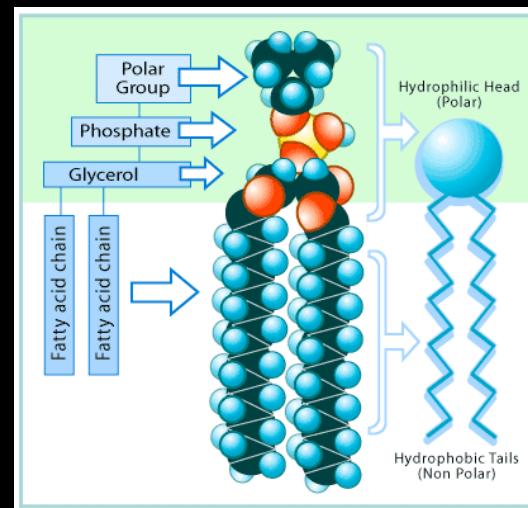


# Nature of Cell Walls

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

# The Origins of Life on Earth

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](http://www.motherjones.com/blue_marble_blog/clay.h4.jpg)

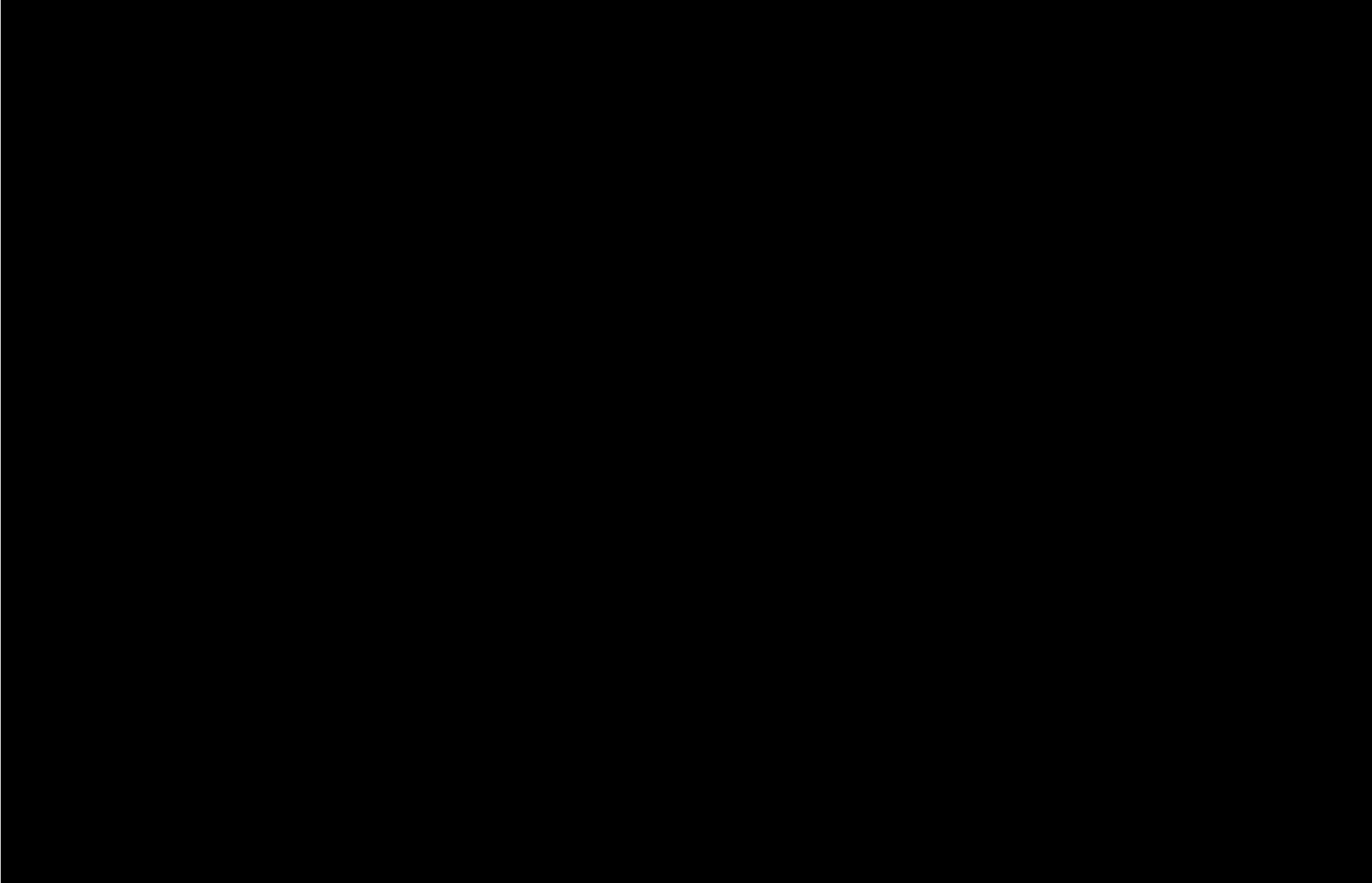
# An Intriguing Idea: Panspermia

- 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](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:  $\sim$ 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