Astronomy 330:

# Extraterrestrial Life

This class (Lecture 20):

Transition to Life

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Next Class:

Biological Evolution


Music: *Bring Me to Life*– Evanescence

# HW #2

Tara Chattoraj
http://ufodigest.com/article/inter-dimensional-hypothesis
supports UFO sightings and historical extradimensional objects without feeling the need to establish the veracity of what he uses as evidence

Zoe Richter
http://area51jrod.com/alien-autopsy-report/
The aliens J-Rod— their bodily systems such as the digestive system or the birthing process and their love of strawberry ice cream



# Drake Equation

That's 45.1 Life-liking systems/year

Frank Drake

$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

| # of advanced civilizations we can contact in our Galaxy today | Star formation rate | Fraction of stars with planets | # of Earthlike planets per system | Fraction on which life arises | Fraction that evolve intelligence | Fraction that communicate | Lifetime of advanced civilizations |
|---|---|---|---|---|---|---|---|
| | 30 stars/yr | 0.8 systems/star | 4 X 0.47 = 1.88 planets/system | life/planet | intel./life | comm./intel. | yrs/comm. |

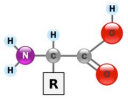
The next term in the Drake equation is fl. Arguably the hardest term to estimate. We do not know much about the early Earth as we do not have the rock from that time period— too much processing by seismic activity. Nonetheless, we can develop likely pathways for life, then try to draw conclusions from those arguments. One of the difficult things here is that we will mostly be examining modern life— not early life. We are looking at the perfected machinery of life, but early life may have been very different. We skip ahead to the top of the line best designed (by evolution) car— sports car, and we do not see the first steps of develop of cars— the first car was slow, clunky, and less efficient, likely just like early life. So although modern life looks like it has too many fine-tuned parameters to have ever happened through the mechanisms we will discuss, remember we are skipping ahead to the Ferrari, by-passing the first Benz.

# Chemical Evolution

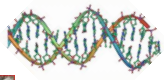
Evolutionary process appears to tend toward greater complexity

3 Steps in chemical evolution:

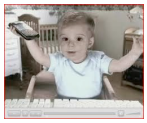
1) Synthesis of Monomers



2) Synthesis of Polymers from the Monomers



3) Transition to Life



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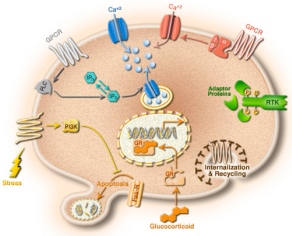
# Transition to Life



Terrestrial life is based on cells.

Protective enclosure made of lipids

Cell contains nucleic acid and protein enzymes.

Instructions for replication

Catalysts for replication

Fossil Evidence!

Cells emerged at least 4-4.3 billion years ago.

Heterotrophs: Uses organic carbon for growth

Cell membrane: Made of lipids.

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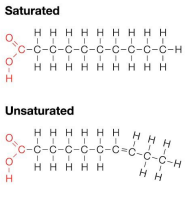
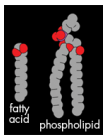
We are heterotrophs— requiring organic (pre-processed if you will) carbon.

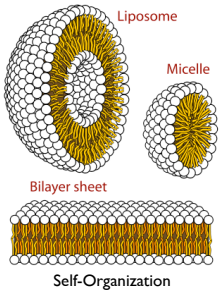
# What about those Lipids?

Lipid molecules form cell membrane.

CHON




Self-Organization

Early cell membranes were probably more simple than modern membranes.

Bilayer lipid membrane is easy to form and might have predated other polymers of life.

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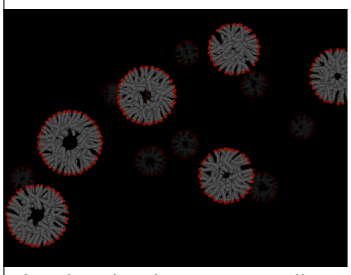
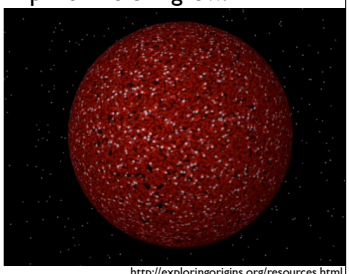
The lipid organization is a natural effect in a bipolar liquid (water being the perfect example).

# Lipid Membranes



Lipid molecules can naturally form spherical shells without anything else

Lipid shells can grow.



http://exploringorigins.org/resources.html

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# Lipid Formation

Lipid Molecules form near hydrothermal vents?

http://exploringorigins.org/resources.html

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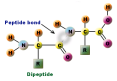
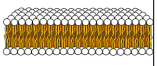
Good news for life starting near vents? Or did the cell walls happen later?

# Just the Facts

The basic requirements for Life:

1. Precise (but not perfect) method to reproduce instructions
2. Ability to control chemical reactions via catalysts
3. Protective enclosure for instructions and catalysts
4. Method for acquiring and consuming energy
5. Interconnections between instructions, catalysts, membrane, and energy cycle



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# Transition to Life

Given set of synthesized polymers, what is next?

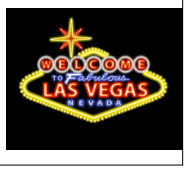
Possibility #1: Primitive Life

Primitive biotic polymers arose independently and combined into a new life form.

Possibility #2: Protolife

One component was dominant early and first life was based on only one polymer. Evolution led to the greater complexity we now see.

Statistical Argument: Favors Protolife

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It seems unlikely that primitive life could occur, so protolife is the preferred pathway.

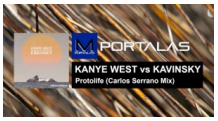
# Protolife

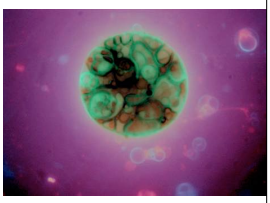
Two protolife concepts based on nucleic acids and proteins.

1. Protein Life

2. RNA Life

Which came first?



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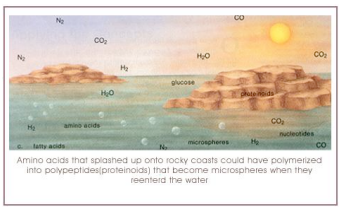
First experimentally shown by Sidney Fox

# Protein World

heat + sand + amino acid monomers = proteinoids

Hypothesis: organic monomers are splashed onto hot rocks or sand.



Amino acids that splashed up onto rocky coasts could have polymerized into polypeptides(proteinoids) that become microspheres when they reentered the water

Heat vaporizes water and links monomers

Later water rinses polymers back into water (or heat will destroy polymer)

Proteinoids + Cold Water = Microspheres

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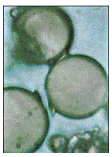
# Protein World

Proteinoids: Can grow into spheres and divide

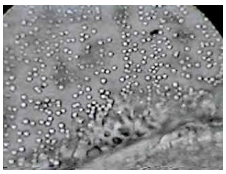


Self-Organization

Similar to cell reproduction.

But no instructions (nucleic acids)

Protocells?



Microspheres: Provide a safe capsule for biochemical processes

Pharmaceutical Companies interested as drug delivery devices

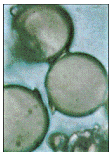


Images are proteinoids grown in the lab. Conditions could have existed in the early oceans.

Sometimes they will grow and break into daughter spheres. It is like cell reproduction, BUT there is no replication of nucleic acids, so not true reproduction. Nonetheless, they might be suitable for protocells.

# Protocell

Protocell: How do nucleic acids enter the picture?



Self-Organization

One proteinoid develops capability for replication.

Passes trait onto *offspring*

Nucleic acid used to store amino acid information

Eventually nucleic acid took over bookkeeping.

Evolution?

Note: Most biologists disfavor since nucleic acid is not required.

Sydney Fox

Professors

Sydney Fox



If so, how do nucleic acids come into play? Perhaps one proteinoid developed the capability to make its own protein from amino acids, then passed that on to its "offspring". Then, nucleic acids might have been used to store the amino acid information.

And only later took over- revolt of the bookkeepers! Most biologist do not like the idea, as life without nucleic acid is hard to accept.

Sydney Fox (the one on the left) was the main researcher behind protocells.

# RNA World

Enhanced! NAKED GENETICS

Transition to life dominated by nucleic acids.

Requires naked genes

Ecosystem of self-replicating RNA with no protein synthesis.

Numerous experiments support RNA World



The other camp believes that the transition to life was dominated by nucleic acids; the opposite problems of the Sydney Fox scenario. These genes are naked! An ecosystem of self-replicating RNA is nice, but without capability for protein synthesis, they could do little else. However, it's the most widely accepted concept due to numerous experiments.

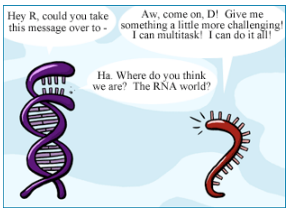
The basic idea is that RNA did all the tasks. Both info storage and enzyme actions. Then, the DNA world evolved out of that. The rRNA encoding of proteins in today's world may be evolutionary left-overs.

# RNA World


Numerous experiments support RNA World

RNA can do all of the tasks:

- information storage
- enzyme actions




DNA evolves from this starting point

- rRNA protein encoding
- evolutionary leftover?

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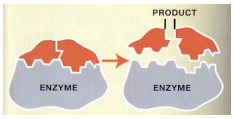
# RNA World

**Overview:**

RNA mutating away

- one develops an enzyme function



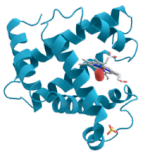

RNA Enzyme = Ribosome

RNA fulfills enzyme role

Eventually, RNA encode and produce proteins

- amino acid encoding
- using enzyme functionality?

Proteins take RNA enzyme functionality



*Is this Possible?*

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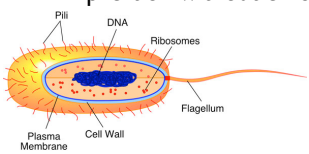
Because proteins can do the enzyme job better.

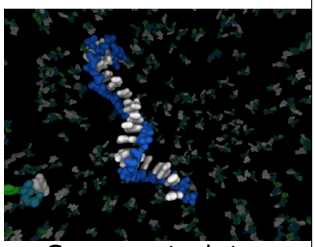
# RNA World

Experiments

RNA replication without cells




Virus RNA + replicase + activated nucleotides = RNA replication



Computer simulations

One experiment did not add in RNA and still RNA was produced

No cells!

Evolution: Fastest variant wins?

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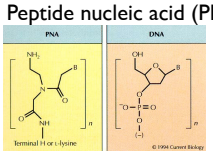
Although proteins were used in this experiment it is thought that RNA enzymes are what played the role on the early Earth.

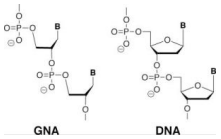
# RNA World: Variations

What if RNA was NOT the first nucleic acid?

On pre-biotic Earth, could other nucleic acids form more easily?

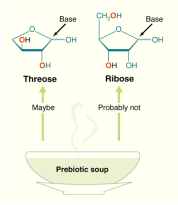
Peptide nucleic acid (PNA)




Glycerol nucleic acid (GNA)

Threose nucleic acid (TNA)




Evolution leads to RNA replacing an earlier nucleic acid

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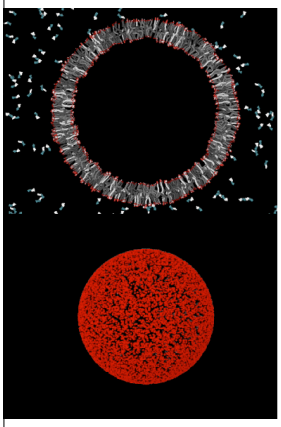
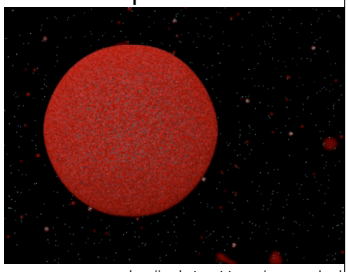
# Protocells



Add nucleic acid to lipid shell: *Protocell*?

Protect Nucleic Acid.
Replication of fitter species.



http://exploringorigins.org/resources.html

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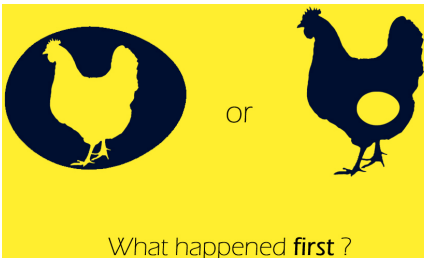
# The Cage Match

Essential to life: Synergy between protein & nucleic acids




Protein World: Protein-like polymers synthesize nucleotides
RNA World: RNA enzymes start constructing proteins

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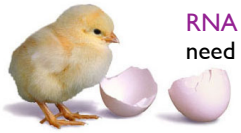
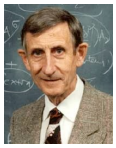
Genetic Code and Origin of Translation

# Neither Chicken nor Egg?



RNA World: Favored model, but still need to make first nucleic acids



Freeman Dyson

Dyson: Nucleic acid was not first information carrying molecule

The Problem: Fine line between living and non-living

Need accurate replication

Need occasional errors

Consistency & Evolution

Other polymers might maintain balance more easily

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Balance between order-preservation and error in replications

# Alternatives: Clay

Clay-based genetic systems

- layers in clay form patterns
- layers separate, settle, grow
- patterns not perfectly copied

Experiments demonstrated replication not sufficiently accurate

Why mention this? Remember Clay Polymerization?

The final word: Transition to life is a giant leap with great uncertainty remaining.

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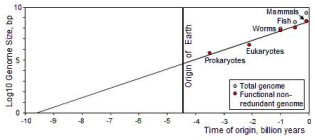
Clay based life: eventually proteins & nucleic acids develop parallel genetic system that moves beyond the clay

# Primitive Life

Shift creation away from

Exogenesis & Panspermia




Evolutionary Scaling?

Increase likelihood elsewhere?

Increase time baseline?

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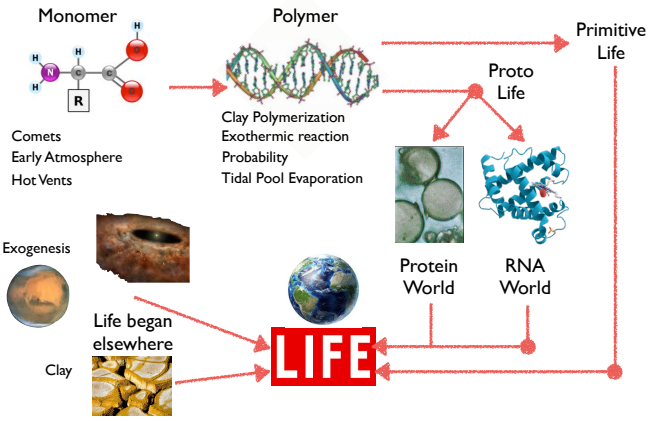
# The Game of *Life*

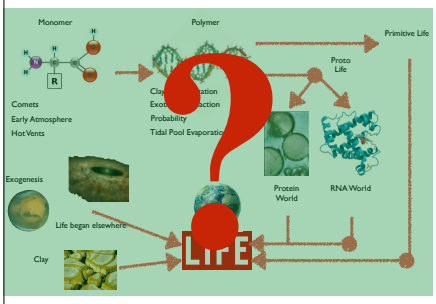





Or Maybe Life too complicated and arose somewhere else?

# The Game of *Life*

**The Answer is …**




Life very different now

Life started quickly …

Unique pathways?

Exoplanet life different?



# Exotic Life

Natural Bias: *Earth Chauvinism*

ET Life? Alien?

**Very Alien?**

Other avenues for life increase f

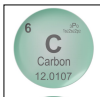
Other polymers for life

Different DNA conformations

Different nucleic acid molecules

Other options in lab or computer

# Silicon Based Life





Earth: Silicon Planet with Carbon Life

Silicon: Four bonds like Carbon

Silicon: 135X more abundant on Earth than Carbon

Problems:

C-C binds twice as strong as Si-Si

Si-O or Si-H stronger than Si-Si
thus hard to make long strands.

Si usually does not make multiple SI bonds

$CO_2$ gas, $SiO_2$ large crystals (silicates)

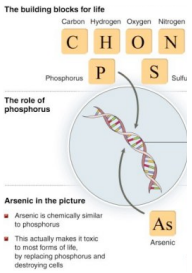
*Remains intriguing possibility*



# Arsenic Life?



| IIIA | IVA | VA | VIA | VIIA |
|---|---|---|---|---|
| 5 B 10.81 | 6 C 12.01 | 7 N 14.01 | 8 O 16.00 | 9 F 19.00 |
| 13 Al 26.98 | 14 Si 28.09 | 15 P 30.97 | 16 S 32.07 | 17 Cl 35.45 |
| 31 Ga 69.72 | 32 Ge 72.61 | 33 As 74.97 | 34 Se 78.96 | 35 Br 79.90 |





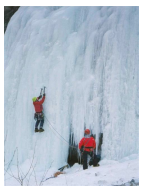


# Solvent Change?

Water as solvent for *Life* on 

Other *Solvents*?

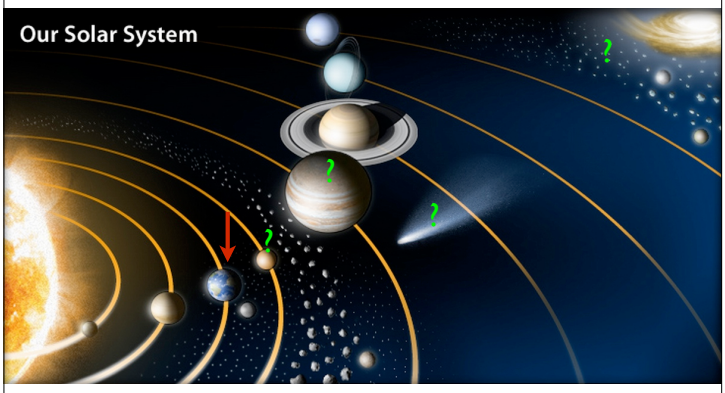
| *Molecule* | *Freezes (K)* | *Boils (K)* |
|---|---|---|
| Water (H | 273 | 373 |
| Ammonia (NH | 195 | 240 |
| Methyl alcohol (CH | 179 | 338 |
| Methane (CH | 91 | 109 |
| Ethane (C | 90 | 184 |



Water has wide liquid temperature range.

Water has high energy of vaporization
(good for evaporative cooling, i.e., sweating).

# Life in the Solar System?

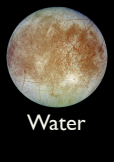





# Life in Solar System


Clay Minerals


Miller-Urey

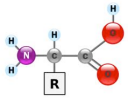

Water



1 in 10 locations.

# Life Fraction

Amino Acids formed in *Space*



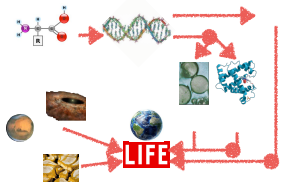

*Sterile* World

2

*Party* Town

Conditions right:

$f_l = 1$




But how often does that happen?