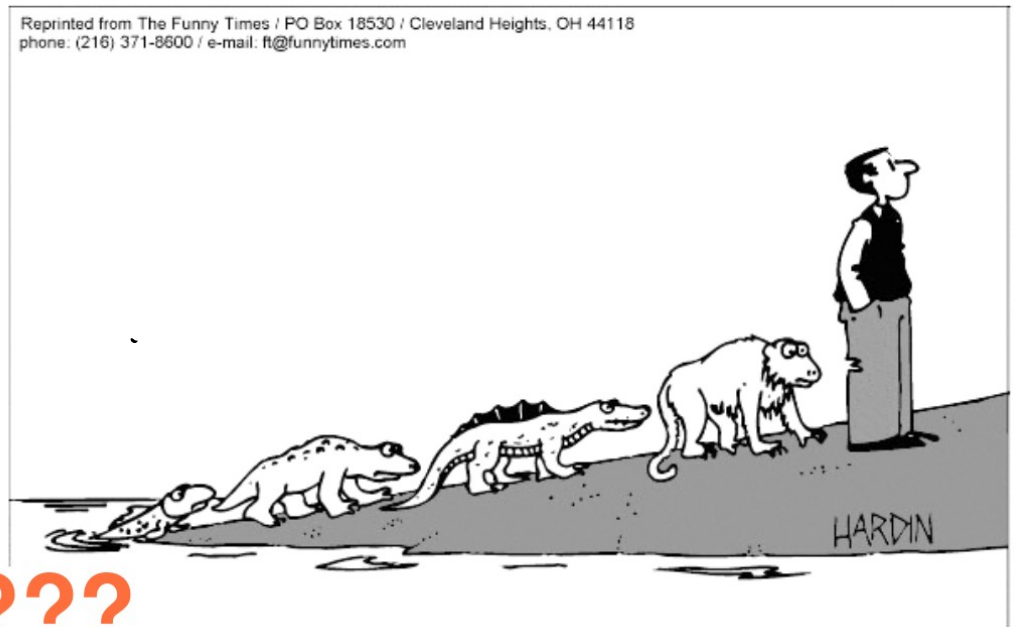
How did we get here?



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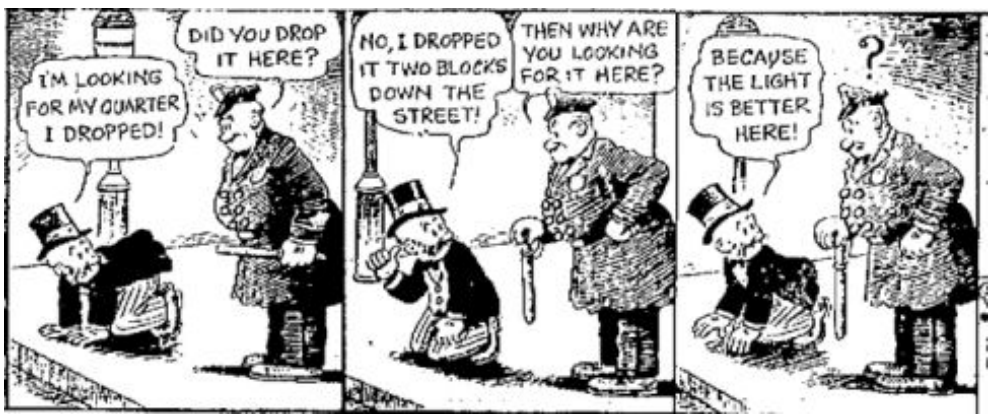
Exams Friday 11th September?

and 24th July (Friday)
9^00, 9^20



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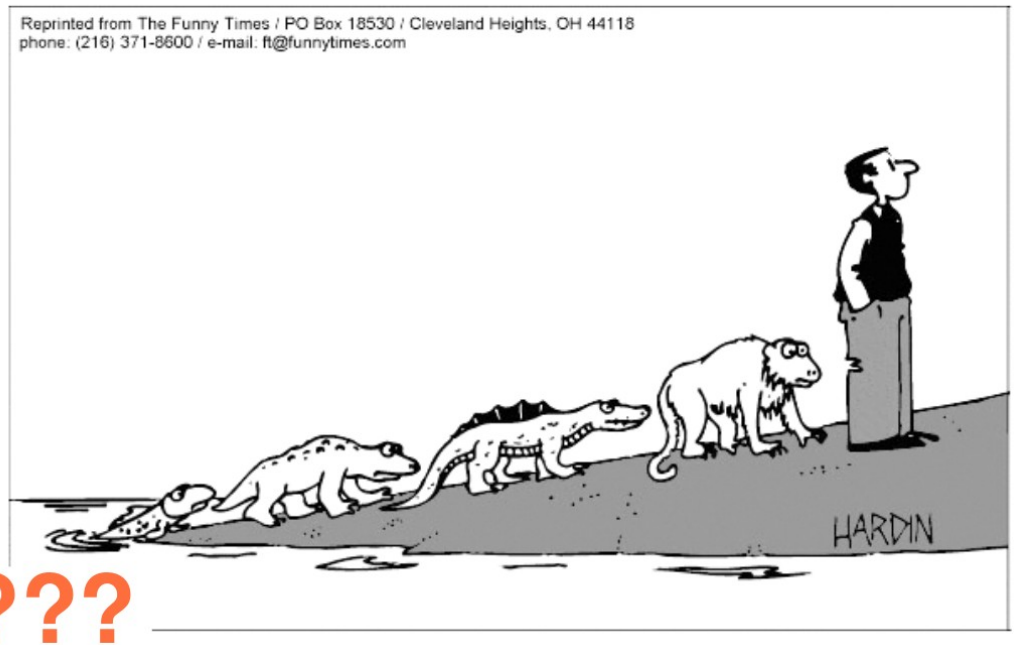

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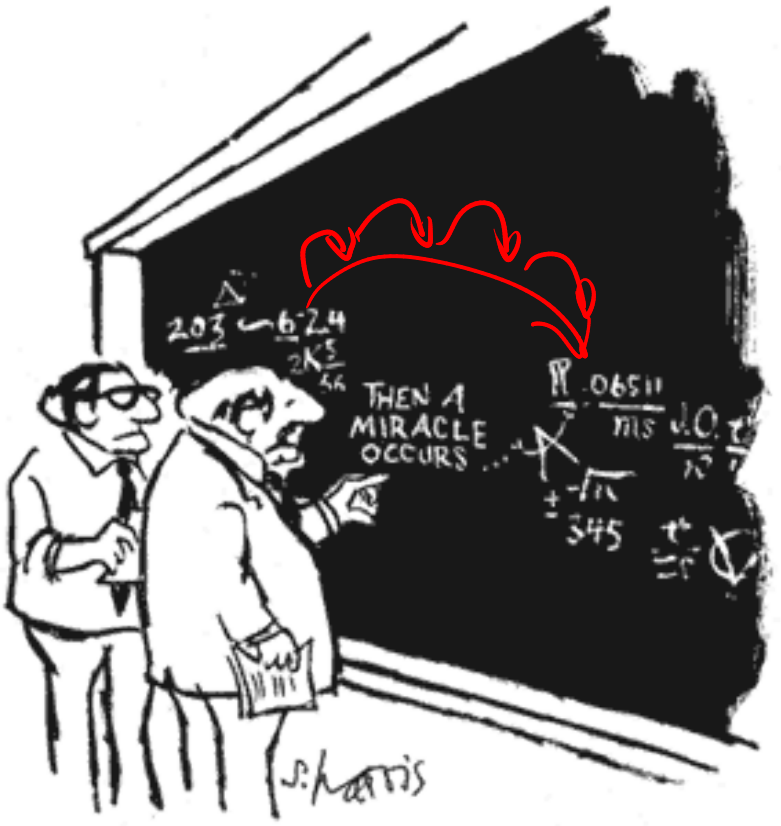
Evolution and the Origins of Life



"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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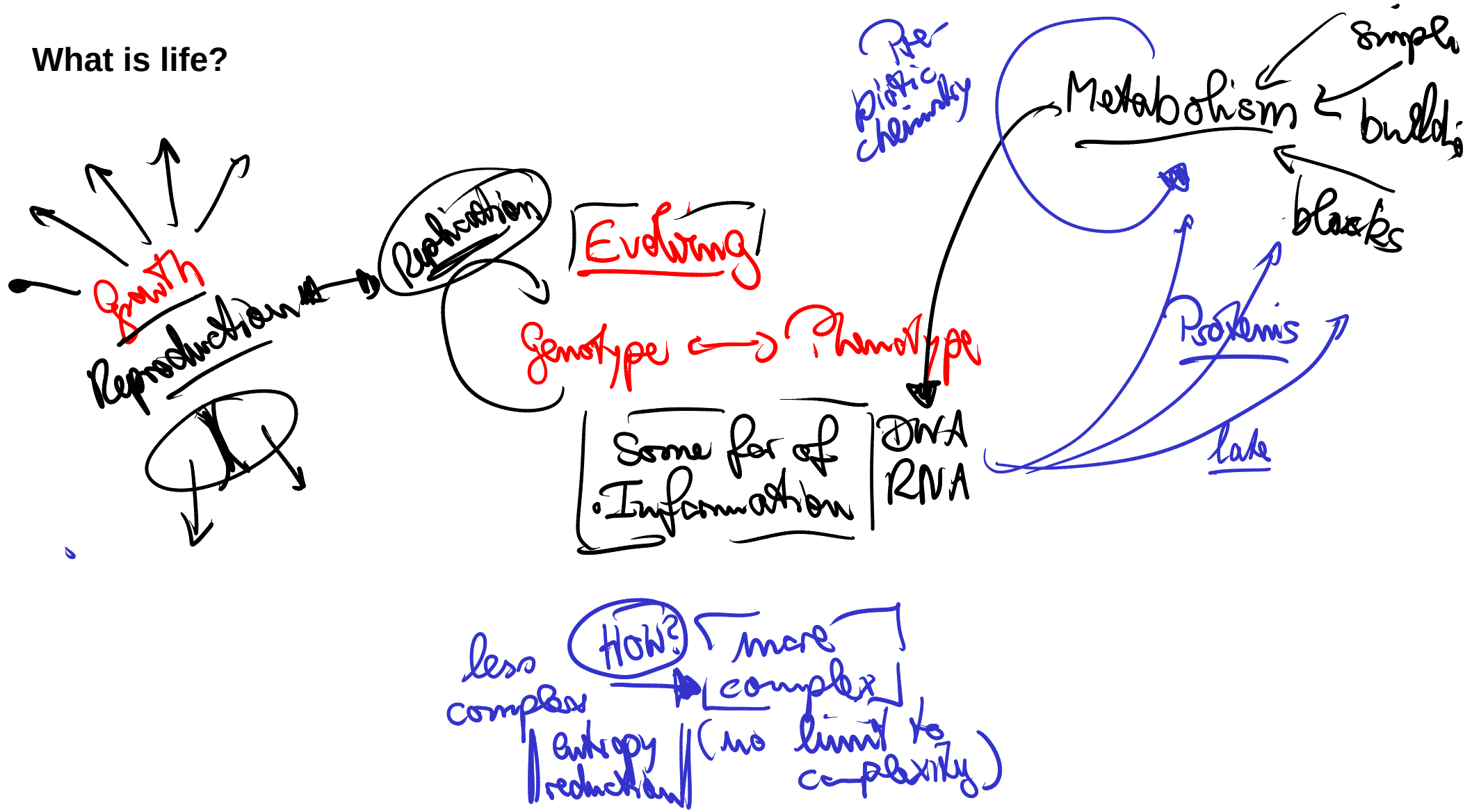
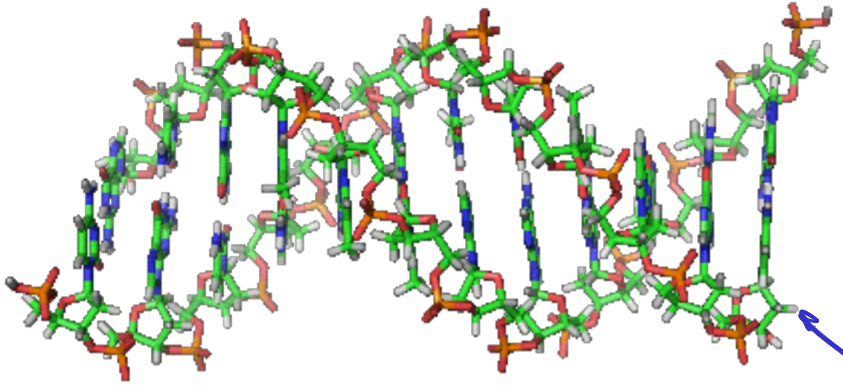
What is life?

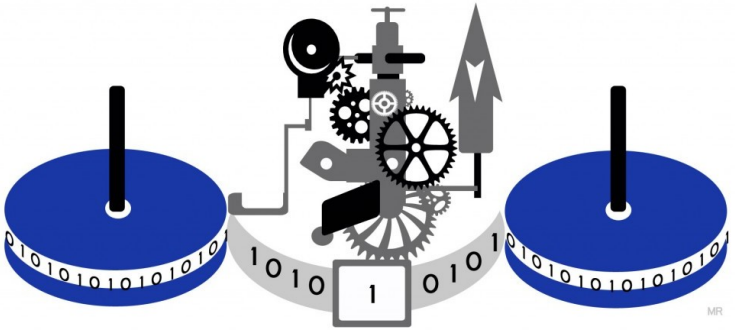

Growth
Reproduction
Replication
Evolving
Genotype → Phenotype
Some for of Information
DNA
RNA
Pre Biotic chemistry
Metabolism
simple
building blocks
Proteins
Lipids
less complex
entropy reduction
HOW?
more complex
(no limit to complexity)

What is life?

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

Logic of Molecular Biology





Storage of information very similar to Turing machine => Computer

Ribosome

RNA

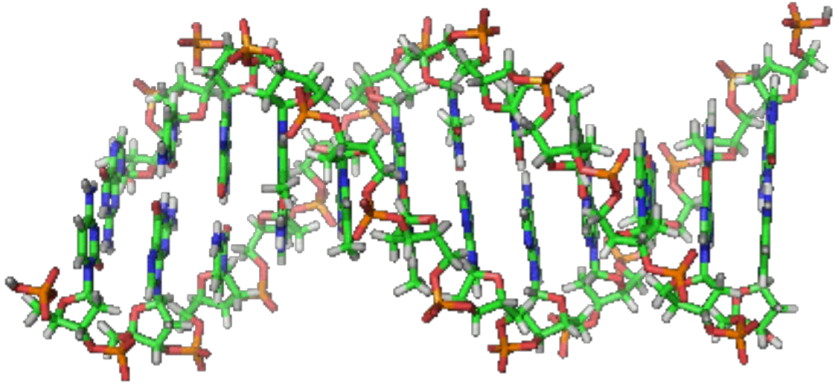
Protein

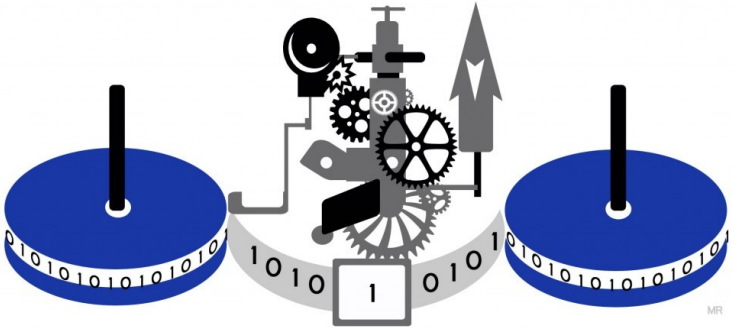
Metabolism

Machine

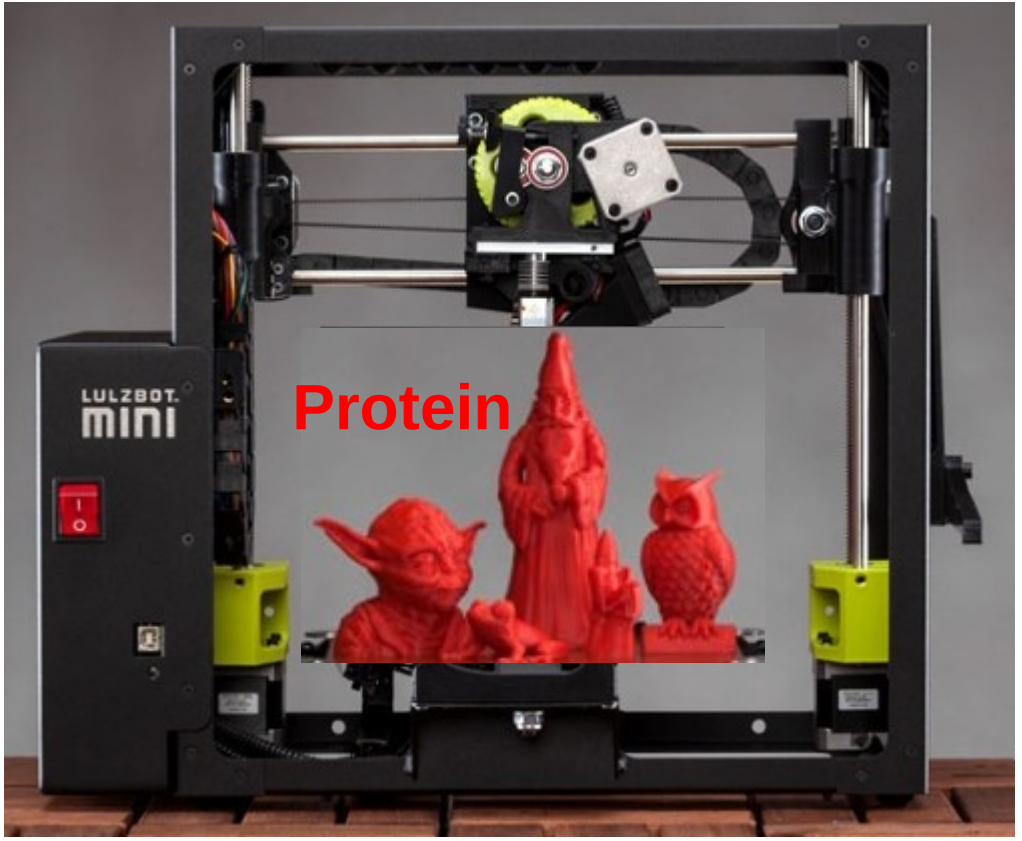
build itself

Logic of Molecular Biology



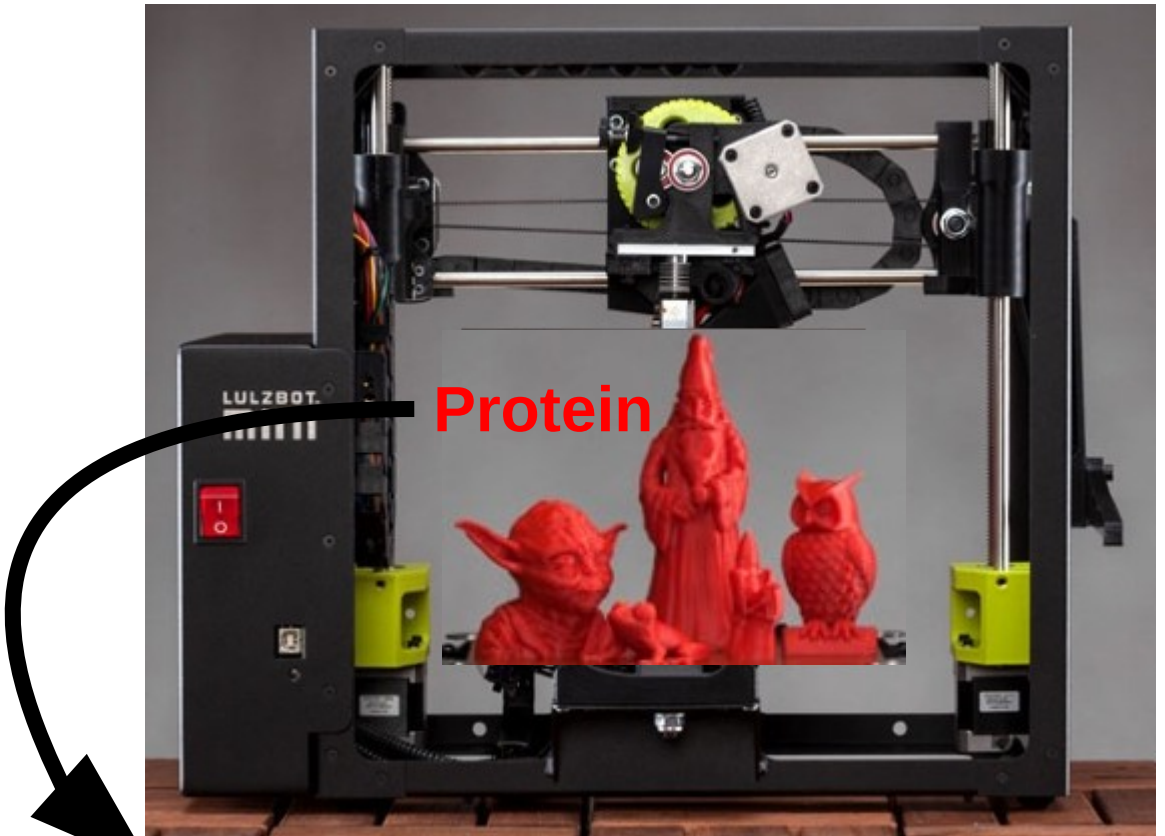


Storage of information very similar to Turing machine => Computer

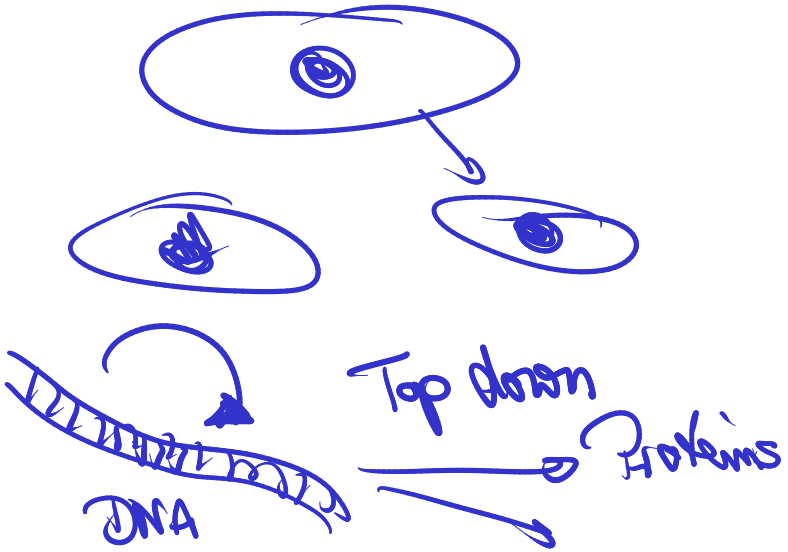


DNA+RNA

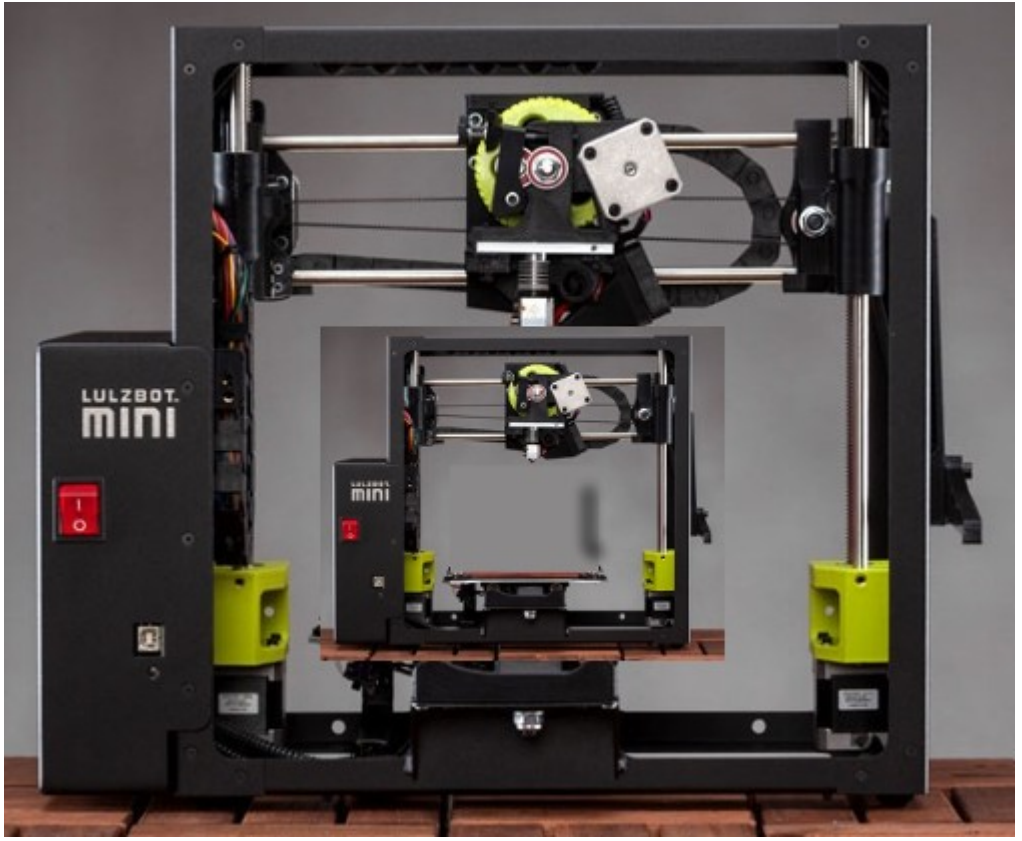
Logic of Molecular Biology



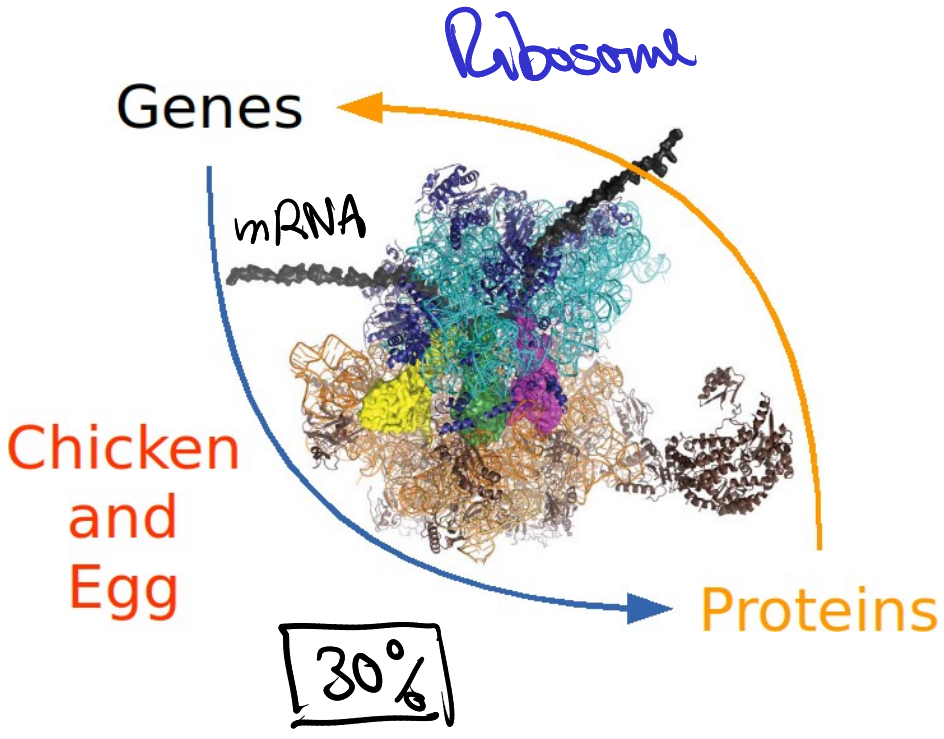
Logic of Molecular Biology



How to make a machine that makes itself?



Logic of Molecular Biology



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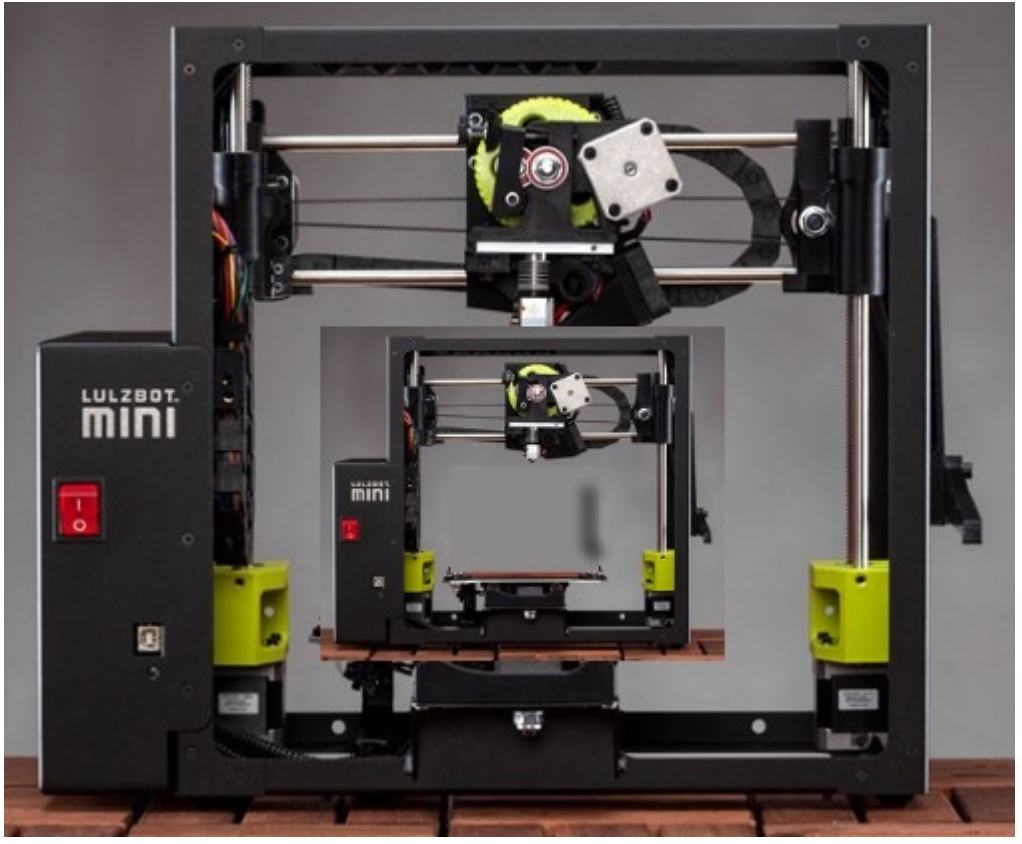
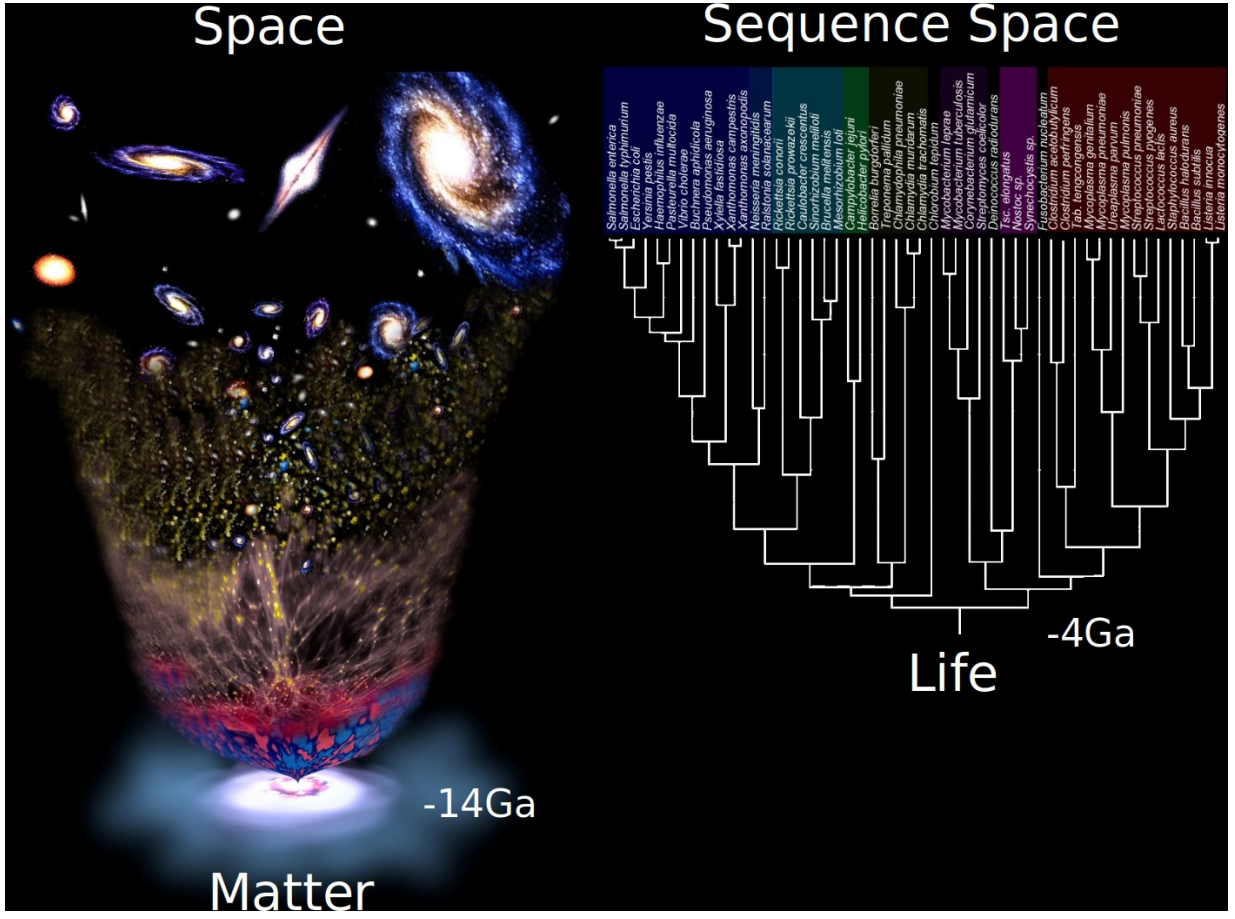
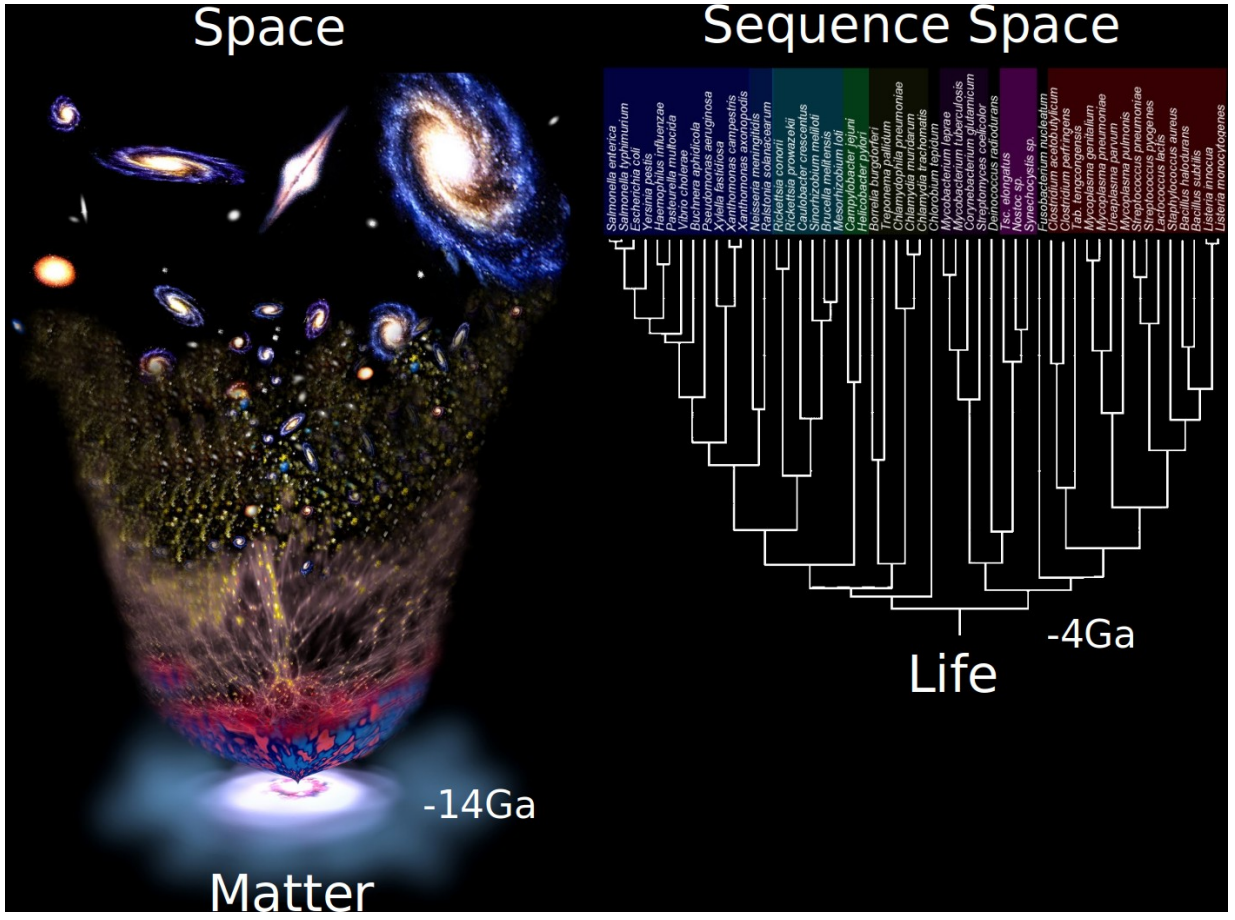
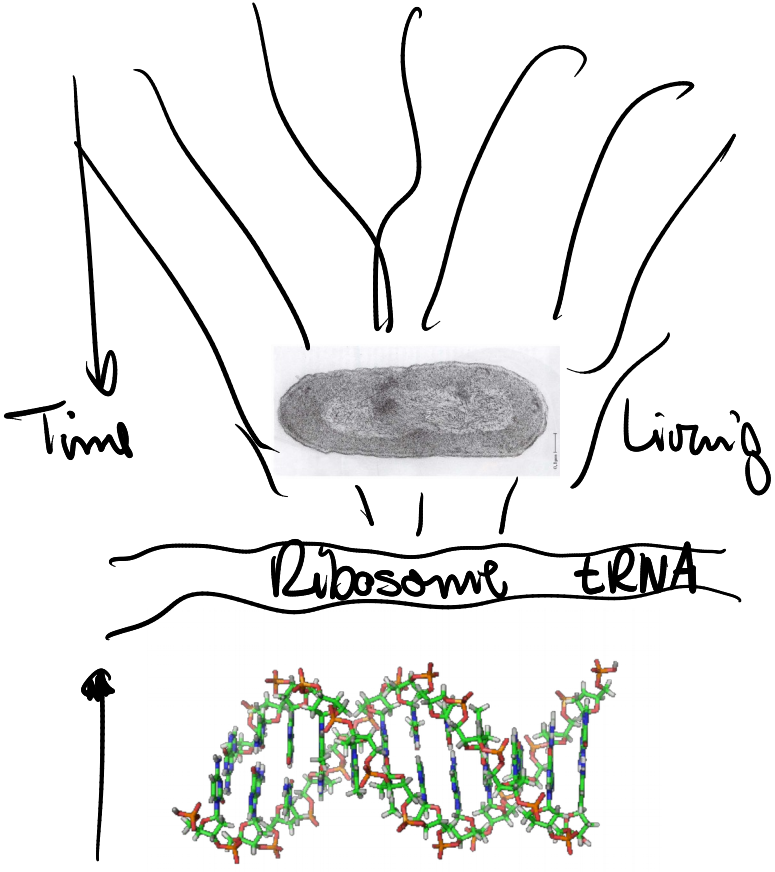


History of Biology

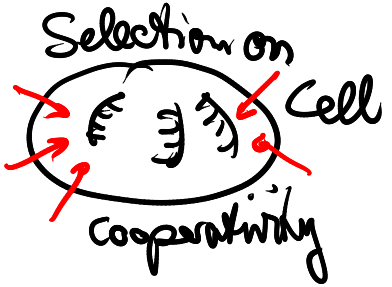


History of Biology





History of Biology



Rocky environment

Porous Environment

Vesicles

RNA+DNA

Ribosome + tRNA

Amino Acids & Peptides

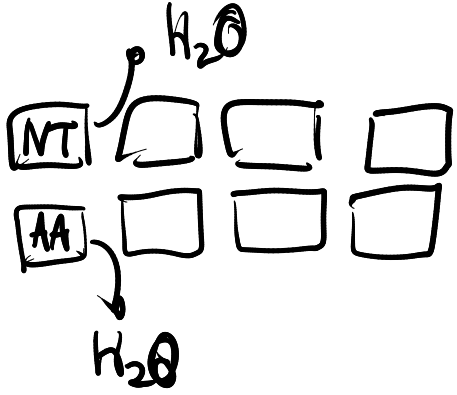
Dead Molecules

?

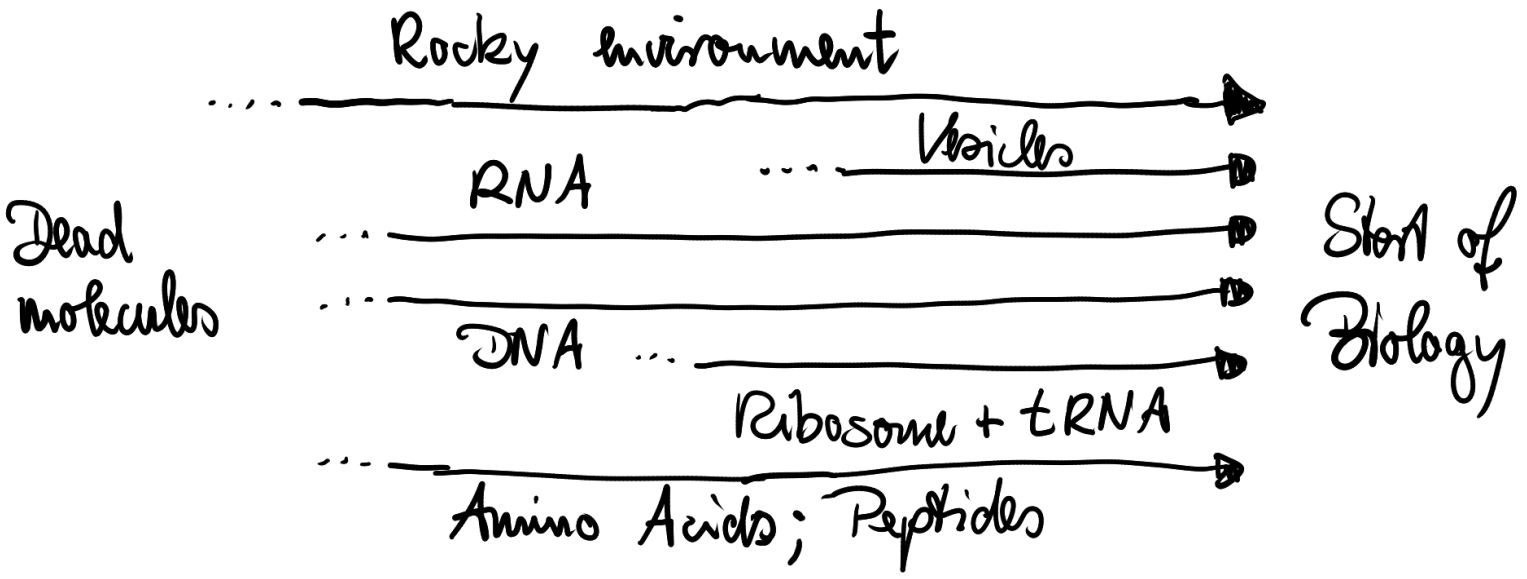
Mess

Start of Biology

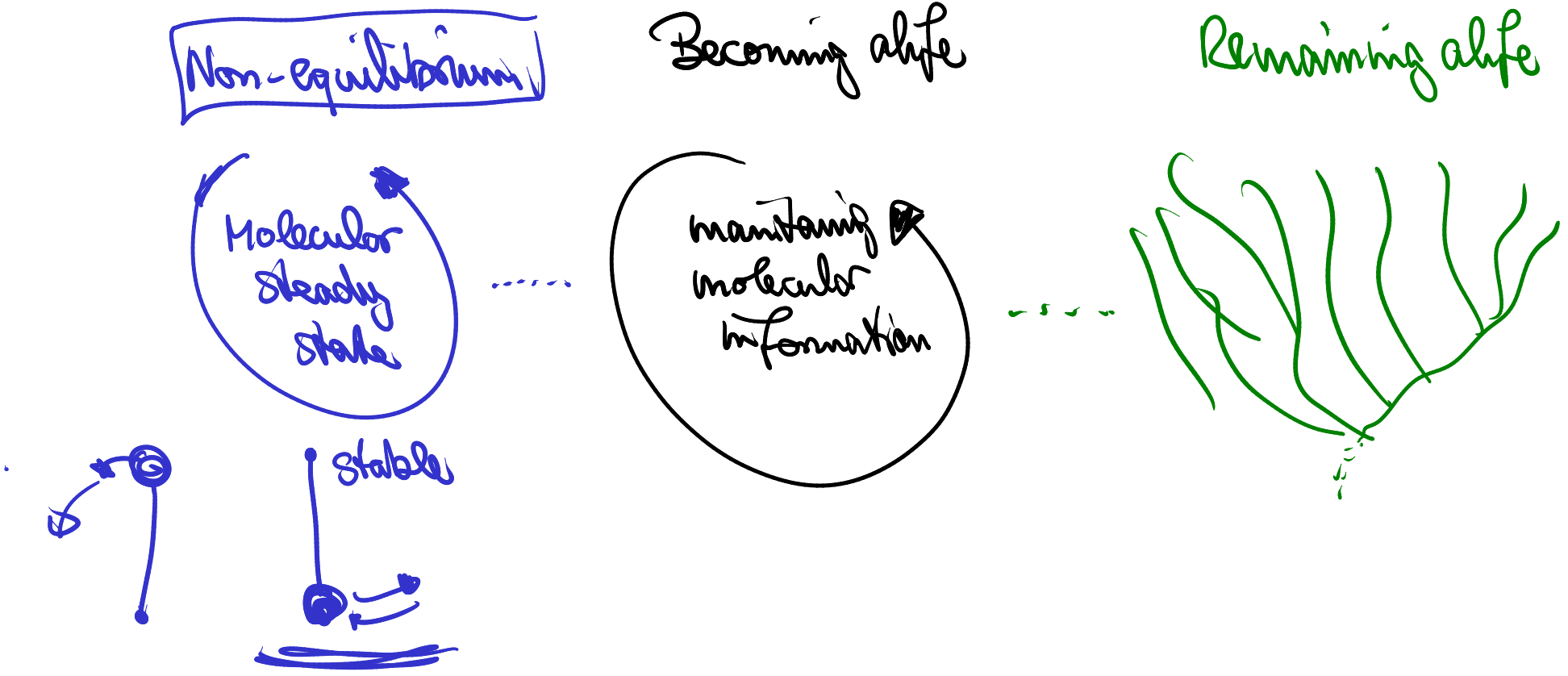
Time



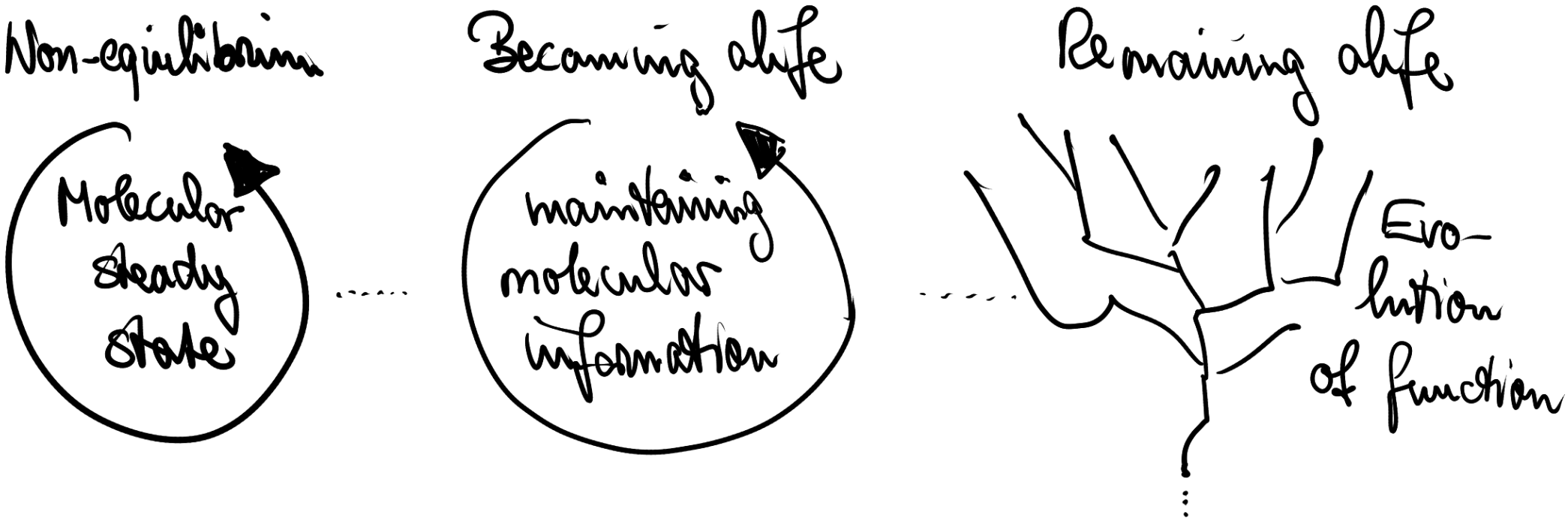
History of Biology



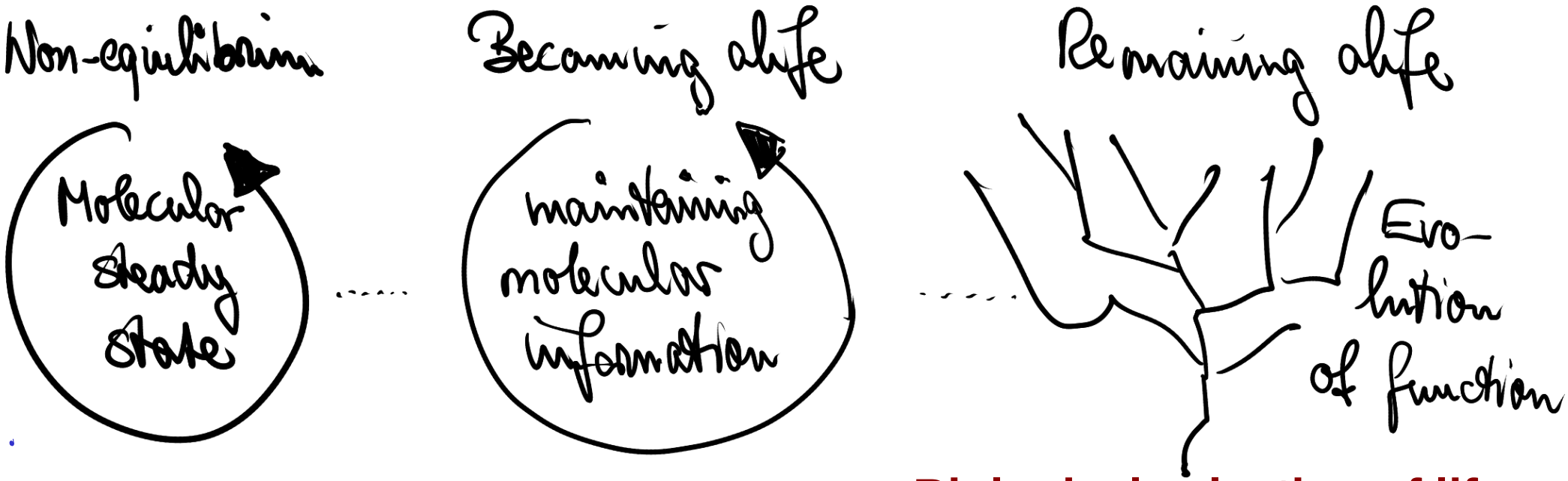
Becoming alive



Becoming alive



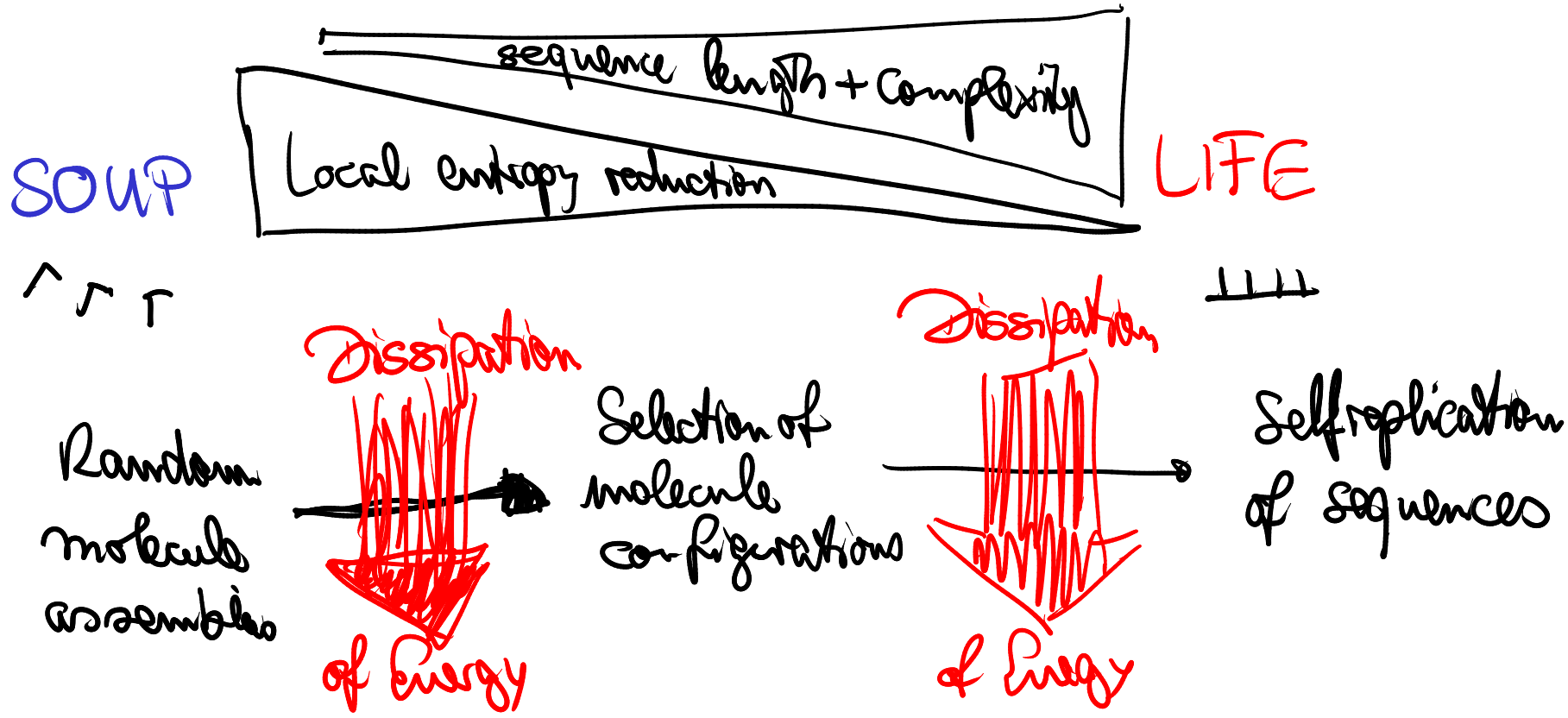
Selection before and within life



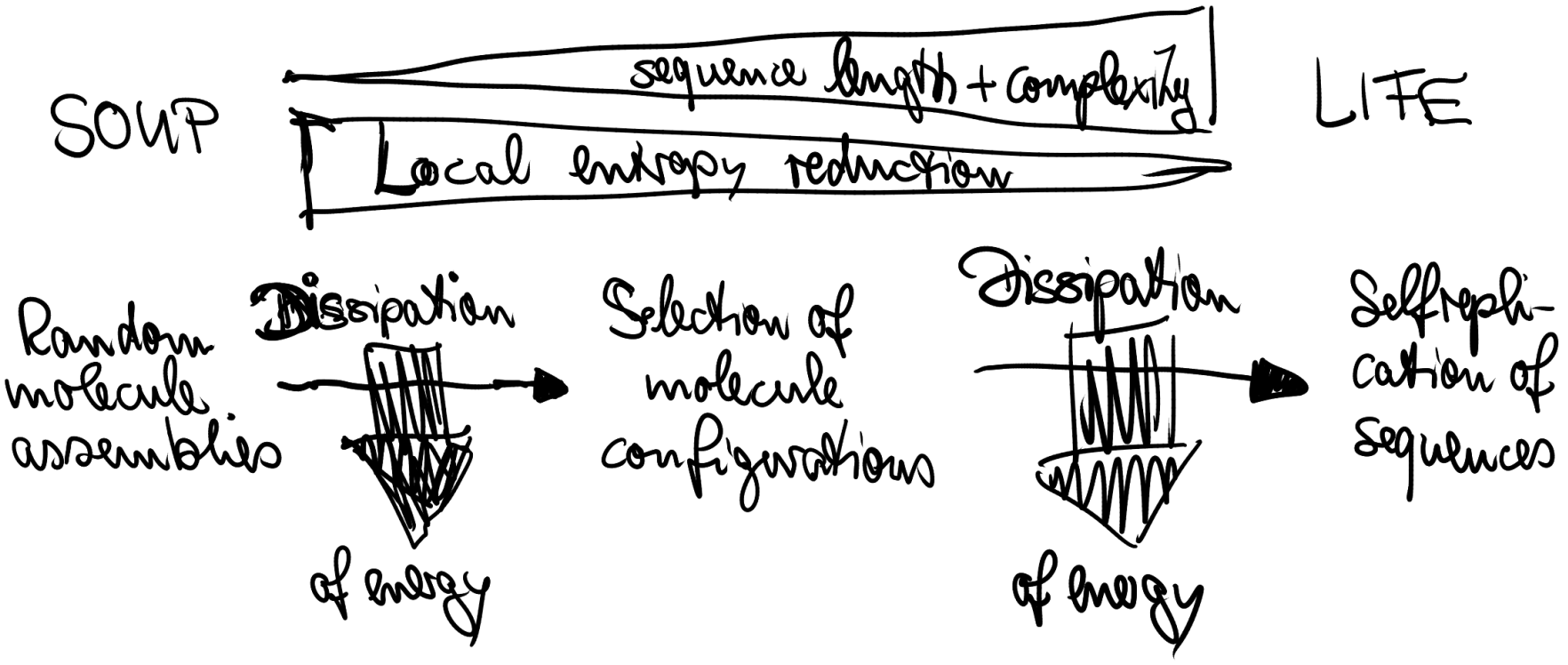
Physical selection from non-equilibrium boundary conditions

Biological selection of life against life for better adaptation to environment

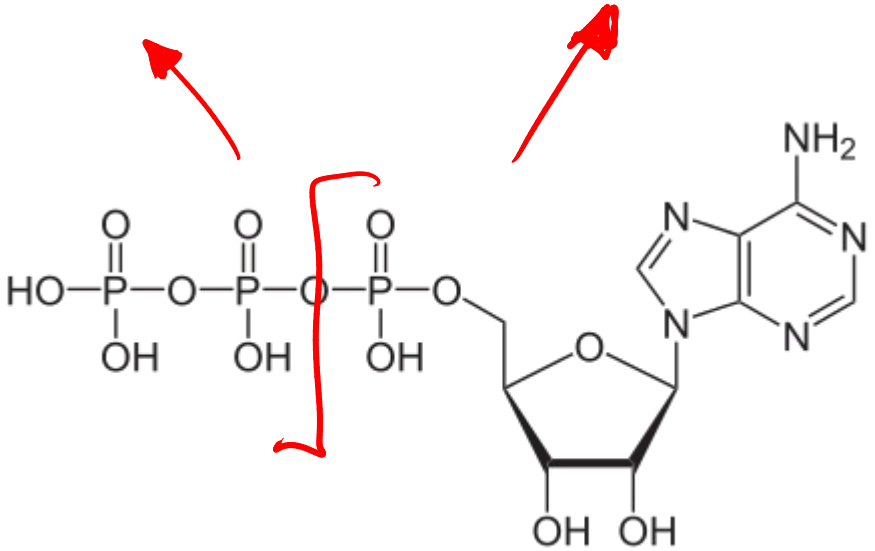
Soup of life

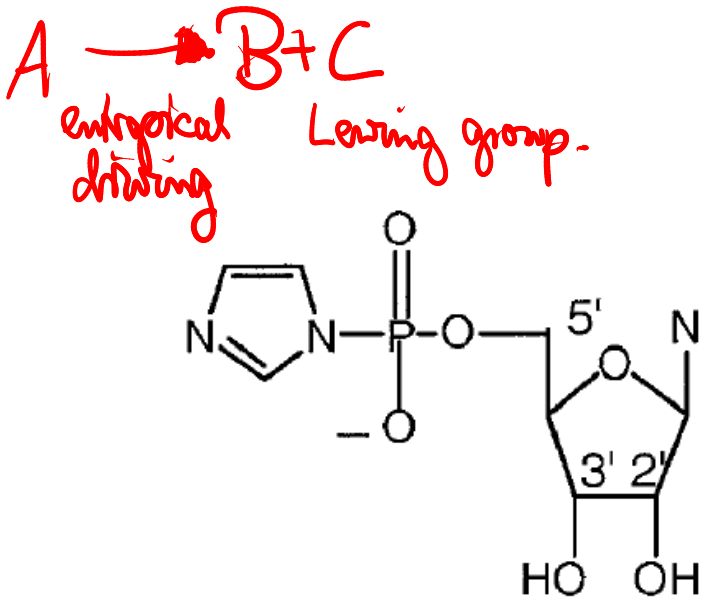

sequence length + complexity
Local entropy reduction
SOUP
LIFE
Random molecule assemblies
Dissipation of Energy
Selection of molecule configurations
Dissipation of Energy
Self-replication of sequences

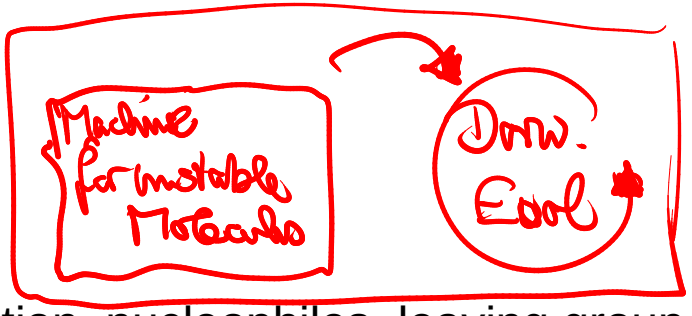
Soup of life


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







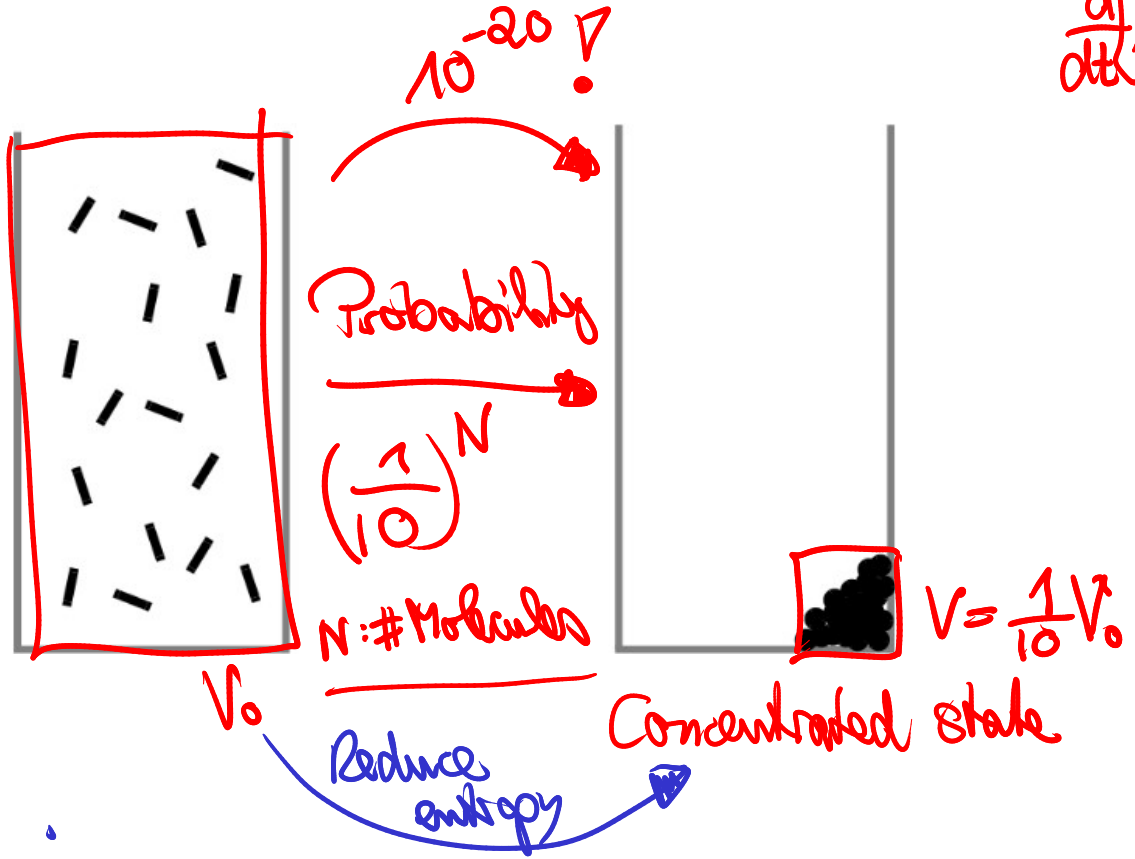
Molecular Entropy: ATP vs AMP, activation, nucleophiles, leaving group

Three faces of entropy

Polymerization reactions. $A + A \xrightarrow{k_{on}} A_2$

$\frac{d}{dt}[A_2] = k_{on} \cdot [A][A]$; $10 \cdot 10$ factor if concentrated

speed of Reaction



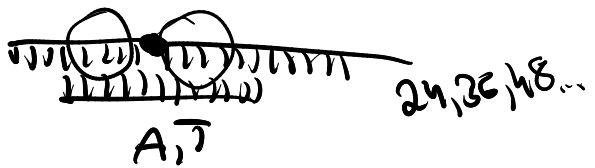
Need:

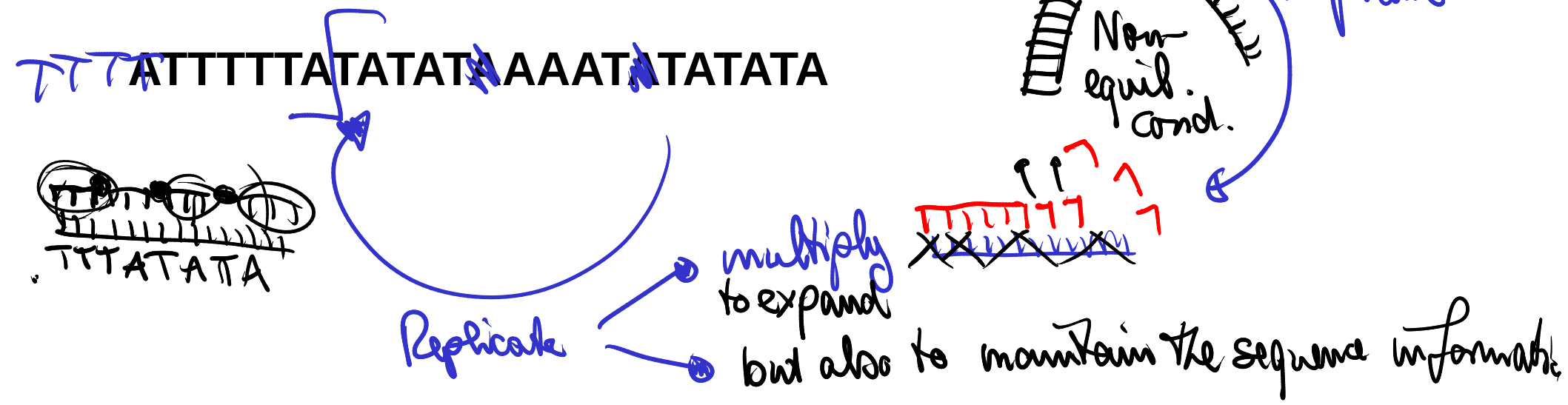
- Nonequil. System for accumulation
- Still: aqueous (from time to time)

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

Three faces of entropy

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





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

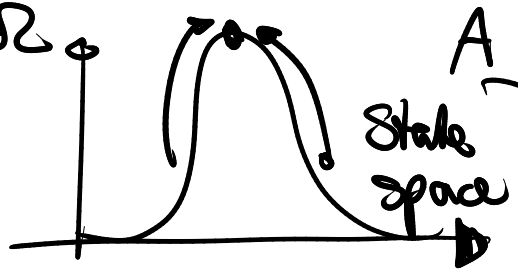
Three faces of entropy

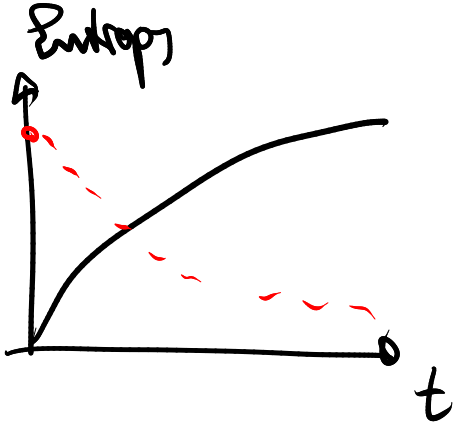
$$H(X) = -\sum_{i=1}^{n} p_i \log_2 p_i$$

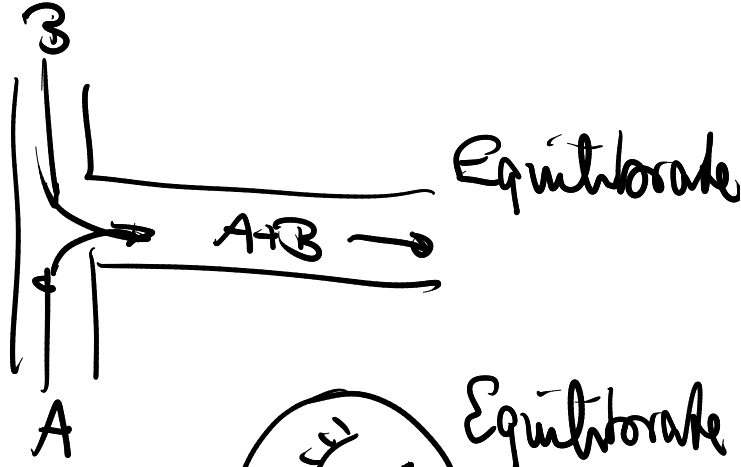
ATTTTTATATATAAAATATATATA

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

Death of equilibrium

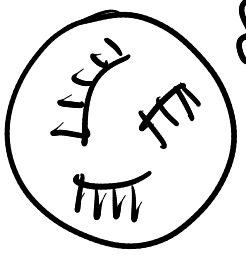






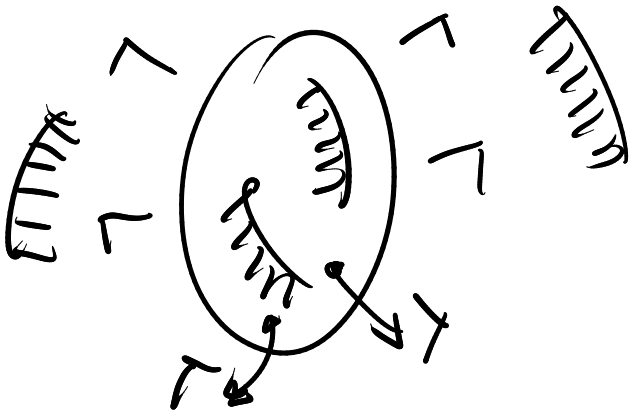
Equilibrate

Equilibrate

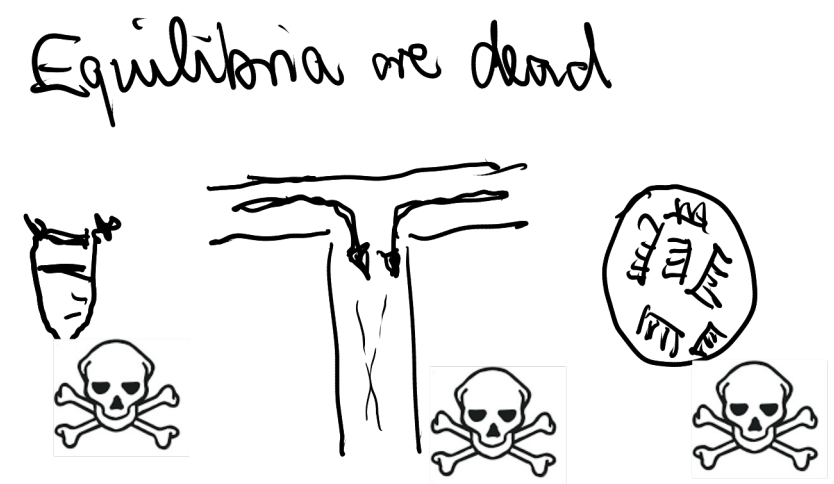


Death of equilibrium

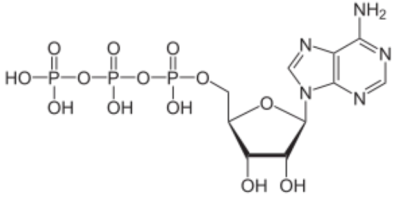
Assumed nonequilibrium: ATP



Death of equilibrium

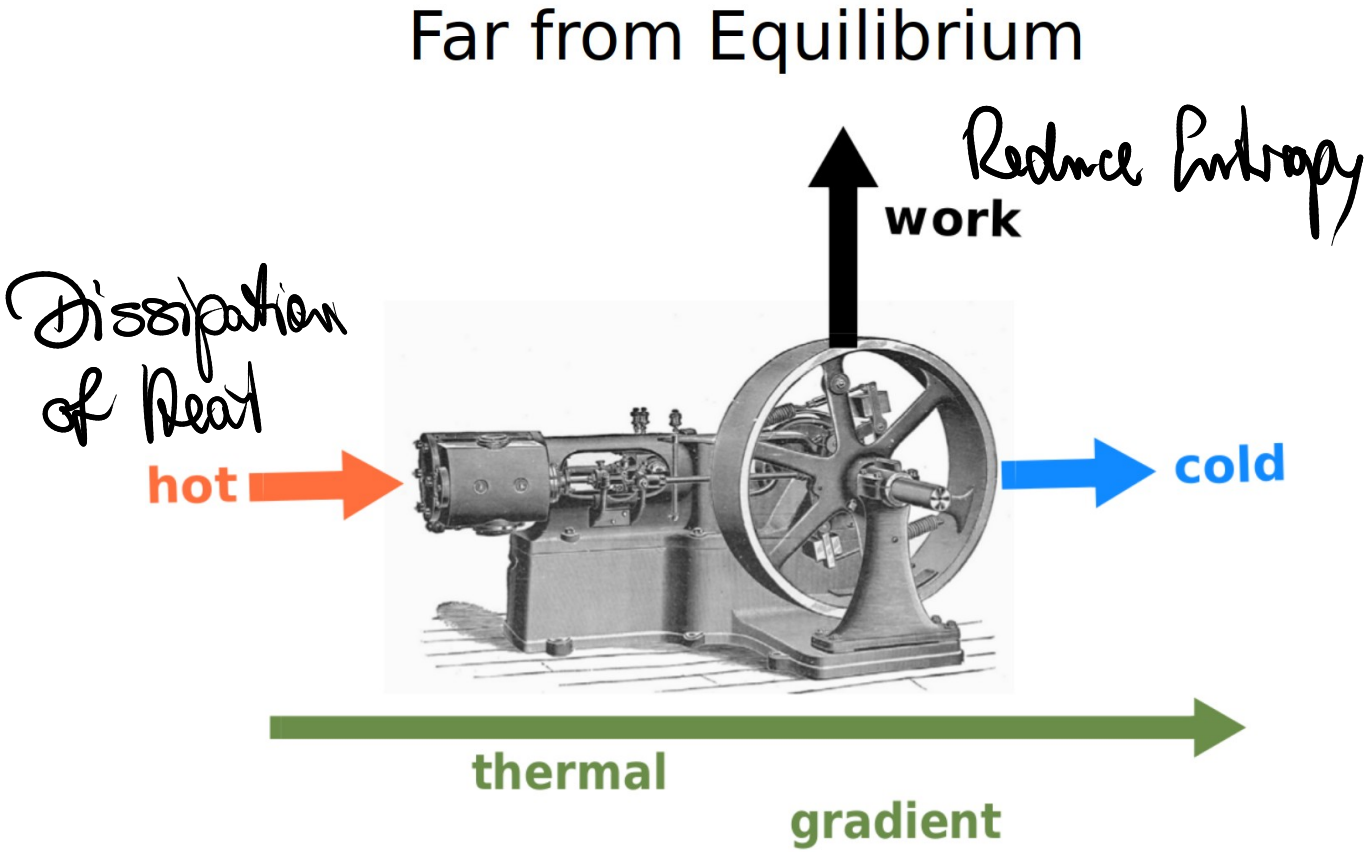


Assumed nonequilibrium

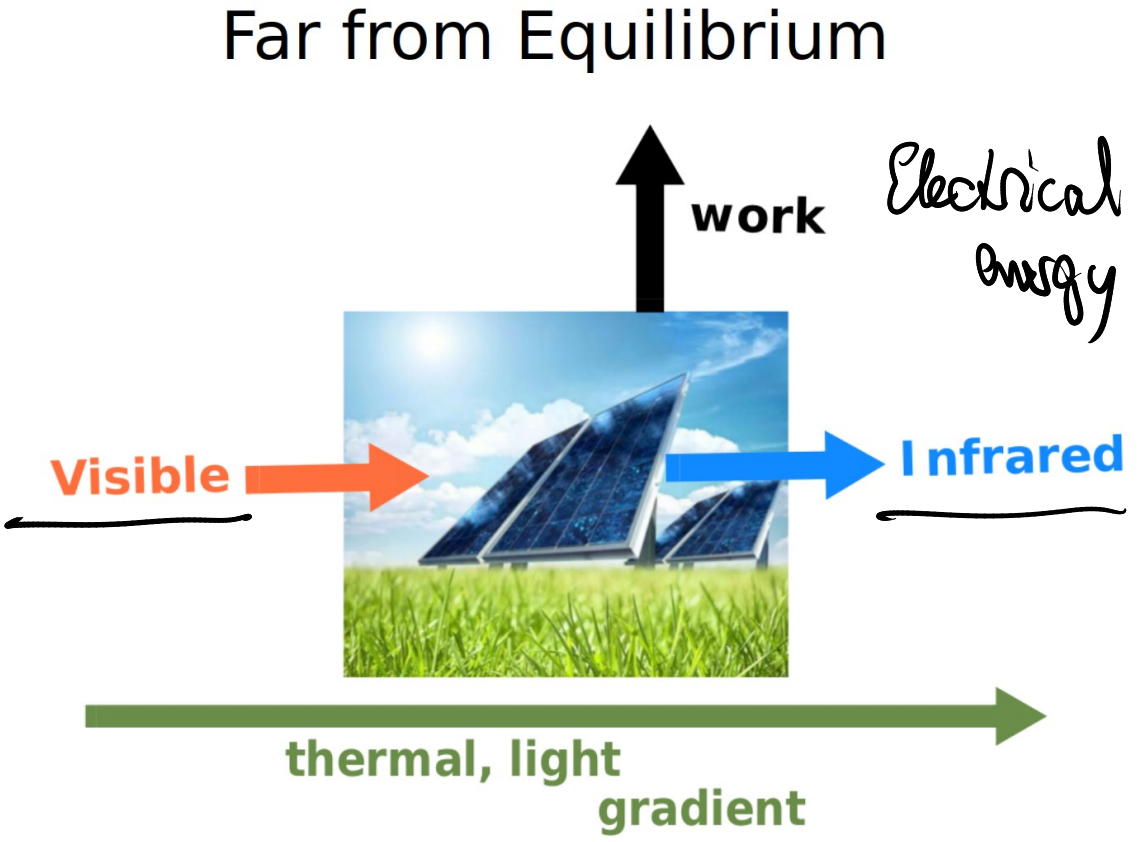


Modes of non-equilibrium

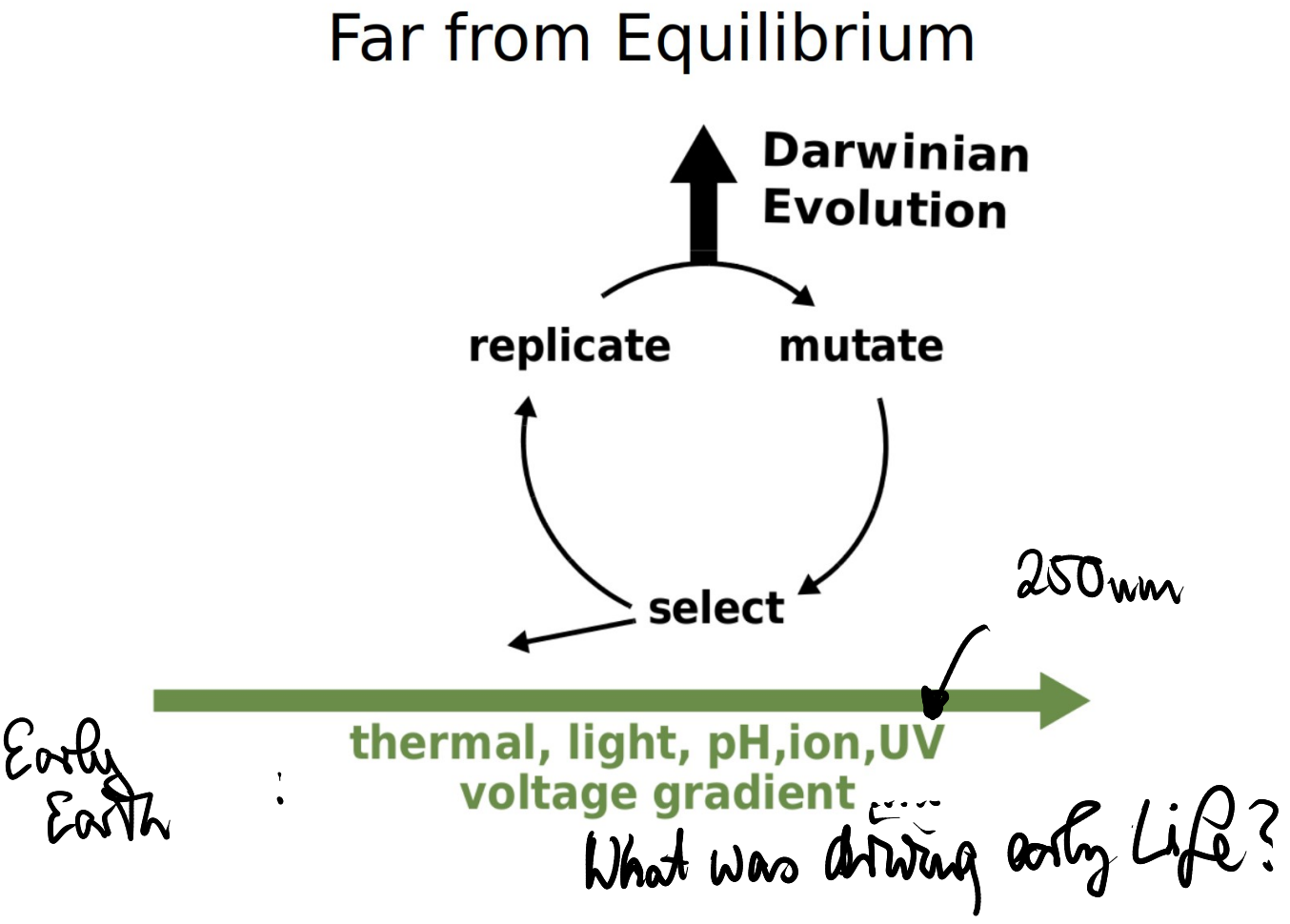
Modes of non-equilibrium



Modes of non-equilibrium

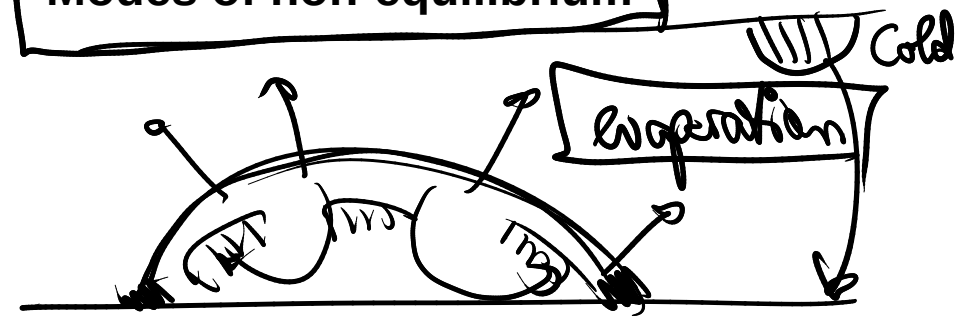


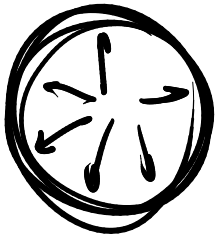
Modes of non-equilibrium

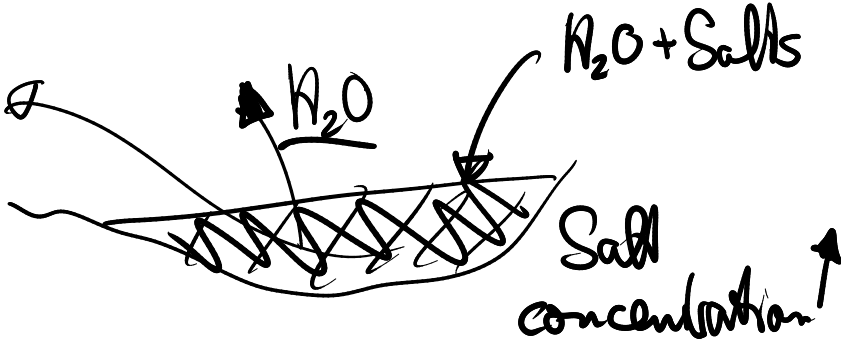


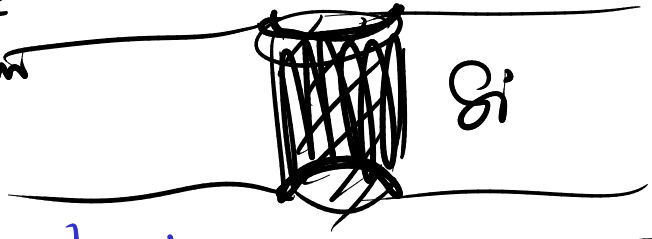
Modes of non-equilibrium

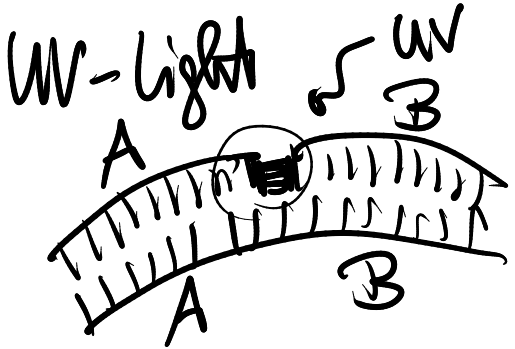
Modes of non-equilibrium

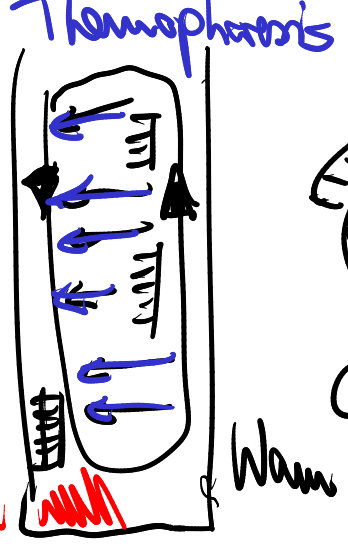


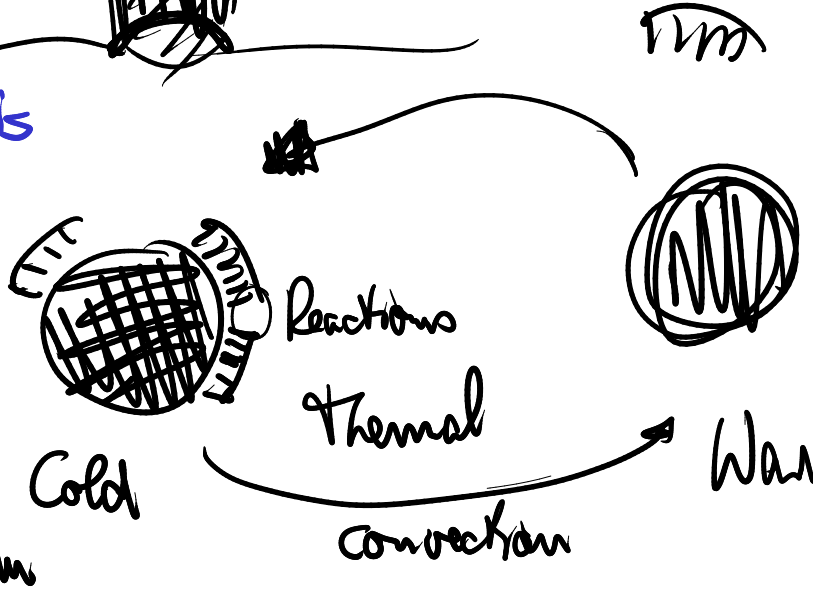


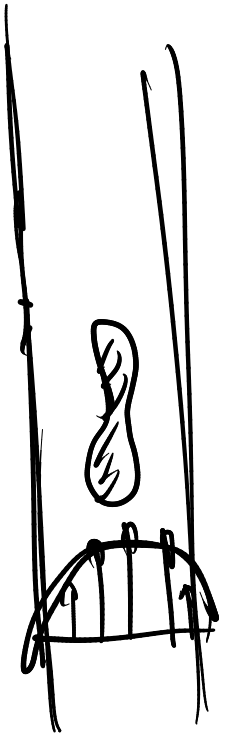






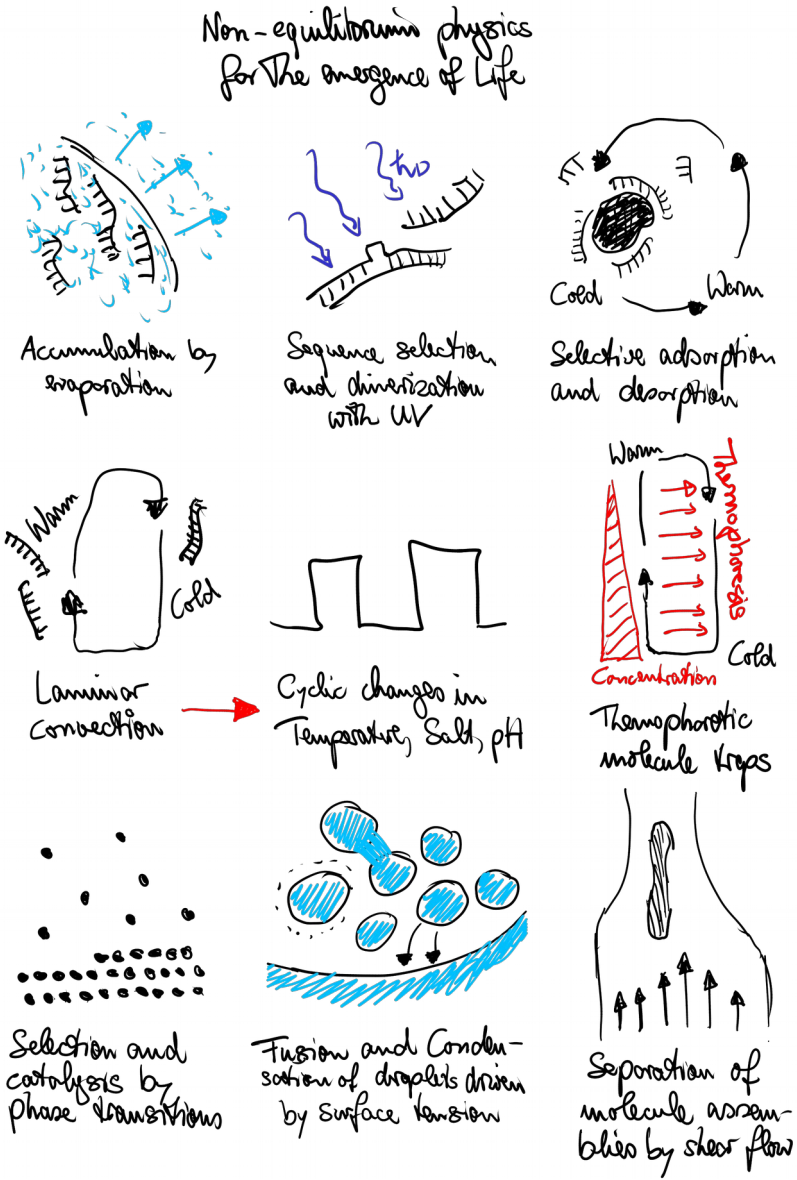






Phase transitions

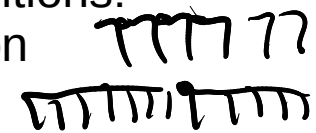
Modes of non-equilibrium



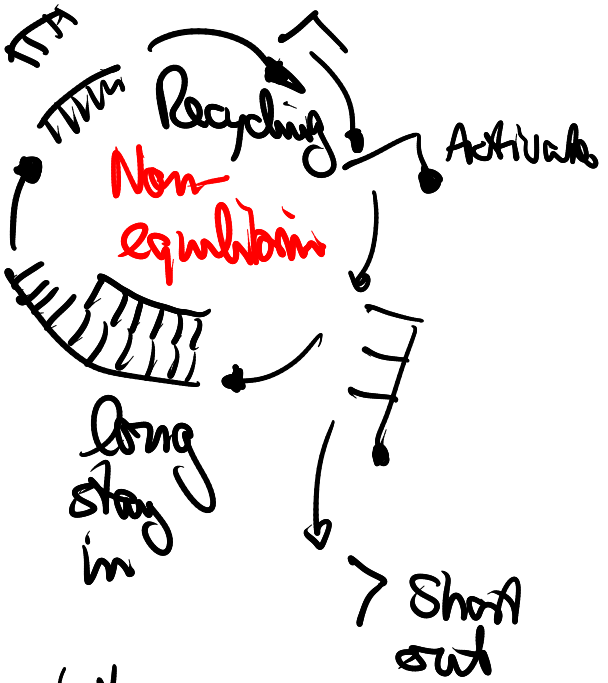
Structure of Origin of Life

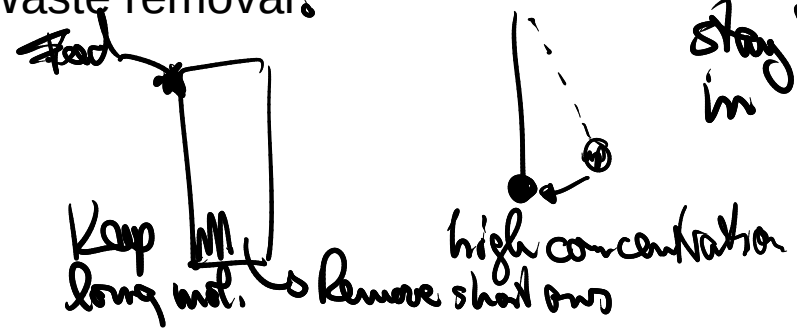
Nucleotides (possibly stored) → Synthesis

- 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

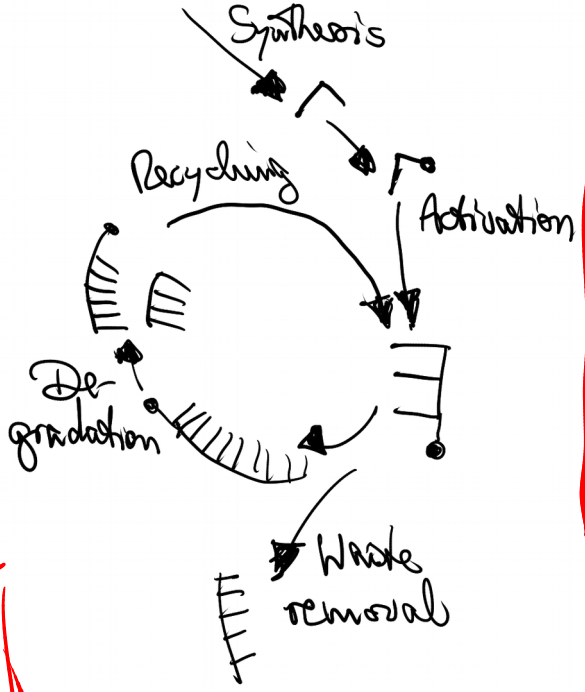
Nucleotides (possibly stored)

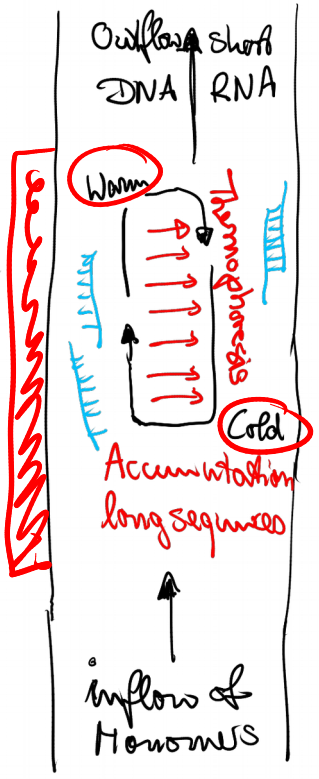
Chemical conditions:
- Polymerization
- Ligation
- Activation

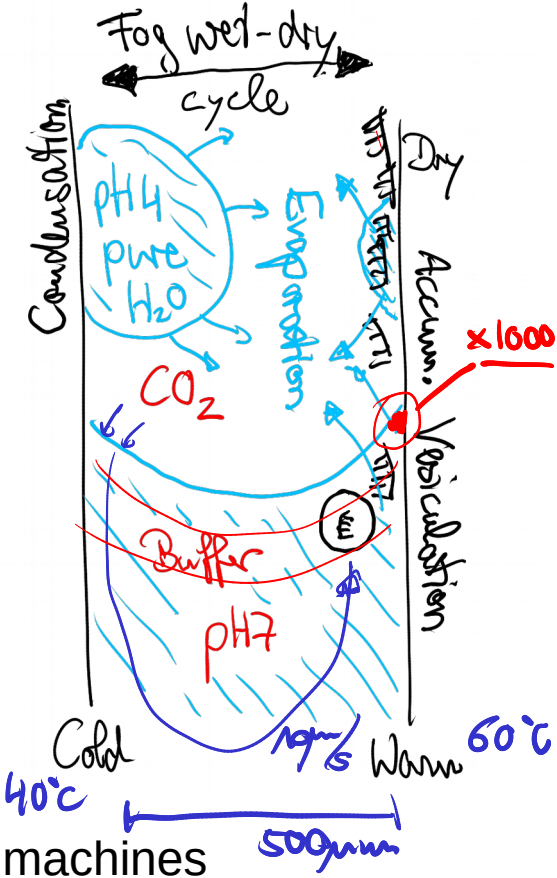
Physical non-equilibrium:
- Strand separation
- Maintaining accumulation
- Feeding and
  Waste removal

Come back @ 16:35

Chemical nonequilibrium in physical nonequilibrium







Some upcoming molecular machines