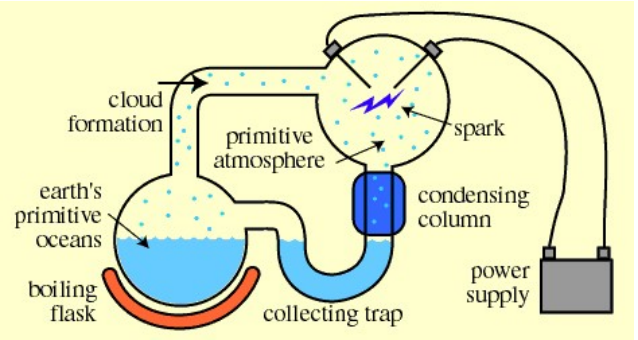
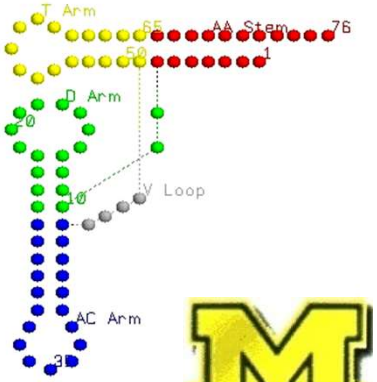
The First Chapter of Life:
Darwinian Chemistry as the Evolutionary Driving Force from Cyanide to Modern Biochemistry

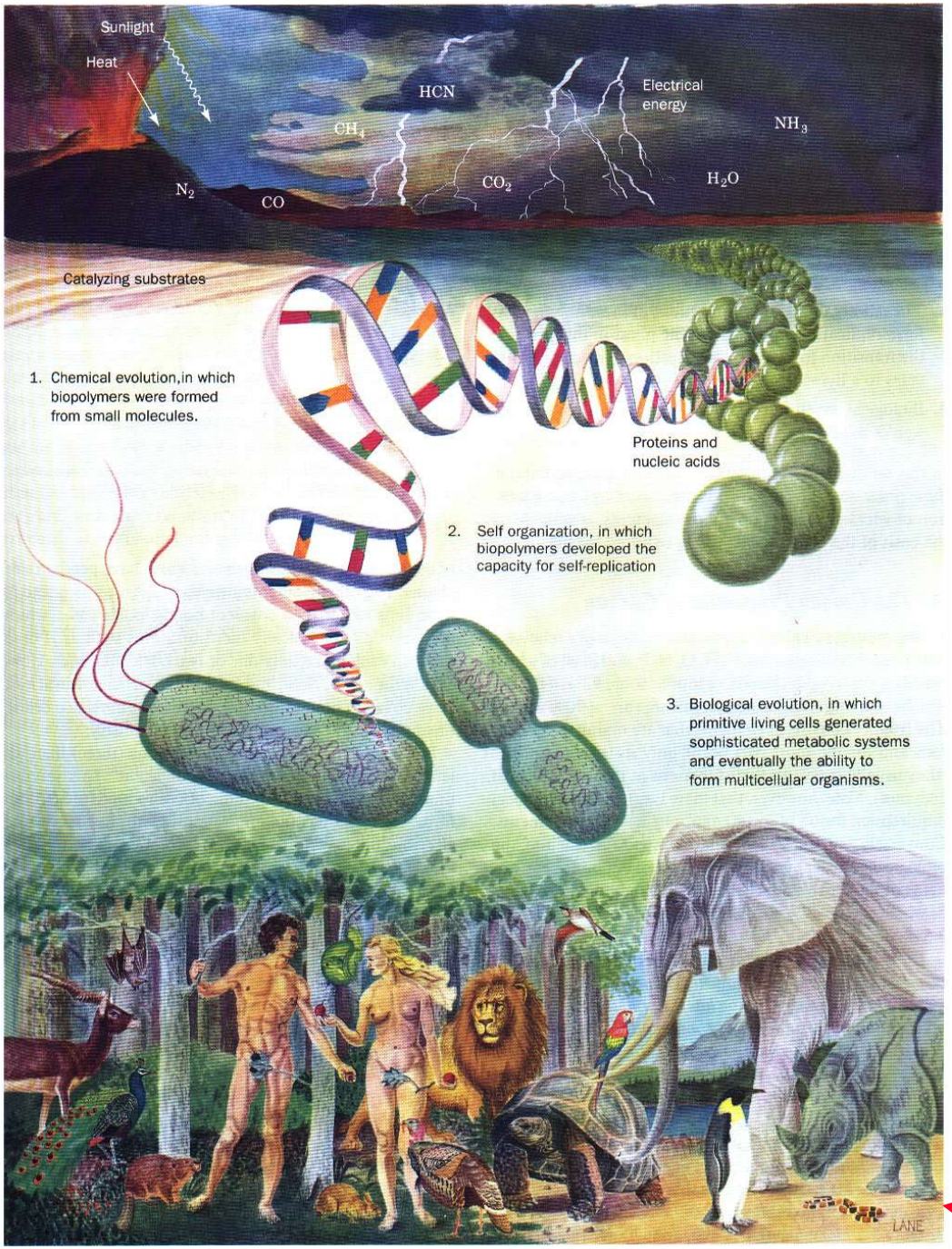




Overview

- What started life? Where do we come from?
- What forces drive Nature toward ever higher complexity?
- How did we get in 6 billion years "around the world", from unanimated molecules to modern biology and human societies?

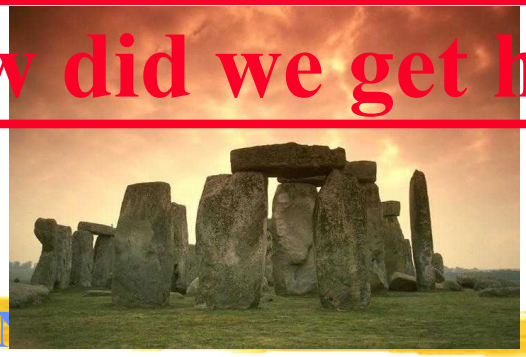
Here it all started...



Chemistry

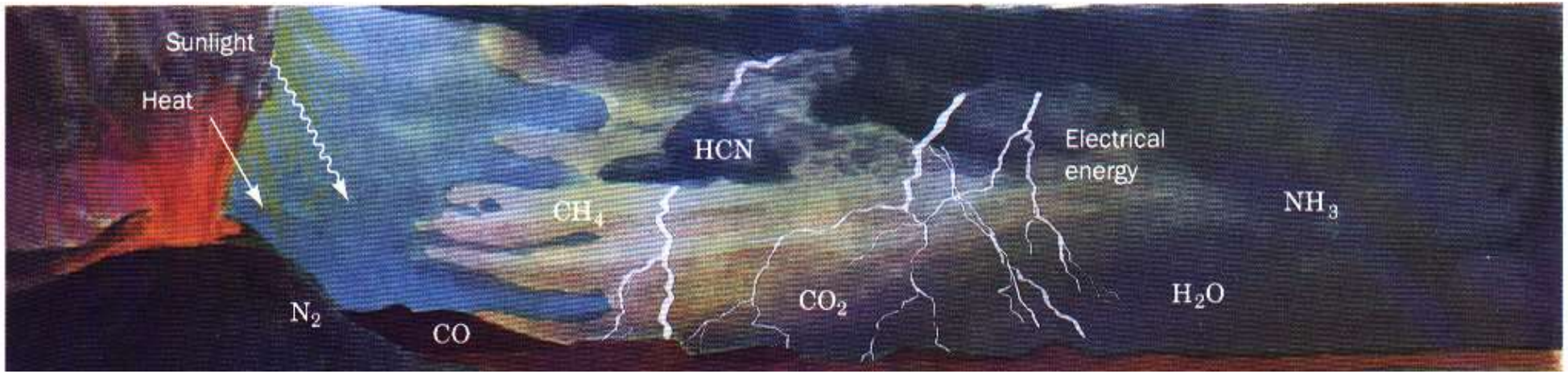
- Chemical Evolution
- Self-organization
- Biological Evolution

How did we get here?

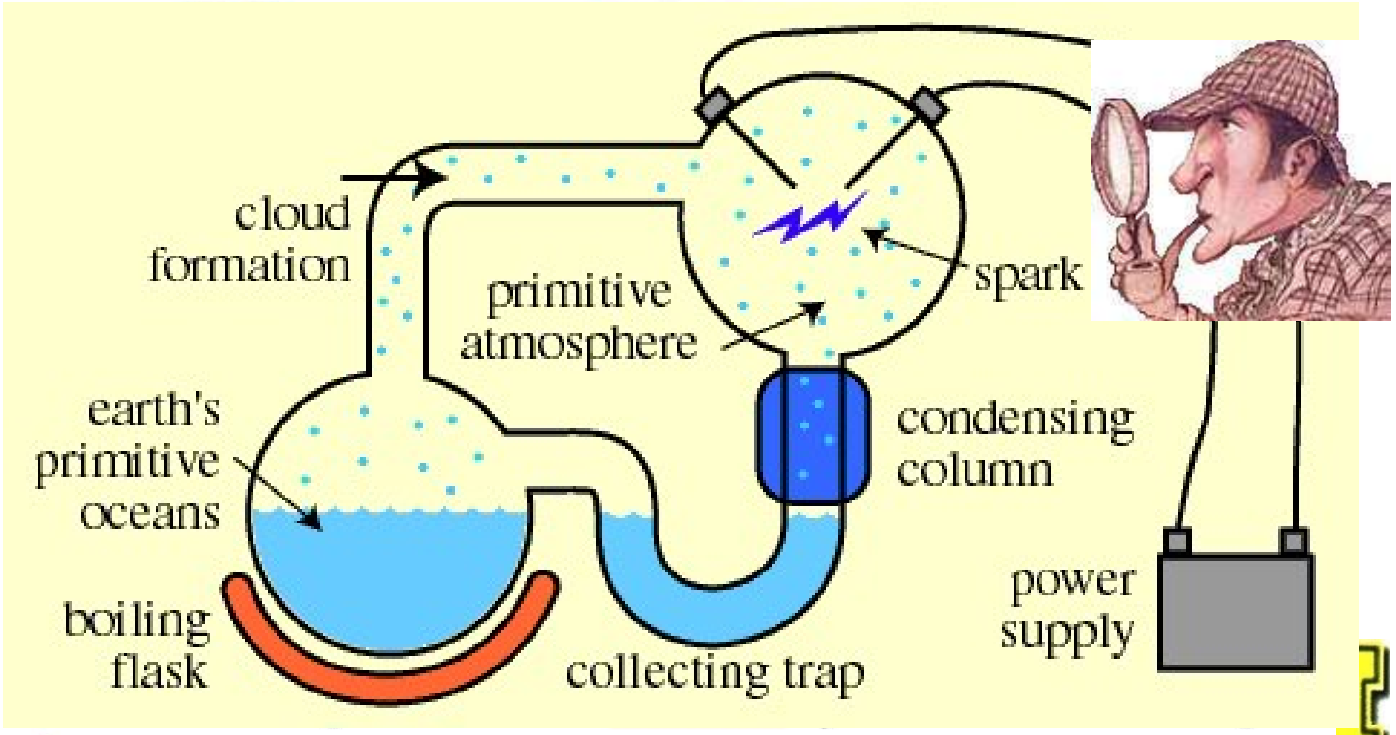


Voet & Voet, Biochemistry

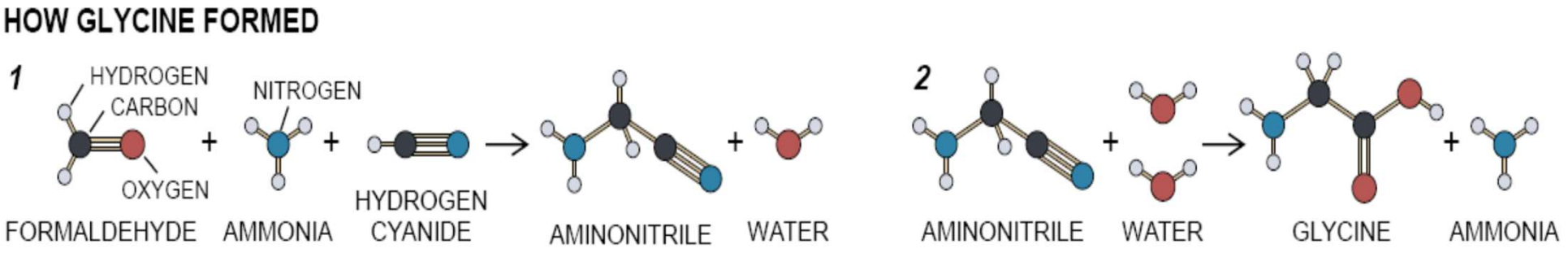
Cyanide and friends: The molecules at the root



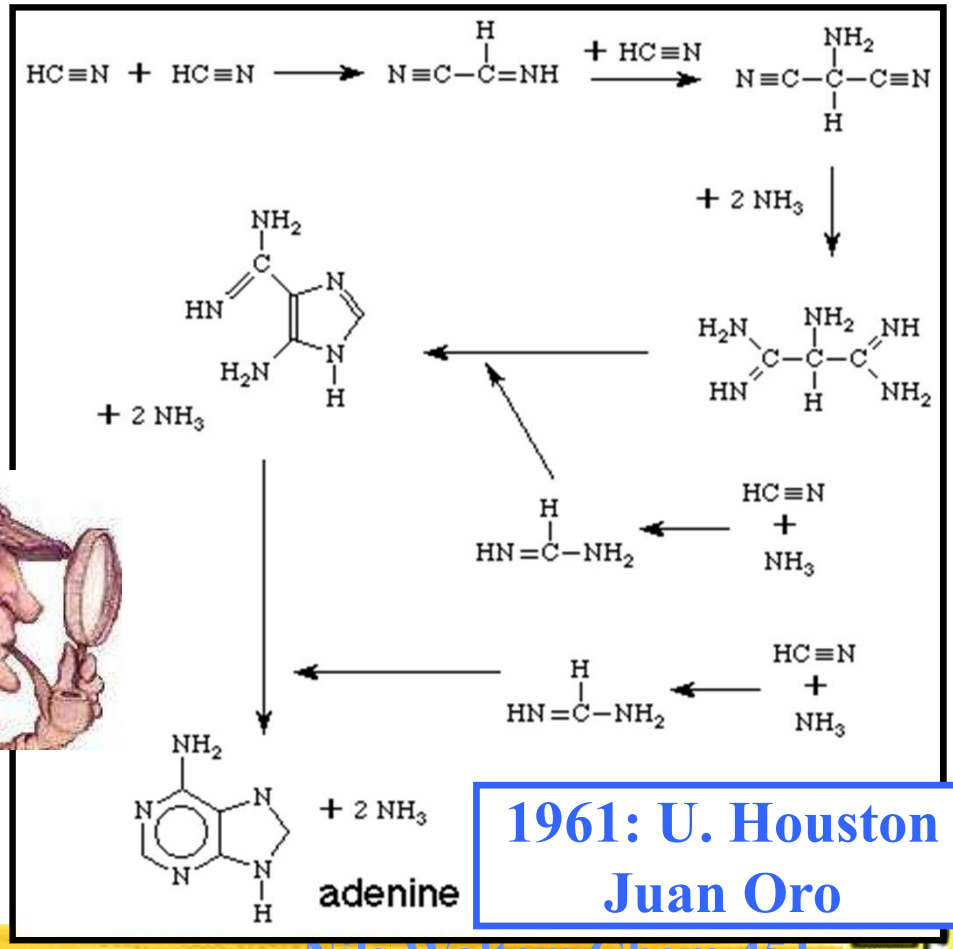
1953, U. Chicago: Stanley L. Miller & Harold C. Urey



How "complex" organic molecules "self-organize"



AMINO ACID	MURCHISON METEORITE	DISCHARGE EXPERIMENT
GLYCINE	• • • •	• • • •
ALANINE	• • • •	• • • •
α-AMINO-*N*-BUTYRIC ACID	• • •	• • • •
α-AMINOISOBUTYRIC ACID	• • • •	• •
VALINE	• • •	• •
NORVALINE	• • •	• • •
ISOVALINE	• •	• •
PROLINE	• • •	•
PIPECOLIC ACID	•	•
ASPARTIC ACID	• • •	• • •
GLUTAMIC ACID	• • •	• •
β-ALANINE	• •	• •
β-AMINO-*N*-BUTYRIC ACID	•	•
β-AMINOISOBUTYRIC ACID	•	•
γ-AMINOBUTYRIC ACID	•	• •
SARCOSINE	• •	• • •
N-ETHYLGLYCINE	• •	• • •
N-METHYLALANINE	• •	• •

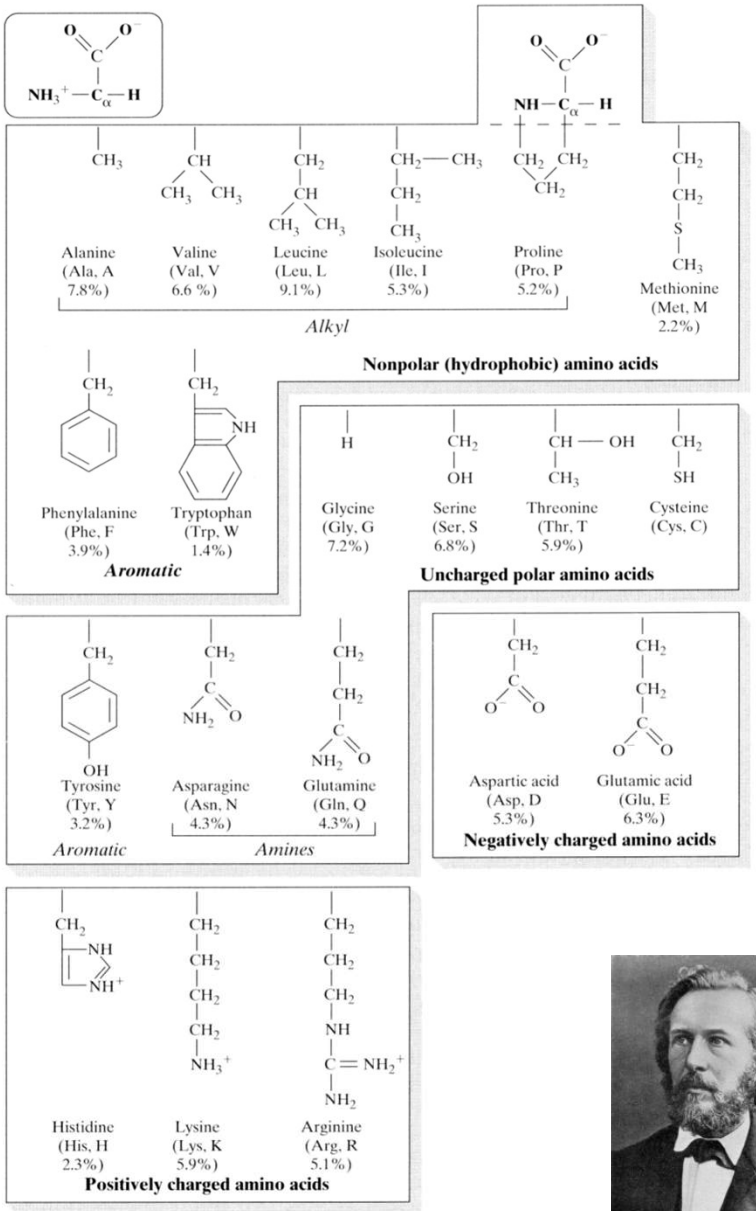


1961: U. Houston
Juan Oro

L.E. Orgel, *Scientific American* 10/1994

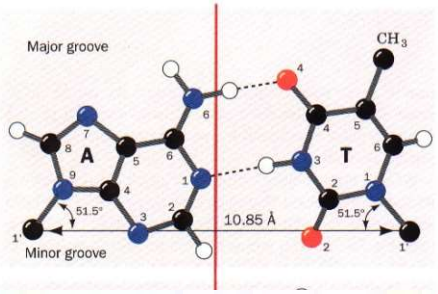
The basic building blocks are all easily made

Amino acids



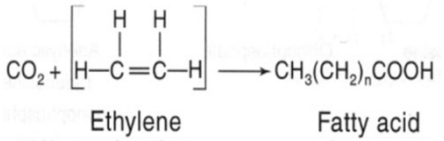
Voet & Voet, Biochemistry

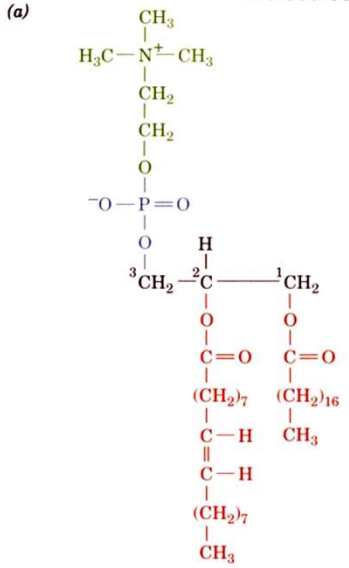
Nucleo bases

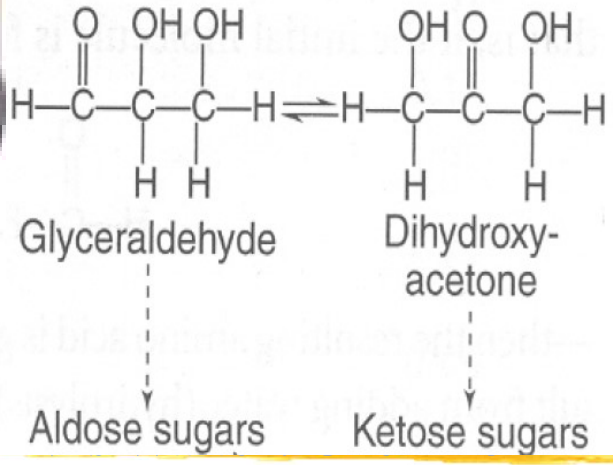


19th century: Ernst Haeckel

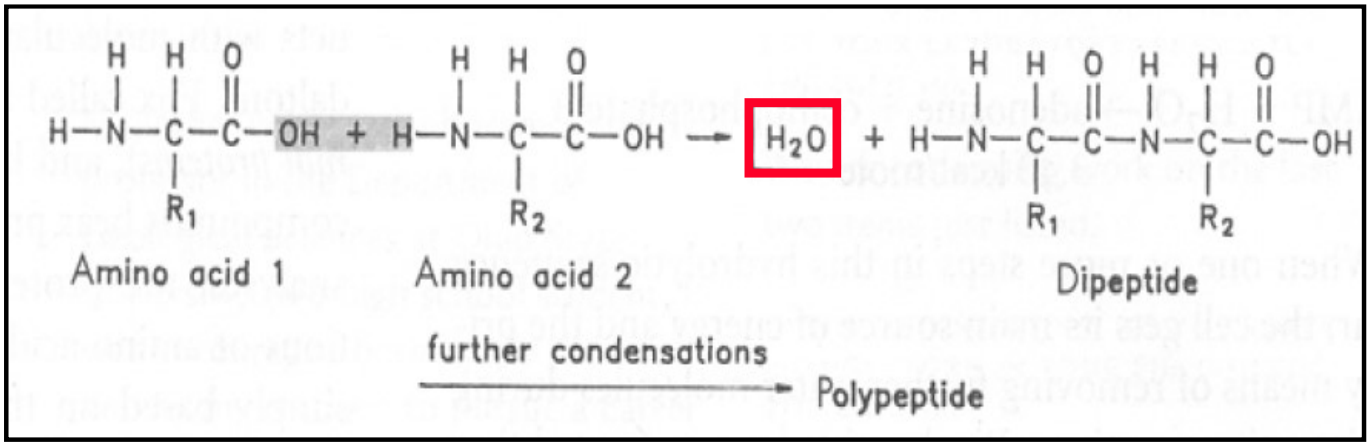
Lipids

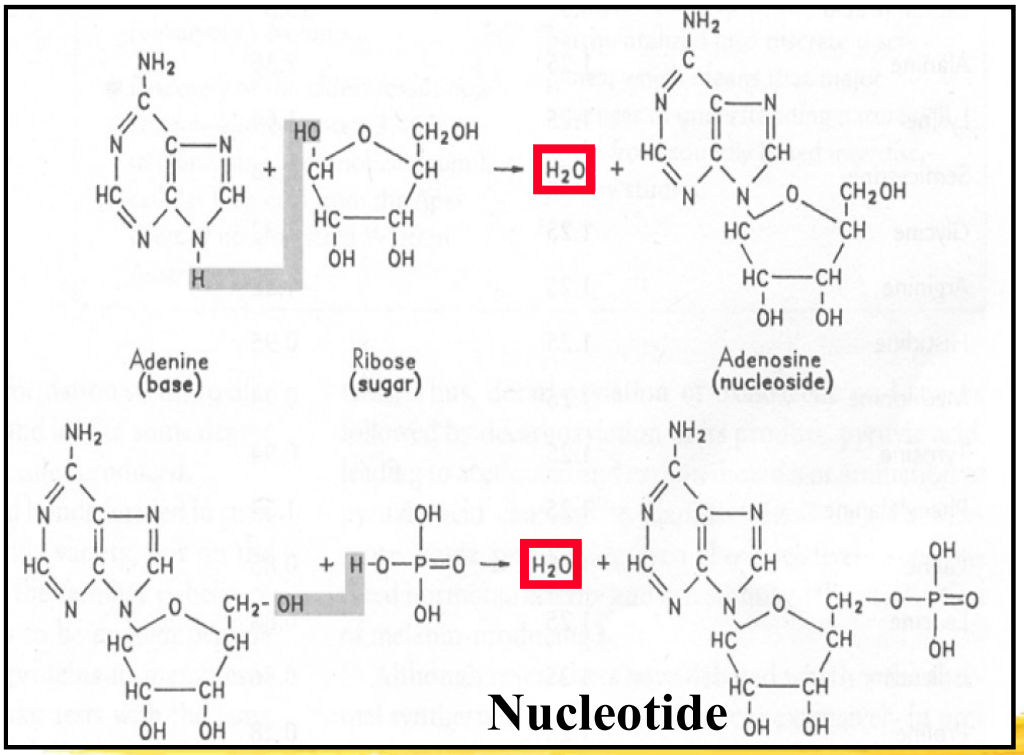


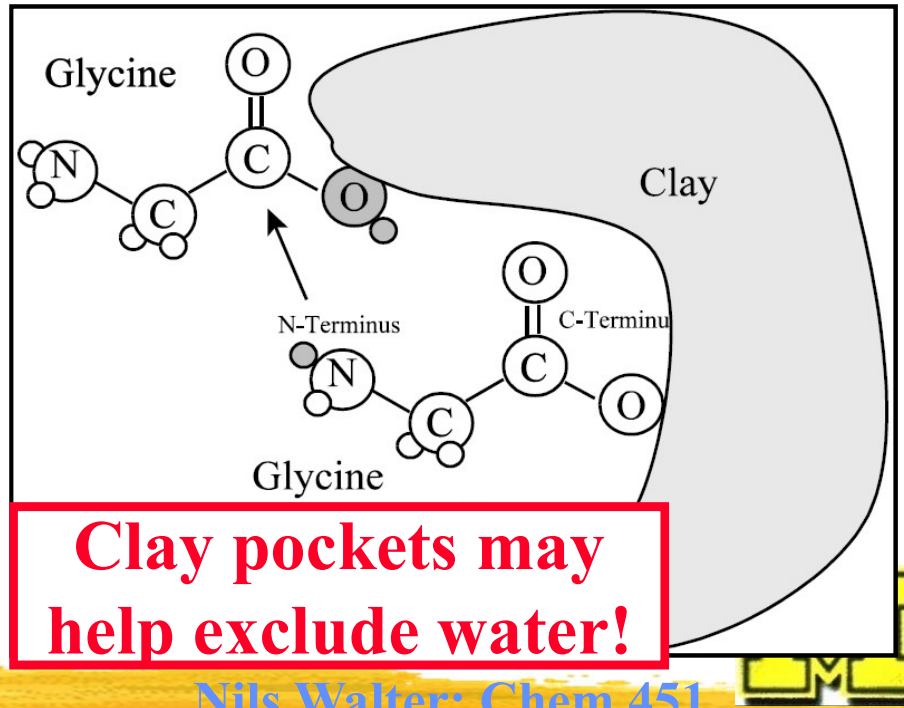




Building larger, "biological" molecules: Condensation and (hydrolytic) decay

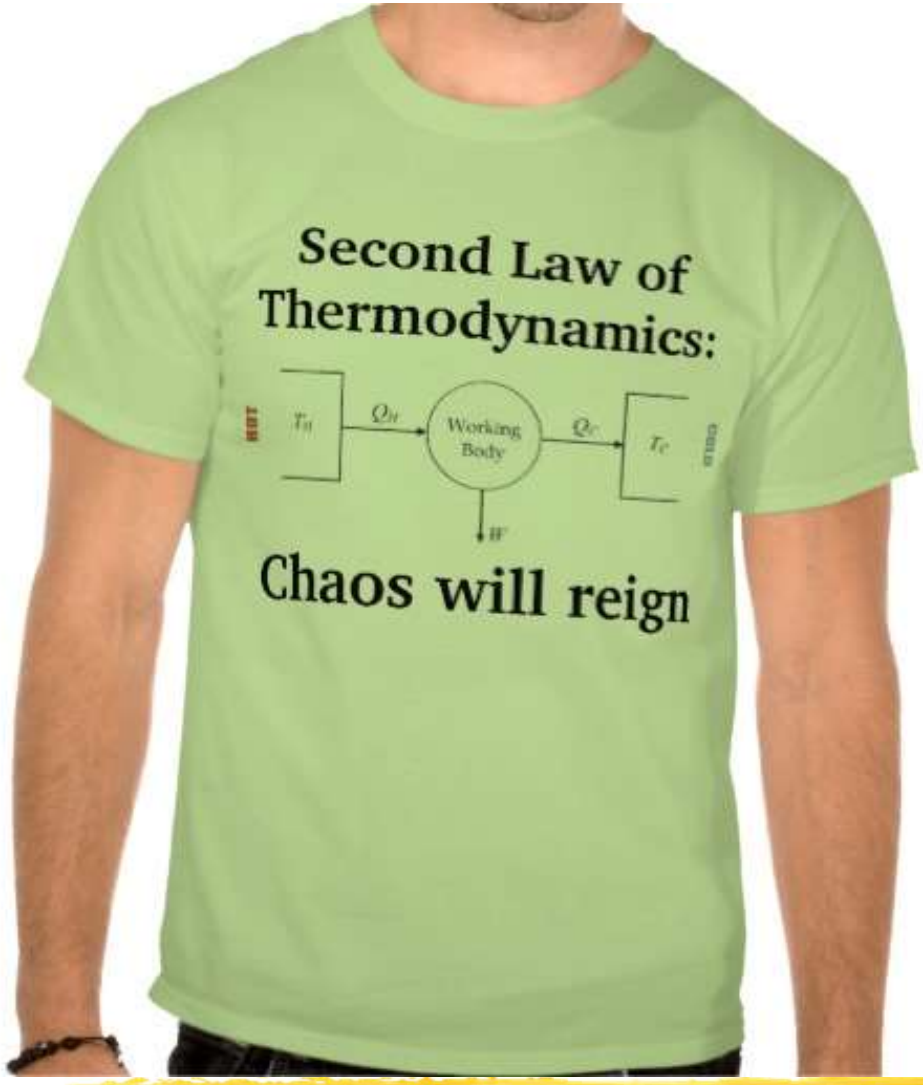


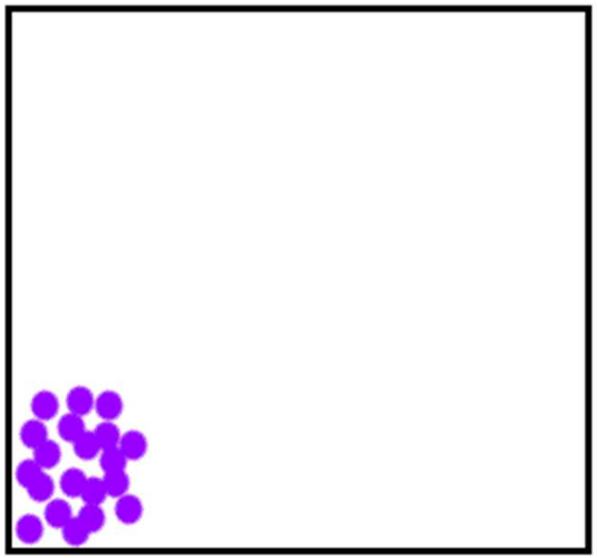




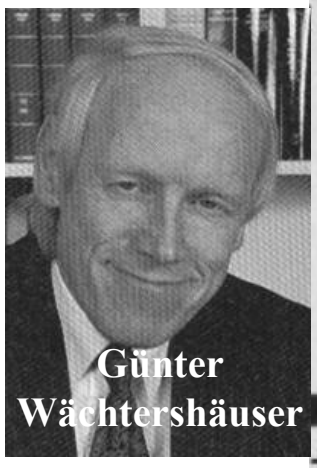
Clay pockets may help exclude water!

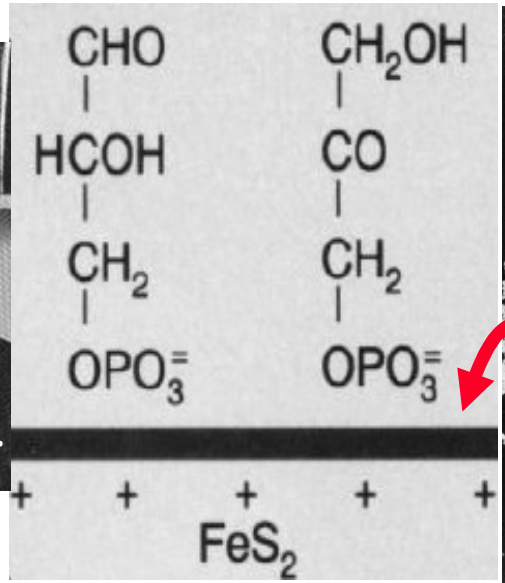
But Wait – If There is Decay, Doesn't the Second Law of Thermodynamics ("Entropy Tends to Increase") Drive Everything Back to Square One?



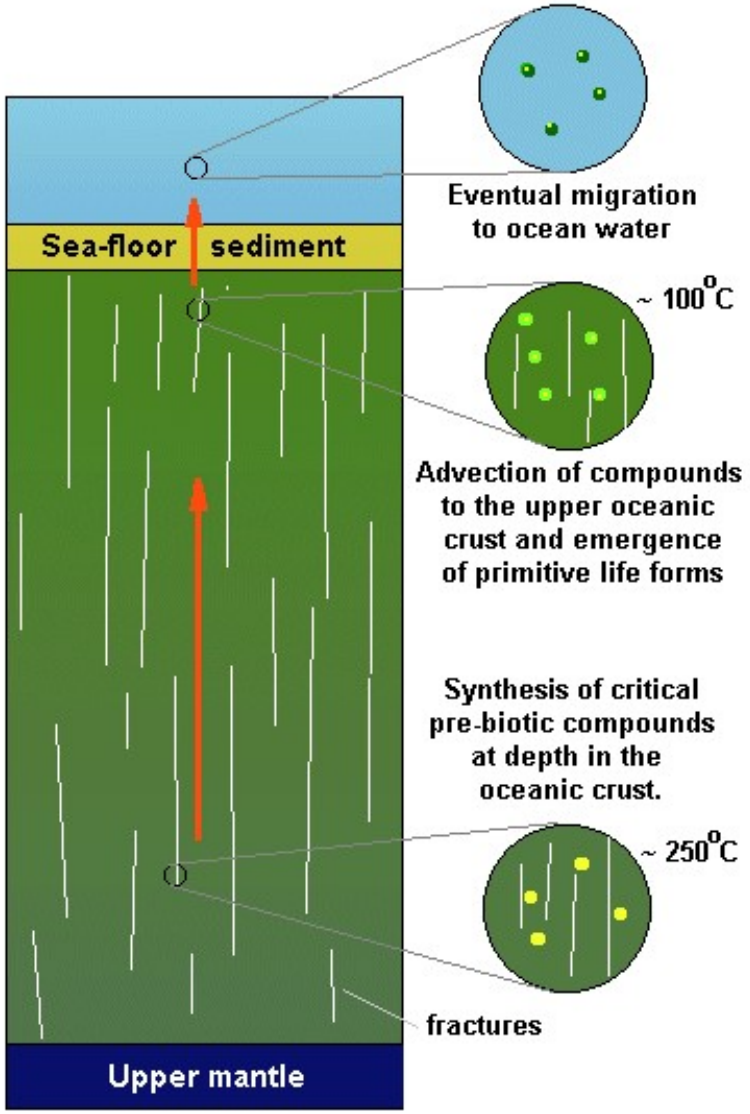


No, not if the system is far from equilibrium and an external energy source drives it to increasing complexity!!!

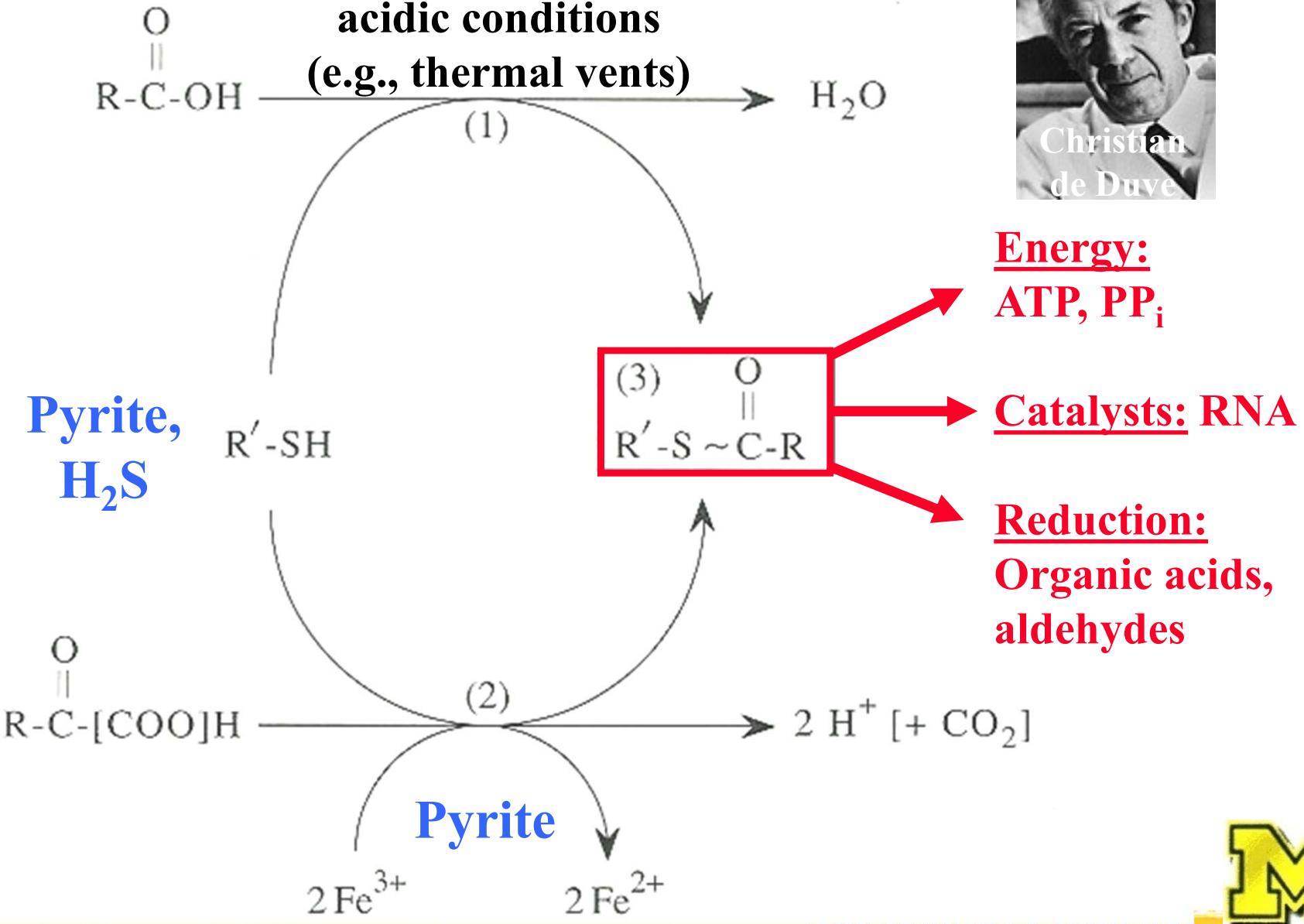




Pyrite

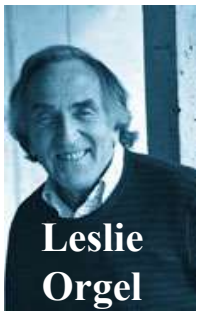


Pumping more fuel into the system: Thioesters

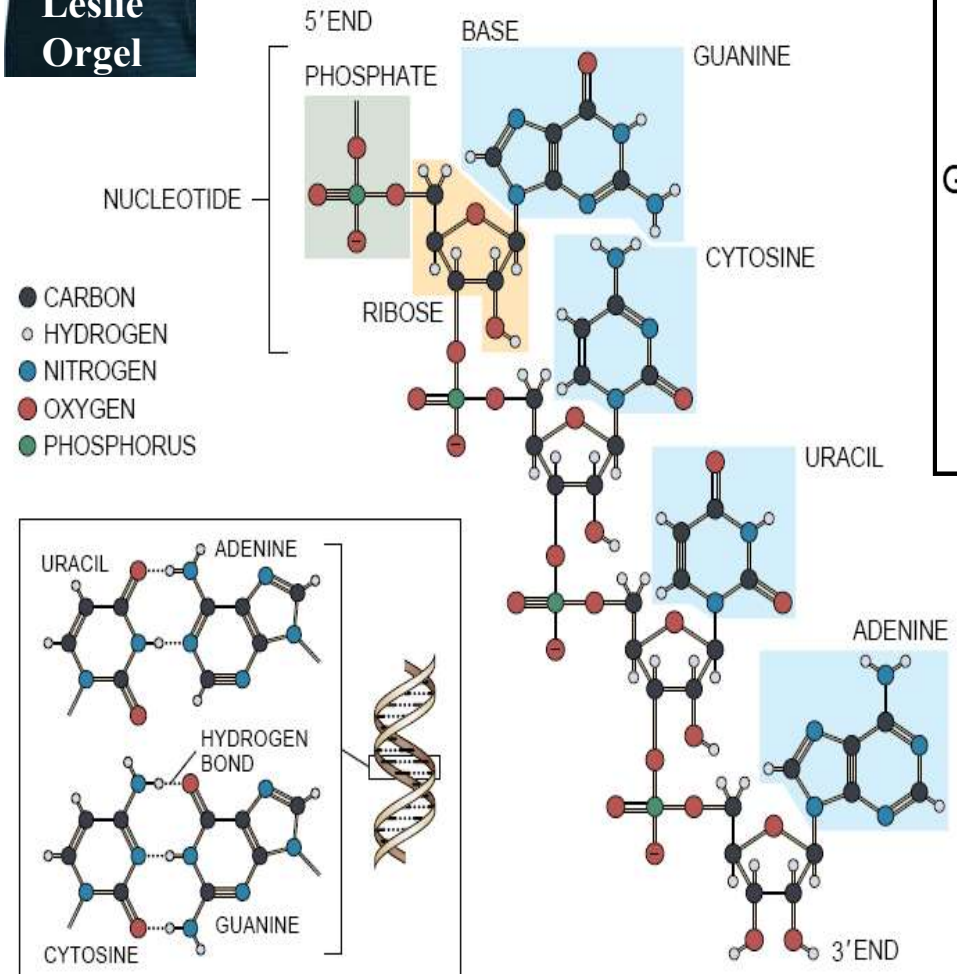


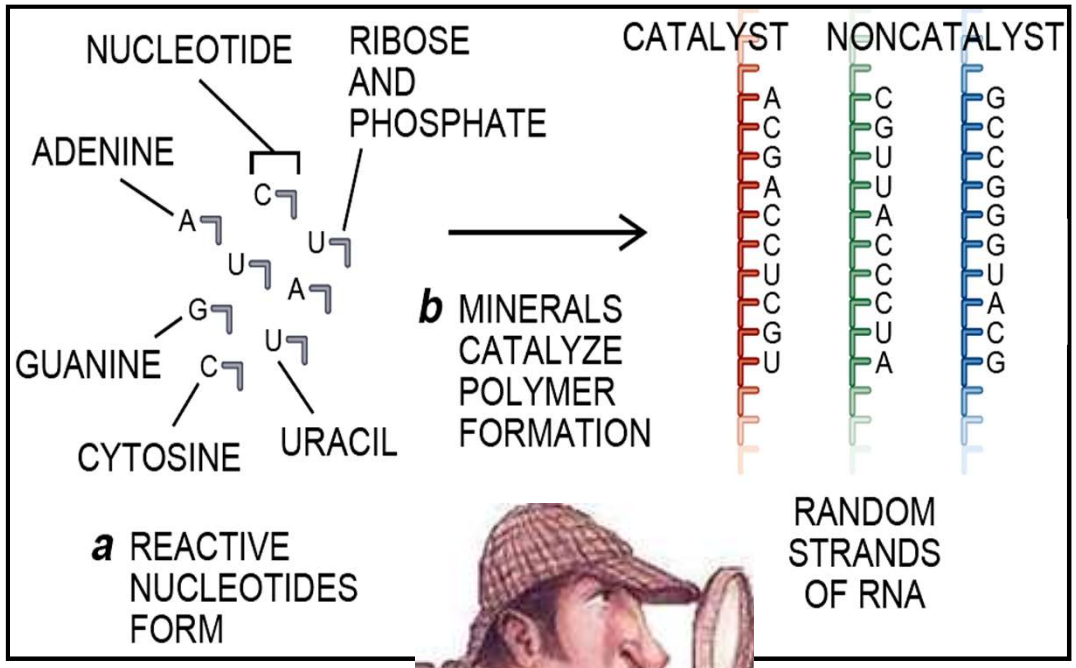
https://www.youtube.com/watch?v=0KRB6fmqvnc

The resultant increase in entropy of the Universe leads to assembly of (bio)polymers: Example RNA



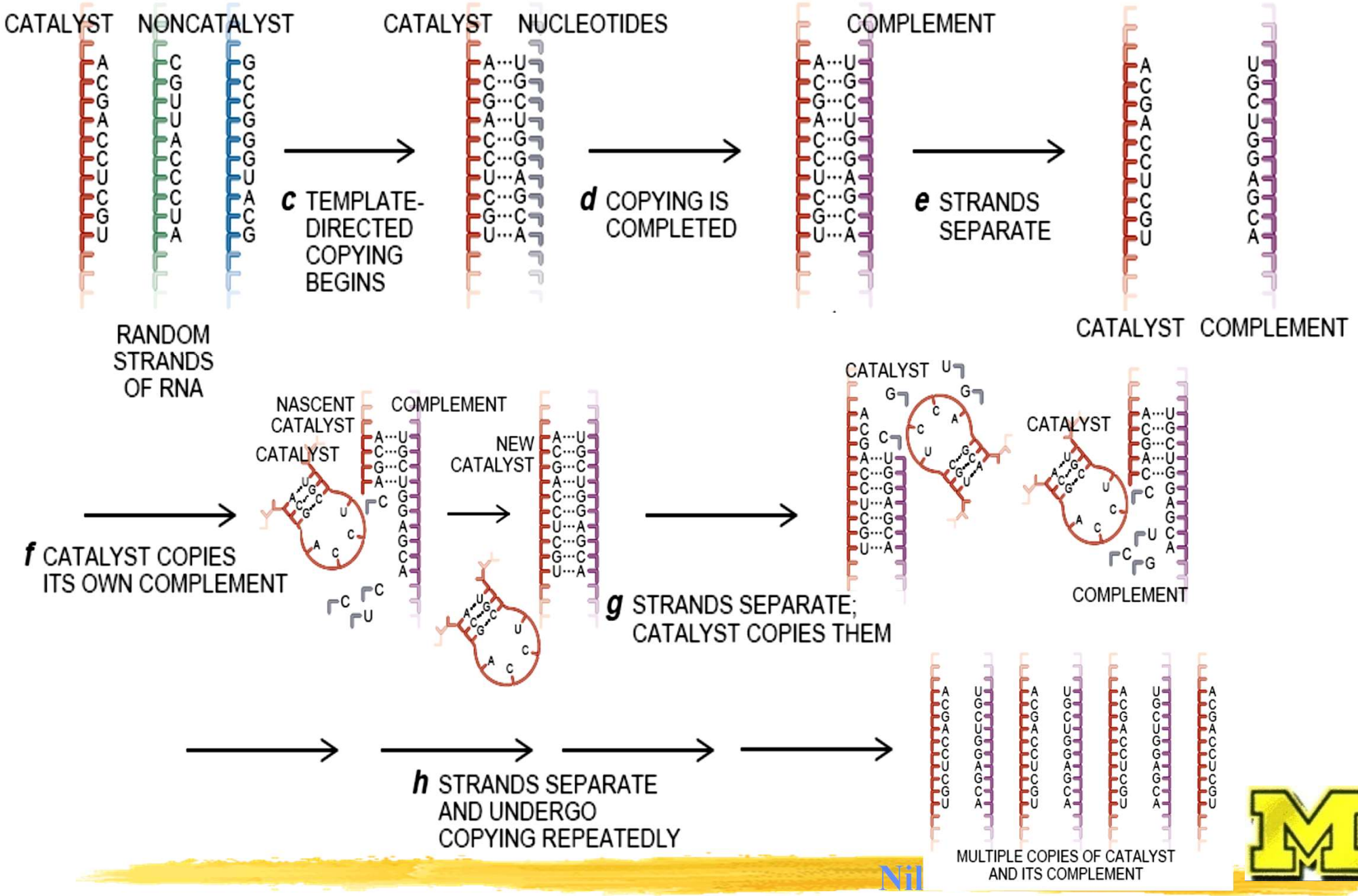
RiboNucleic Acid





- **Other (bio)polymers may have preceded RNA**

The RNA World: Living molecules



Nil

L.E. Orgel, *Scientific American* 10/1994

The Nobel Prize in Chemistry 1989

"for their discovery of catalytic properties of RNA"

Sidney Altman

◐ 1/2 of the prize

Canada and USA

Yale University
New Haven, CT, USA

Thomas R. Cech

◐ 1/2 of the prize

USA

University of Colorado
Boulder, CO, USA