

Alternative Ideas

Something else...

- Neither the chicken nor the egg came first
- Transitional forms that were later discarded

Or was it the “egkin”?

Some experiments with peptide nucleic acid (PNA).

PNA: Peptide backbone with bases

Can act as template for polymerization of RNA

From activated nucleotides

(Böhler, et al., *Nature*, **376**, 578

& comments by Piccirilli, pg. 548

17 Aug. 1995

PNA could be simpler to form under prebiotic conditions

Main point is that a simpler thing (not necessarily PNA)

could have preceded RNA

Membranes

- Membranes provide enclosure
 - Also fundamental for metabolism
- Membranes never arise from scratch
 - Always passed down and added to
 - All derived from ancestral cell
- T. Cavalier-Smith proposes membranes
 - Plus nucleic acid formed “ob-cell”
 - Merger of 2 ob-cells formed first cell

Focus on Energy

G. Wächtershäuser

Inorganic - organic connection

FeS_2 (Iron pyrite)

Attracts negatively charged molecules

Surface catalysis provides energy via formation from

$\text{FeS} + \text{H}_2\text{S}$

Scene is hot sulfur vents on sea floor

Some recent successes in simulations

Amino acids formed peptide bonds

Thioester World

1. Need precursor to RNA world

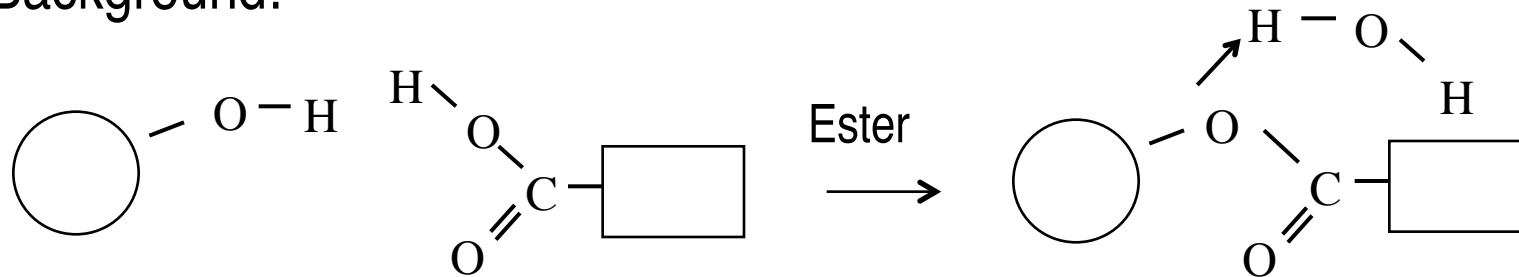
C. deDuve

2. Need energy conversion

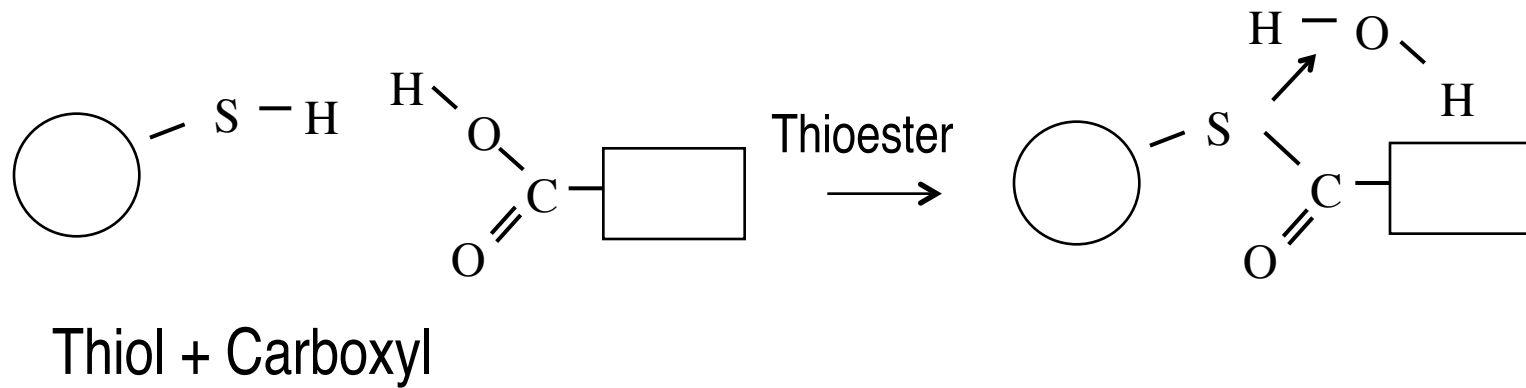
In Vital Dust

Protometabolism

Background:



Hydroxyl + Carboxyl



Thiols involved in metabolism, particularly in ancient pathways

Also can catalyze ester formation by group transfer
 Reactions
 e.g. peptide bonds

Catalytic Multimers

C. de Duve

“Multimer” short peptides and esters

(NH₂) (OH)

of amino acids and hydroxy acids

Will form from thioesters. Assume some catalytic ability,
lead to protometabolism

Energy Sources

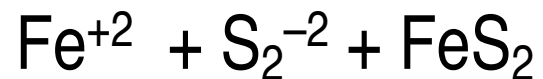
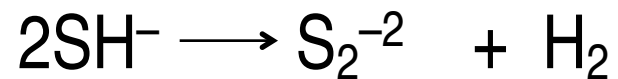
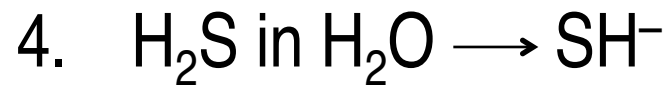
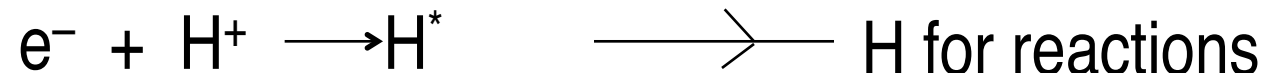
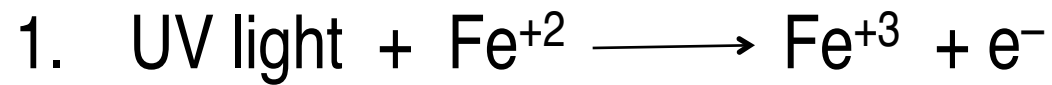
Basic need is hydrogen atoms
(or electrons in excited states)

In pure water $\frac{\text{H}^+ + \text{OH}^-}{\text{H}_2\text{O}}$ more if acidic



Now chlorophyll + sunlight

Then?



iron pyrite

Transition to Phosphate

Remember that energy currency in life now is ATP

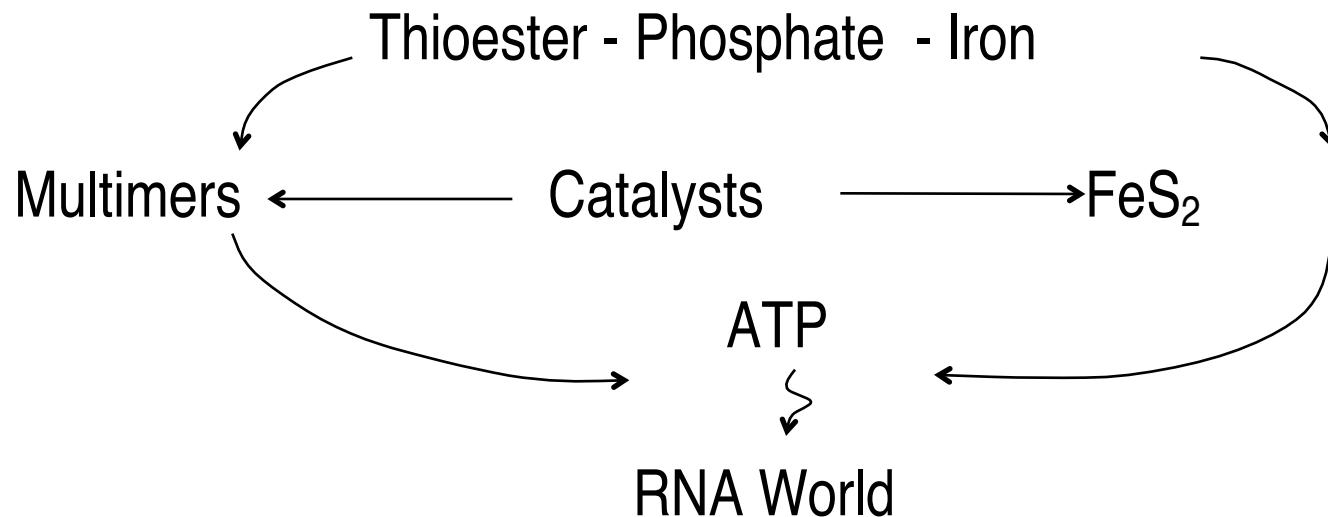
Adenosine Triphosphate

used to make bonds, remove H₂O

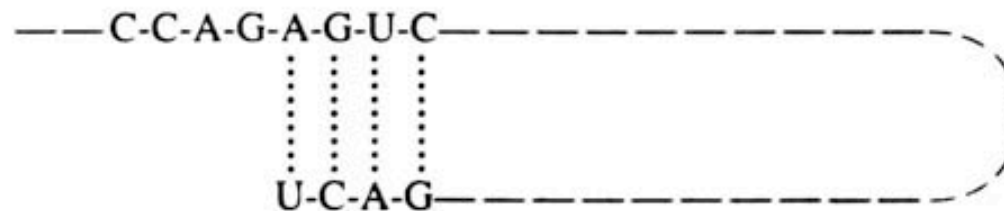
Earlier, inorganic phosphate

p-p diphosphate or polyphosphate

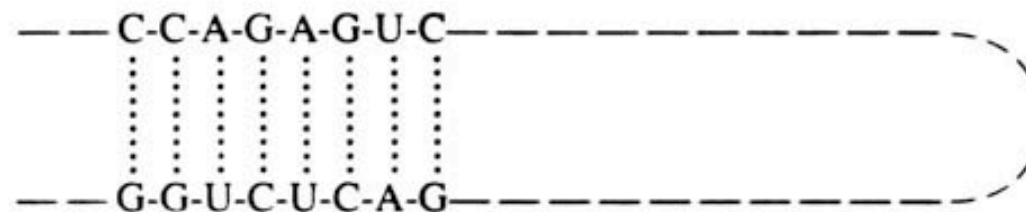
still involved in ATP reactions



age—will be followed by GUC. This AGUC sequence is complementary to the terminal sequence written in antiparallel fashion, and will cause the chain to double up as follows:



Assume now that this folded chain is subject to elongation, by the addition of new nucleotides, from right to left, to the U end. The presence of G next to the A paired with the terminal U is likely to favor the addition of a complementary C over that of the other three possible nucleotides. Repeat the process and you get U added opposite A, G opposite C, G again opposite the next C, and so on. What you get is the formation of a stretch complementary over all its length to the other end of the molecule:



Summary of Proto-Life Development

<u>Stage</u>	<u>Proteins</u>	<u>Halfway # 1</u> Peptide Nucleic Acids	<u>Halfway # 2</u> RNA Ribozyme	<u>Nucleic Acids</u>
Monomers	Amino Acids	Bases Amino Acids	Ribose Sugars Bases Phosphates Amino Acids	Ribose Sugars Bases Phosphate
Polymerization	Proteinoids	Short strands of PNA's	Short strands of RNA + amino acids	Short strands of RNA
Replication	?	Affinity for complementary bases + ease of peptide bonding	Affinity for complementary bases	Affinity for complementary bases
Pre-life	Proteinoids + RNA?	Separation of proteins and nucleic acids	Separation of nucleic acids and protein parts	RNA adapts proteinoids as needed
Life	Proteins	Disappears	Disappears	DNA and RNA

Other ideas

A different initial genetic substance + genetic takeover

e.g., clay life

Panspermia

Various versions

Creationism

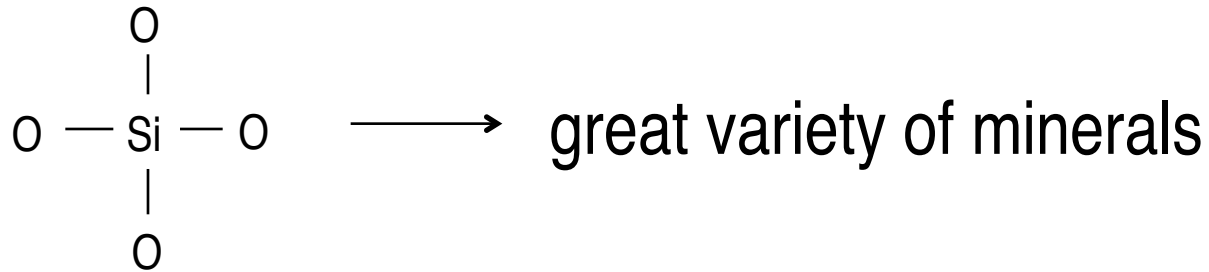
Clay Life

A. G. Cairns-Smith

Silicate Life?

Early Genetic Material

$O = Si = O$ but O can make another bond instead



Layers - clay

Also occasional impurity (Al, Mg, ...)

Can grow by adding dissolved material

Tends to copy pattern of impurities in adjacent layers.

Could this be a kind of reproduction?

Defects - different impurity, ... (mutations?)

Sheets can separate - move - and then
“reproduce”

Advantages

Clay clearly present

Simpler genetic structure

Crystal growth occurs naturally

Problem

How to get to
life as we know it

Clay Life $\xrightarrow{?}$ Life

Clay life begins to synthesize, use “organic”

[carbon] molecules

Clays do have some catalytic activity

Genetic takeover

organics \longrightarrow protein/RNA mechanisms

Clay discarded

Tests

1. Surviving clay life - unlikely
3. New clay life - maybe in some places
4. Demonstrate in lab

Not much further development of this idea.

Panspermia

- Life arose elsewhere and was delivered here
 - Original idea was bacterial spores
 - Hoyle and Wickramasinghe
 - Life originates on dust grains, comets, ...
 - Or on another planet (meteorites from Mars)
- Directed panspermia
 - Crick and Orgel (tongue in cheek)
 - Earth seeded by intelligent ET

Creationism

- Traditional biblical literalism
- Intelligent design
 - Seeks evidence of design in complexity
 - Current version of creationist movement
 - Hoyle and Wickramasinghe later ideas
 - Life designed by silicon chip
 - Where did the chip come from?
- None of these are scientific theories
 - The key is whether they can be tested

From "Scientific Creationism" by Henry Morris

Uniformitarianism

Matter existed
in the beginning
Sun and stars
before the earth
Land before the oceans
Sun, earth's first light
Contiguous atmosphere
and hydrosphere
Marine organisms,
first forms of life
Fishes before fruit trees
Insects before birds

Sun before land plants

Reptiles before birds

Woman before man
(by genetics)
Rain before man
"Creative" processes still continuing
Struggle and death necessary
antecedents of man

Bible

Matter created by God
in the beginning
Earth before the sun
and stars
Oceans before the land
Light before the sun
Atmosphere between
two hydrospheres
Land plants, first life
forms created
Fruit trees before fishes
Birds before insects

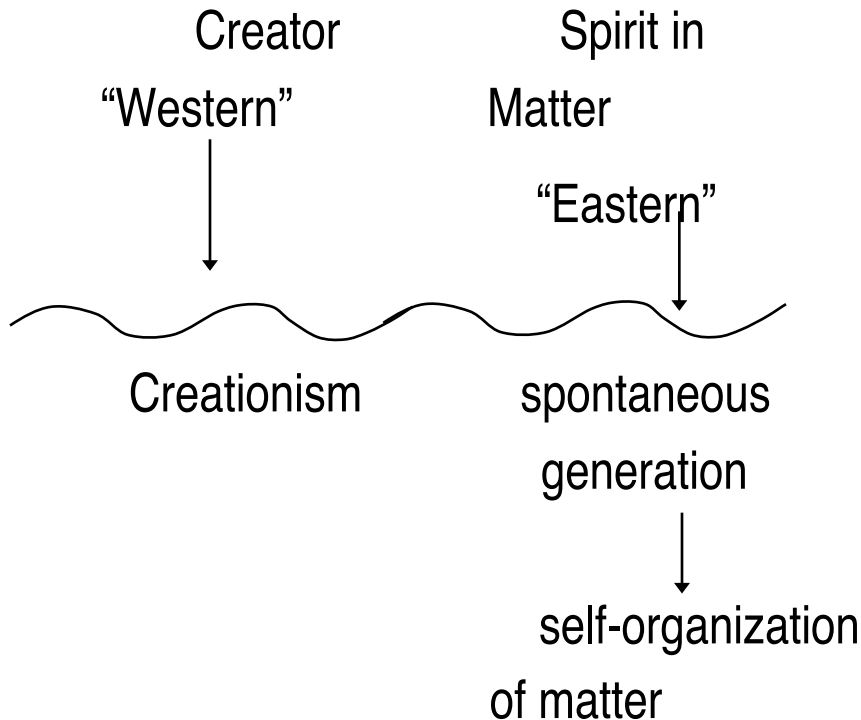
Land vegetation before the sun
Birds before reptiles

Man before woman
(by creation)
Man before rain
Creation completed
Man, the cause of struggle and death

Myth (Mythos)

Revealed truth unquestioned

Two strands in
Creation Myths:



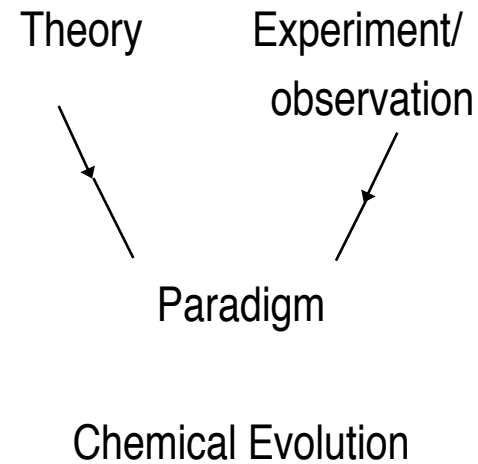
Science (Logos)

Provisional truth

Skepticism essential
(falsifiability)

Method important

Interplay:



related?

Artificial Life?

- Polio virus constructed from “scratch” in 2002
- Have they created life?
- Viruses are parasites, but “protolife”?
- Entire bacterial genome (not the bacterium) constructed from scratch in 2008
 - 582,970 base pairs
- Could we create a bacterium from scratch?
- Far too complex for current abilities

Exotic Life Forms?

Antidote to Earth Chauvinism

1. Different organic molecules (e.g., PNA)
possibility of life based on other polymers
2. Not based on Carbon
Silicon (Si) instead of Carbon?
(also 4 bonds)
& more (135 ×) more abundant on Earth

Negatives for replacing carbon with silicon:

- a. C - C bond $2 \times$ stronger than Si - Si
- b. Si - O stronger than Si - Si
forms silicates, not .. Si - Si - Si ...
- c. C forms multiple bonds (e.g. $C \equiv N$)
Si rarely does
- d. C + O forms CO or CO₂ (gas - further reacts)
Si + O \longrightarrow SiO₂ - silicate rocks

\Rightarrow Si unlikely to replace C in “organic” molecules
but could forms of SiO₂ produce clay life?

3. Other Solvents

Earth: Liquid water 273-373 K

Alternatives:		T_{freeze}	T_{boil}
Ammonia	NH_3	195	240
Methyl Alcohol	CH_3OH	179	338
Methane	CH_4	91	109
Ethane	C_2H_6	90	184

Water is better solvent

Also better for temperature regulation

But others could play a role in colder zones

extend CHZ?

4. Non-chemical life?

Disembodied intelligence

Black cloud life?

Other forces

Strong nuclear force?

$$\tau \sim 10^{-15} \text{ s}$$

Gravity?

Estimates for f_ℓ

- Possible range is very large
 - Perhaps 10^{-6} (one in a million) to 1 (all)
- Arguments for large value
 - Life part of overall evolution in complexity
 - Arises naturally from interplay of forces

Estimates for f_ℓ

- Arguments for small value
 - May need more than liquid water
 - Large tides, so large moon
 - Dry land (for polymerization)
 - Life may be a fluke
 - A rare statistical event

Can we estimate f_ℓ from early origin of life?

Very ancient microfossils (now disputed)

\Rightarrow Life arose as early as 3.8×10^9 yr ago
[soon after end of heavy bombardment]

Lineweaver & Davis argued:

Early origin $\Rightarrow f_\ell > 0.33$

For suitable planets older than 1×10^9 yrs.

Statistics from one example!

Others have disputed this conclusion

What is your choice and why?

- The most uncertain factor so far (f₀)
- Think about various ideas for origin of life
- Put together a plausible story for the origin of life
 - Can use parts of various ideas, but need to be consistent.