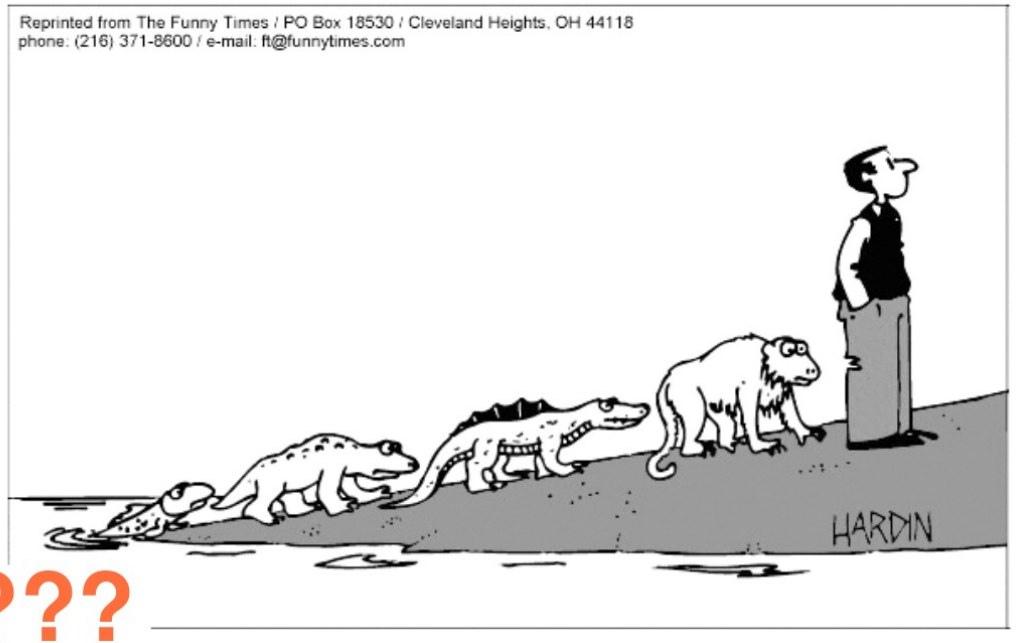
How did we get here?



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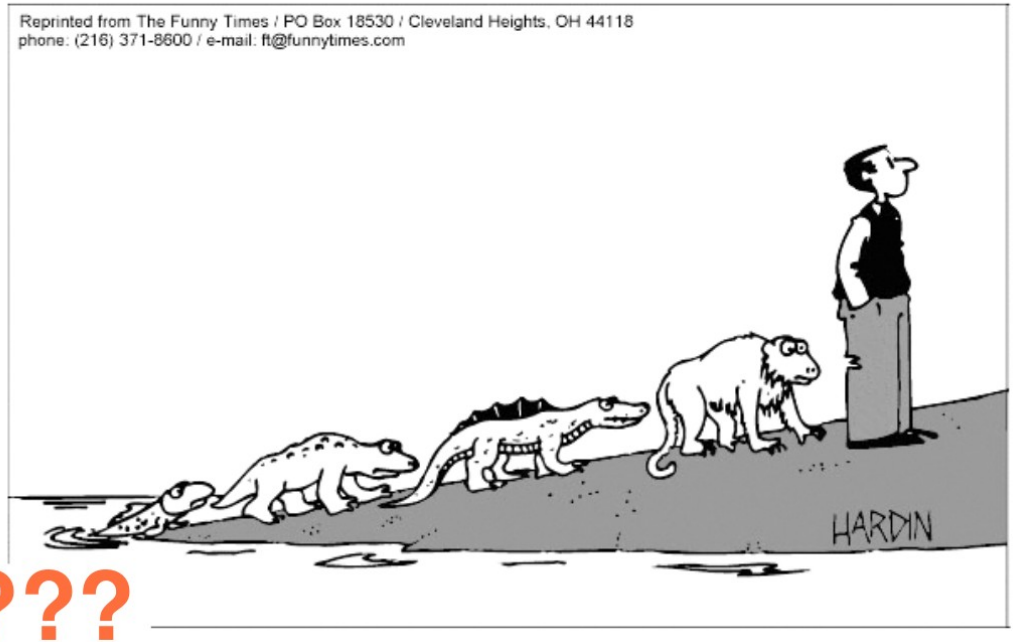
How did we get here?



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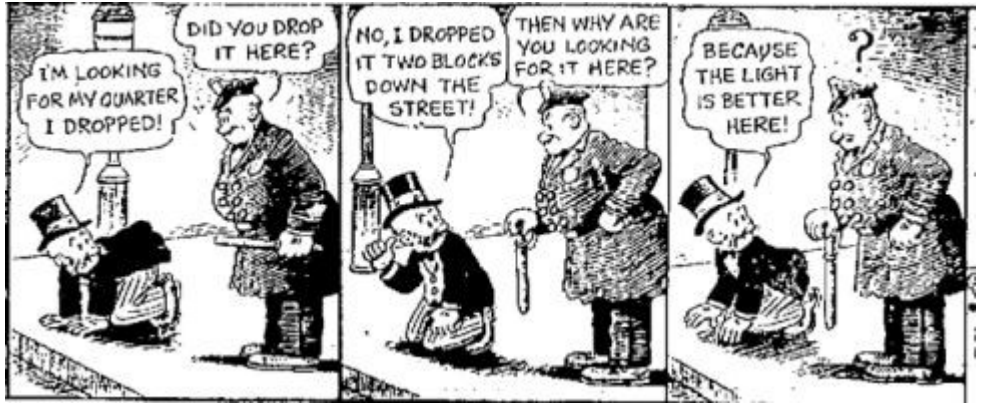

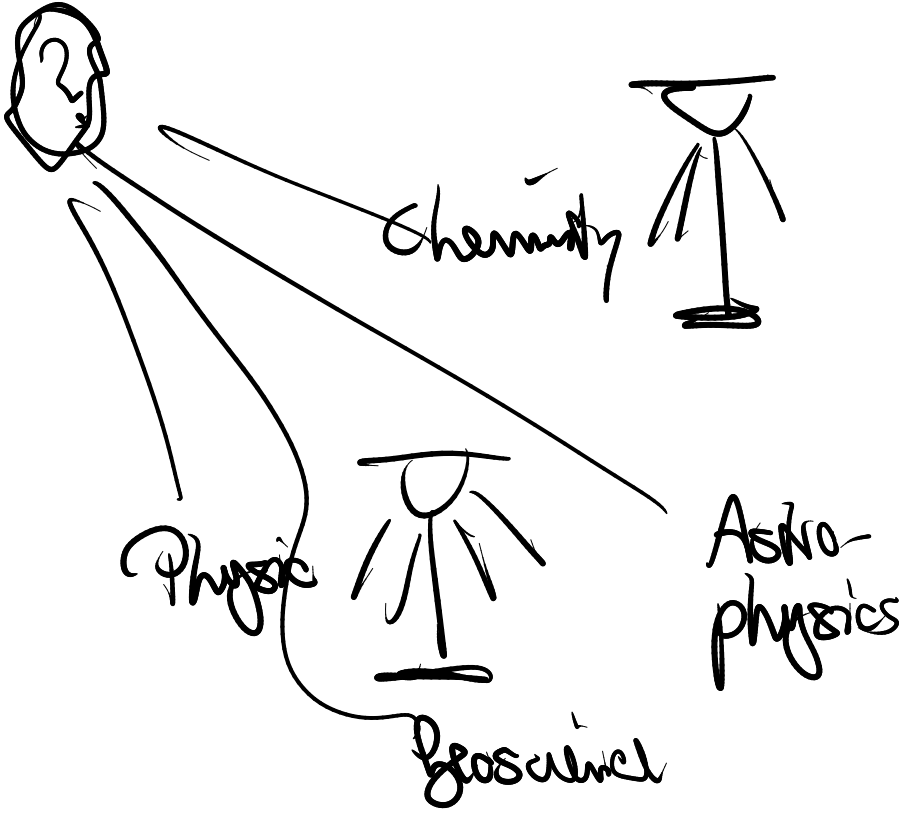

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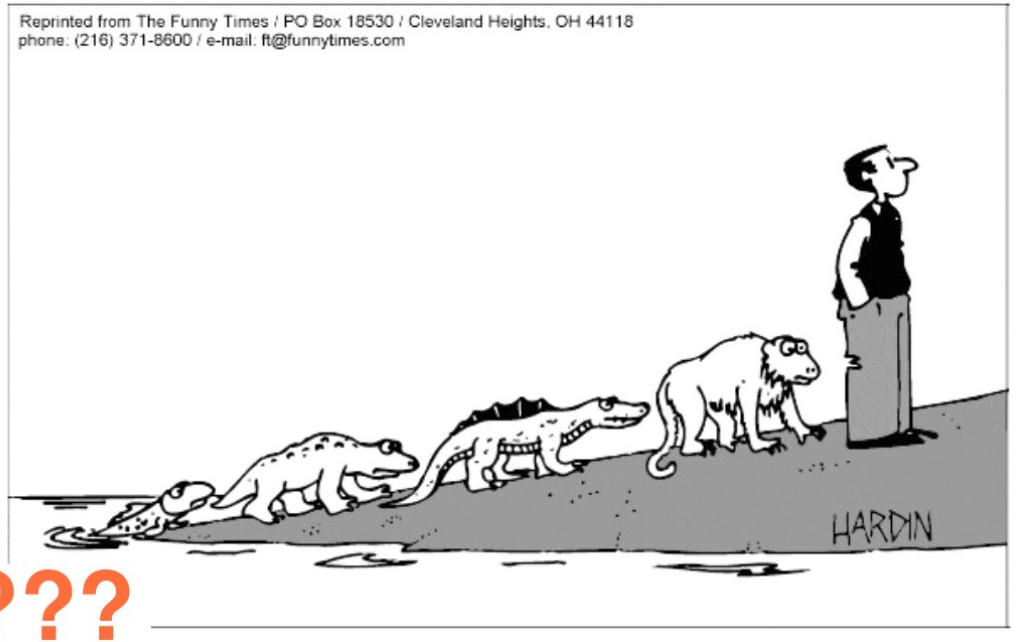

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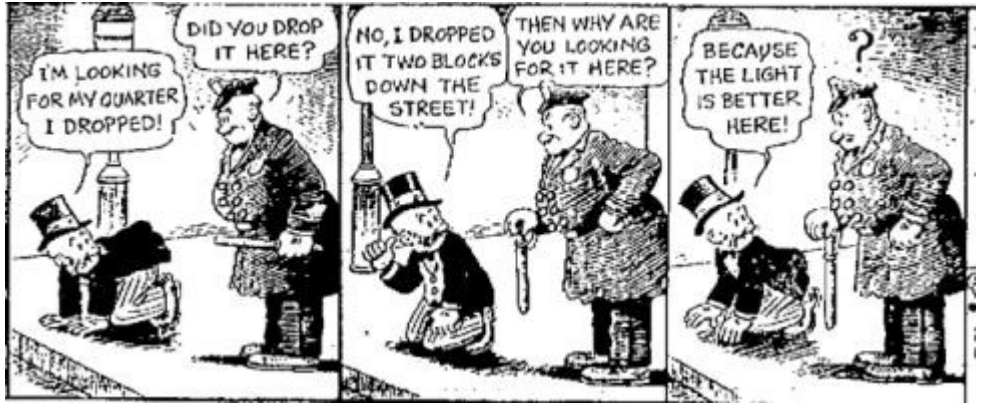
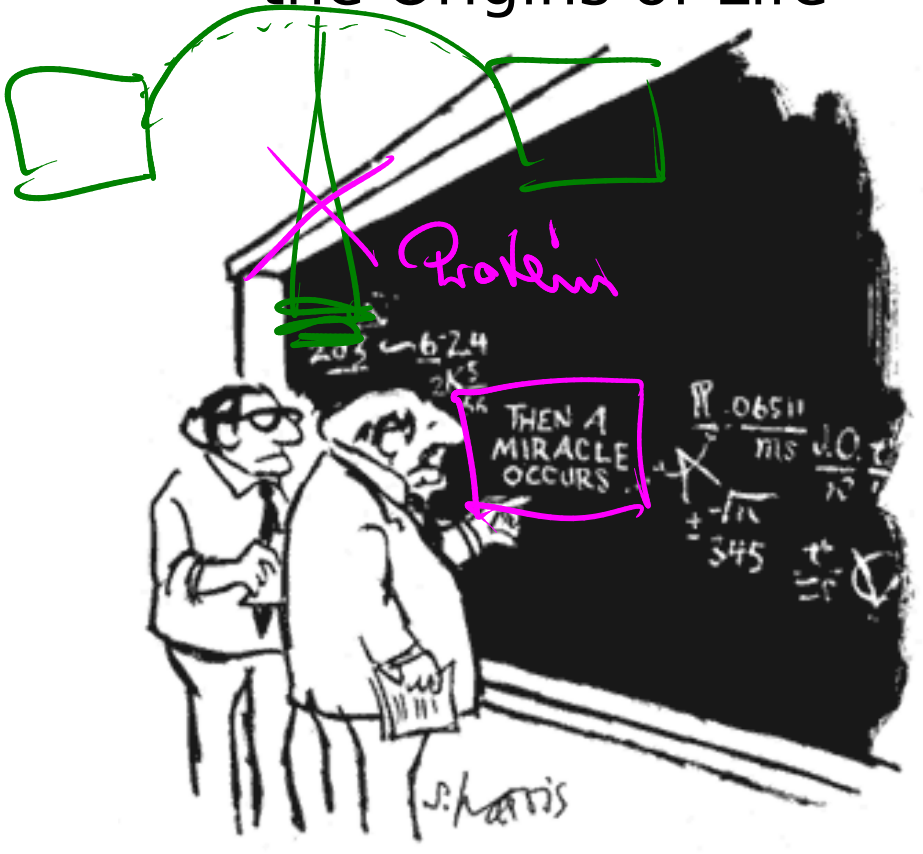


Evolution and the Origins of Life



"I THINK YOU SHOULD BE MORE EXPLICIT HERE IN STEP TWO."

A: Fundamentals of Life

- Definition of Life
- Logic of Molecular Biology
- History of Biology
- Becoming alive
- Soup of Life
- Selection: before and in life
- Three faces of Entropy
- Death and equilibrium
- Missing non-equilibrium
- Structure of Origin of Life
- Modes of non-equilibrium
- Examples of evolution

B: Physics for Chemistry

Polymerization
- Theory of polymerization
- P. by fast cooling
- P. by stacking with 3’-5’-Ph.
- Activation groups
- P. on clay
- P. by thermophoresis
- Phase transitions with DNA
- Sedimentation of DNA
- Drying and its problems
- Elegance of air interface

Replication
- Templated polymerization
- Ligation
- Strand separation problem
- PCR in convection
- Ribo-PCR in convection

C: Evolution Machines

Replication with accumulation
- Case of Ribo-PCR
- Spiegelman problem
- Case of trapped PCR
- Trapped PCR with flow
- Feeding problem
- Replication with heated tRNA
- Replication in driven Fog

Rebustness of evolution
- Error threshold
- Instability of four bases
- Hypercycles with ligation
- Spont. Symmetry breaking
- Spont. sequence selection
- Cooperation within cells

A: Fundamentals of Life

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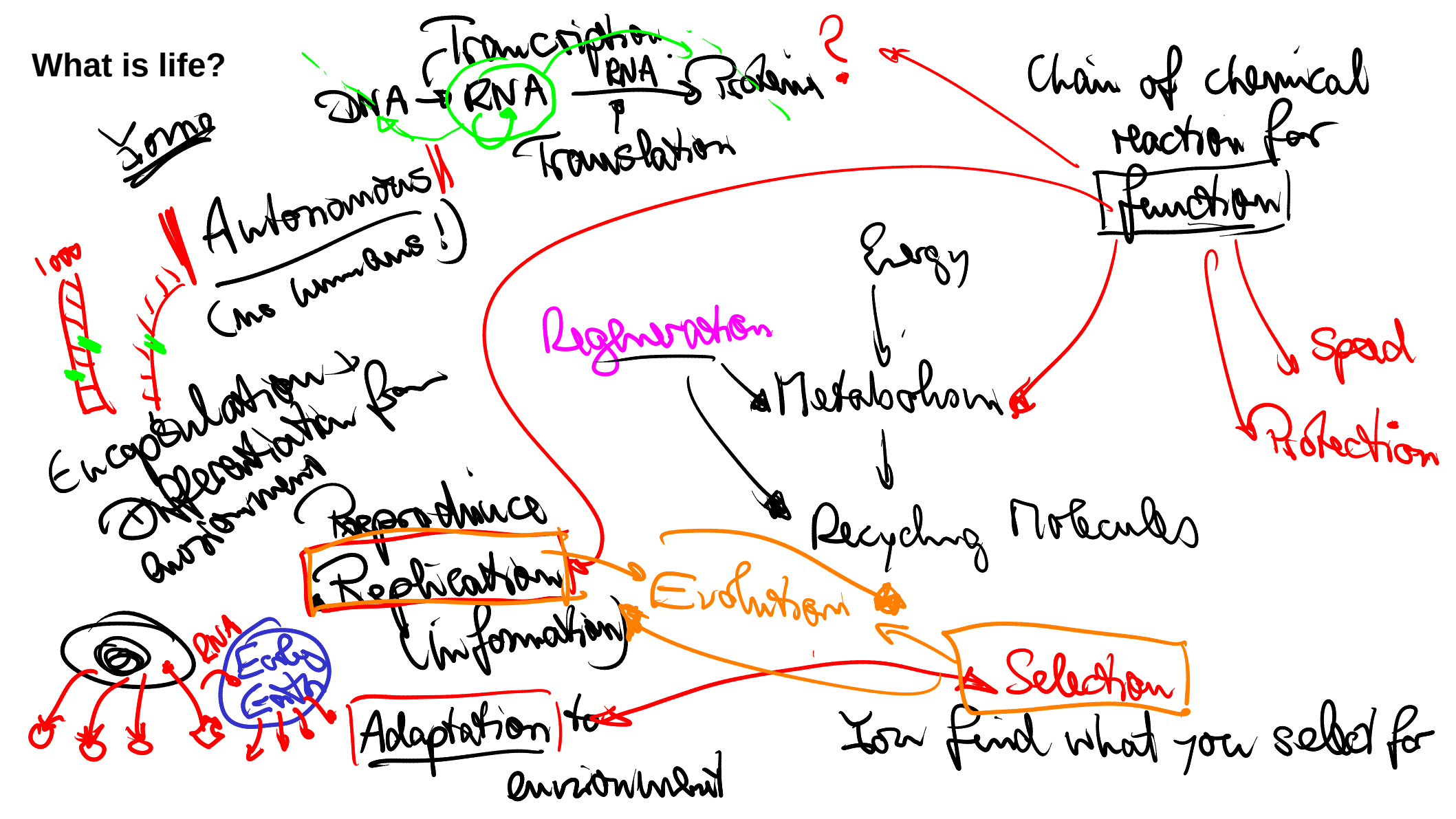
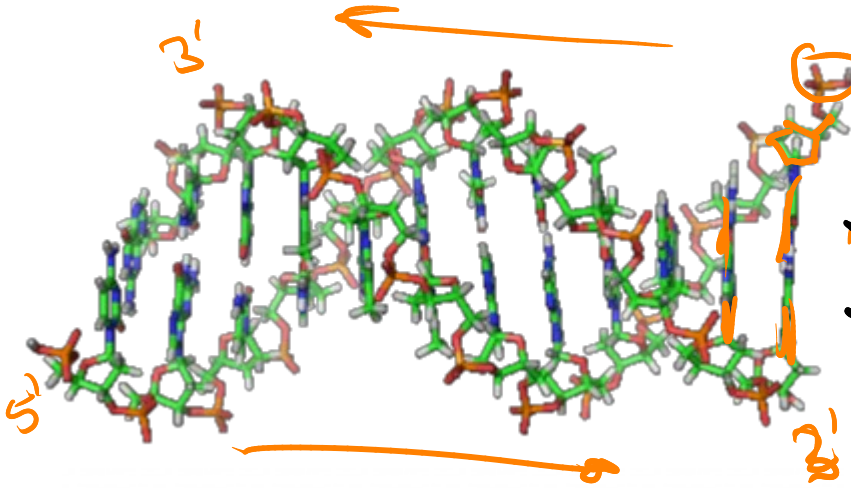

What is life?
Transcription
DNA → RNA
RNA → Proteins
Translation
?
Chain of chemical reaction for
Function
Some
Autonomous
(no humans!)
Encapsulation
Differentiation from environment
Energy
Regeneration
Metabolism
Recycling Molecules
Spend
Protection
Reproduce
Replication
Information
Evolution
DNA
Selection
Adaptation to environment
You find what you select for

What is life?

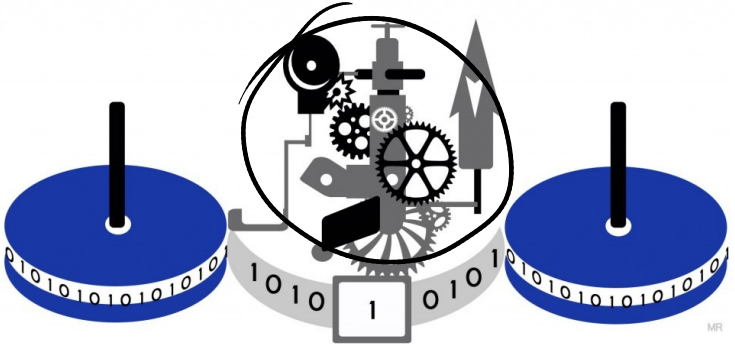
Nasa working definition of Life:
A self-sustained chemical system
capable of undergoing Darwinian Evolution

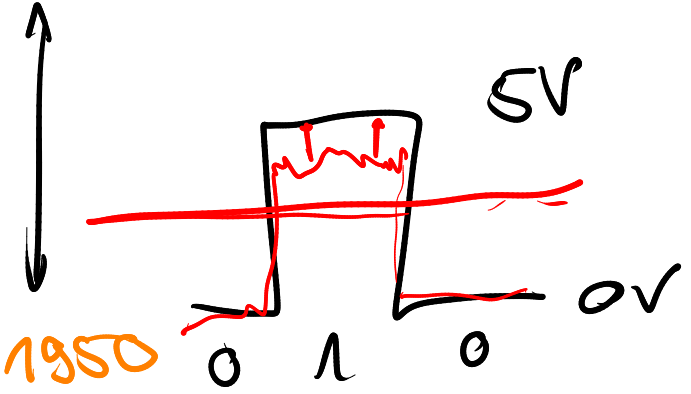
Logic of Molecular Biology



ATGC

ATGC

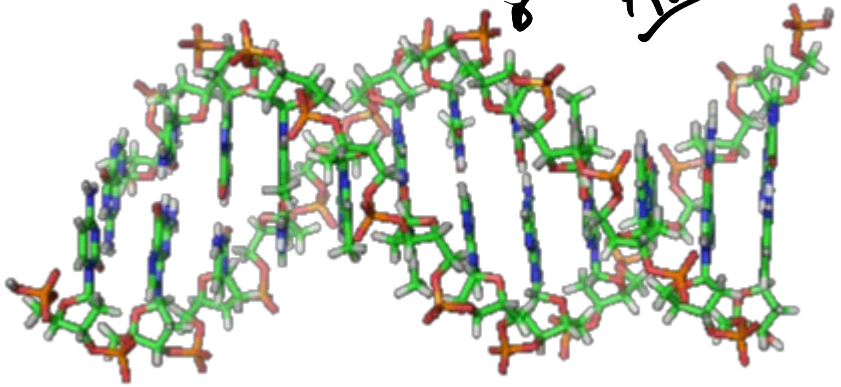


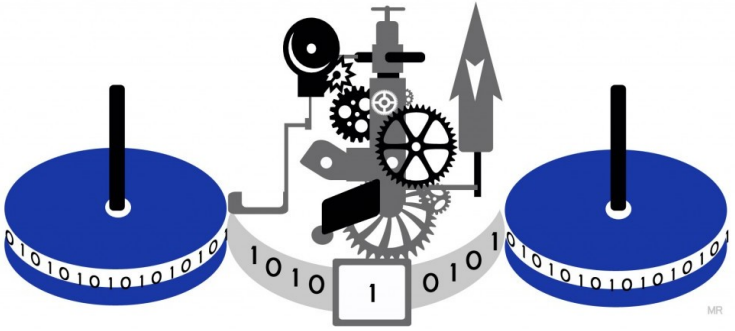


Storage of information very similar to Turing machine => Computer

Logic of Molecular Biology

Amino Acids (no control initially over A.A. sequences)





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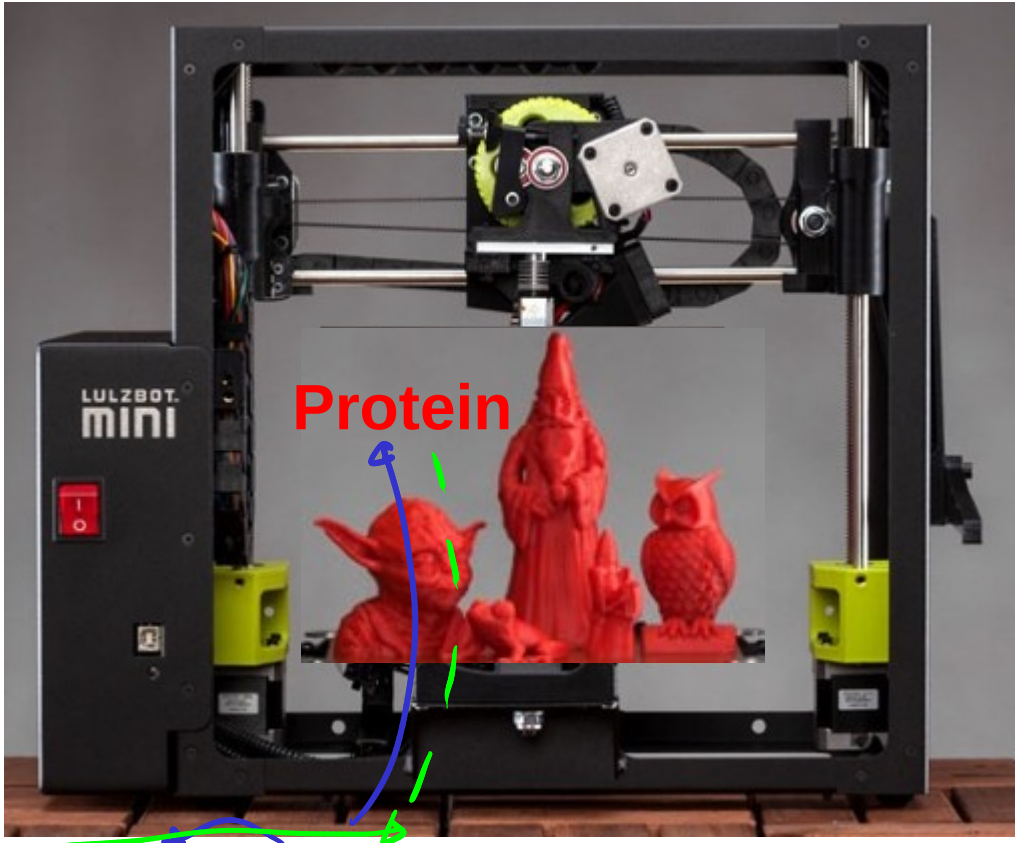
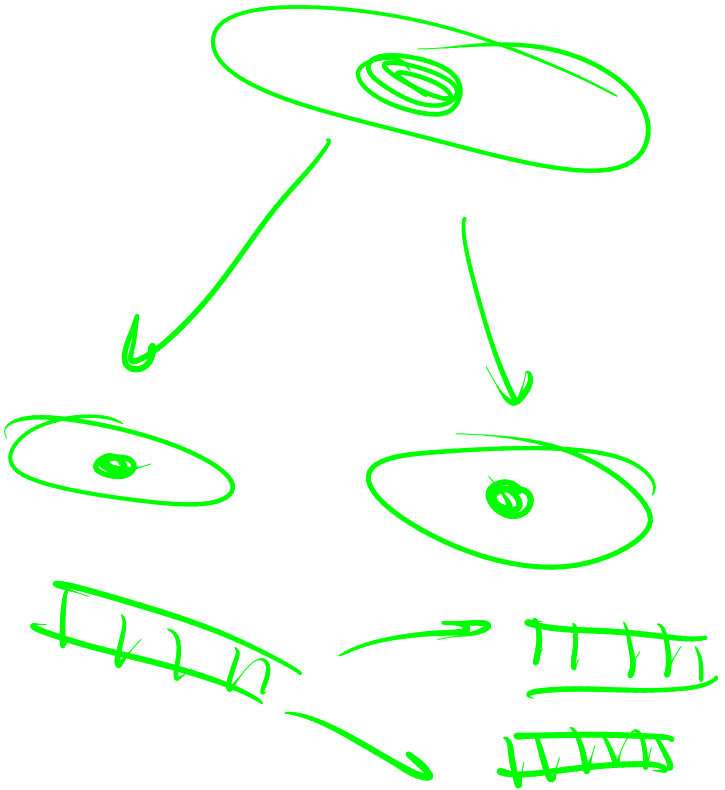
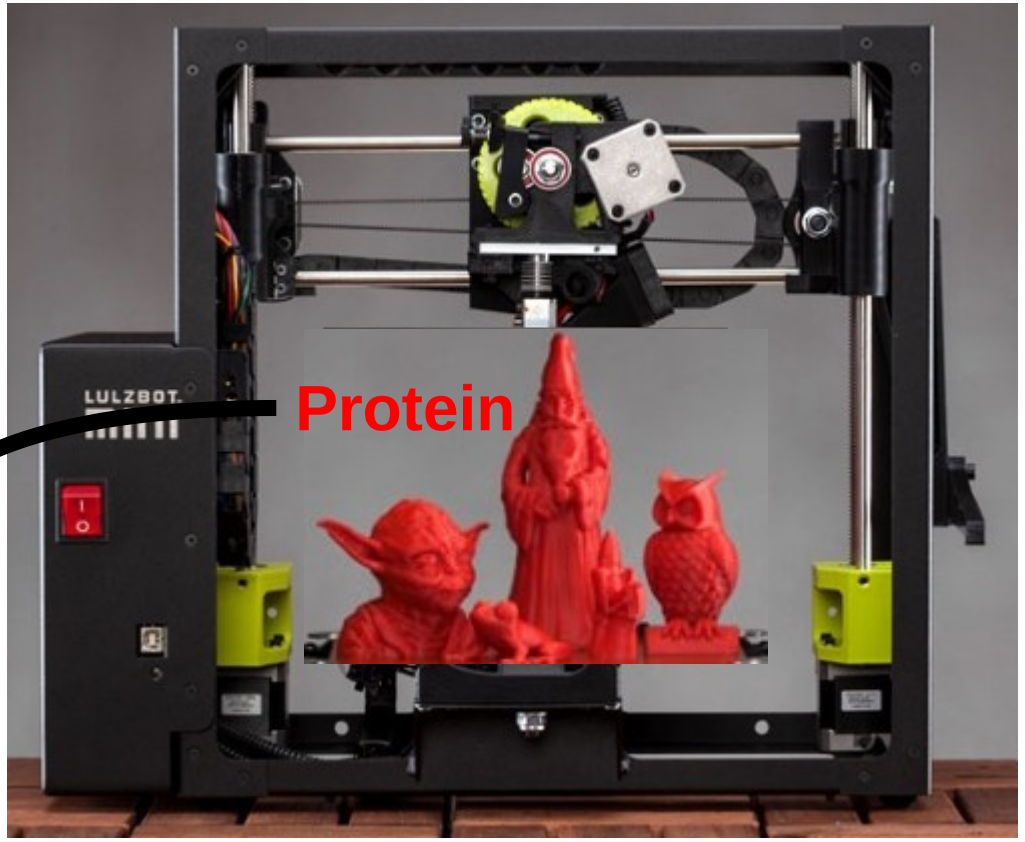


Logic of Molecular Biology

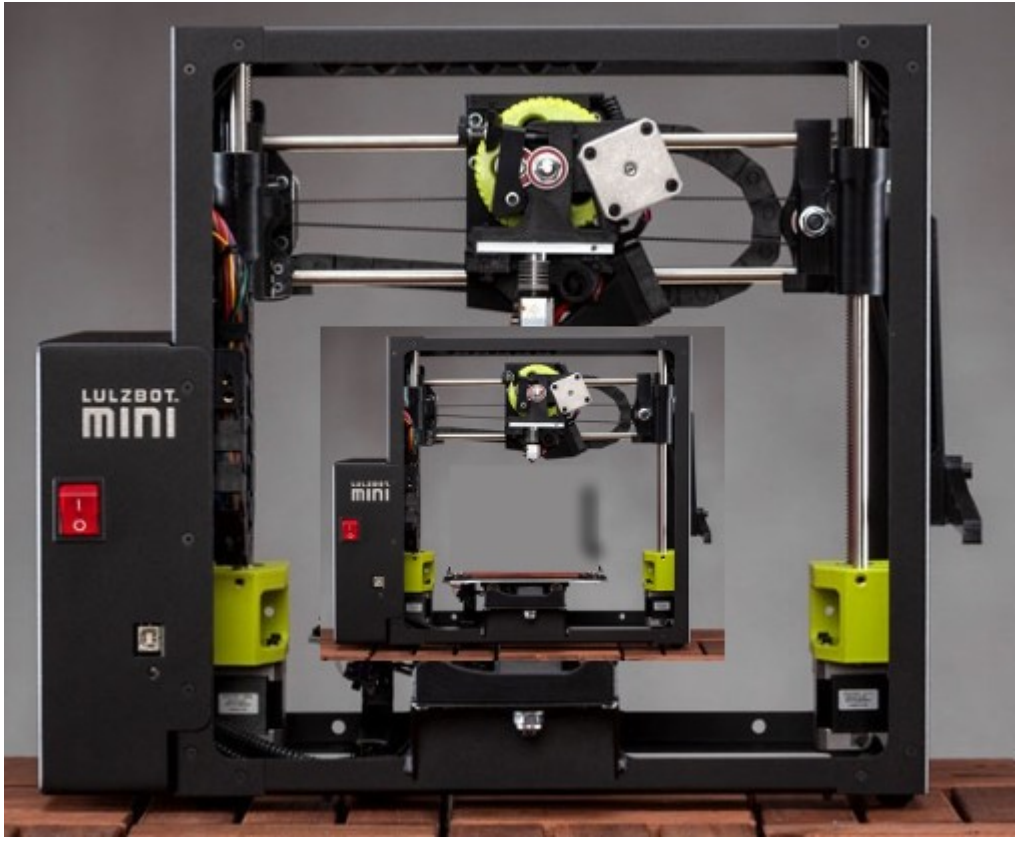




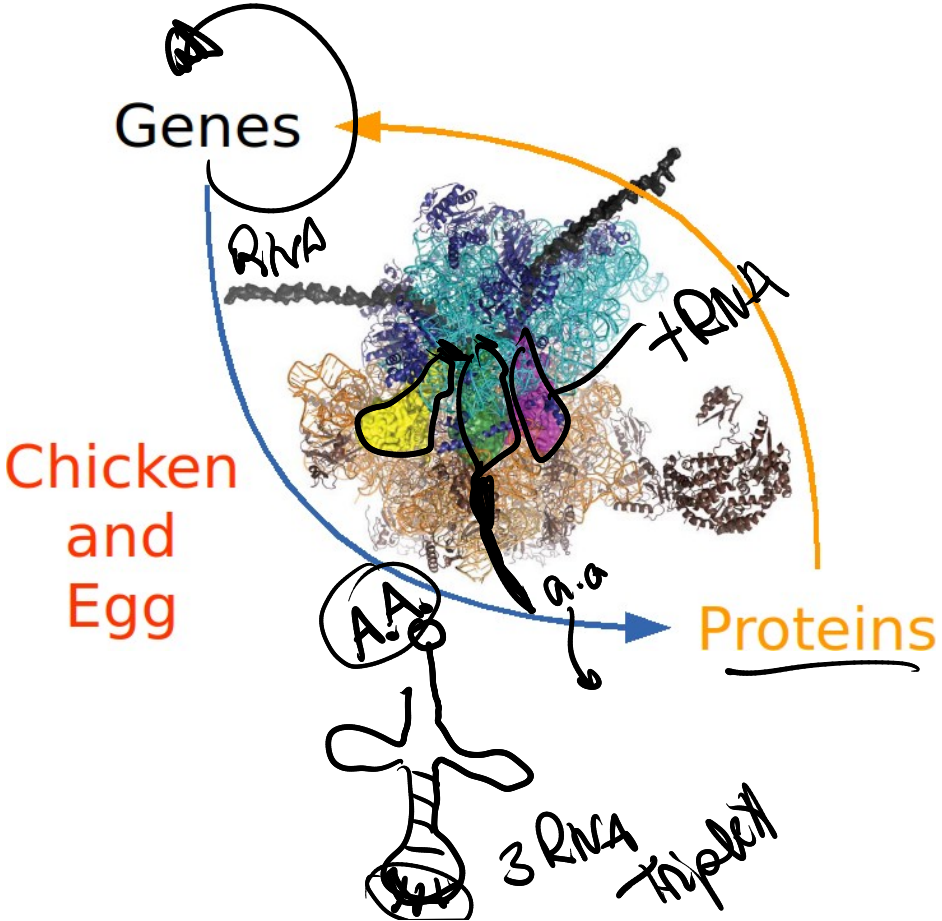
DNA+RNA

Logic of Molecular Biology

How to make a machine that makes itself?

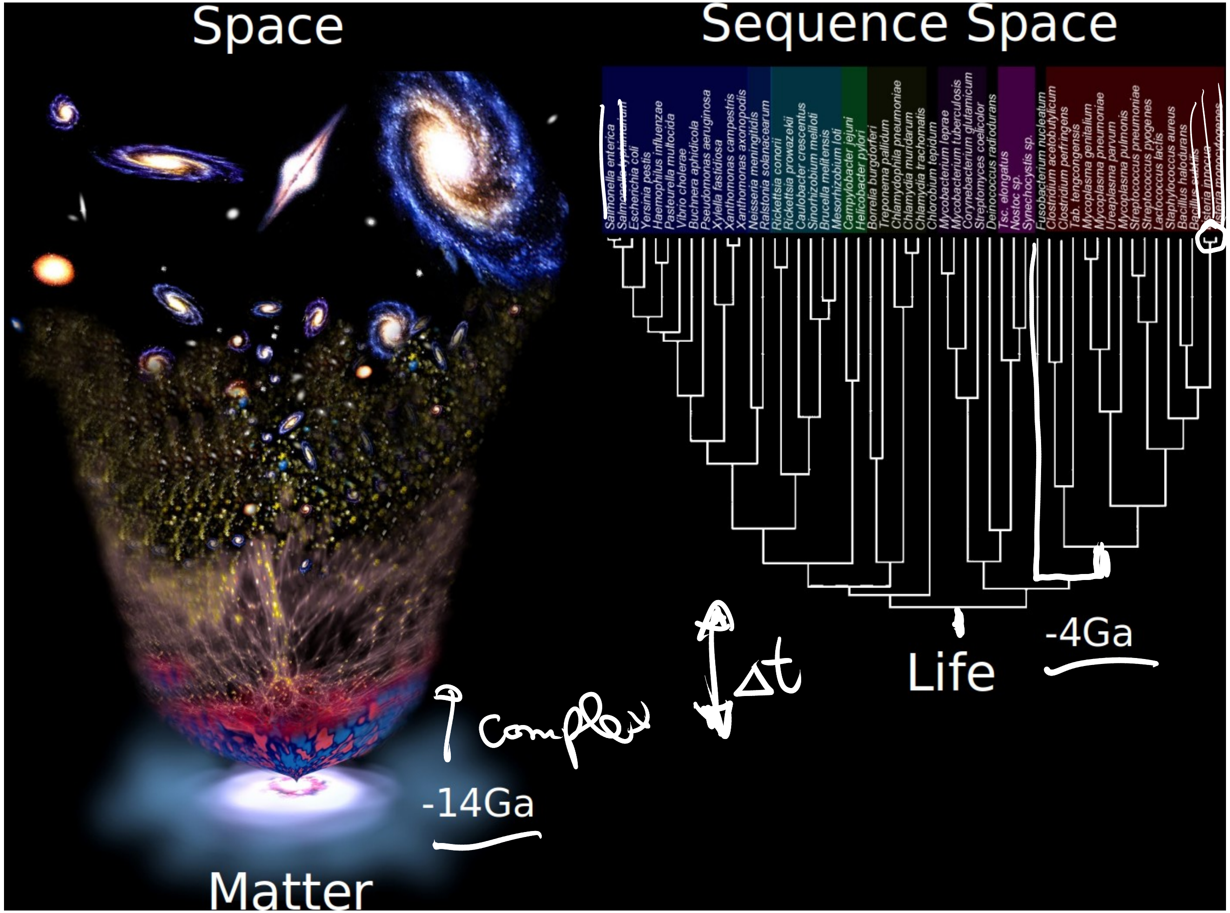


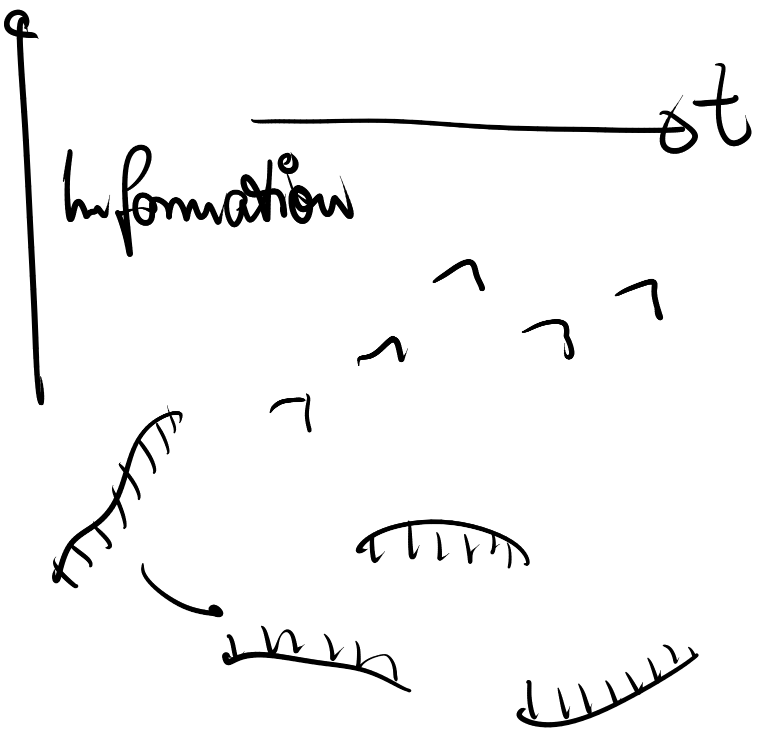
Logic of Molecular Biology



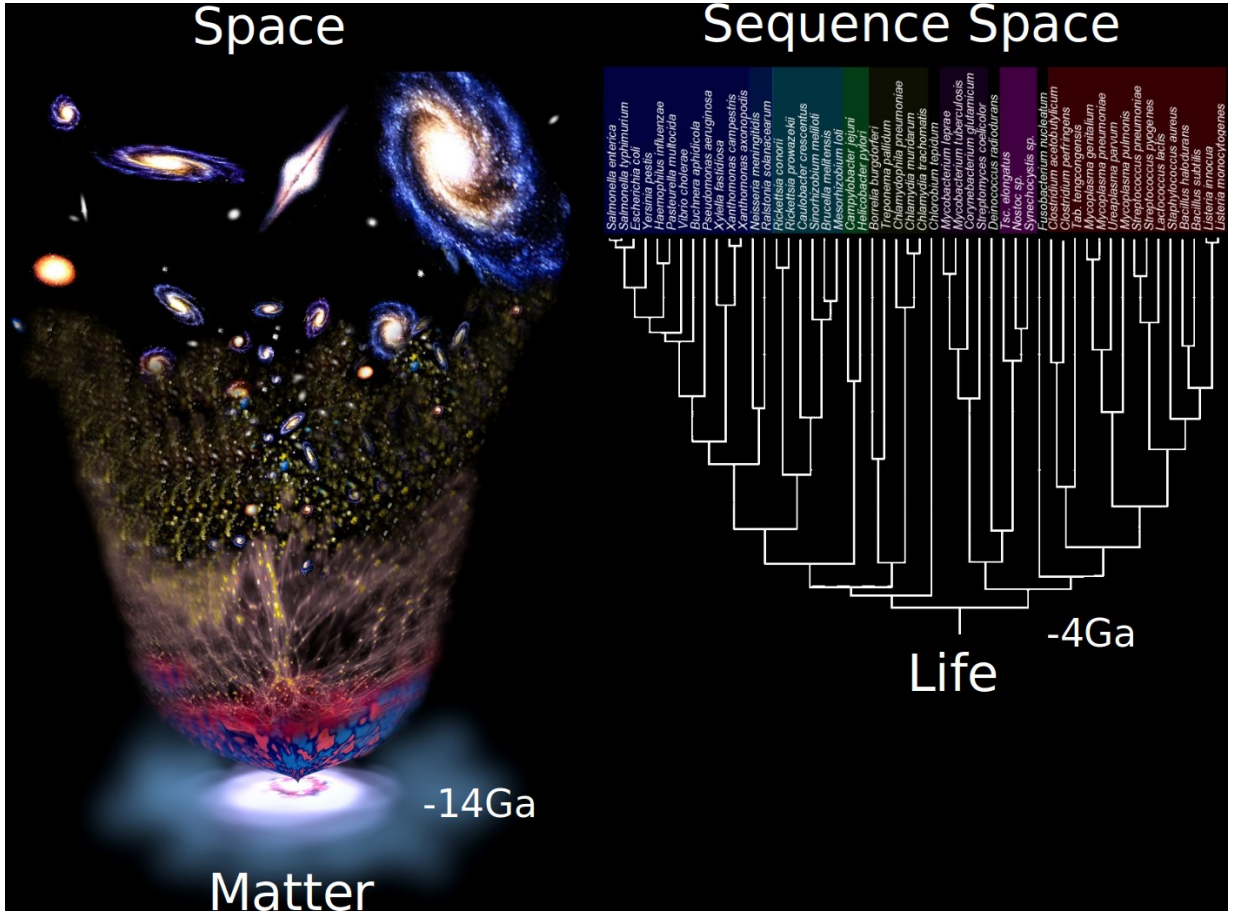
How to make a machine that makes itself?

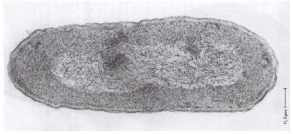
History of Biology

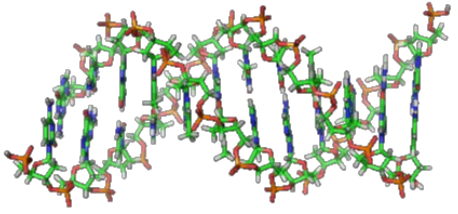




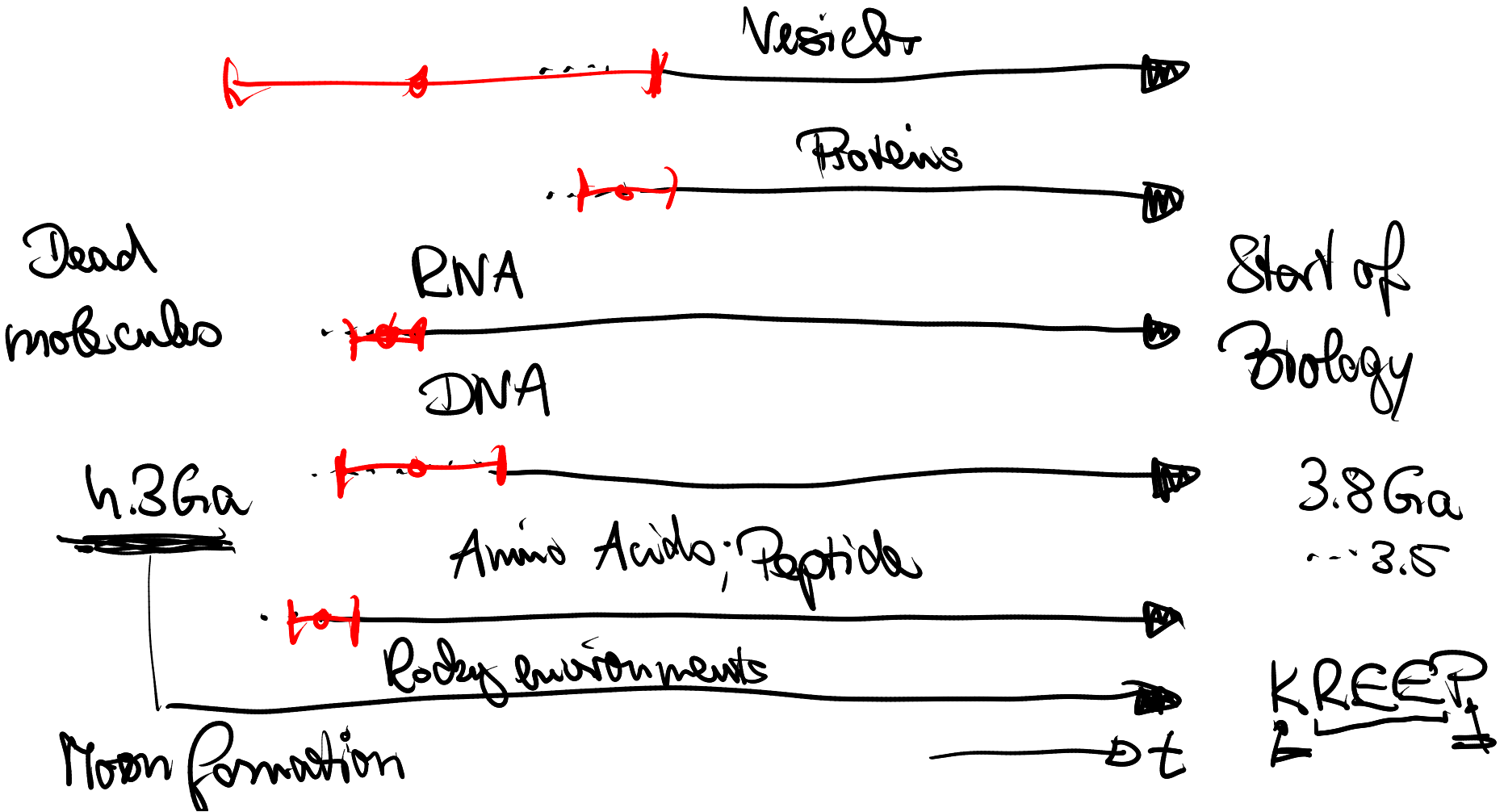
History of Biology



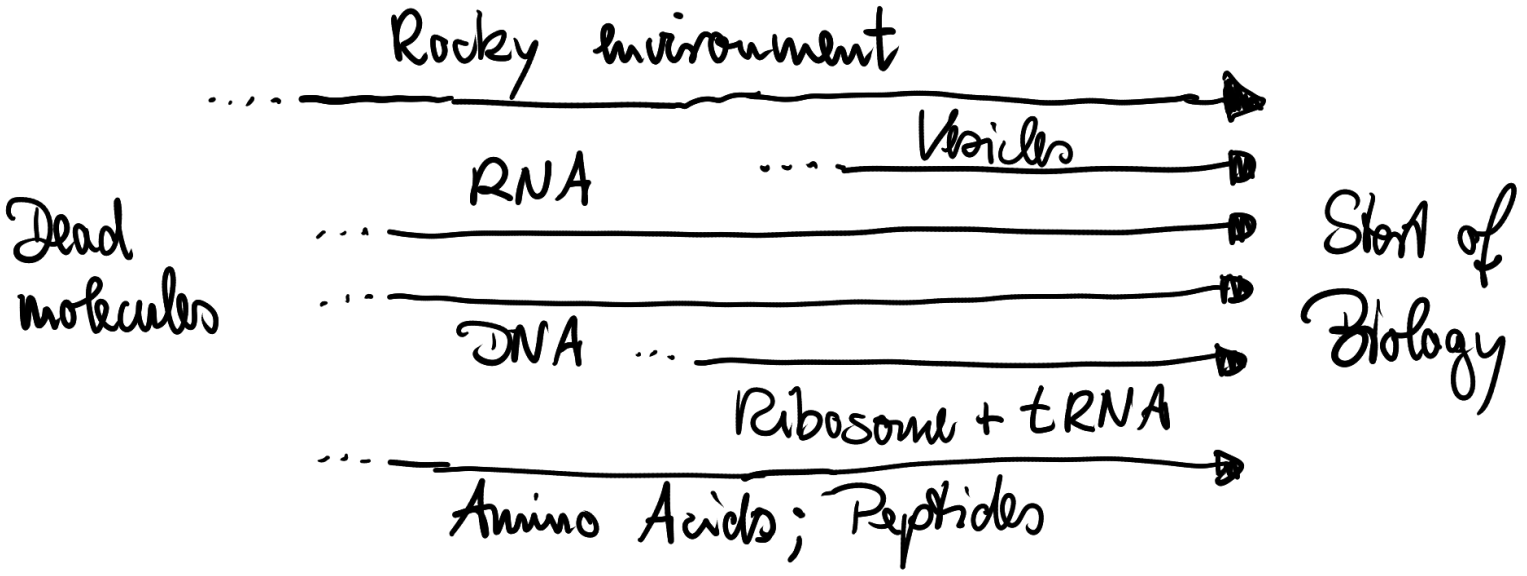




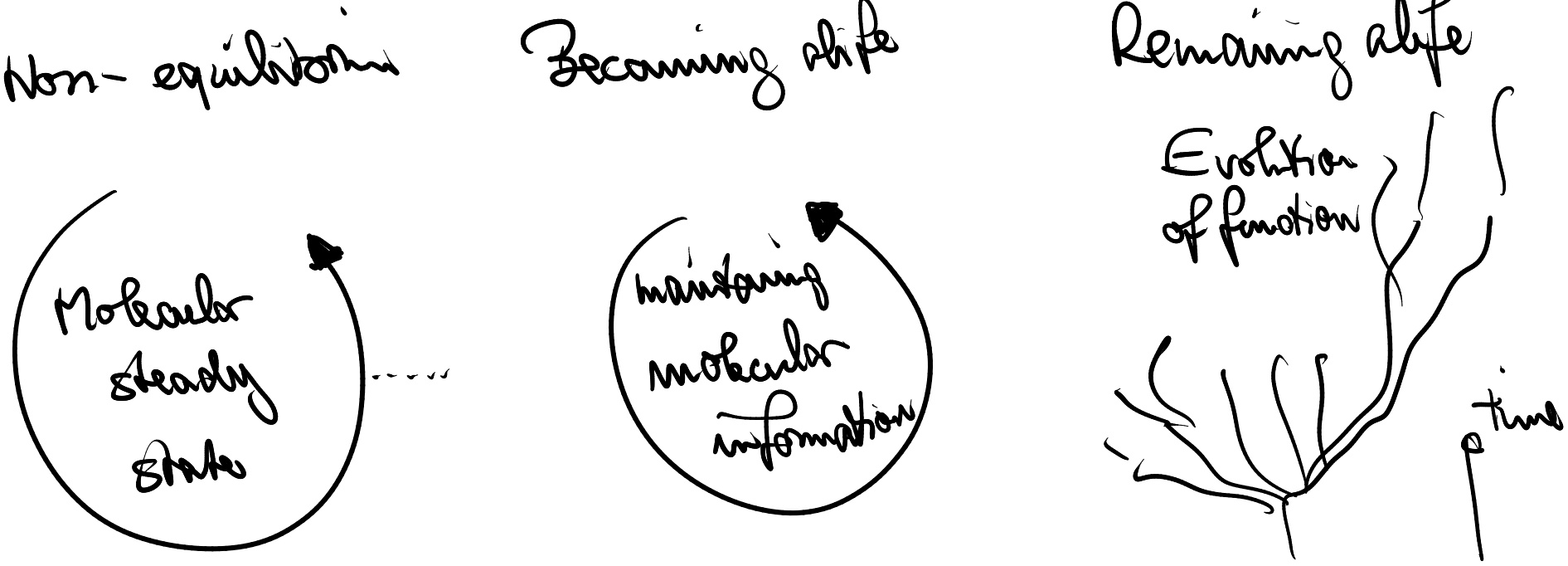
History of Biology



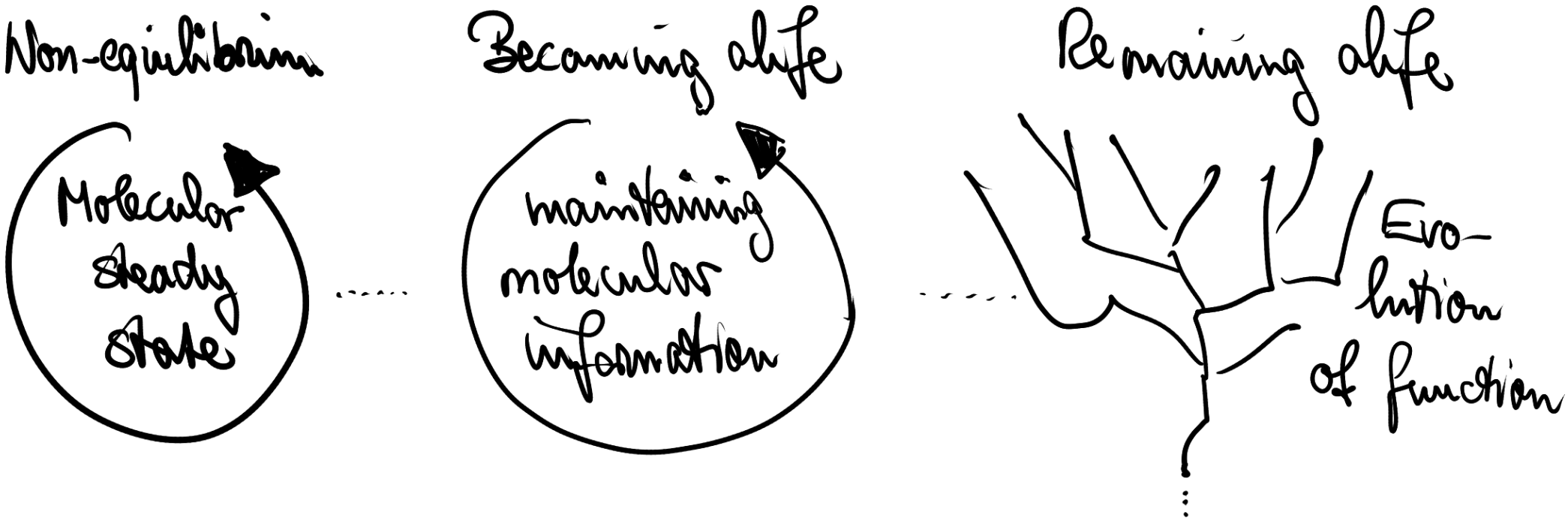
History of Biology



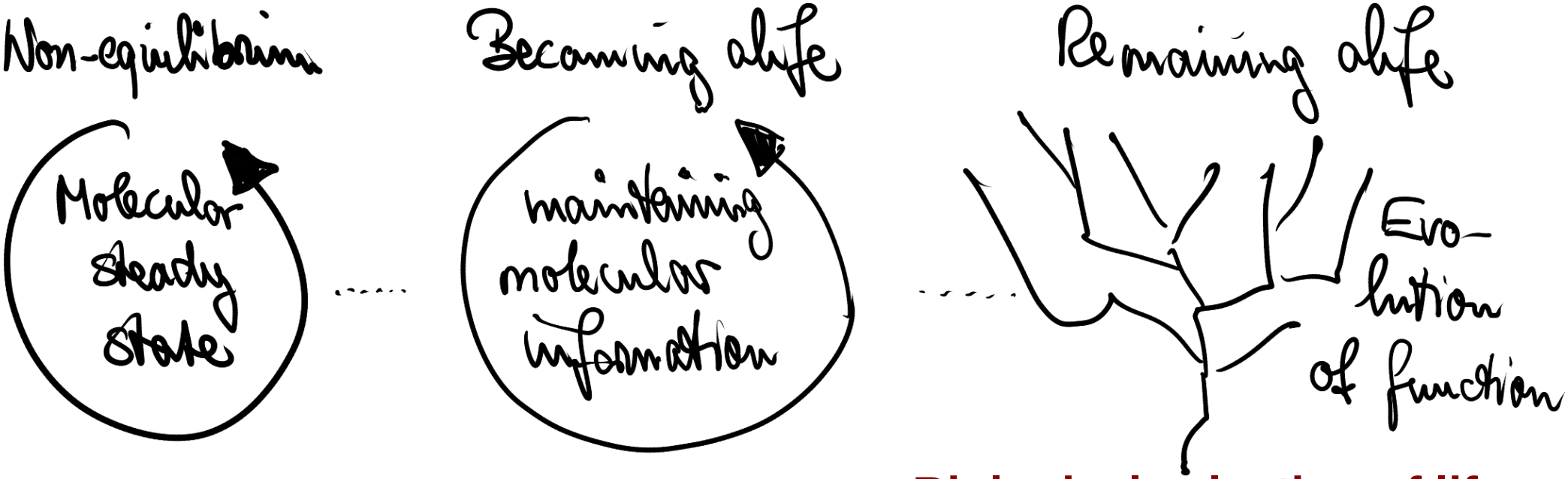
Becoming alive



Becoming alive



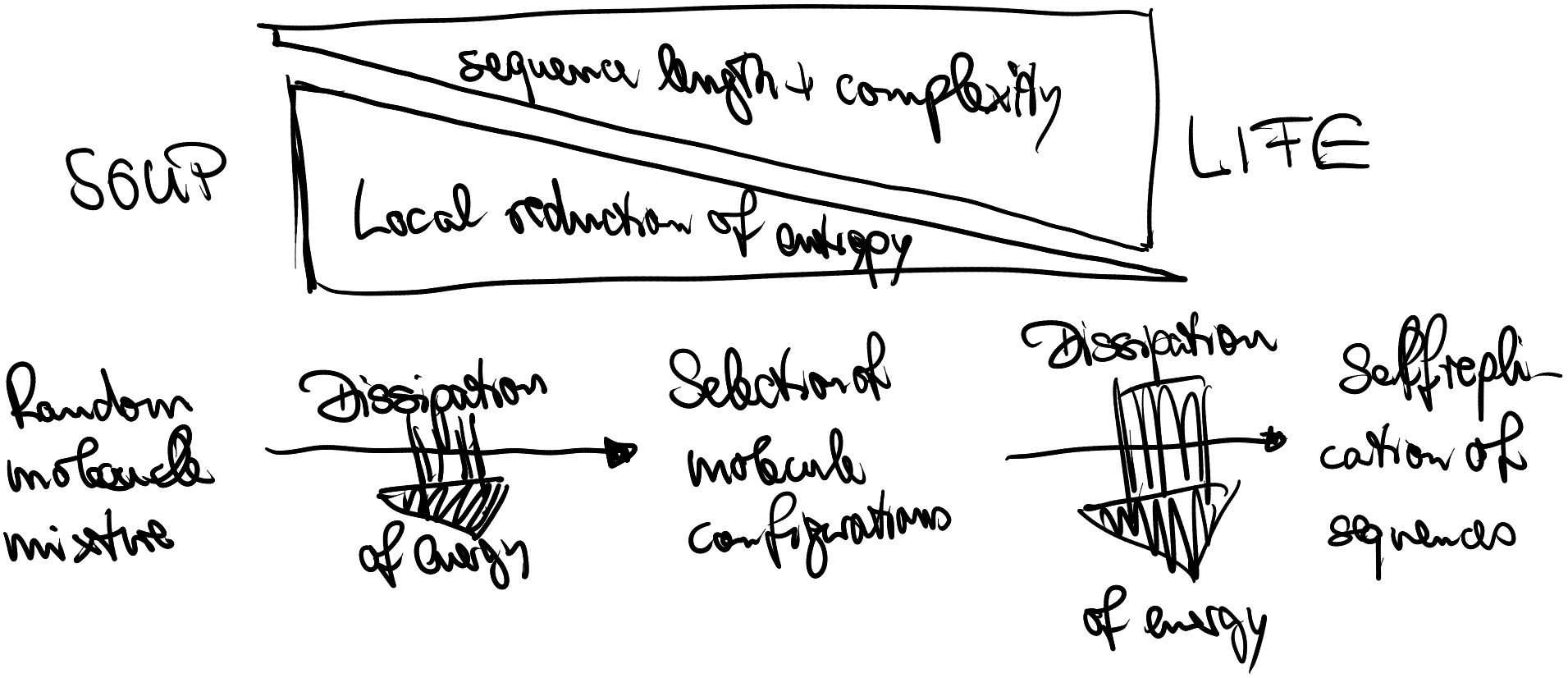
Selection before and within life



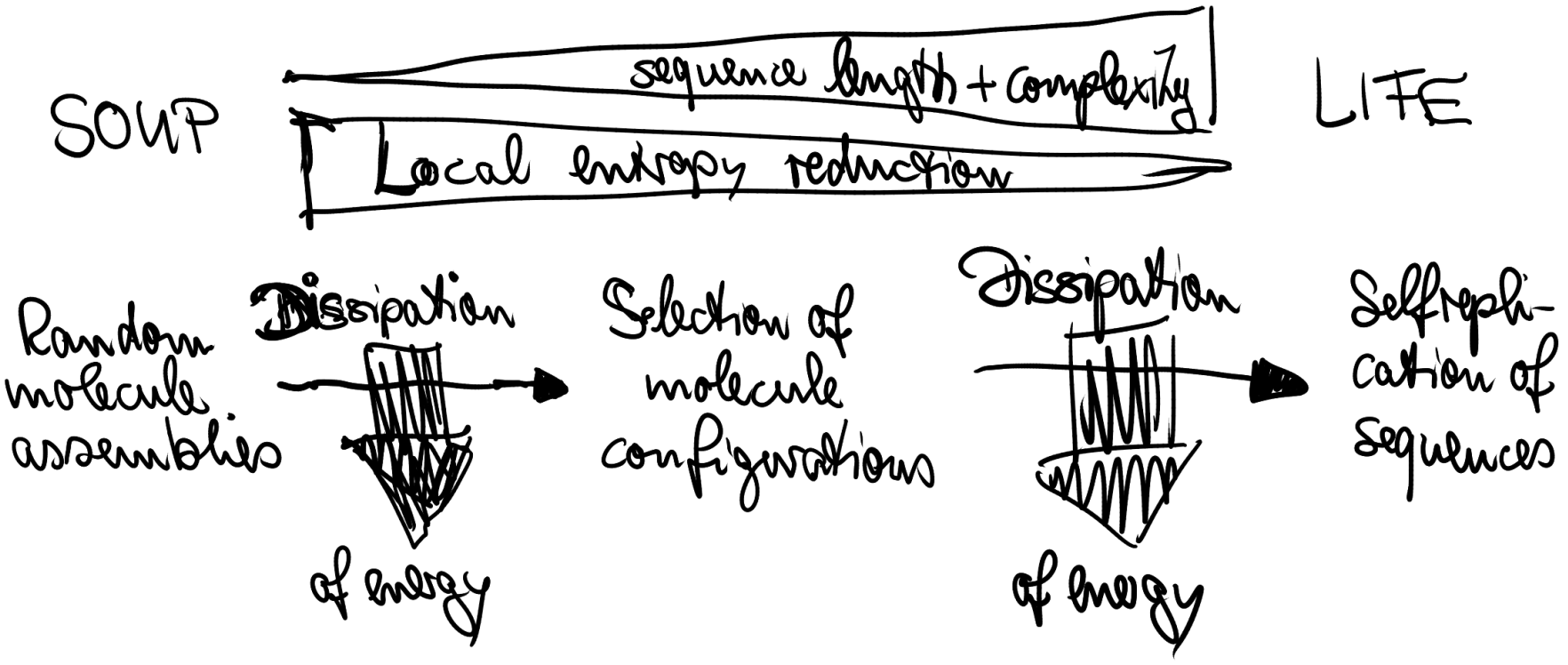
Physical selection from non-equilibrium boundary conditions

Biological selection of life against life for better adaptation to environment

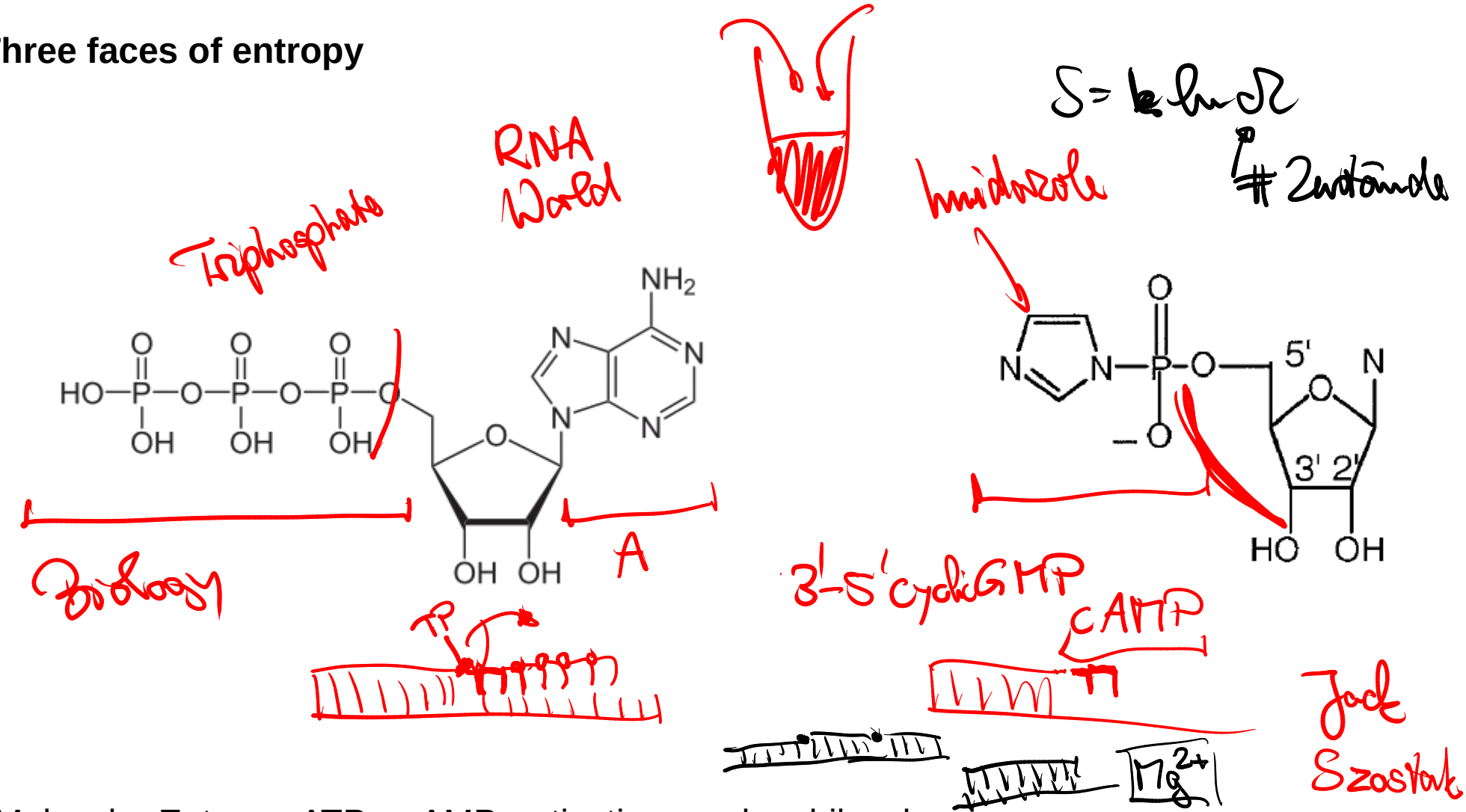
Soup of life


SOUP
sequence length + complexity
Local reduction of entropy
LIFE
Random molecule mixture
Dissipation
of energy
Selection of molecule configurations
Dissipation
of energy
Self replication of sequences

Soup of life

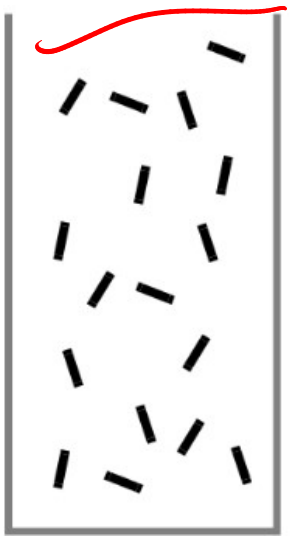

SOUP
sequence length + complexity
Local entropy reduction
LIFE
Random molecule assemblies
Dissipation of energy
Selection of molecule configurations
Dissipation of energy
Self-replication of sequences

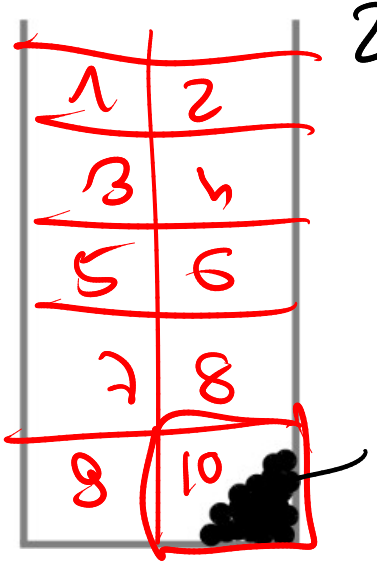
Three faces of entropy



Molecular Entropy: ATP vs AMP, activation, nucleophiles, leaving group

Three faces of entropy





1 Molecule: $\frac{1}{10}$ (Enhancement of concentration 10x)

20 Molecules: $\frac{1}{10^{20}}$

$S \sim \ln V$

Concentration: Entropy part of chemical potential

Localization Entropy: chances to find molecules, probability of reaction, leaving group

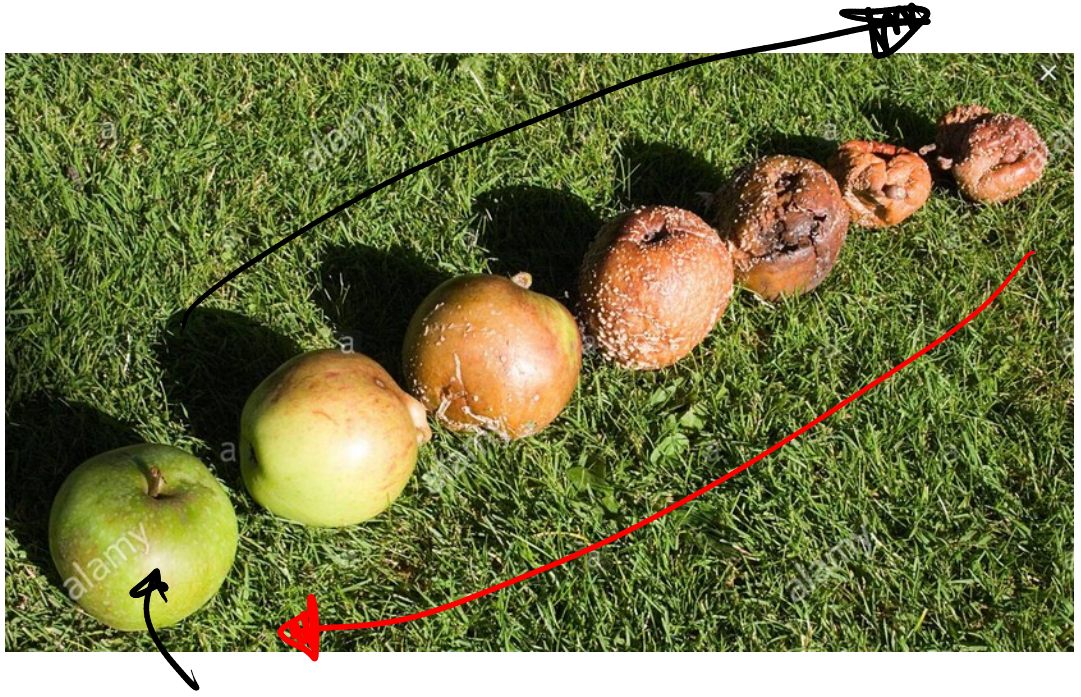
Three faces of entropy

$$H(X) = -\sum_{i=1}^{n} p_i \log_2 p_i$$

ATTTTTATATATAAAATATATATA

Sequence Entropy: information stored in DNA or RNA to be replicated

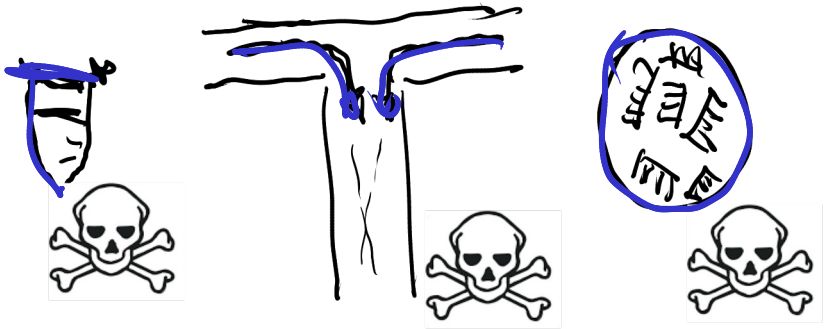
Death of equilibrium

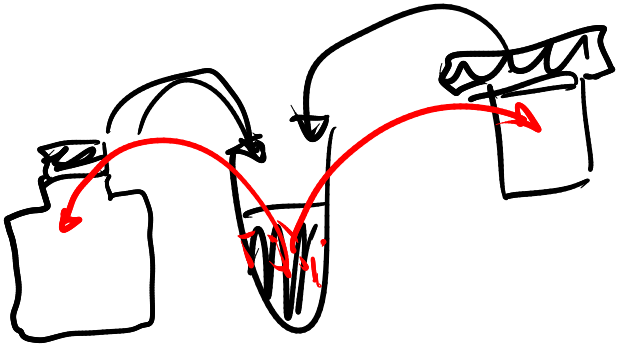


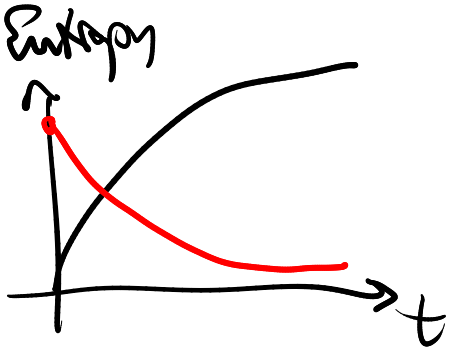
Death of equilibrium

Death of equilibrium

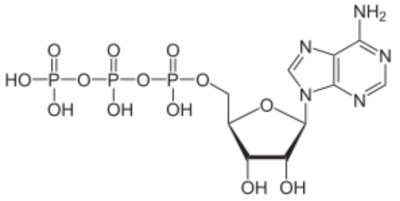
Equilibria are dead







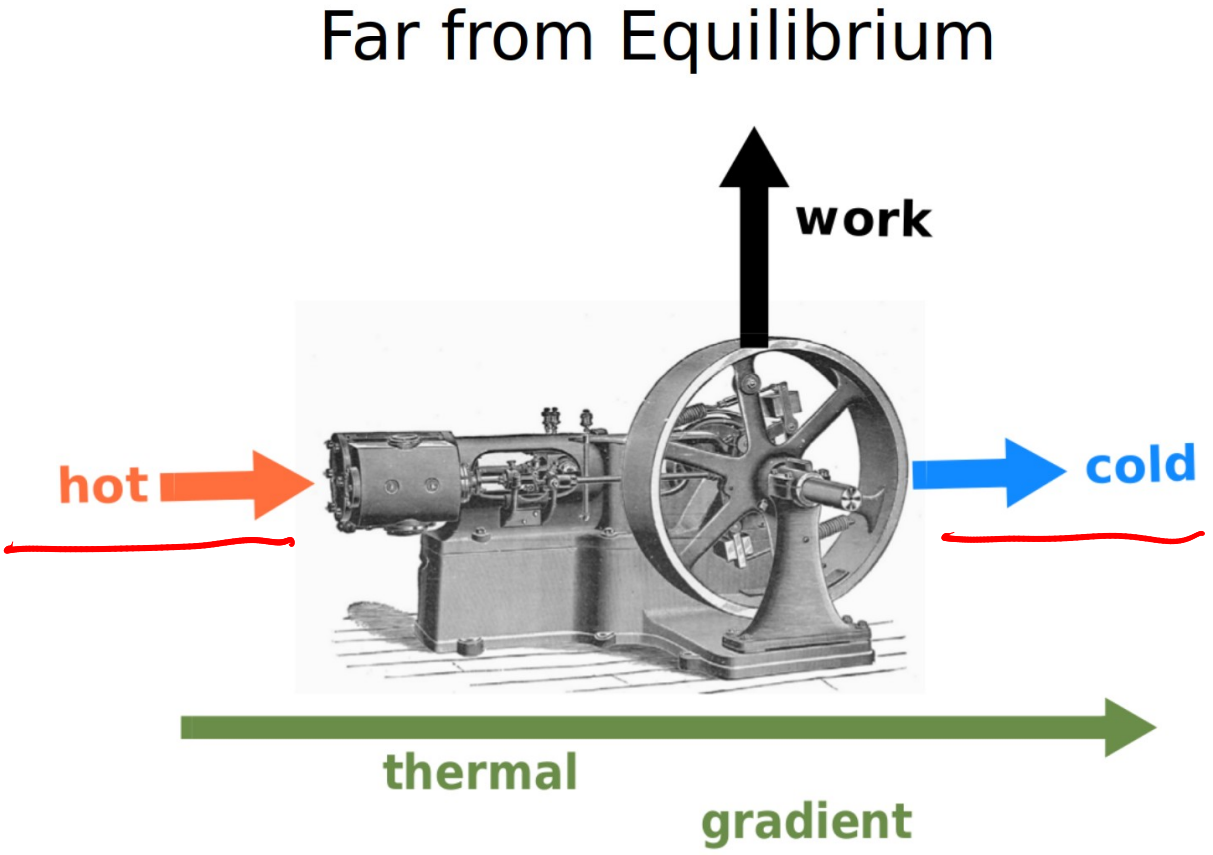
Assumed nonequilibrium



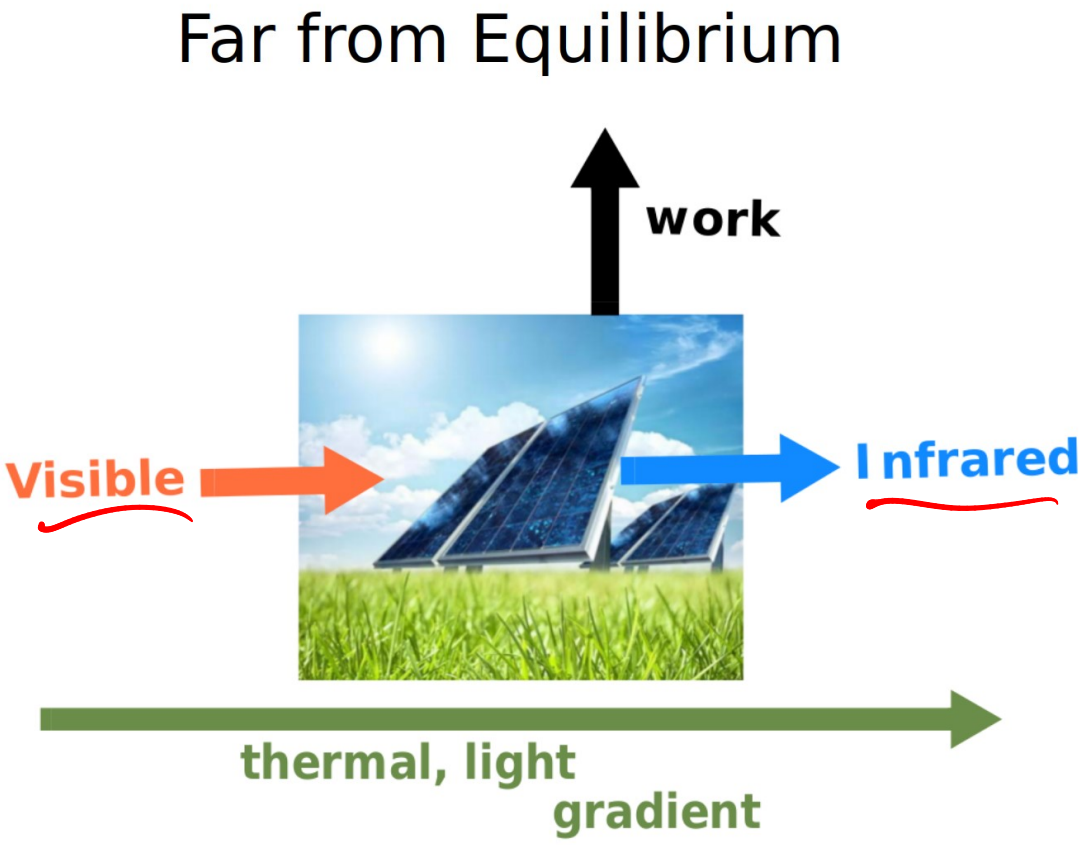
→ Experimentally make the non-equilibrium.

Modes of non-equilibrium

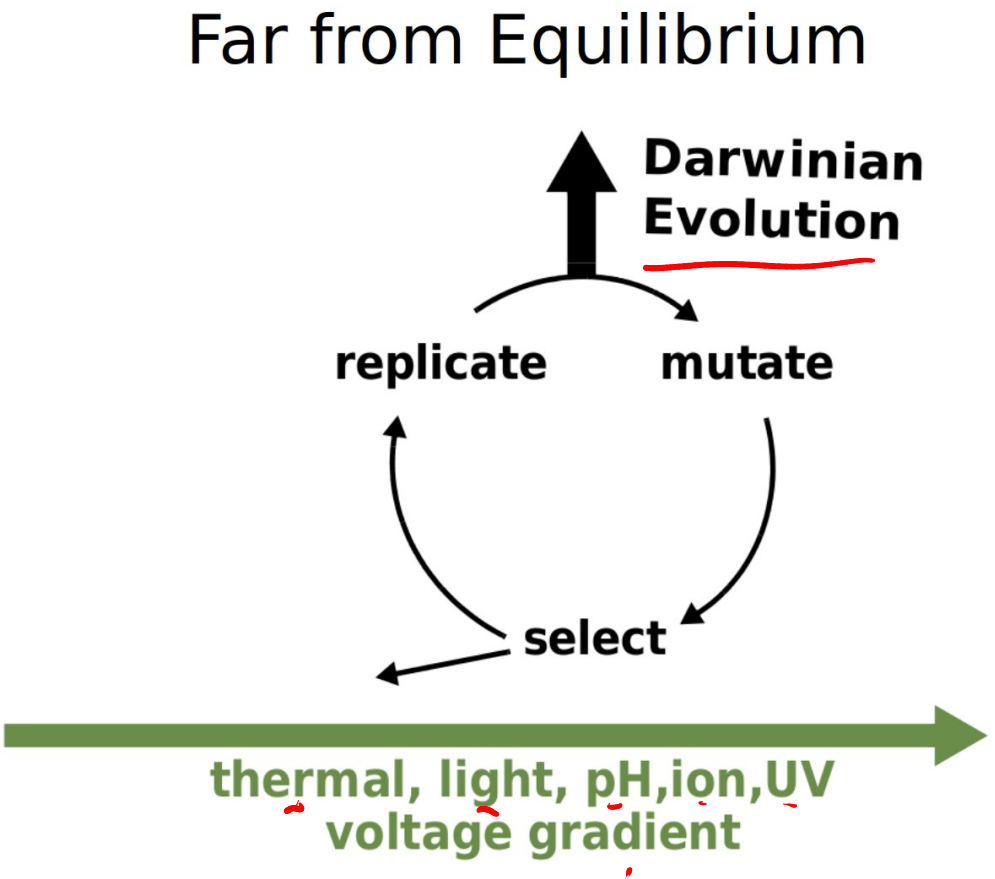
Modes of non-equilibrium



Modes of non-equilibrium



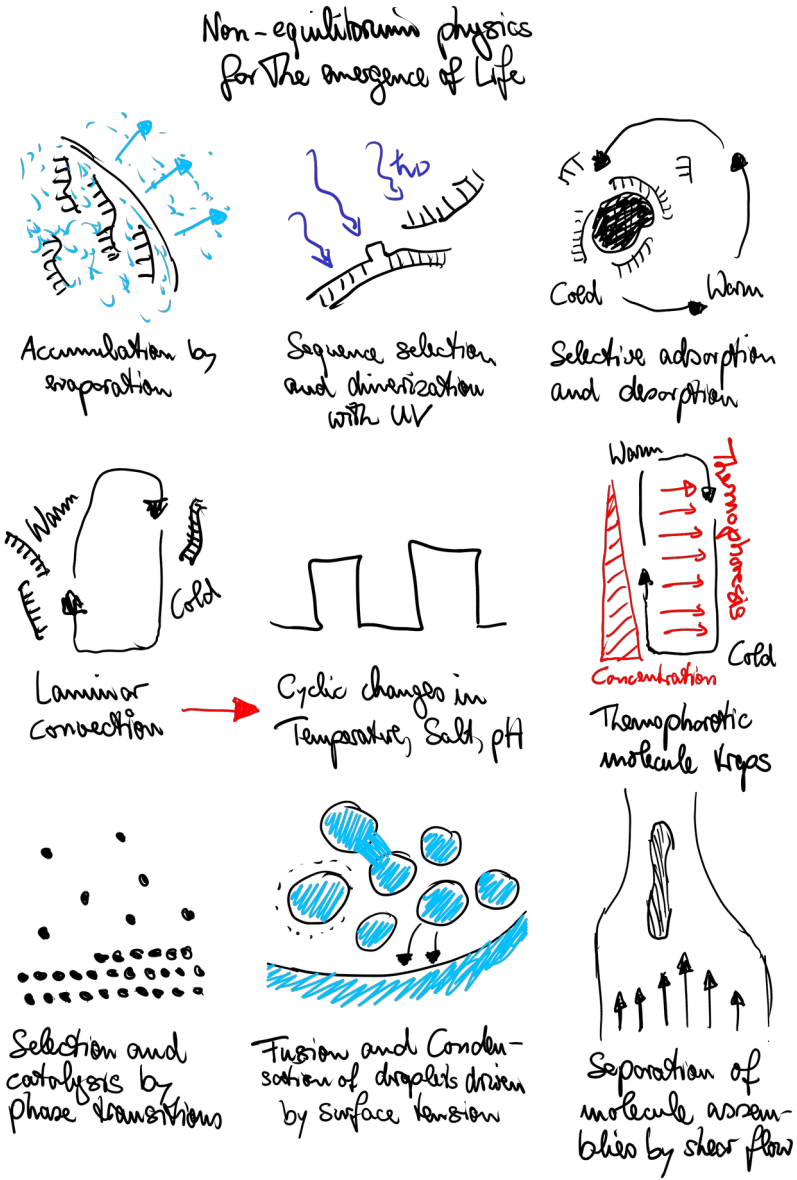
Modes of non-equilibrium



Modes of non-equilibrium

Modes of non-equilibrium

Modes of non-equilibrium



Structure of Origin of Life

Nucleotides (possibly stored)

Chemical conditions:
- Polymerization
- Ligation
- Activation

Physical non-equilibrium:
- Strand separation
- Maintaining accumulation
- Feeding and
  Waste removal

Some upcoming molecular machines

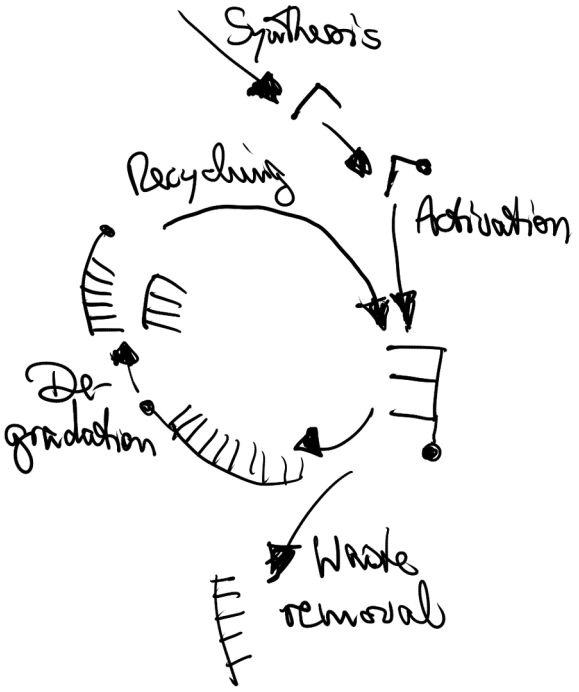
Structure of Origin of Life

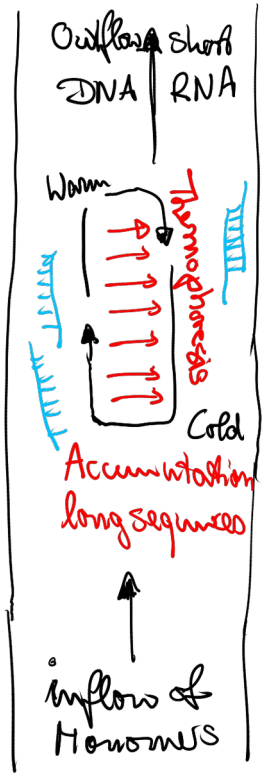
Chemical nonequilibrium in physical nonequilibrium

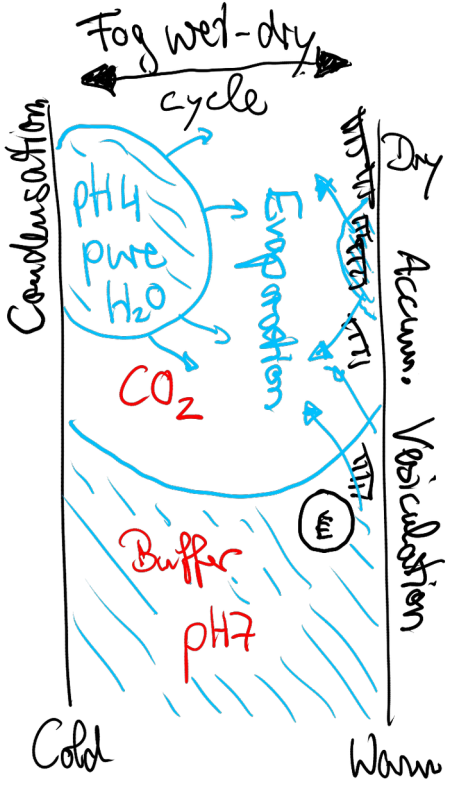
Nucleotides (possibly stored)

Chemical conditions:
- Polymerization
- Ligation
- Activation

Physical non-equilibrium:
- Strand separation
- Maintaining accumulation
- Feeding and
  Waste removal







Some upcoming molecular machines

Structure of Origin of Life

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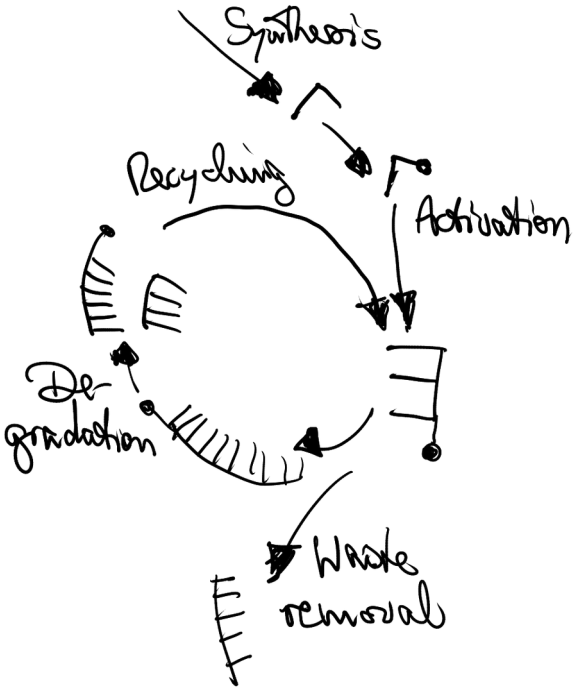
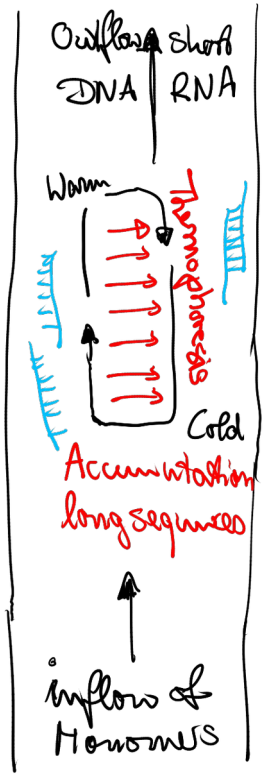
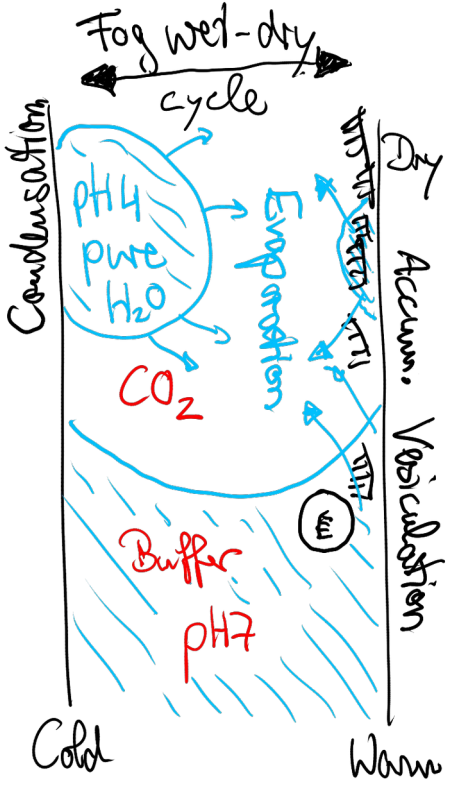
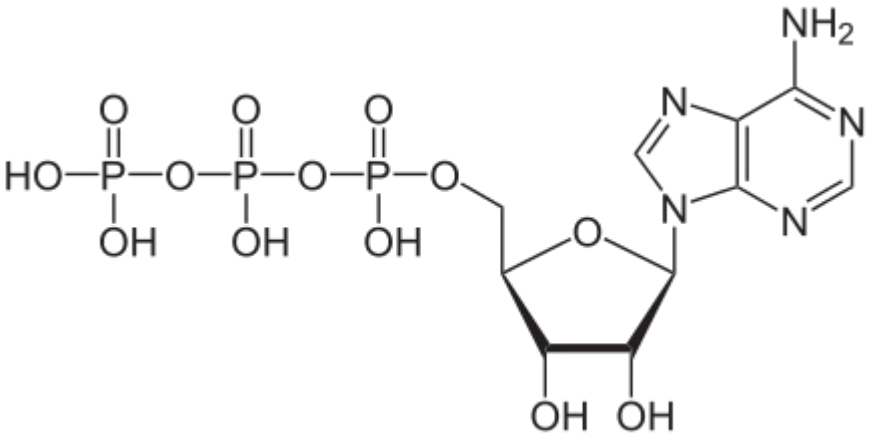


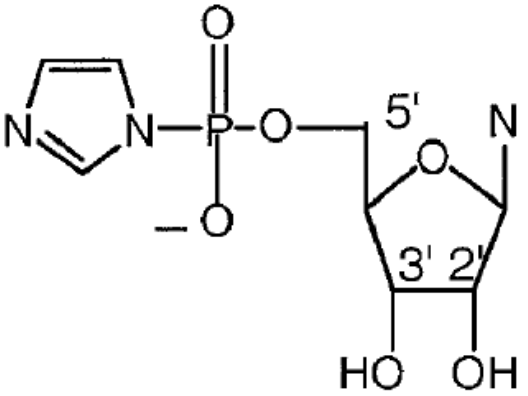




Some upcoming molecular machines

Three faces of entropy





Molecular Entropy: ATP vs AMP, activation, nucleophiles, leaving group