The Westheimer Institute for Science and Technology

the foundation for applied molecular evolution

Paradoxes of molecular biosignatures

Molecular systems that cannot possibly arise *without* life

The paradox: Such a life form could never arise.

For example, amino acids are bad biosignatures, as they can arise abiologically

Even enantiomerically enriched amino acids seem to arise without life (Sandra Pizzarello)

Paradoxes of molecular biosignatures

Molecular systems that cannot possibly arise *without* life

The paradox: Such a life form could never arise.

For example, amino acids are bad biosignatures, as they can arise abiologically

Even enantiomerically enriched amino acids seem to arise without life (Sandra Pizzarello)

The paradox is naively formulated

The (in)organic molecules are formed universally

We then look for Darwinian capability within them

A biopolymer requires homochiral building blocks to be evolvable. Further, it must be build from a controlled library.

What does Darwinism need by way of a genetic molecule?

(a) A one-dimensional biopolymer*, that…
(b) can change its structure to change its information, but …
(c) any changes in the structure of the biopolymer *cannot* change its physical chemical behavior substantially, e.g.: *its solubility, its molecular recognition, reactivity*

* We have tried to assemble a two dimensional Cairns-Smith life form; so far no luck.

Data show that such systems are scarce …

Proteins, polysaccharides, most every other class of molecules, including abiological polymers, physical behavior and reactivity change dramatically even with small sequence changes.

Sickle cell hemoglobin. Change one lousy amino acid in 576, and the protein precipitates.

The Westheimer Institute for Science and Technology

the foundation for applied molecular evolution

If DNA/RNA precipitated every time a nucleotide changed, evolution would grind to a halt

A genetic biopolymer must have fairly constant properties if it is to support Darwinism, where it is replicated with imperfections, with the imperfections themselves replicable

Pretty much true with DNA and RNA

Pretty much every DNA/RNA sequence dissolves in water
Pretty much every DNA/RNA sequence binds its complement
Pretty much every DNA/RNA sequence precipitates in ethanol
Pretty much every DNA/RNA sequence templates polymerases

What is it about the structure of DNA/RNA ?

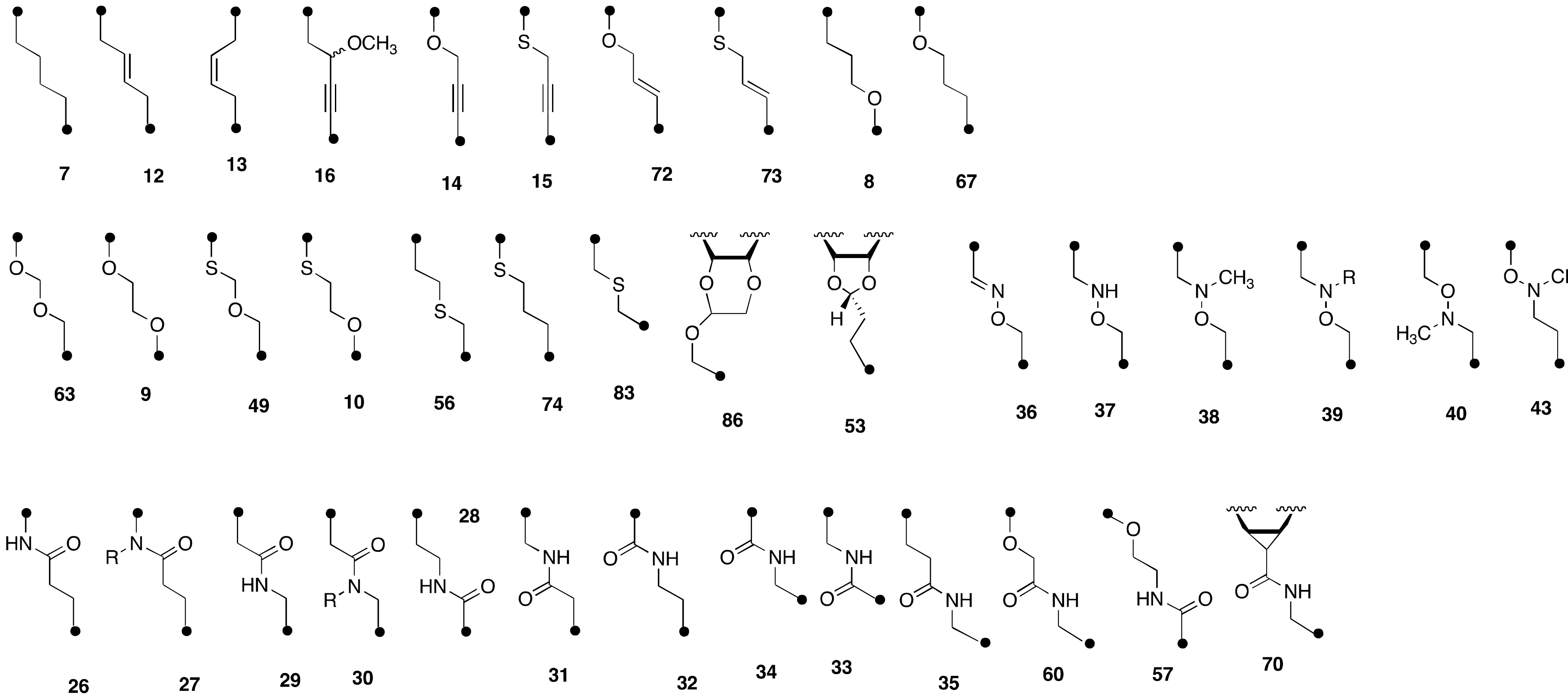
Proteins have a repeating backbone dipole;
DNA has a repeating backbone monopole.

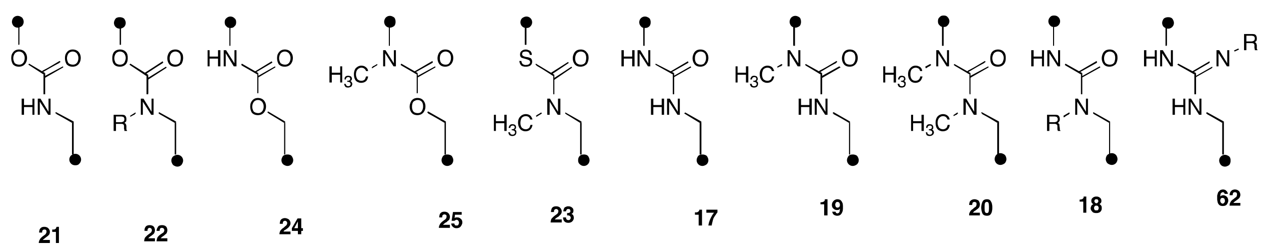
Westheimer Institute

the foundation for applied molecular evolution FAME

Experimental evidence?

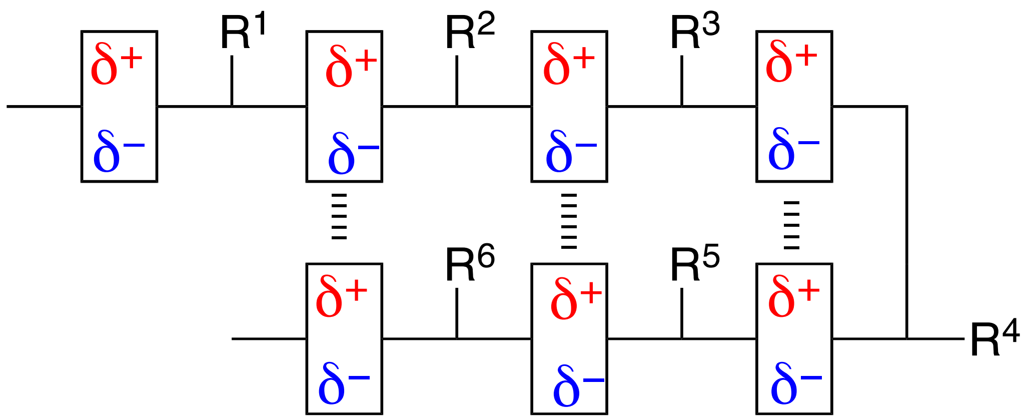
Many DNA analogs without the backbone charge have been synthesized

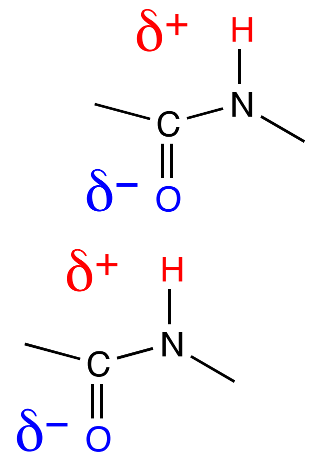




They fold, precipitate, like proteins

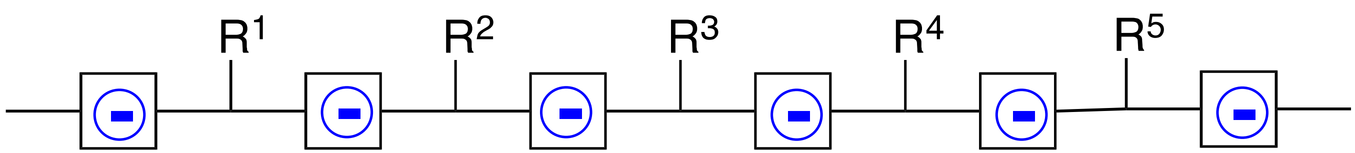
Compare peptides, with repeating dipole, to DNA/RNA, with a repeating monopole





Think of magnets on a string

(above) A backbone with a repeating dipole easily folds
(below) A backbone with a repeating charge extends to template



Polyelectrolyte backbone prevents folding, allows templating.

= polyelectrolytes are soluble in water.

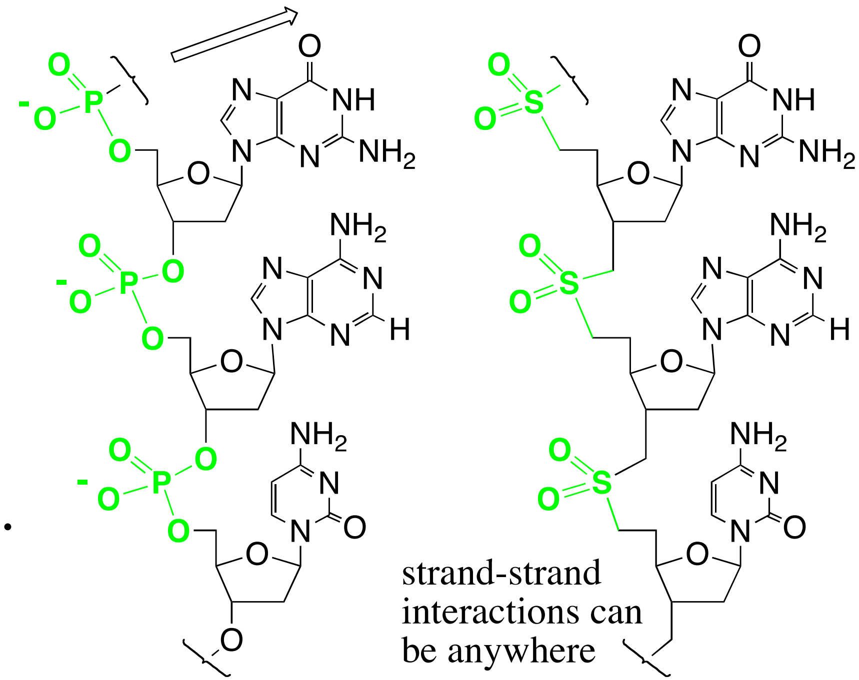
The Westheimer Institute for Science and Technology

the foundation for applied molecular evolution

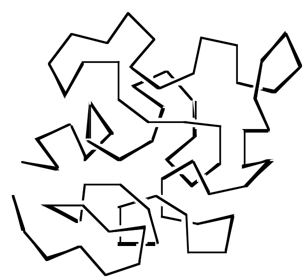
FAME

Why genetic systems in water must have a polyelectrolyte backbone

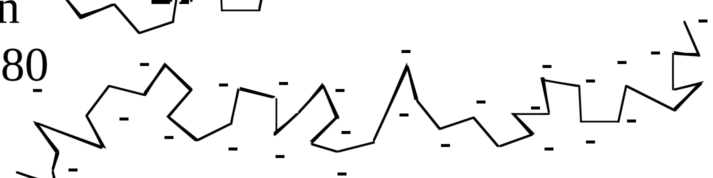
1. Keeps DNA soluble in water.
2. Backbone-backbone coulombic interactions force strand-strand contacts to Watson-Crick edges of the nucleobases (= rules).
3. Repeating charges discourages folding; "excluded volume" effect.
4. Repeating charge dominates the molecule's properties, allowing mutation to occur without changing the bulk properties of the molecule



Benner, S. A., Hutter, D. (2002) Phosphates, DNA, and the search for nonterrean life. Second generation model for genetic molecules. *Bioorg. Chem.* **30**, 62-80



neutral polymer
Radius = length $^{(1/2)}$



polyanionic polymer
Radius = length $^{>>(1/2)}$

Polyelectrolyte Theory of the Gene

True for all life in water

NASA

FIREBIRD BIOMOLECULAR SCIENCES, LLC

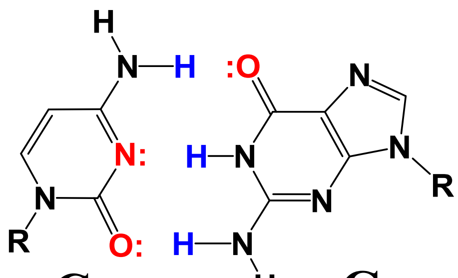
www.firebird.com

We can change the bases and retain Darwinism …

the foundation for applied molecular evolution

FAME

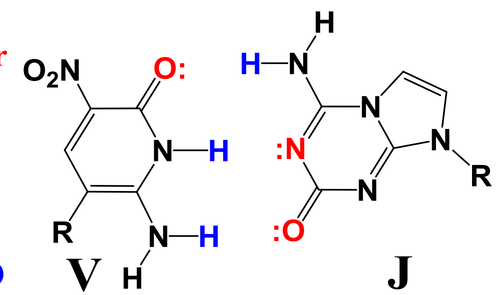
Donor
Acceptor
Acceptor
pyDAA



C G

Acceptor
Donor
Donor
puADD

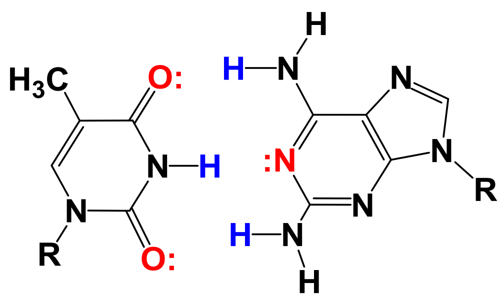
Acceptor
Donor
Donor
pyADD



V J

Donor
Acceptor
Acceptor
puDAA

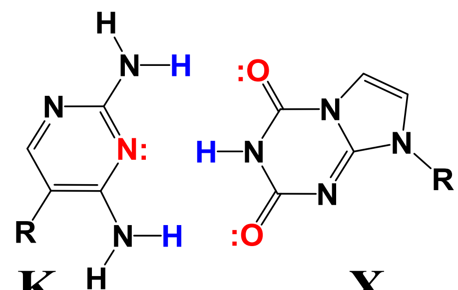
Acceptor
Donor
Acceptor
pyADA



T aminoA

Donor
Acceptor
Donor
puDAD

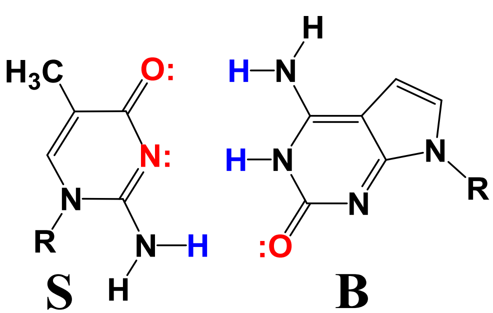
Donor
Acceptor
Donor
pyDAD



K X

Acceptor
Donor
Acceptor
puADA

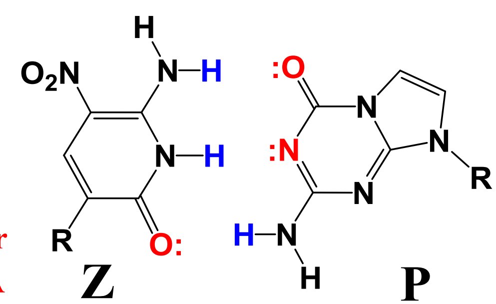
Acceptor
Acceptor
Donor
pyAAD



S B

Donor
Donor
Acceptor
puDDA

Donor
Donor
Acceptor
pyDDA



Z P

Acceptor
Acceptor
Donor
puAAD

But we cannot change the backbone charges. A universal.

Polyelectrolytes make excellent universal biosignatures

1. Universal genetic biopolymers in water have repeating charges

2. This allows them to be easily concentrated from plumes, bulk water

3. Darwinian biopolymers having this features are easily distinguished

We can today detect extant life in H_2O *in situ*, terran & weird,

4. we still lack a clear path to get RNA as the first terran Darwinian biopolymer, but it seems that we *will* find those paths.

5. These paths are defeated by dilution into a global ocean

6. Defeat is easily avoided in deserts with occasional water (e.g. Mars)

And non-aqueous life? An analogous universal biosignature?

7. Efforts to get life in cryosolvents defeated by solubility issues

8. Warm Titans, exotic polar solvents, still possible

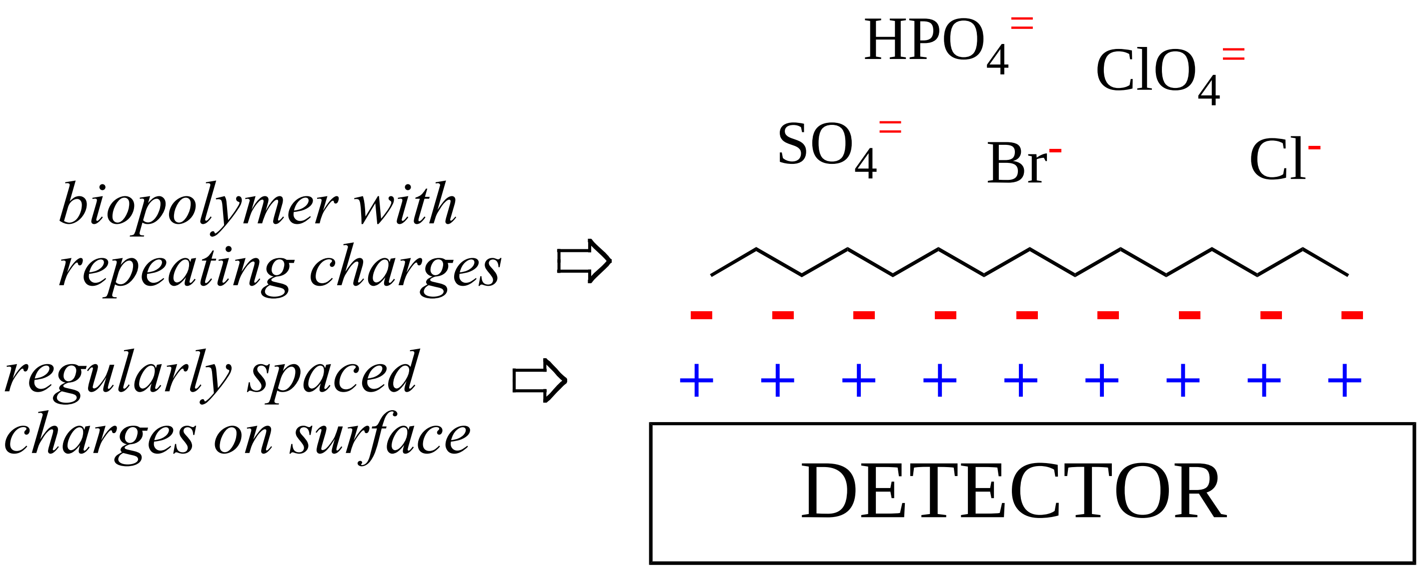
Disequilibrium and the impotence of Darwinism

9. Smart life will escape Darwinism to gain Lamarckianism

Polyanions are easily captured dilute water on polycation supports

This is for a *universal* genetic biopolymer

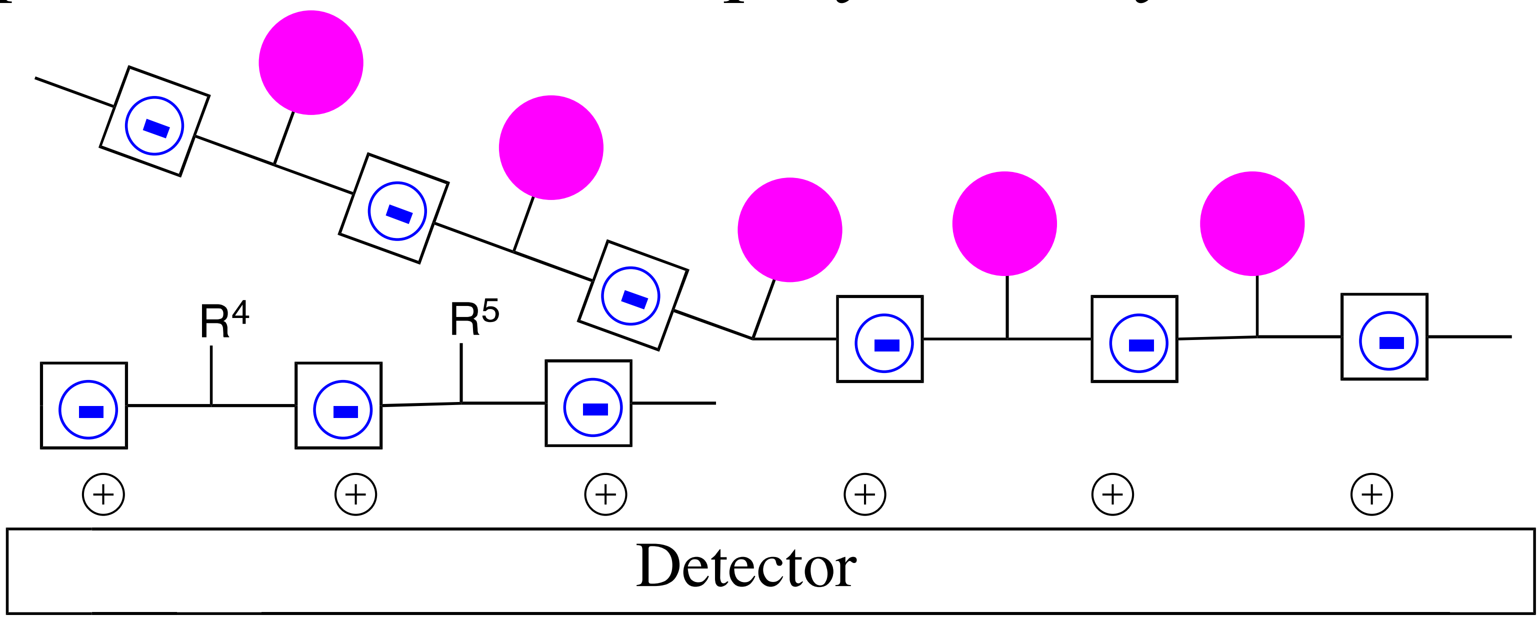
Polyelectrolytes bind in competition with simple ions



The sample can be indefinitely large and indefinitely dilute; no matter what the specifics of the molecule that support alien genetics, the detector will capture it, and present it to a "detection zone".

The polyanion is easily detected as part of this capture

Displacement of labeled polyelectrolyte



Sensitivity depends on tags on displaced polyelectrolyte. Can be radiolabels, fluorescent, UV active, chemically reactive, electrochemically reactive.

Once captured, polyanion easily analyzed to prove that it is Darwinian

1. Universal genetic biopolymers in water have repeating charges
2. This allows them to be easily concentrated from plumes, bulk water
3. Darwinian biopolymers having this features are easily distinguished

We can today detect extant life in H_2O *in situ*, terran & weird,

4. we still lack a clear path to get RNA as the first terran Darwinian biopolymer, but it seems that we *will* find those paths.
5. These paths are defeated by dilution into a global ocean
6. Defeat is easily avoided in deserts with occasional water (e.g. Mars)

And non-aqueous life? An analogous universal biosignature?

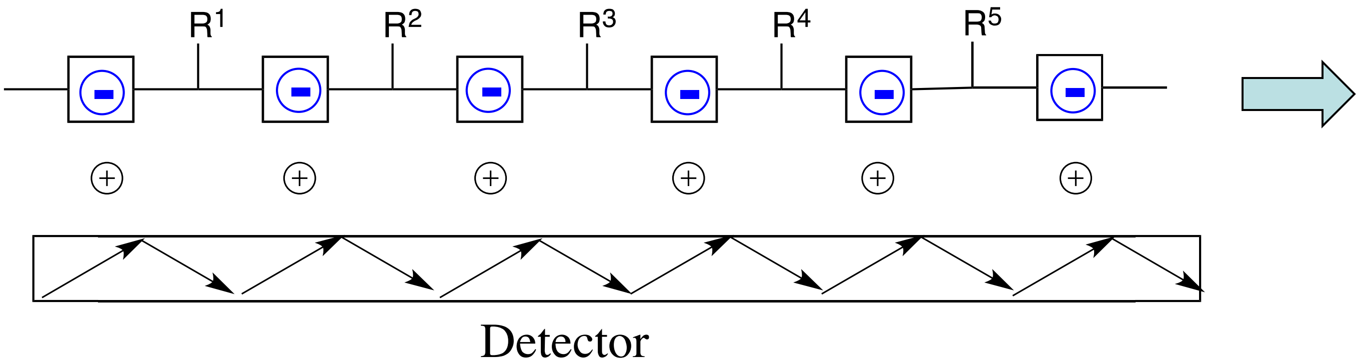
7. Efforts to get life in cryosolvents defeated by solubility issues
8. Warm Titans, exotic polar solvents, still possible

Disequilibrium and the impotence of Darwinism

9. Smart life will escape Darwinism to gain Lamarckianism

Darwinian polyelectrolytes are built from a “controlled vocabulary”, a small set of building blocks.

Displace adsorbed polyelectrolyte → Mass spec → fragments

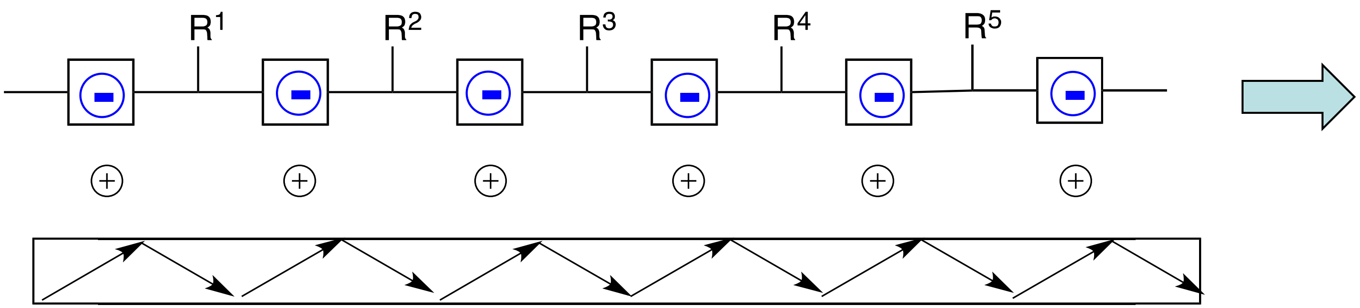


ESI MS
MALDI MS

Of course, these must be homochiral to support Darwinism

Darwinian polyelectrolytes are built from a “controlled vocabulary”, a small set of building blocks.

Displace adsorbed polyelectrolyte → Mass spec → fragments



Detector

ESI MS
MALDI MS

Of course, these must be homochiral to support Darwinism

This assay is available today for *in situ* biodetection.
It is universal for any life form in water, anywhere.
Assumes only the universality of Darwinism
and the polyelectrolyte theory of the gene.

The Westheimer Institute for Science and Technology

the foundation for applied molecular evolution

Which is why I raised my hand to say "yes". We are ready to go.

1. Universal genetic biopolymers in water have repeating charges
2. This allows them to be easily concentrated from plumes, bulk water
3. Darwinian biopolymers having this features are easily distinguished

We can today detect extant life in H_2O *in situ*, terran & weird,

4. We still lack a clear path to get RNA as the first terran Darwinian biopolymer, but it seems that we *will* find those paths.
5. These paths are defeated by dilution into a global ocean
6. Defeat is easily avoided in deserts with occasional water (e.g. Mars)

And non-aqueous life? An analogous universal biosignature?

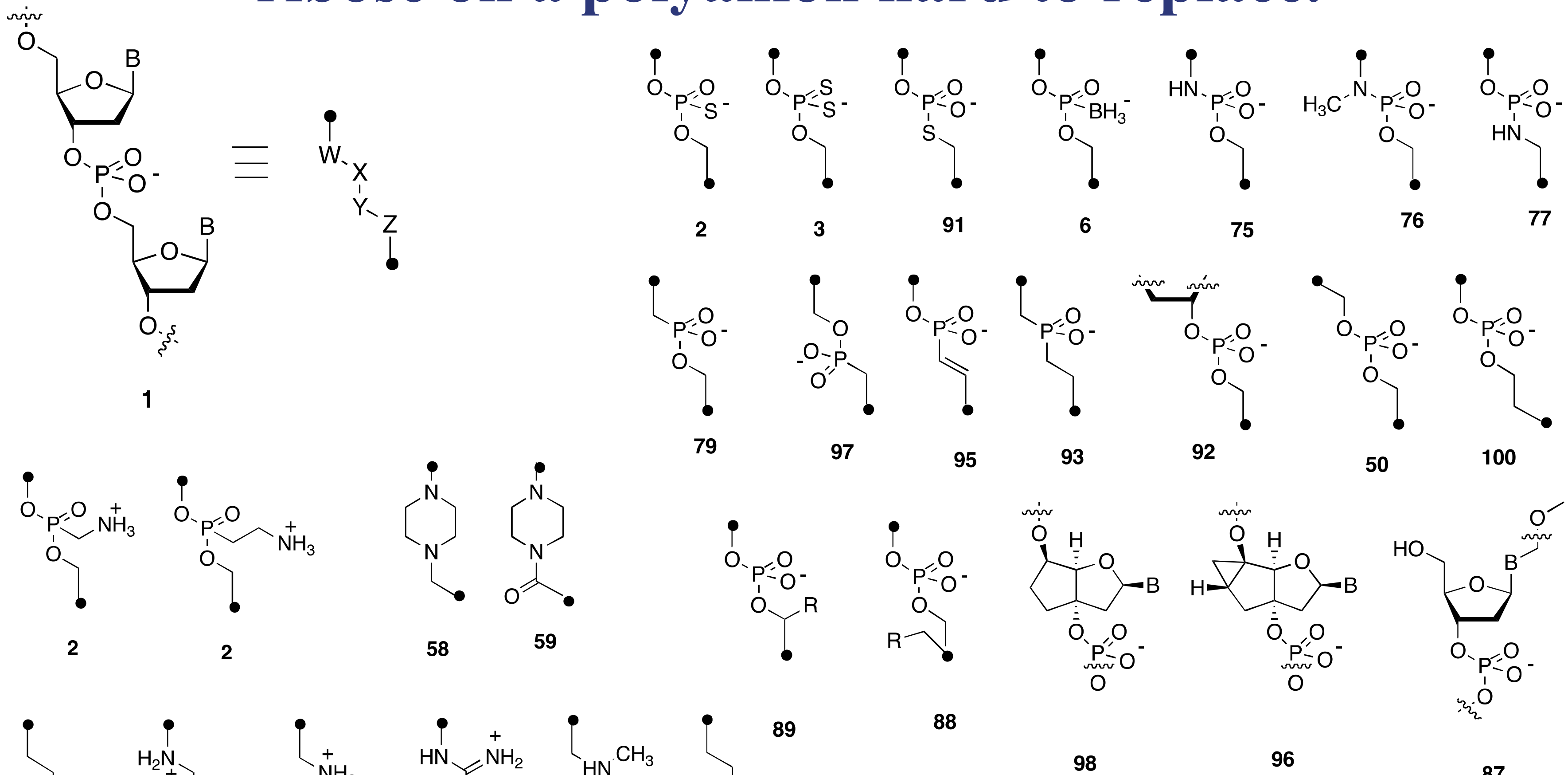
7. Efforts to get life in cryosolvents defeated by solubility issues
8. Warm Titans, exotic polar solvents, still possible

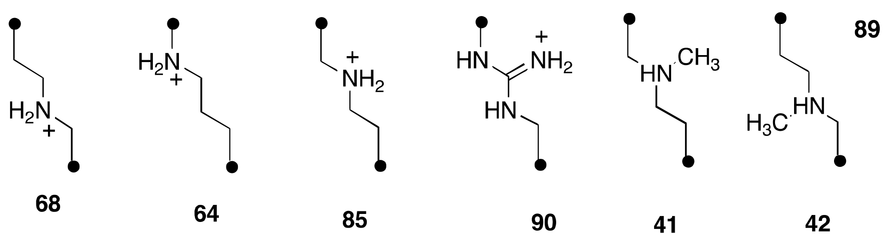
Disequilibrium and the impotence of Darwinism

9. Smart life will escape Darwinism to gain Lamarckianism

NASA

The rest of genetic biopolymer can be anything. But again, synthesis teaches: ribose on a polyanion hard to replace.





Few work as well as ribose.

So the origins community is still focused on ribose RNA

The Westheimer Institute for Science and Technology

the foundation for applied molecular evolution

We are learning more about how prebiotic RNA might be made

1. Universal genetic biopolymers in water have repeating charges
2. This allows them to be easily concentrated from plumes, bulk water
3. Darwinian biopolymers having this features are easily distinguished

We can today detect extant life in H_2O *in situ*, terran & weird,

4. We still lack a clear path to get RNA as the first terran Darwinian biopolymer, but it seems that we *will* find those paths.
5. These paths are defeated by dilution into a global ocean
6. Defeat is easily avoided in deserts with occasional water (e.g. Mars)

And non-aqueous life? An analogous universal biosignature?

7. Efforts to get life in cryosolvents defeated by solubility issues
8. Warm Titans, exotic polar solvents, still possible

Disequilibrium and the impotence of Darwinism

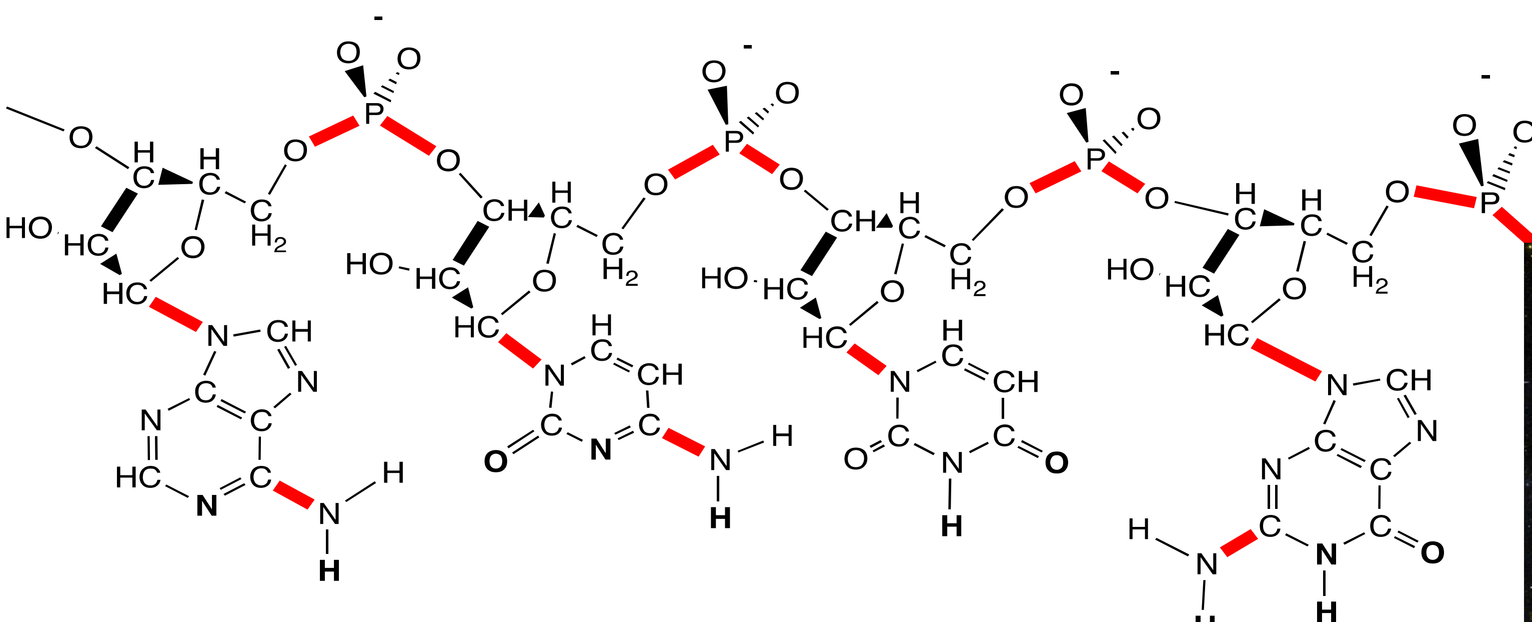
9. Smart life will escape Darwinism to gain Lamarckianism

Westheimer Institute

the foundation for applied molecular evolution FAME

I am optimistic because the main problems see solution

- Tar : Give energy to organic matter but no access to Darwinian evolution, one gets **tar**, not RNA building units.
  Well validated, from the kitchen to the coal field.
- Phosphate. **Hard** to get high **phosphate** in RNA
- **Water**. Even if we get RNA, it is **unstable** in **water**.
  Water essential but corrosive

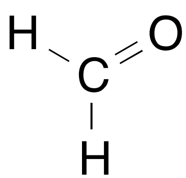


The tar paradox is especially well known with sugars

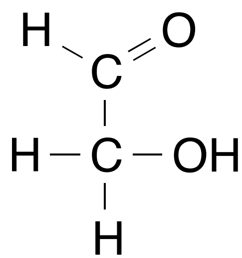
Sucrose:
"Rock candy"

And well known to *you*;
Heat it a bit, get carmel
Heat more, get more.

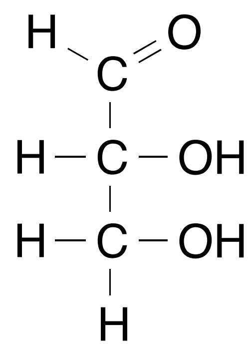
$$C_nH_{2n}O_n$$



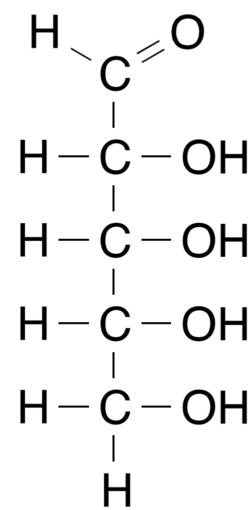
$C_1H_2O_1$
formaldehyde



$C_2H_4O_2$
glycolaldehyde



$C_3H_6O_3$
glyceraldehyde



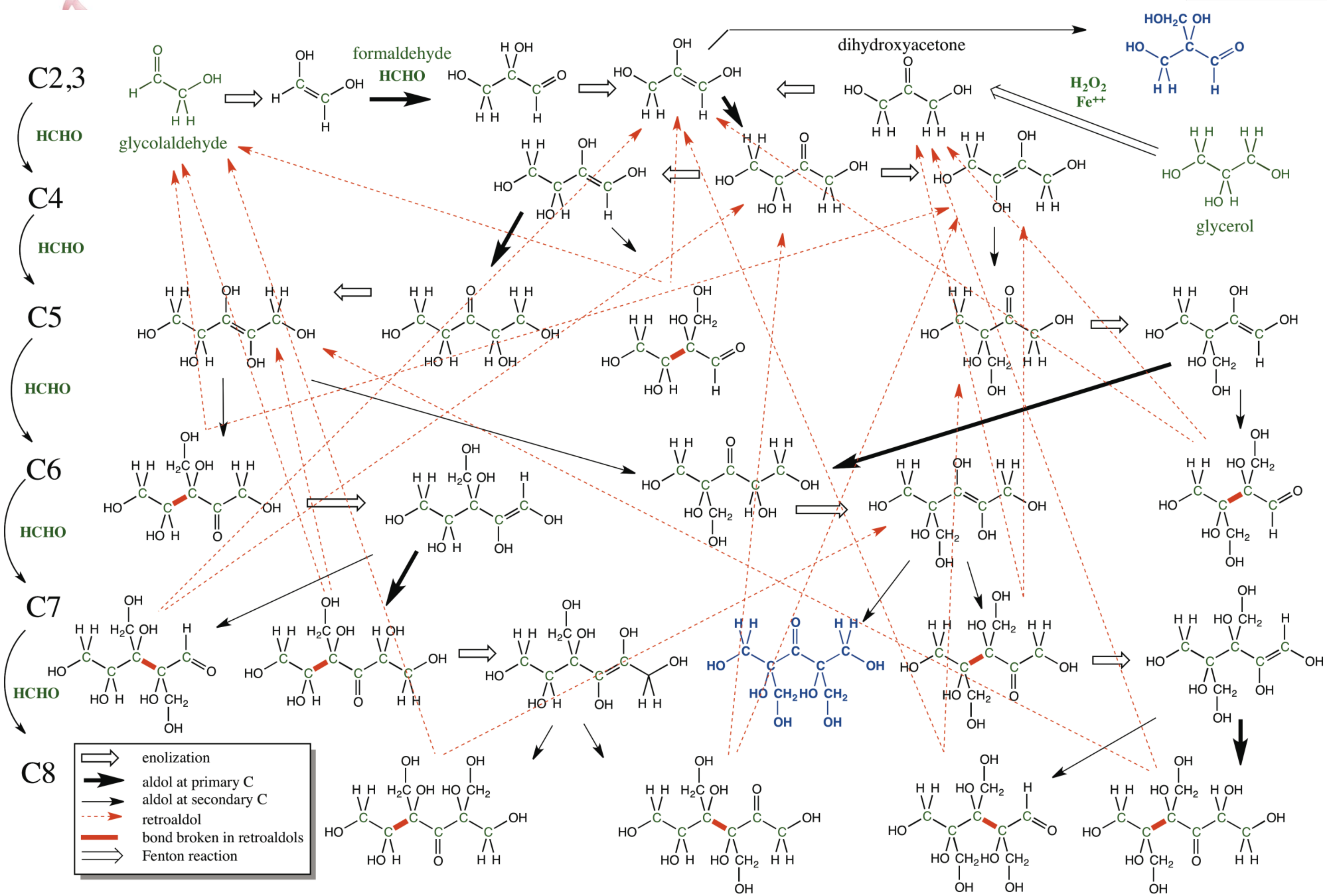
$C_5H_{10}O_5$
ribose

Unfortunately, RNA has a sugar component (R)

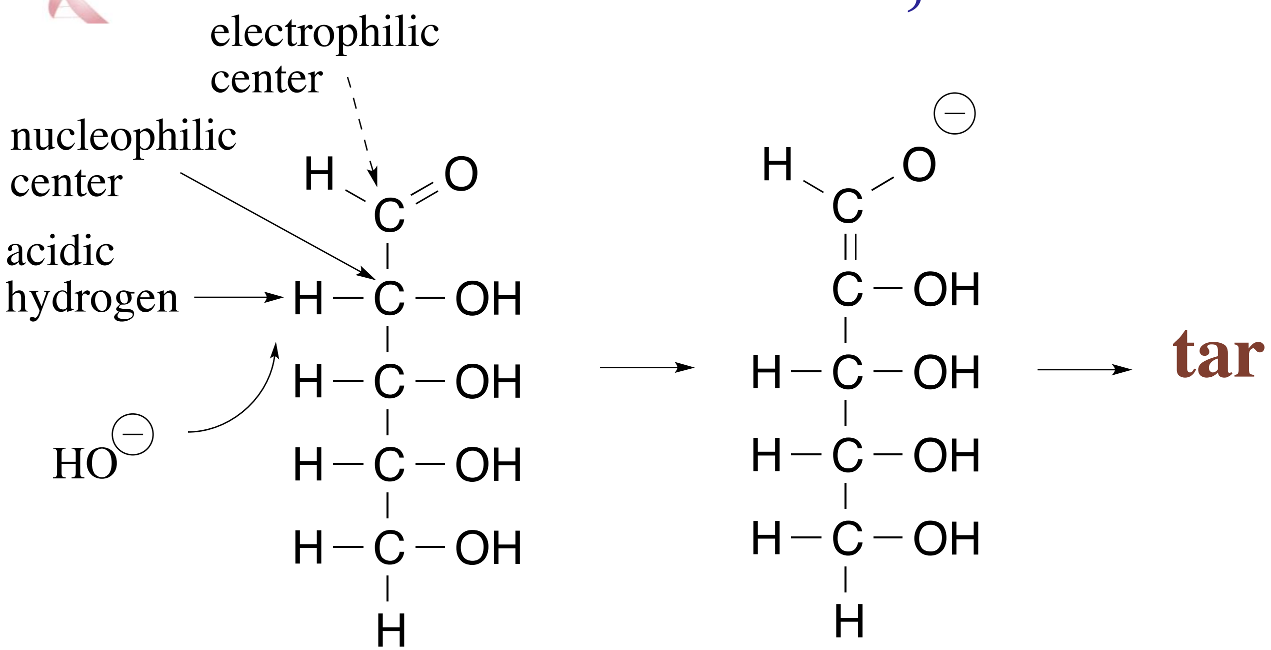
Westheimer Institute

Complexity from C=O is horrible

the foundation for applied molecular evolution FAME



Ribose has C=O, enolizes, reacts with itself, and forms tar



D-ribose (open form with reactive C=O)

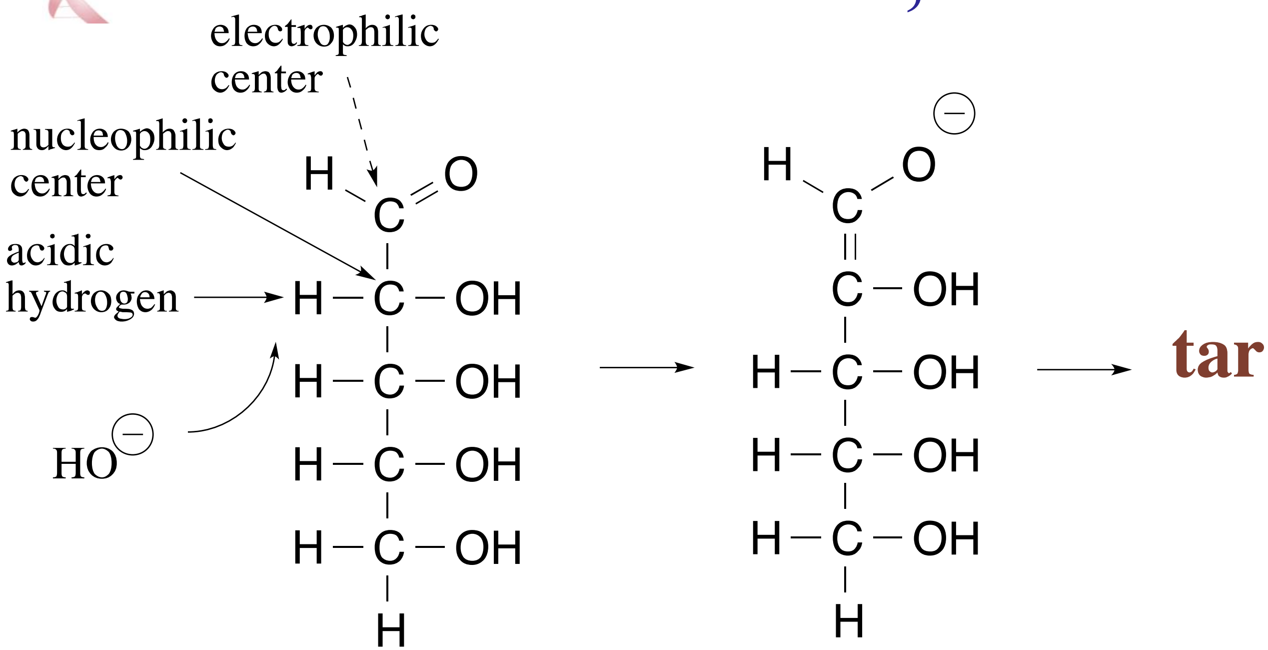
negatively charged enediolate

Stanley Miller measured the rate at which ribose formed tar; it is fast (~75 years at pH 7 at 50 °C, not millions of years

Larralde, Robertson, and Miller (1995) Rates of decomposition of ribose and other sugars. Implications for chemical evolution. *Proc. Natl. Acad. Sci. USA* 92, 8158

"stability considerations preclude the use of ribose and other sugars as prebiotic reagents …. It follows that ribose and other sugars were not components of the first genetic material…"

Ribose has C=O, enolizes, reacts with itself, and forms tar



D-ribose (open form with reactive C=O)

negatively charged enediolate

Stanley Miller measured the rate at which ribose formed tar; it is fast (~75 years at pH 7 at 50 °C, not millions of years

Larralde, Robertson, and Miller (1995) Rates of decomposition of ribose and other sugars. Implications for chemical evolution. *Proc. Natl. Acad. Sci. USA* 92, 8158

"stability considerations preclude the use of ribose and other sugars as prebiotic reagents …. It follows that ribose and other sugars were not components of the first genetic material…"

No R = no RNA

We turned mineralogy

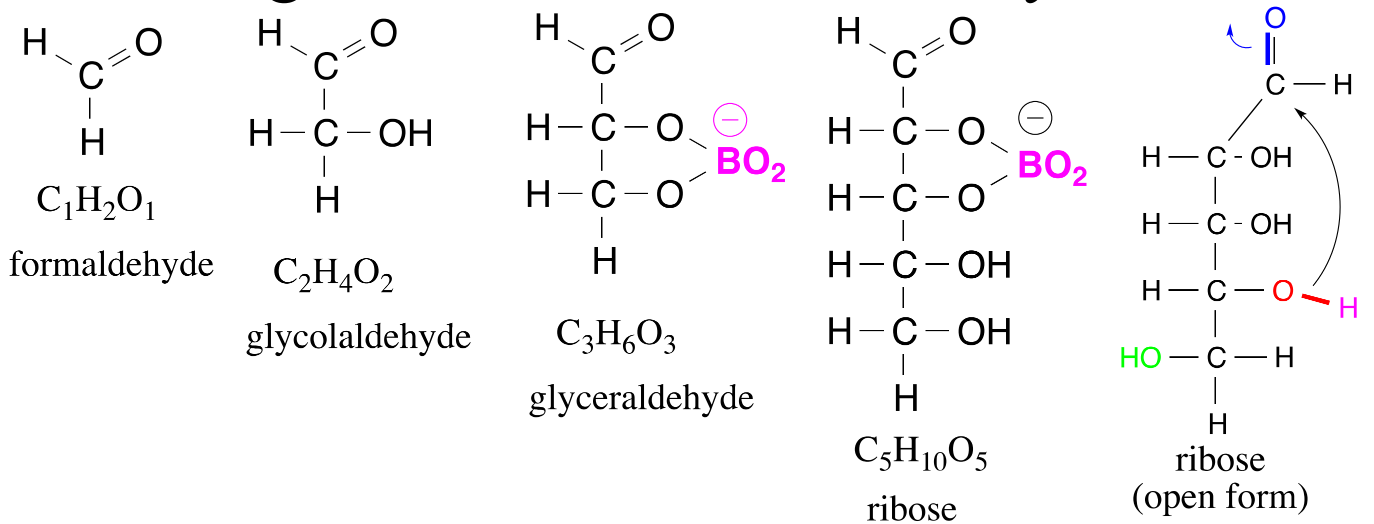
Life did not begin in a Pyrex baking pan

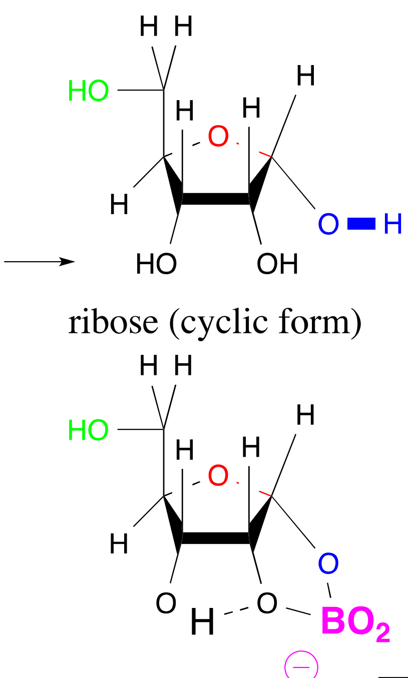
Sugars have adjacent hydroxyl (-OH) groups

Borate binds adjacent hydroxyl groups

Borate binds **ribose**; removes C=O, prevent tar-ization, allows **ribose** to form.

Borate guides reaction of carbohydrates





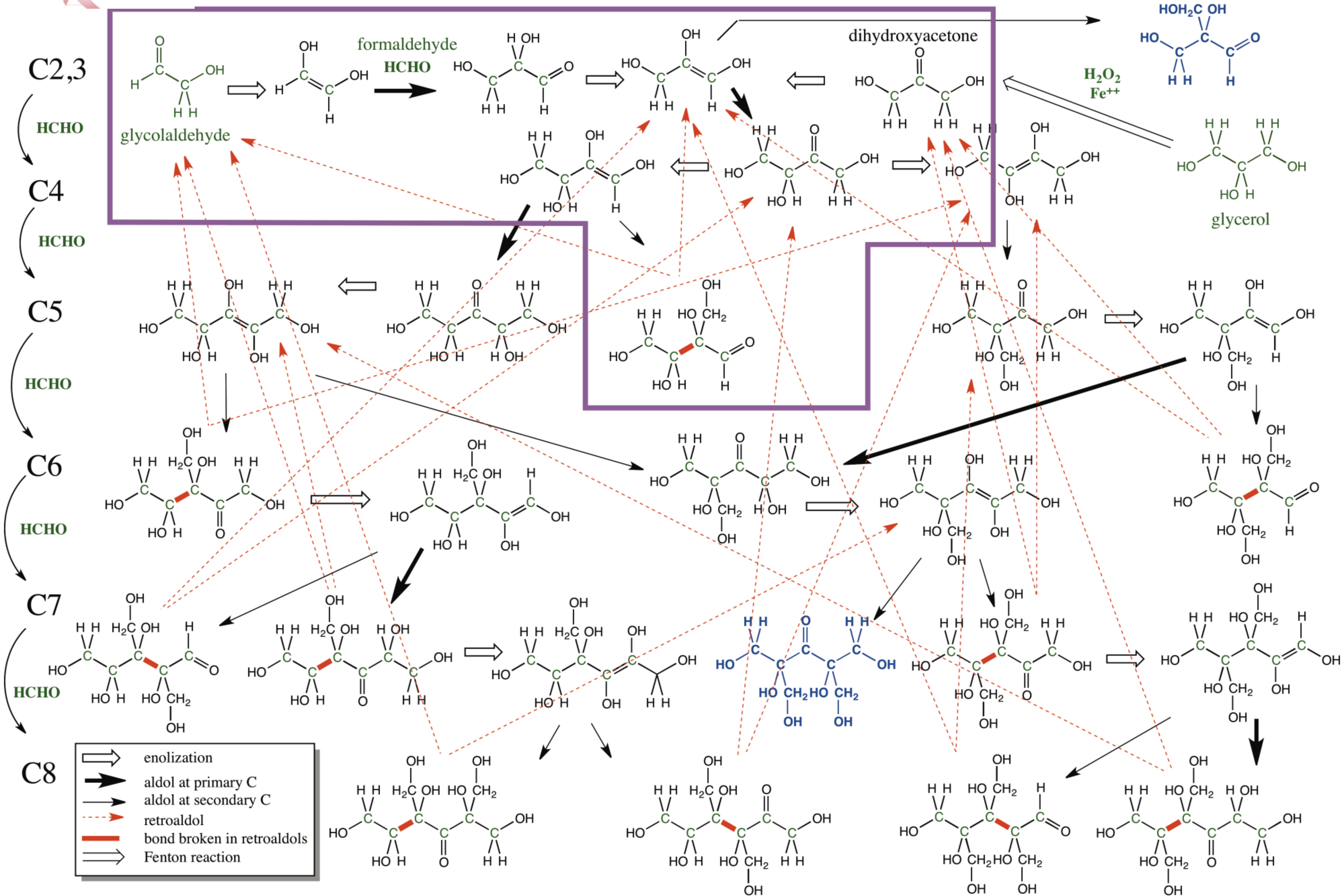
Ricardo, A., Carrigan, M.A., Olcott, A., Benner, S.A. (2004) Borate minerals stabilize **ribose**. *Science* **303**, 196

Kim, et al. (2011) Synthesis of carbohydrates in mineral-guided prebiotic cycles. *J. Am. Chem. Soc.* **133**, 9457-9468

Westheimer Institute

the foundation for applied molecular evolution

Borate constrains reactivity, makes ribose



Desert environments where borate minerals accumulate also have low water activity.

Peridot in basalt ⟶

generates the base

Tourmaline (borate)

Death Valley

Borate excluded from silicates, comes to surface in igneous rocks, easily weathered, most salts water soluble, collect in dry basins. Peridot in basalt weathers to creates alkali.
--> Borate moderated formose

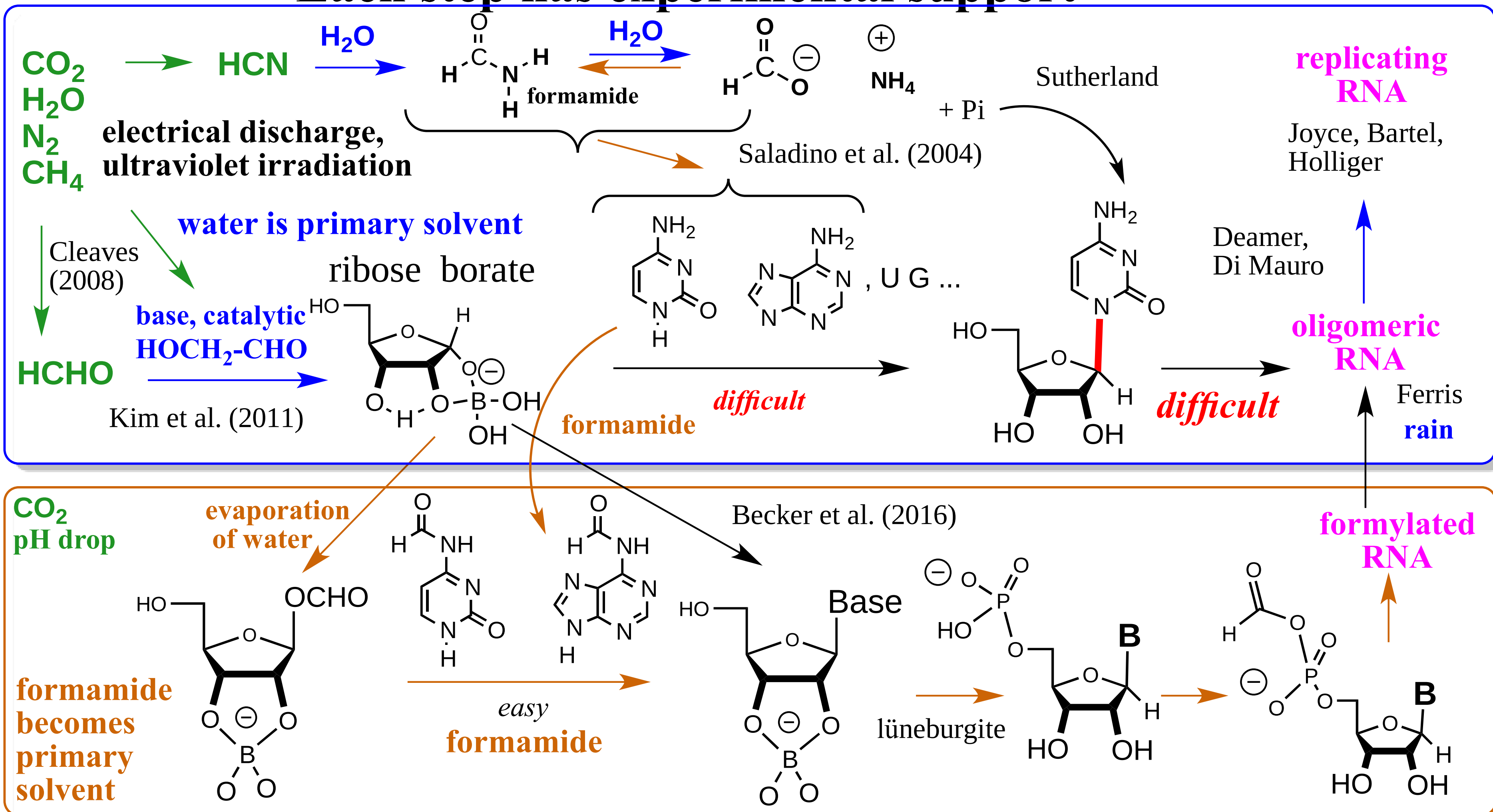
Evaporite minerals saturated borate
Colemanite= boron, calcium, oxygen, hydrogen

Wulfenite (molybdate)

Discontinuous Model for RNA synthesis

I think the solution will look something like this.

Each step has experimental support



Key: in the atmosphere | in the aquifer; Nucleophilic Context | in desert evaporite; Electrophilic Context

Discontinuous RNA synthesis needs intermittant water

1. Universal genetic biopolymers in water have repeating charges
2. This allows them to be easily concentrated from plumes, bulk water
3. Darwinian biopolymers having this features are easily distinguished

We can today detect extant life in H_2O *in situ*, terran & weird,

4. We still lack a clear path to get RNA as the first terran Darwinian biopolymer, but it seems that we *will* find those paths.
5. These paths are defeated by dilution into a global ocean
6. Defeat is easily avoided in deserts with occasional water (e.g. Mars)

And non-aqueous life? An analogous universal biosignature?

7. Efforts to get life in cryosolvents defeated by solubility issues
8. Warm Titans, exotic polar solvents, still possible

Disequilibrium and the impotence of Darwinism

9. Smart life will escape Darwinism to gain Lamarckianism

Westheimer Institute

the foundation for applied molecular evolution

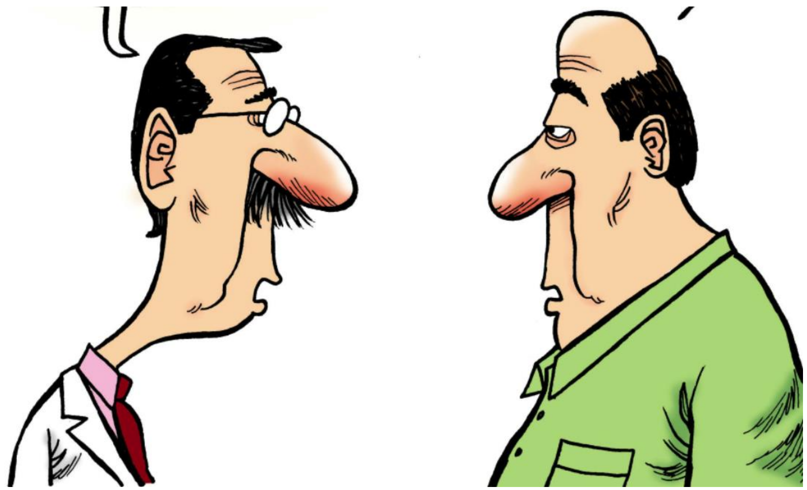
FAME

Were these minerals and deserts present on early Earth?

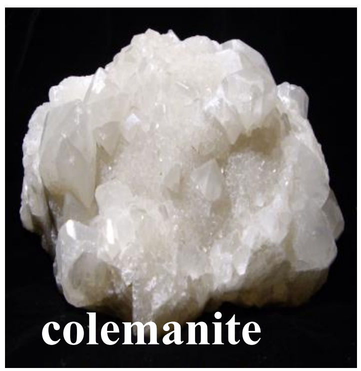
Early Earth borate? Hazen and Grew say "no".
Early Earth evaporites? Kirschvink says "no".

What can you give me by way of minerals on early Earth?

What do you need?



Molybdates are highly oxidized



Tourmalines, colemanite, and other borate minerals are formed only if scarce boron is enriched. In the lithosphere, only after some cycling time? In the hydrosphere, only in deserts.

But our work has caused geologists to look again

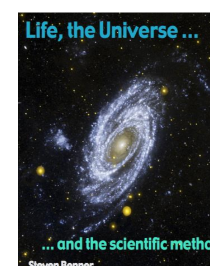
If geologists *look* for Archaean borate …

They find it

Borate minerals unstable to metamorphosis, give monazite, apatite, and tourmaline. These are in ~3.8 Ga metasedimentary rocks from the Isua supracrustal belt (Greenland) with biogenic (?) graphite.

Mishima, S., Ohtomo, Y., Kakegawa, T. (2016) Occurrence of tourmaline in metasedimentary rocks of the Isua supracrustal belt, Greenland. Implications for ribose stabilization in Hadean Marine Sediments. *Origin Life Evol. Biosphere* **46**, 247-271.

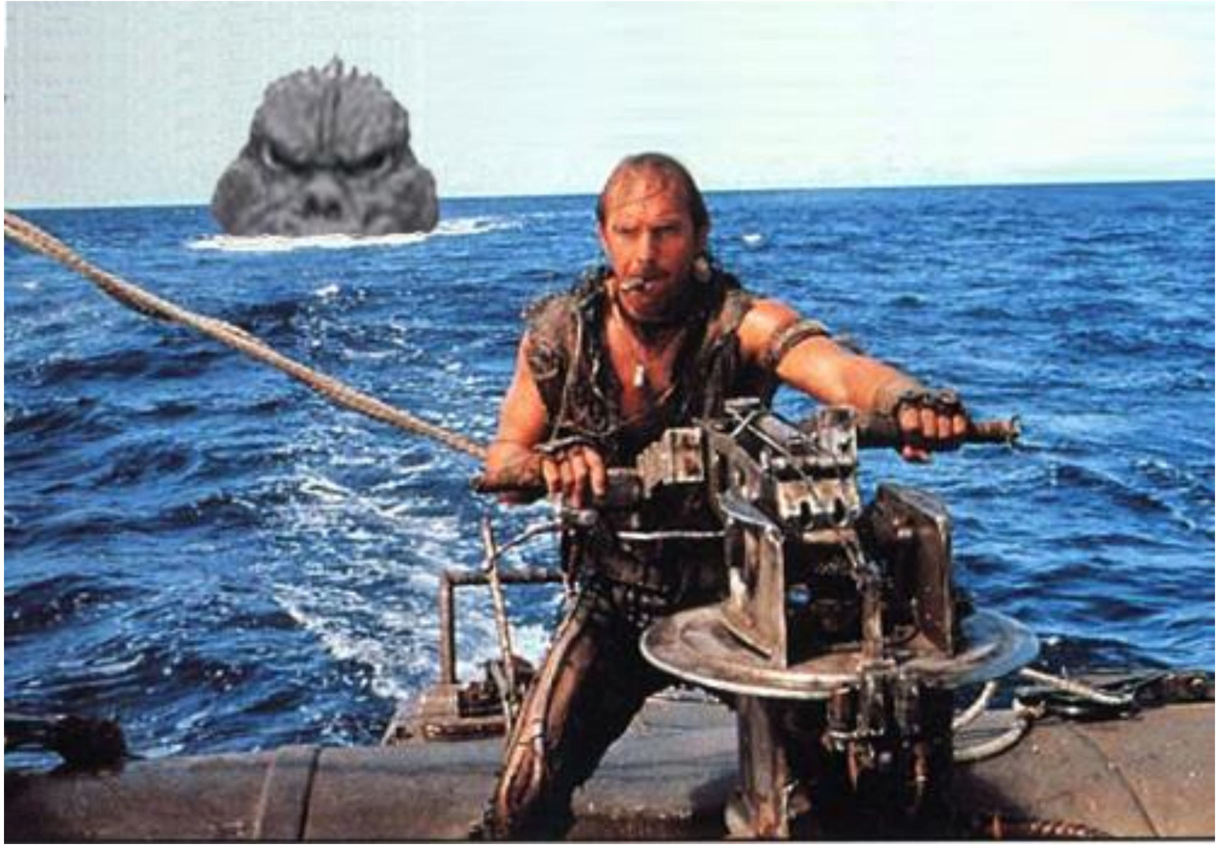
Grew, E. S. et al., (2015) Boron isotopes in tourmaline from the ca. 3.7-3.8 Ga Isua supracrustal belt, Greenland: Sources for boron in Eoarchean continental crust. and seawater. *Geochim. Cosmochim. Acta*. **163**, 156-177.



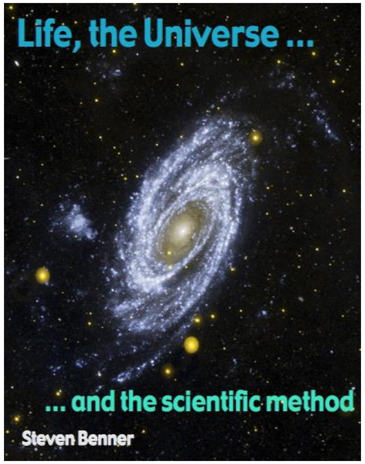
Are deserts available on early Earth?

Joe Kirschvink's objection to the Benner model. Models for planetary formation suggest that the inventory of water on early Earth did not leave *any* dry land before continental drift.

No deserts, no borate evaporites, no ***ribose****, no* ***R****, no* ***RNA****.*



Waterworld



The Kirschvink Modification of the Benner Model

Move it to Mars, where water was never as abundant and oxidation level has always been higher. *Perhaps borate-ribose is there today*.

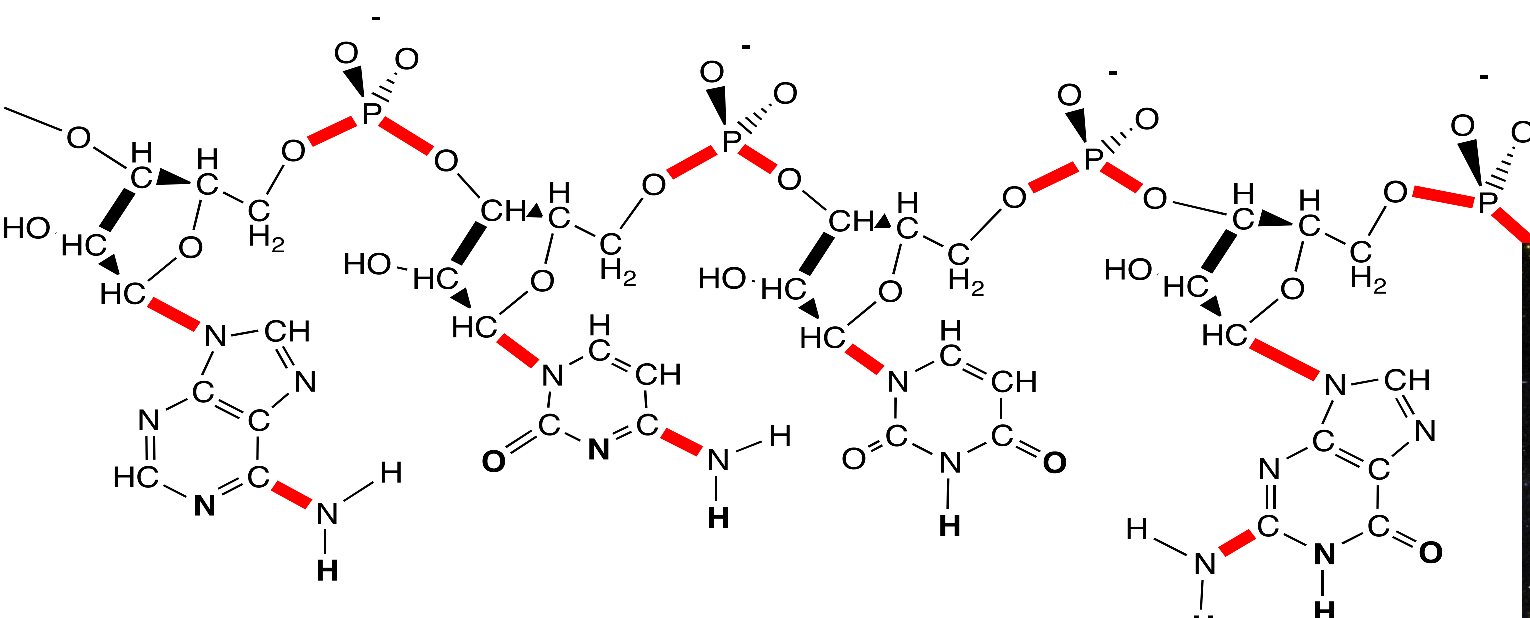
Westheimer Institute

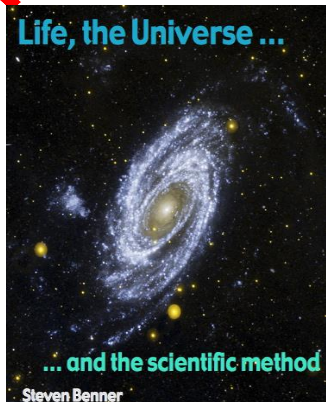
the foundation for applied molecular evolution

FAME

I am optimistic because the main problems see solution

- Tar : Give energy to organic matter but no access to Darwinian evolution, one gets **tar**, not RNA building units.
  Well validated, from the kitchen to the coal field.
- Phosphate. **Hard** to get high **phosphate** in RNA
- **Water**. Even if we get RNA, it is **unstable** in **water**.
  Water essential but corrosive





The Westheimer Institute for Science and Technology

the foundation for applied molecular evolution

FAME

Borate +phosphate = borophosphate minerals, not inaccessible apatite

27. LÜNEBURGITE [$Mg_3 (PO_4)_2 B_2O (OH)_4 \times 6 H_2O$] IN UPPER MIOCENE SEDIMENTS OF THE EASTERN MEDITERRANEAN SEA

Jens Müller and Frank Fabricius, Lehrstuhl für Geologie, Technische Universität, München, West Germany

Lüneburgite

ABSTRACT

Upper Miocene dolomitic marls drilled at Site 374 (Messina Abyssal Plain, Ionian Sea) contain small white mm-sized spherules which have been identified by X-ray, chemical, and IR-spectrometry techniques as lüneburgite [$Mg_3 (PO_4)_2 B_2O (OH)_4 \times 6 H_2O$].

We assume that the lüneburgite formed as a secondary product by upward migrating brines from the Miocene evaporites which contain highly soluble Mg- and B- salts. Enrichment of phosphorus may be the result of
evaporites or to diage
decomposition of org
reducing environment.

chiefly of authigenic Ca-dolomite ($CA_{55}Mg_{45}$) and the detrital components quartz, feldspar, smectite, illite, kaolinite, chlorite, and traces of (?)attapulgite. The fine-grained black sediment is slightly enriched in organic carbon (0.3-0.7%; Sigl, this volume) and when fresh, expells a bituminous odor. Secondary(?) gypsum occurs within the sequence containing lüneburgite. These homogeneous sediments were deposited as a transitional facies between the formation of evaporites and deposition of more open marine sediments (Site 374 Report, this volume).

Tribal jargon

Gypsum = $CaSO_4 \cdot 2H_2O$

Lüneburgite = $Mg_3B_2(PO_4)_2(OH)_6 \cdot 8H_2O$)

What does it mean if gypsum + lüneburgite occur together?

The phosphate problem in the "RNA first" model

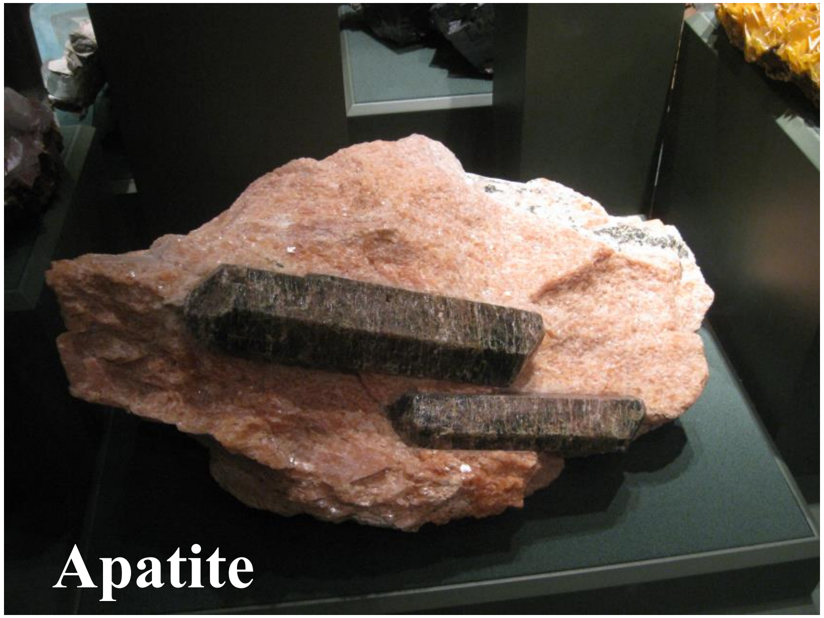
Clearly stoichiometric phosphate is necessary for RNA itself

Powner et al. (200) need it in quantity (1 M, 98 g/L)

But phophate + calcium precipitate = apatite

Ca^{+2} PO_4^{-3}	SO_4^{-2} Mg^{+2}
⇩	⇩
apatite	epsomite

What happens with borate?



Benner collection of fine minerals

The Westheimer Institute for Science and Technology
the foundation for applied molecular evolution
FAME
Supported by a grant from John Templeton Foundation
NASA

Borate keeps phosphate away from apatite

In natural environments, shown by observational geology

Partitioning of species in absence of **borate**

Ca^{+2}	SO_4^{-2}
PO_4^{-3}	Mg^{+2}
⇩	⇩
apatite	epsomite

Partitioning of species in presence of **borate**

Ca^{+2} SO_4^{-2} ⇨ gypsum

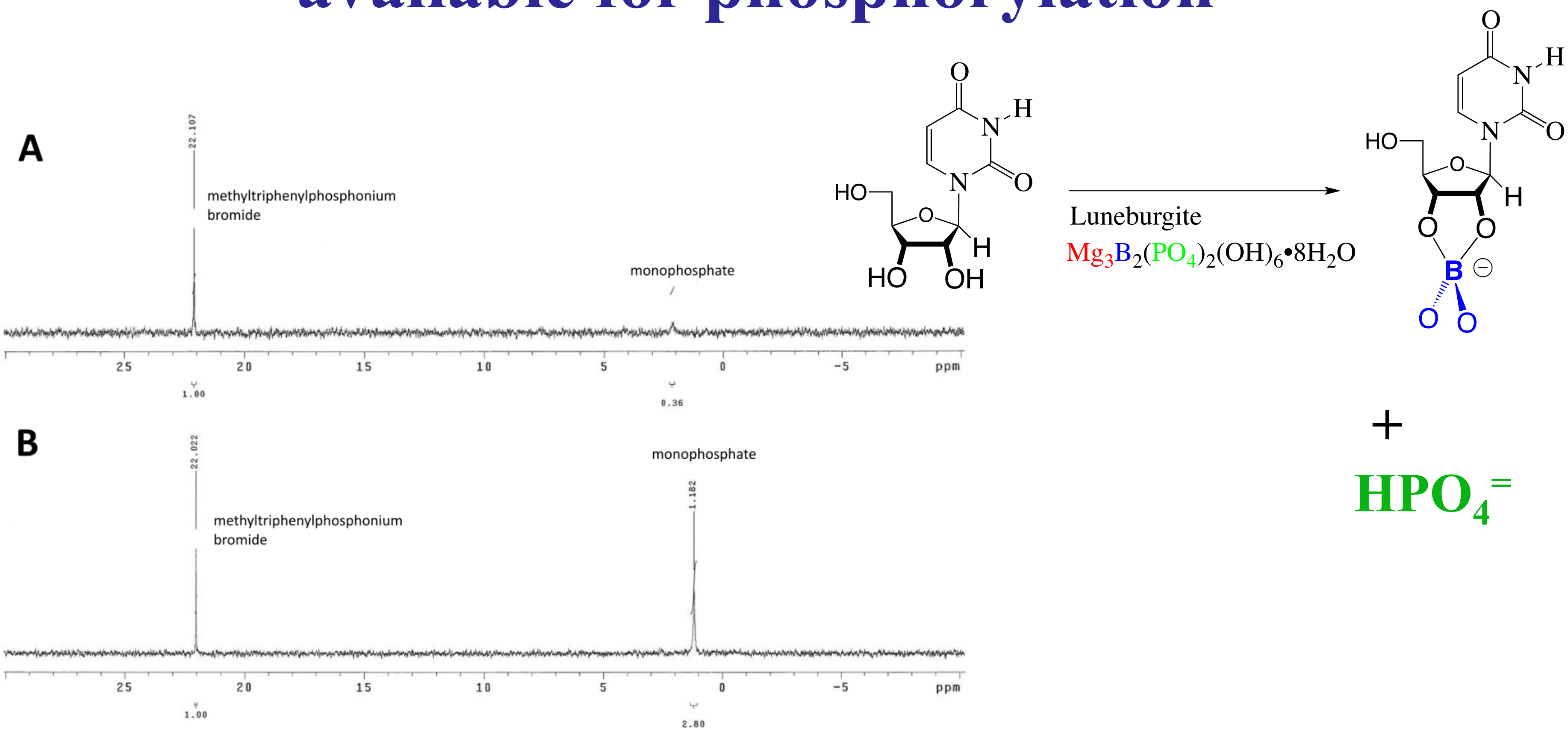
PO_4^{-3} BO_3^{-3} Mg^{+2} ⇨ lüneburgite

This also happens in the laboratory if you mix MgO, CaO, H_3BO_3, H_3PO_4, and H_2SO_4 and evaporating.

Borate keeps phosphate from being lost by calcium capture. Borophosphate formed instead.

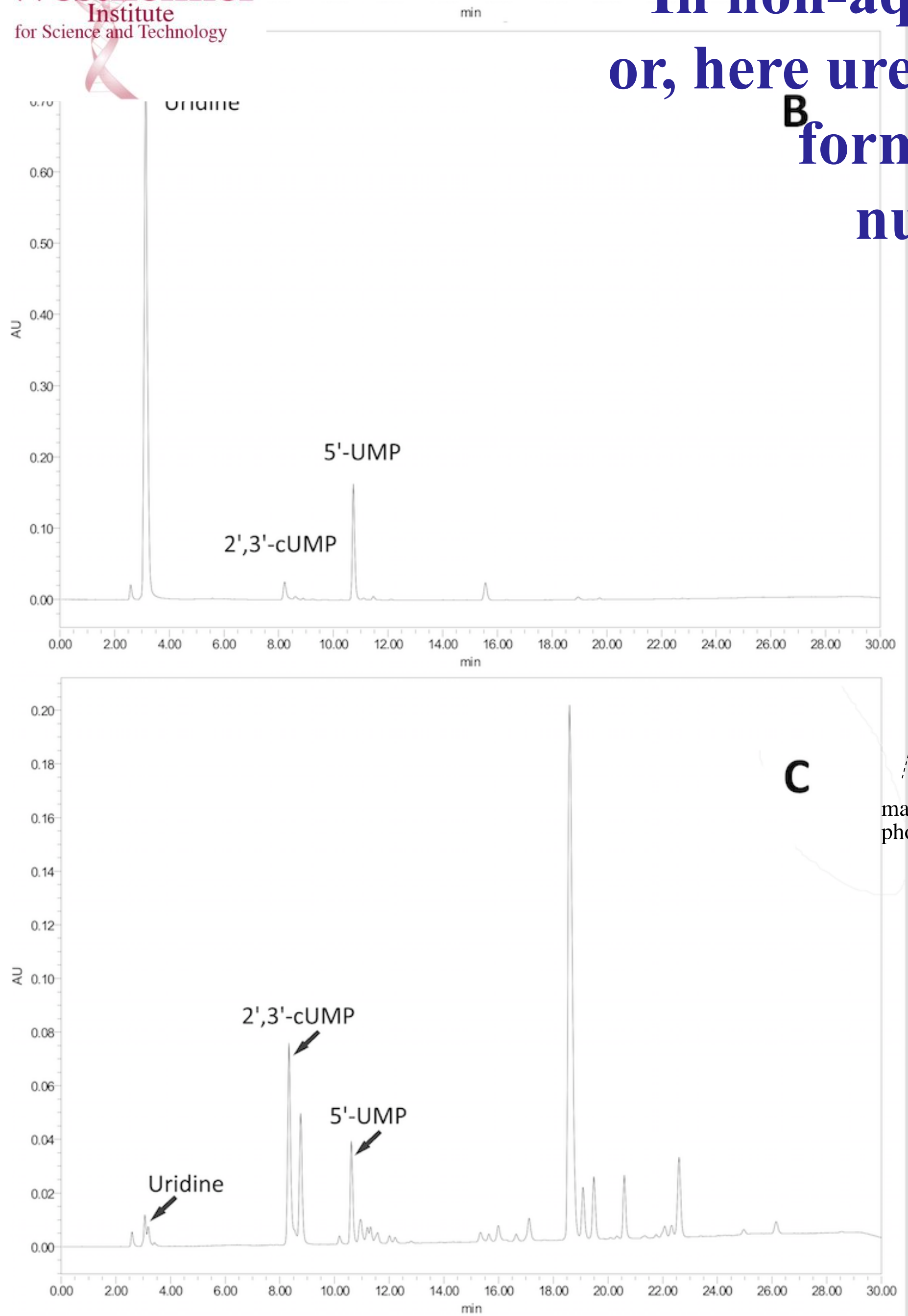
The Westheimer Institute for Science and Technology
the foundation for applied molecular evolution FAME
Supported by a grant from John Templeton Foundation
NASA

Ribose extracts borate out of luneburgite, makes phosphate available for phosphorylation

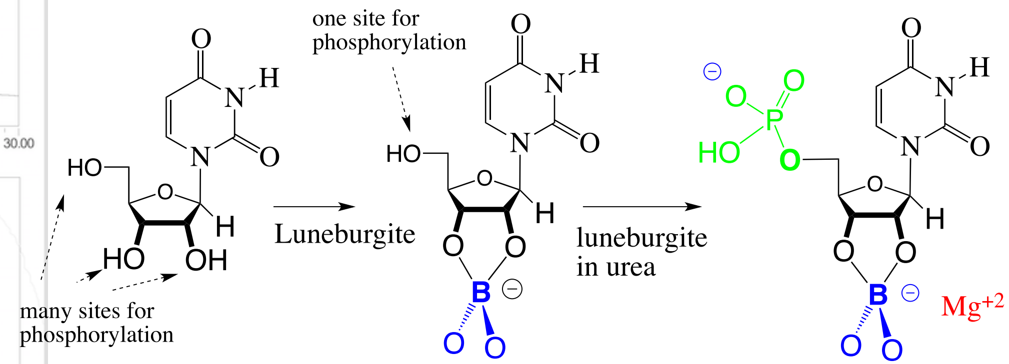


Kim, H. J., Furukawa, Y., Kakegawa, T., Bita, A., Scorei, R., Benner, S. A. (2016) Evaporite borate-containing mineral ensembles make phosphate available and regiospecifically phosphorylate ribonucleosides: Borate as a multifaceted problem solver in prebiotic chemistry. *Angew. Chem.* DOI: 10.1002/ange.201608001

In non-aqueous media (formamide or, here urea) where phosphate ester formation is thermodynamic, nucleosides regioselectively phosphorylated.



Absent borate, one gets a mixture.



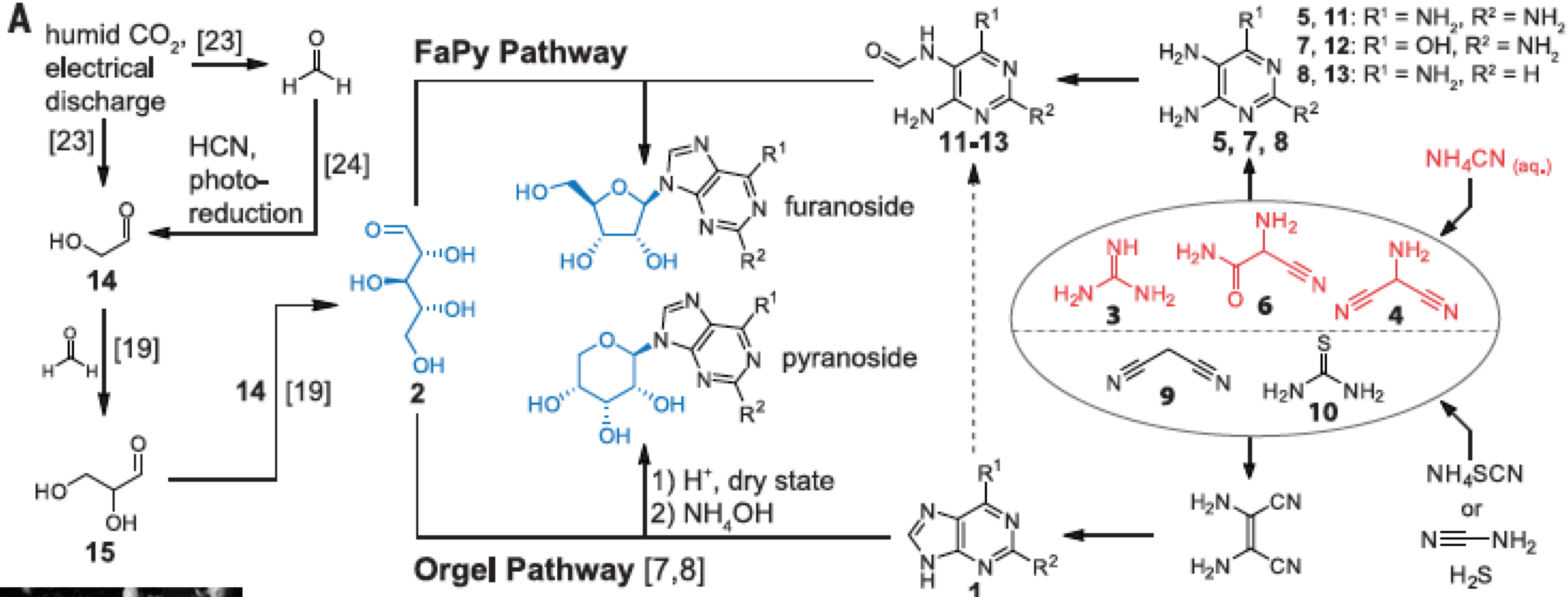
Two for the price of one.

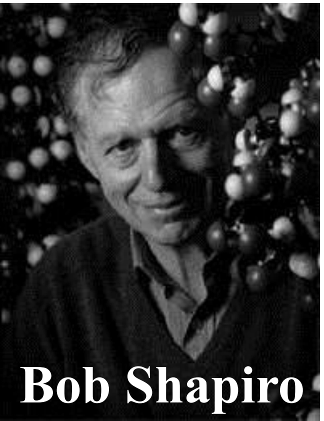
Lüneburgite sequesters phosphate from calcium until nucleosides are present, then phosphorylates nucleosides regio-specifically after nucleosides decompose the mineral to release phosphate.

Where do nucleosides come from?

Powner and Sutherland have a route

Thomas Carell et al. have a better route




Bob Shapiro

Carell route starts with ribose borate, *Unstable carbohydrates (glyceraldehyde) need not accumulate for Carell's route to work.*

Westheimer Institute

the foundation for applied molecular evolution FAME

I am optimistic because the main problems see solution

- Tar : Give energy to organic matter but no access to Darwinian evolution, one gets **tar**, not RNA building units.
  Well validated, from the kitchen to the coal field.

- Phosphate. **Hard** to get high **phosphate** in RNA
- **Water**. Even if we get RNA, it is **unstable** in **water**.
  Once RNA formed, adsorbed onto CT-Opal

John Grotzinger, David Blake, **exactly like 3 Ga Mars**

The Westheimer Institute for Science and Technology

the foundation for applied molecular evolution

A logic tree

RNA first?

No — Yes

A different set of problems

Need to make RNA prebiotically

Benner's stupid chemistry?

No — Yes

Get your own alternative

Need oxidized minerals, a desert

Can we have these on early Earth?

No — Yes

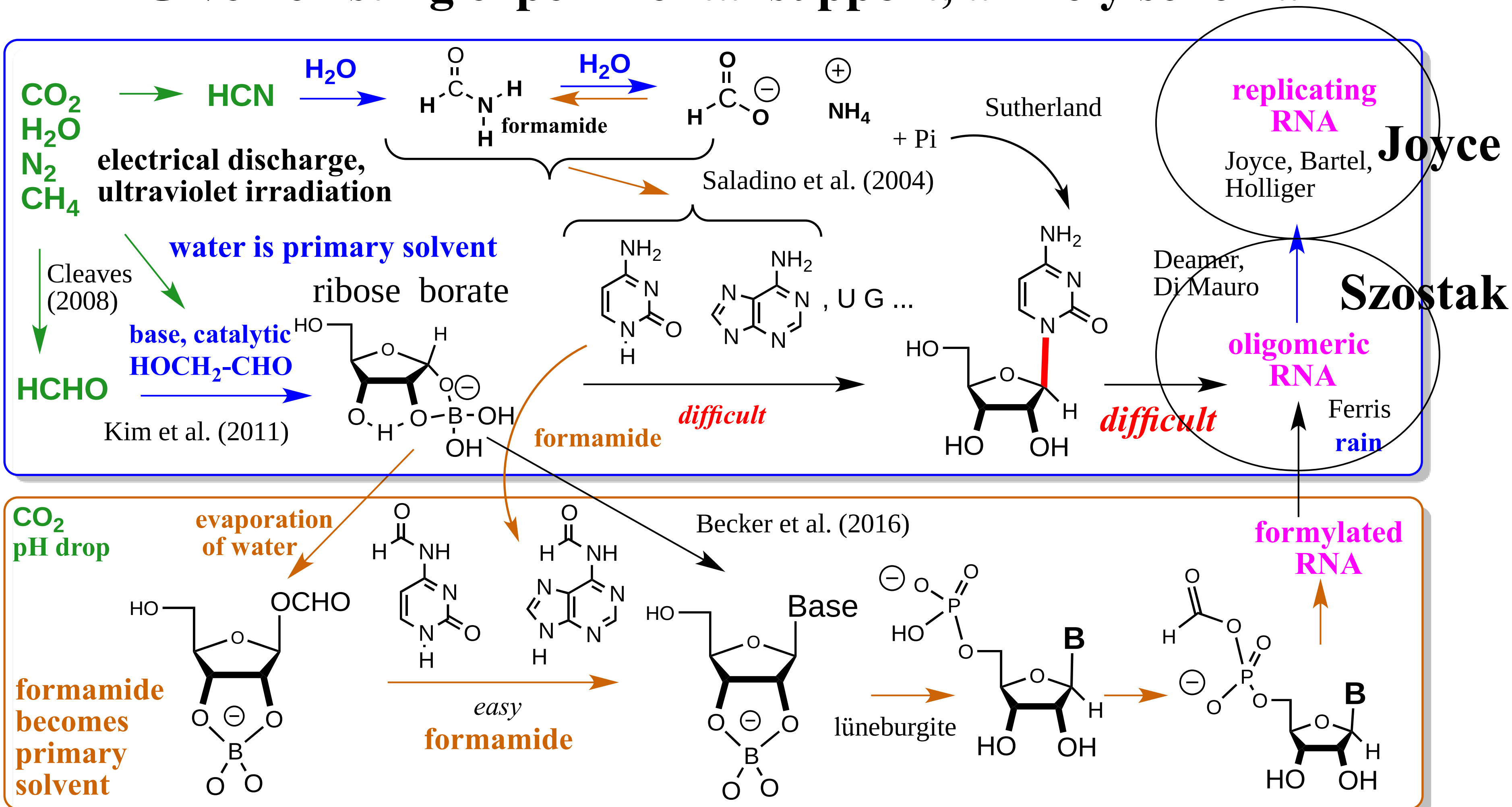
We are all Martians

Templeton-FfAME Origins Collaboration.
Steve Mojzsis;
2 x California land.
Granite @ 4.2 Ga

Supported by a grant from John Templeton Foundation

Model for prebiotic synthesis of RNA

Given existing experimental support, a likely schema



Key: in the atmosphere | in the aquifer; Nucleophilic Context | in desert evaporite; Electrophilic Context

There is hope, even though problems remain

Aqueous life needs dry land.
Perpetual water worlds a problem.

1. Universal genetic biopolymers in water have repeating charges
2. This allows them to be easily concentrated from plumes, bulk water
3. Darwinian biopolymers having this features are easily distinguished

We can today detect extant life in H_2O *in situ*, terran & weird,

4. We still lack a clear path to get RNA as the first terran Darwinian biopolymer, but it seems that we *will* find those paths.
5. These paths are defeated by dilution into a global ocean
6. Defeat is easily avoided in deserts with occasional water (e.g. Mars)

And non-aqueous life? An analogous universal biosignature?

7. Efforts to get life in cryosolvents defeated by solubility issues
8. Warm Titans, exotic polar solvents, still possible

Disequilibrium and the impotence of Darwinism

9. Smart life will escape Darwinism to gain Lamarckianism

The Westheimer Institute for Science and Technology

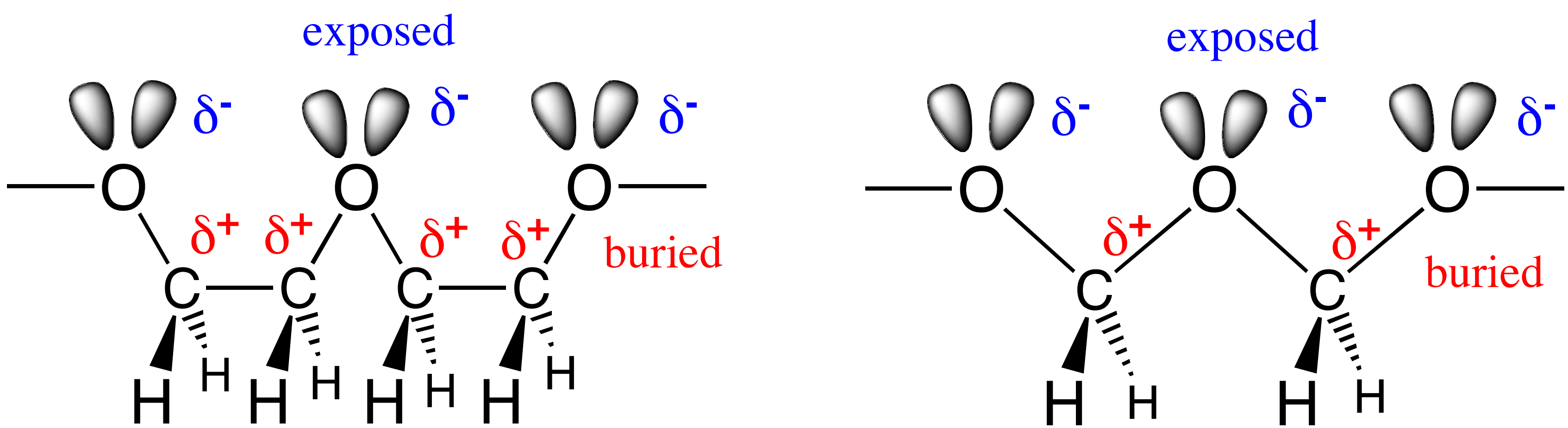
the foundation for applied molecular evolution

FAME

Biopolymer with a repeating charge will not dissolve in hydrophobic solvents.

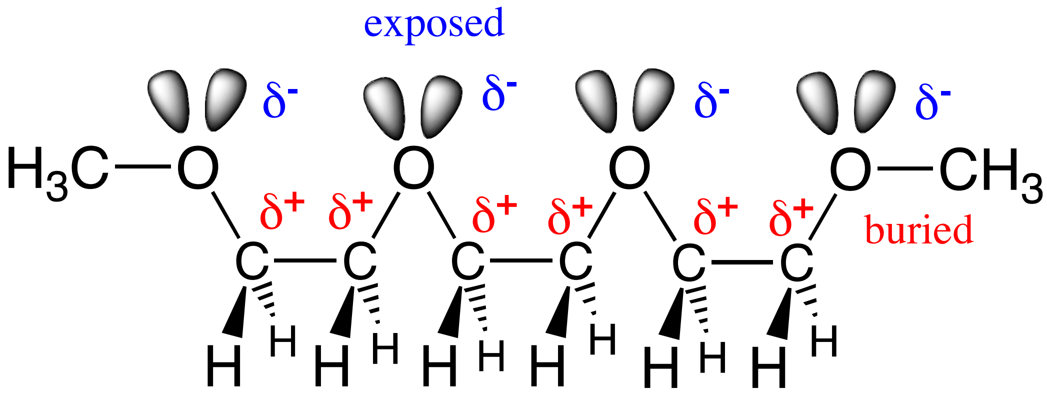
What about a biopolymer with a dipole, where the exposed part of the dipole is negatively charged?

By burying consistently one end of the dipole, and exposing the other, maybe the polymer cannot aggregate.

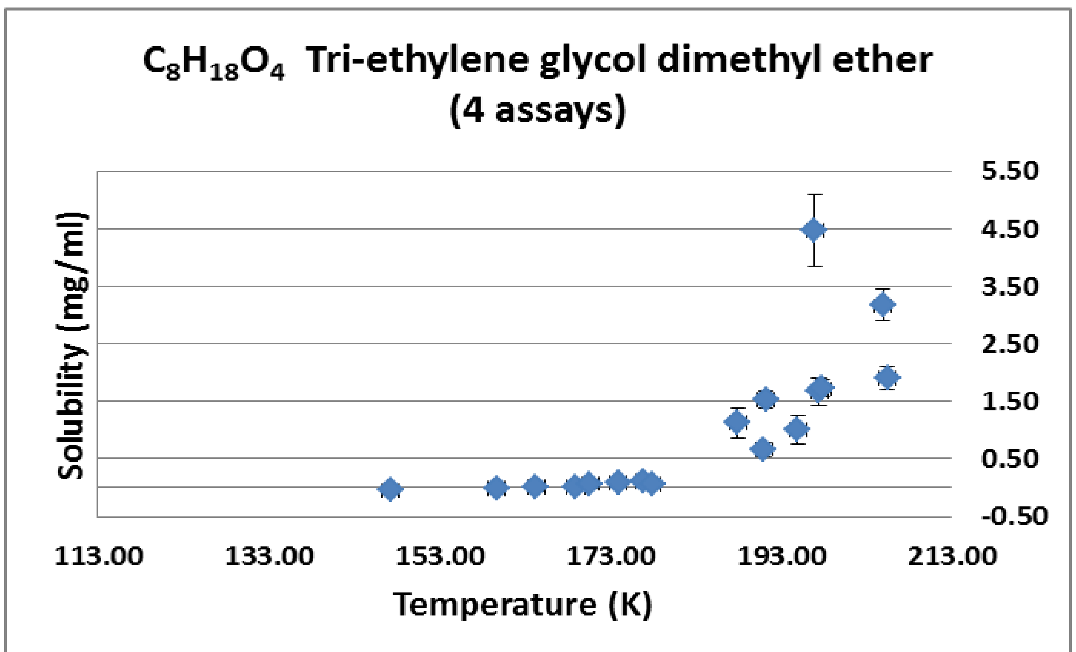


McLendon, C., Opalko, F. J., Illankoon, H. I., Benner, S. A. (2015) Solubility of polyethers in hydrocarbons at low temperatures. A model for potential genetic backbones on warm Titans. *Astrobiol.* **15**, 200-206.

They dissolve in warm hydrocarbons; aggregate (precipitate) in cold



Hydrocarbon	Freeze	Boil
Methane	91 K	112 K
Ethane	89 K	184 K
Propane	**85 K**	**231 K**
Butane	135 K	273 K



A "warm Titan" is OK.

Water is a good solvent because it is hot.

William Bains

Cryosolvents are not good, if you think that biology needs dissolution

1. Universal genetic biopolymers in water have repeating charges
2. This allows them to be easily concentrated from plumes, bulk water
3. Darwinian biopolymers having this features are easily distinguished

We can today detect extant life in H_2O *in situ*, terran & weird,

4. We still lack a clear path to get RNA as the first terran Darwinian biopolymer, but it seems that we *will* find those paths.
5. These paths are defeated by dilution into a global ocean
6. Defeat is easily avoided in deserts with occasional water (e.g. Mars)

And non-aqueous life? An analogous universal biosignature?

7. Efforts to get life in cryosolvents defeated by solubility issues
8. Warm Titans, exotic polar solvents, still possible

Disequilibrium and the impotence of Darwinism

9. Smart life will escape Darwinism to gain Lamarckianism

Disequilibrium and the impotence of Darwinism

A disequilibrium that shows the impotence of Darwinism.
It has not created a life form able to exploit the energy in the tree-dioxygen combination. **The solution?**

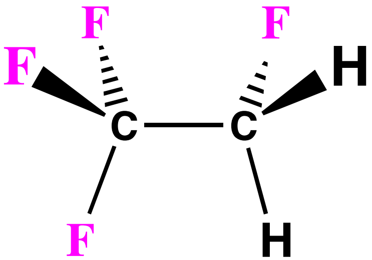
The solution: Lamarckianism

Homo erectus invented Lamarckian evolution

Any life form smart enough to talk to with us will soon get control of its biology to not need dying babies die to prevent sickle cell anemia. *Germ line gene therapy.*

Universal for life, regardless of core molecular biology.

What biosignatures would come from this life form?



Lamarckianism: universal end point for intelligent Darwinian systems

1. Universal genetic biopolymers in water have repeating charges
2. This allows them to be easily concentrated from plumes, bulk water
3. Darwinian biopolymers having this features are easily distinguished

We can today detect extant life in H_2O *in situ*, terran & weird,

4. We still lack a clear path to get RNA as the first terran Darwinian biopolymer, but it seems that we *will* find those paths.
5. These paths are defeated by dilution into a global ocean
6. Defeat is easily avoided in deserts with occasional water (e.g. Mars)

And non-aqueous life? An analogous universal biosignature?

7. Efforts to get life in cryosolvents defeated by solubility issues
8. Warm Titans, exotic polar solvents, still possible

Disequilibrium and the impotence of Darwinism

9. Smart life will escape Darwinism to gain Lamarckianism

Search for Lamarckian biosignatures escapes conundrum of remote detection of unknown molecular biology.