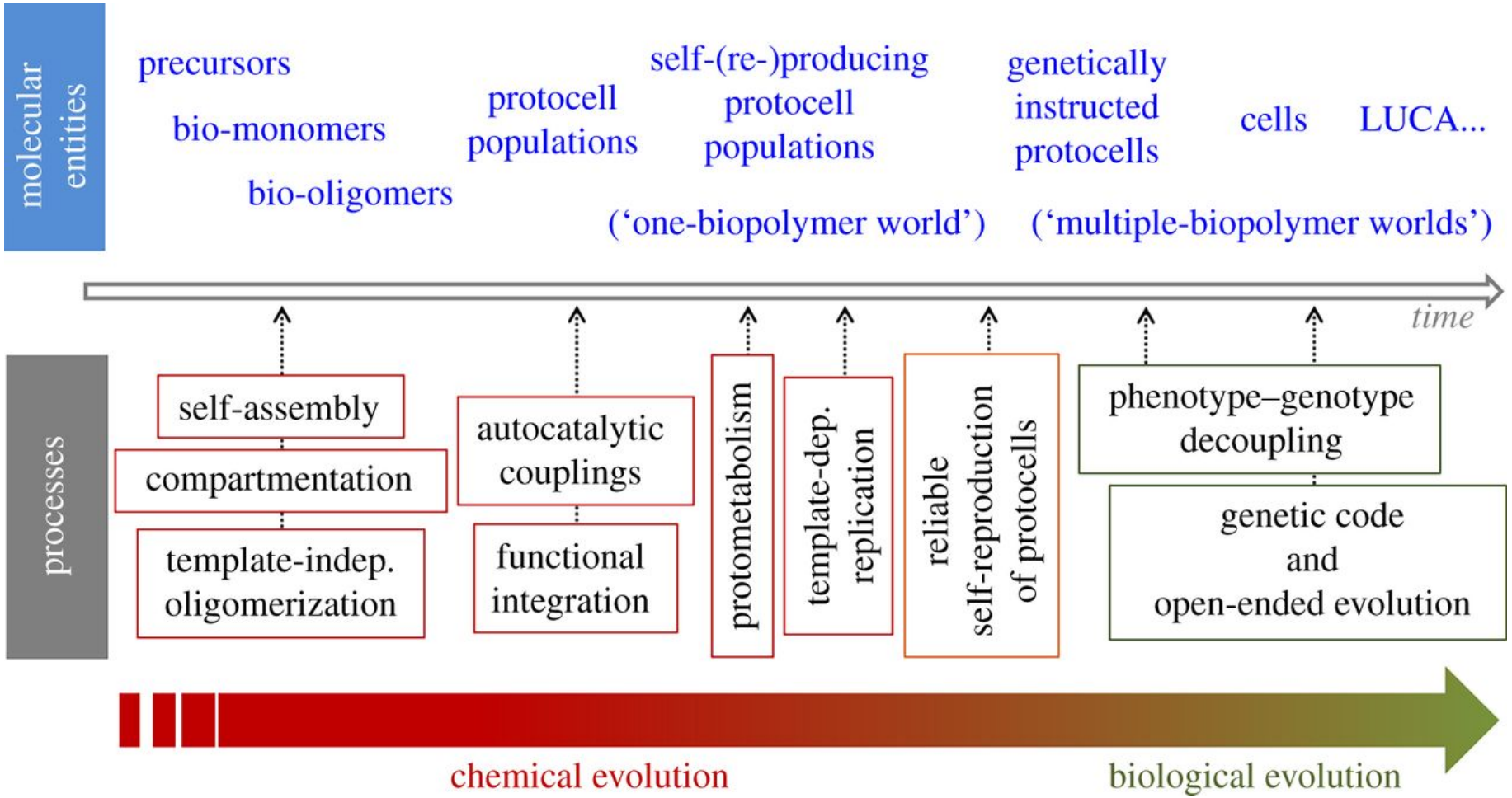
Biology
ES131

Module 2

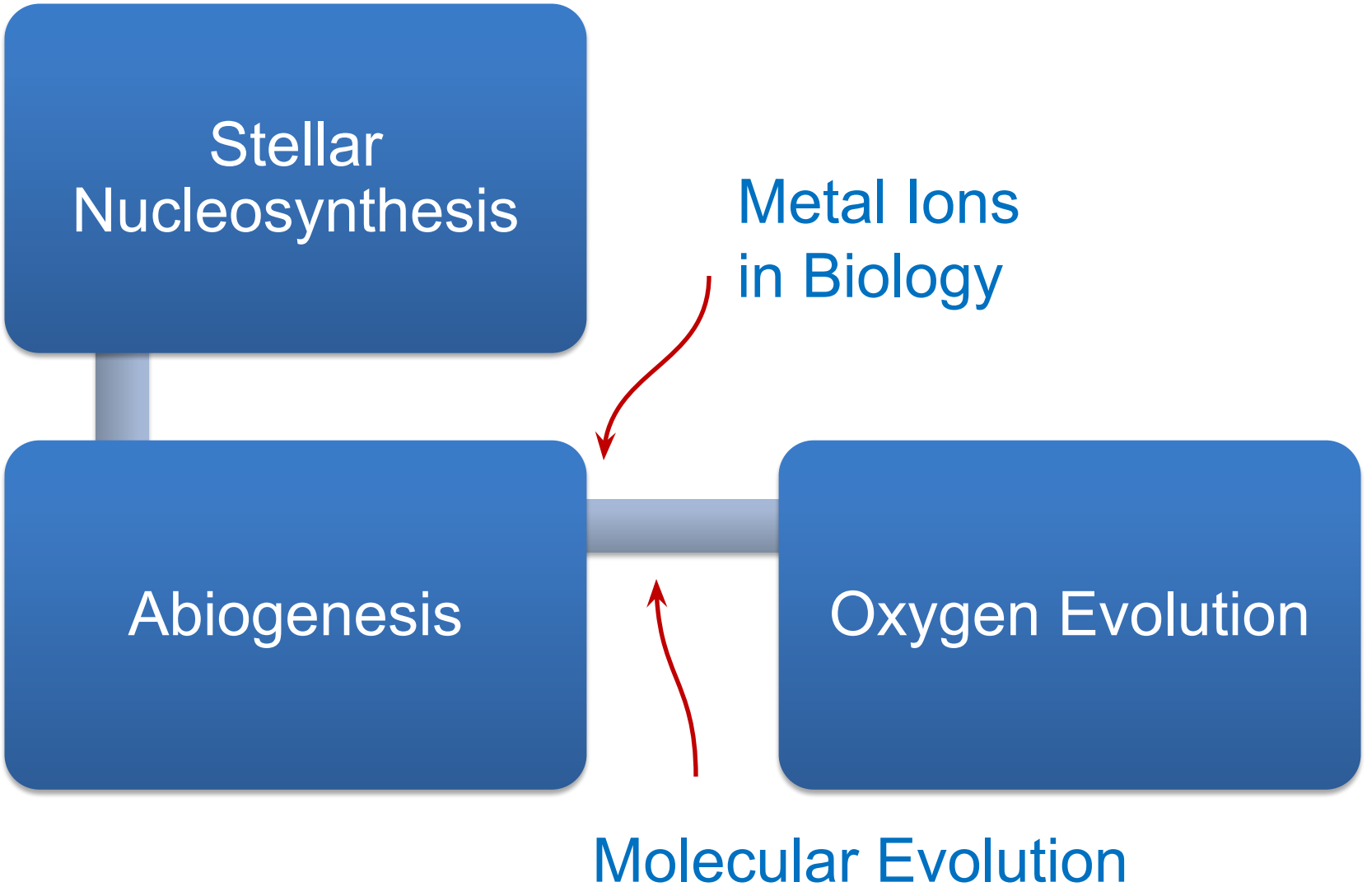
Chemistry in Biology (Part 2)

Chemical Evolution, Metabolism, Synthetic Biology

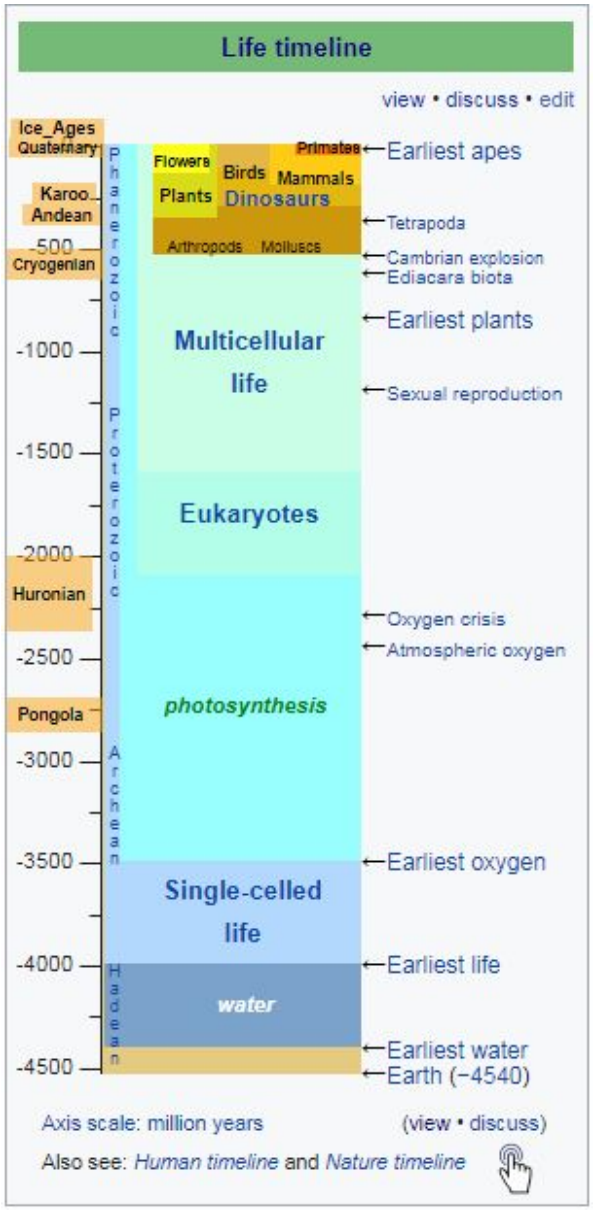
Chemical Evolution

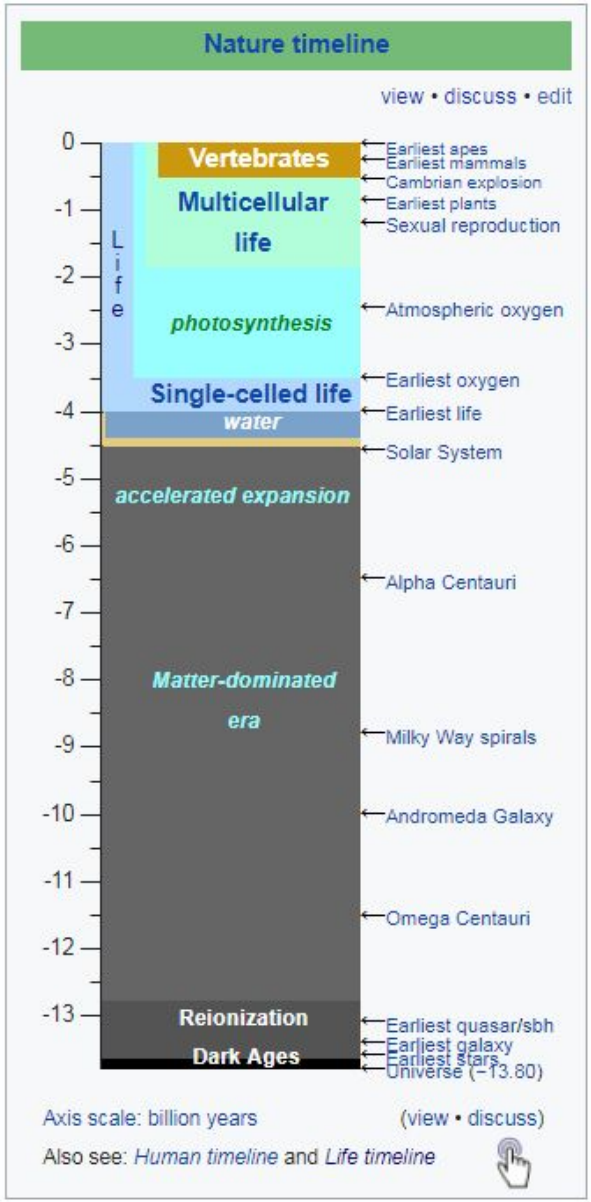


Chemical Evolution



Chemical Evolution





wikipedia

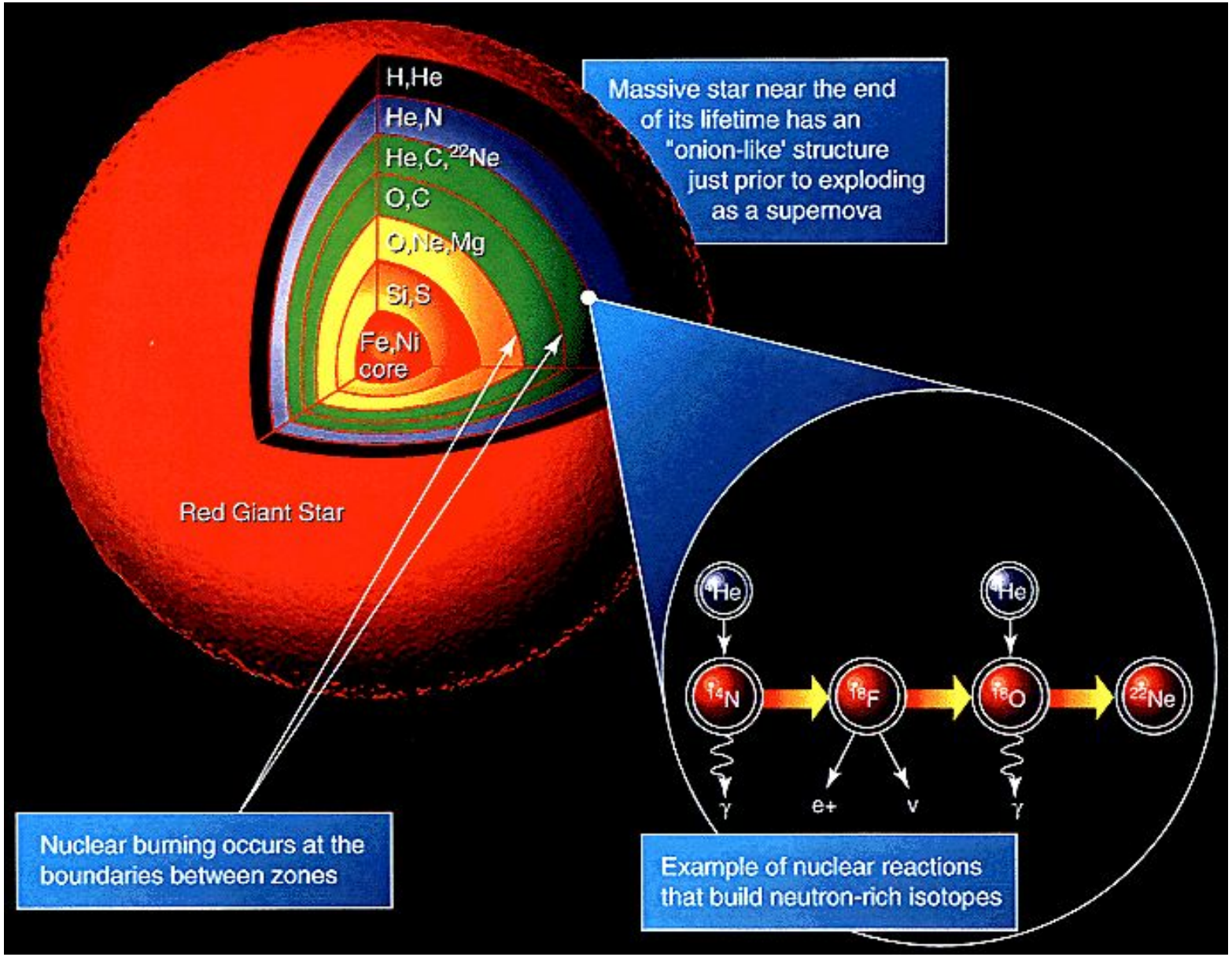
Stellar Nucleosynthesis

- Why some elements and their isotopes are much abundant than others?

- Proposed that stars obtained their energy from nuclear fusion of hydrogen to form helium and raised the possibility that the heavier elements are produced in stars

Arthur Edington

Stellar Nucleosynthesis



Abiogenesis / Origin of Life

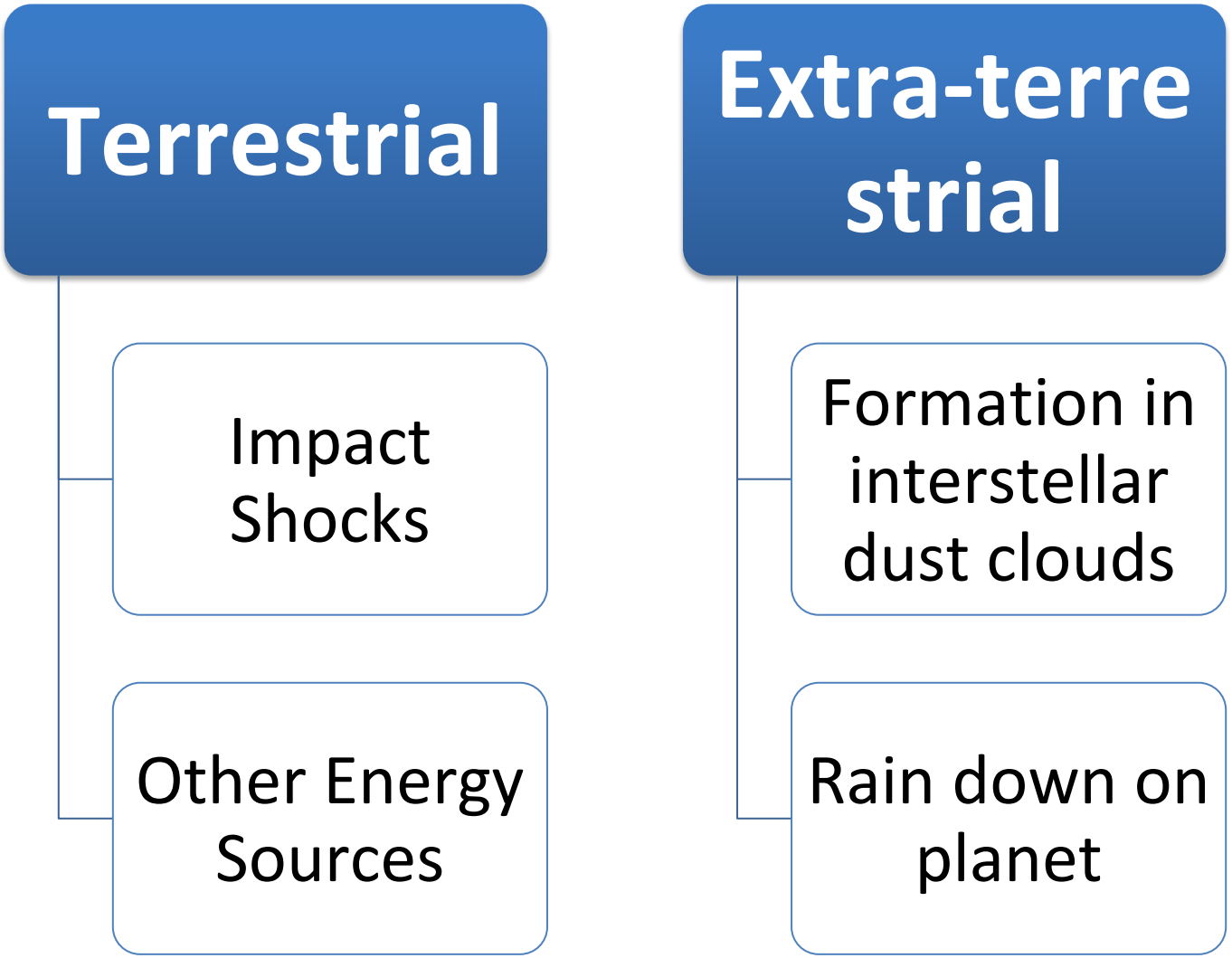
- The transition from non-living to living entities was not a single event, but a gradual process of increasing complexity

- It involved
molecular self-replication, self-assembly, autocatal ysis and cell membranes.

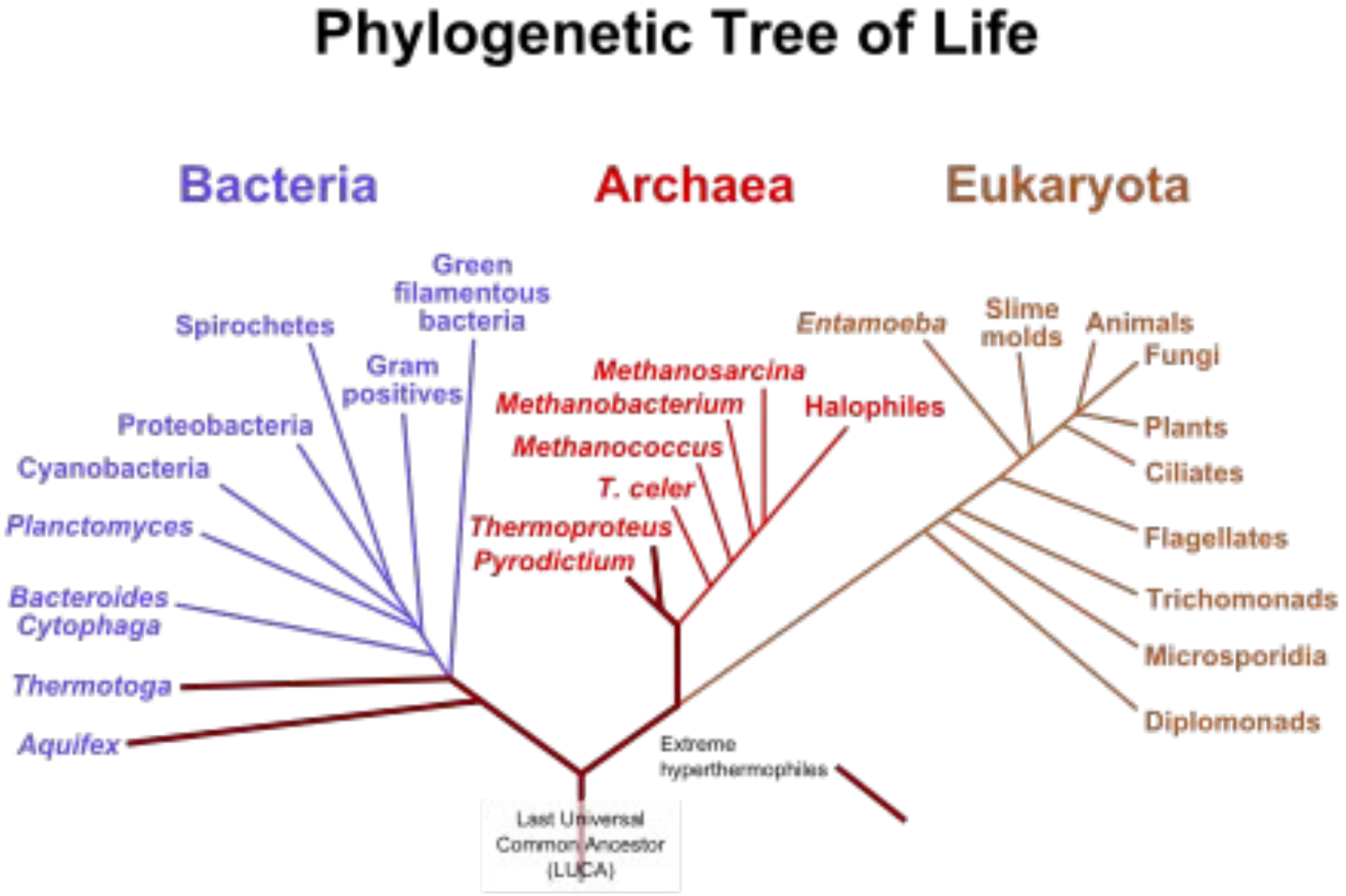
- Multiple models, no single explanation

https://en.wikipedia.org/wiki/Abiogenesis

Origin of Organic Molecules



Origin of Organic Molecules



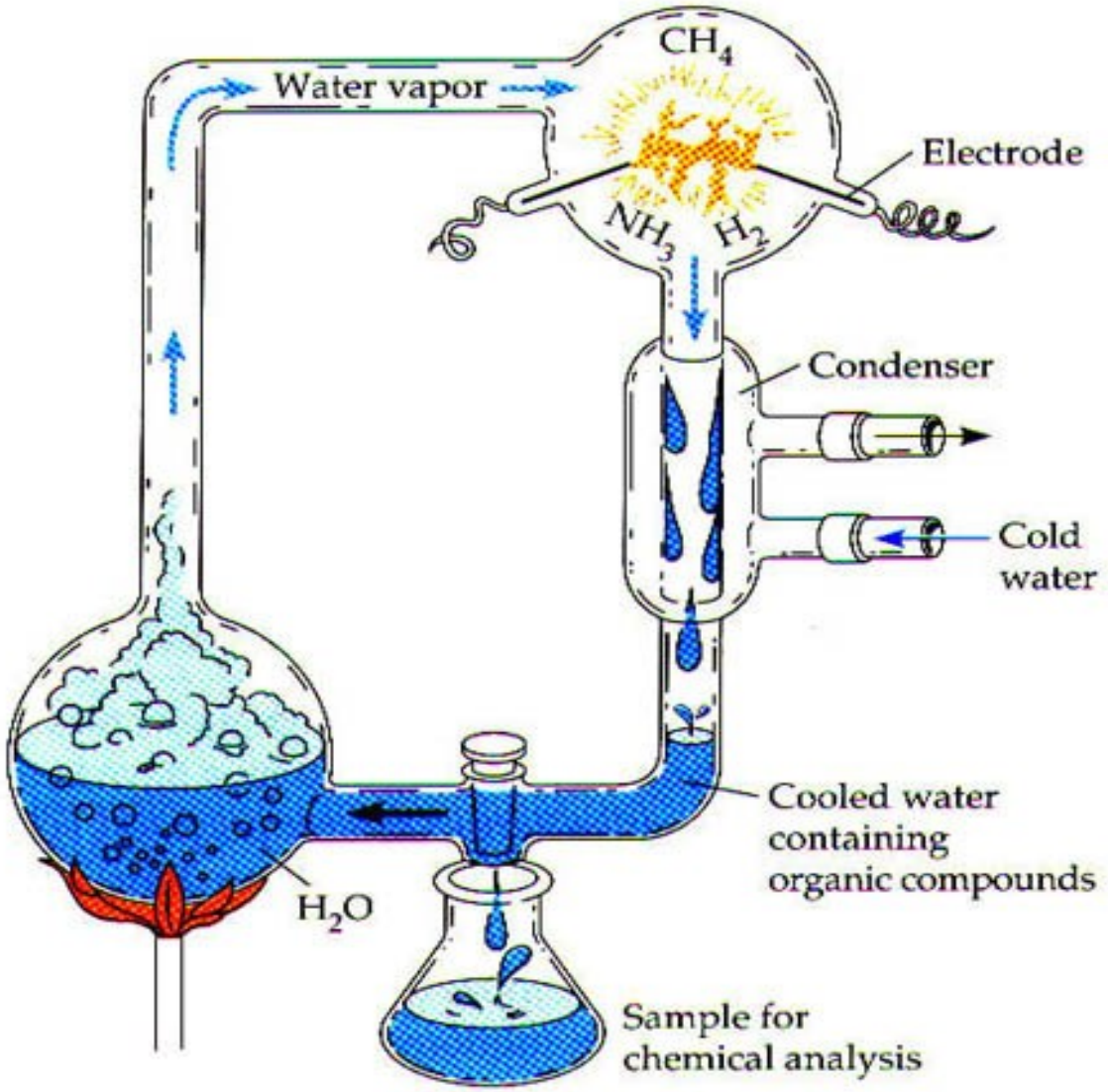
Origin of Organic Molecules

1. Chemical Synthesis
   - Self Replication
   - Self Assembly

2. Autocatalysis

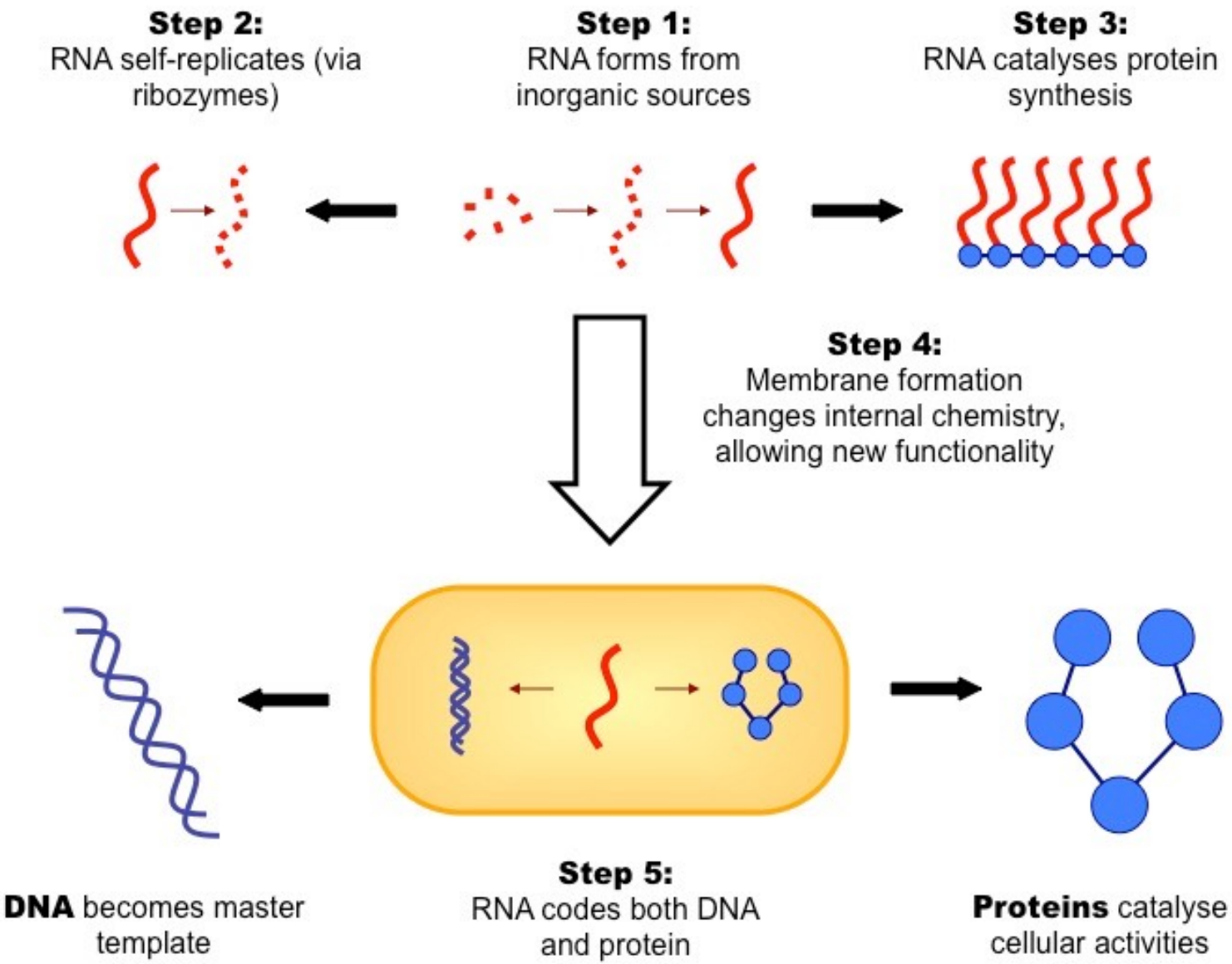
3. Homochirality

Chemical Evolution

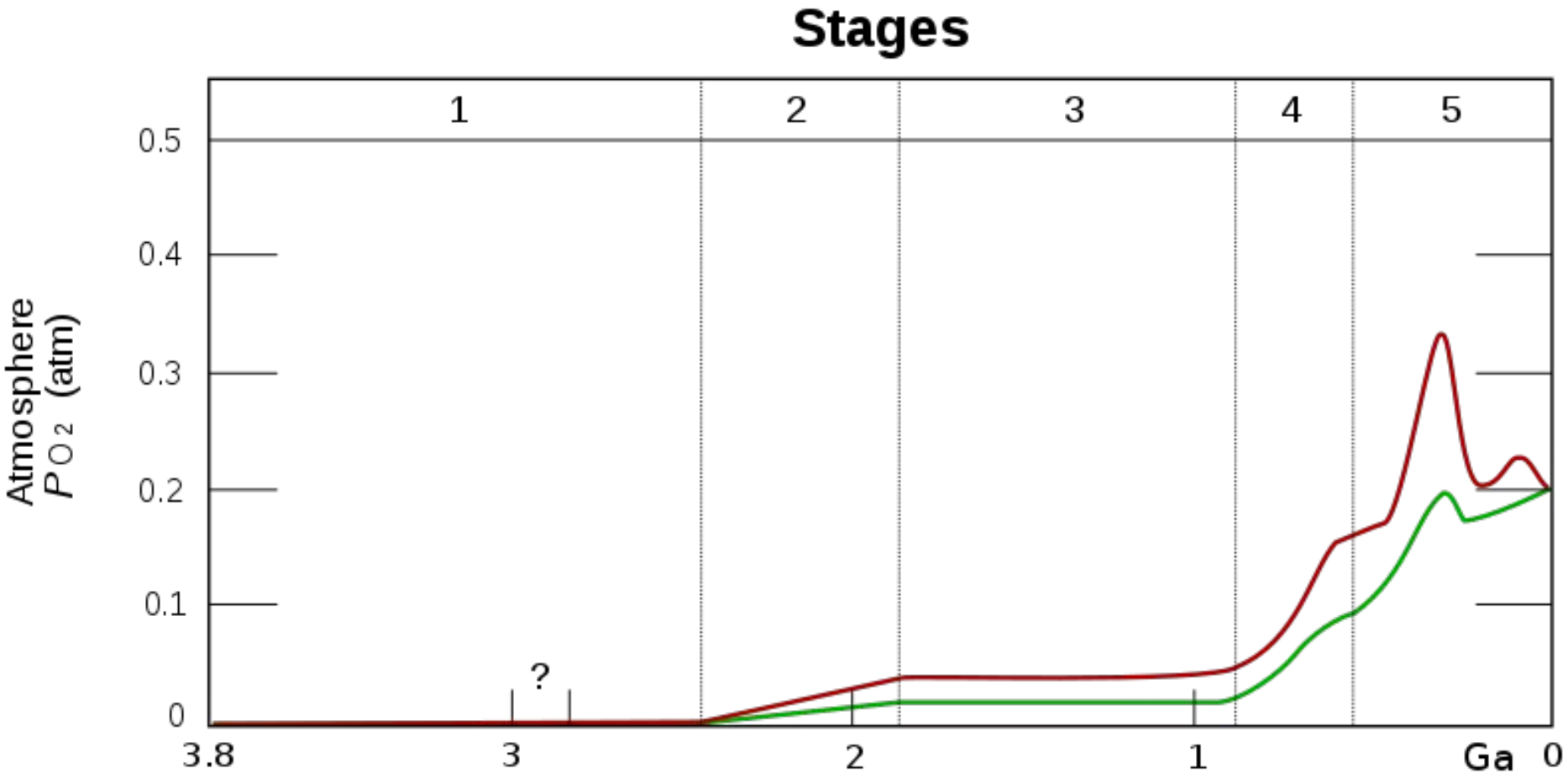


Miller-Urey Experiment 1953

The RNA World Hypothesis



The Great Oxygenation Event

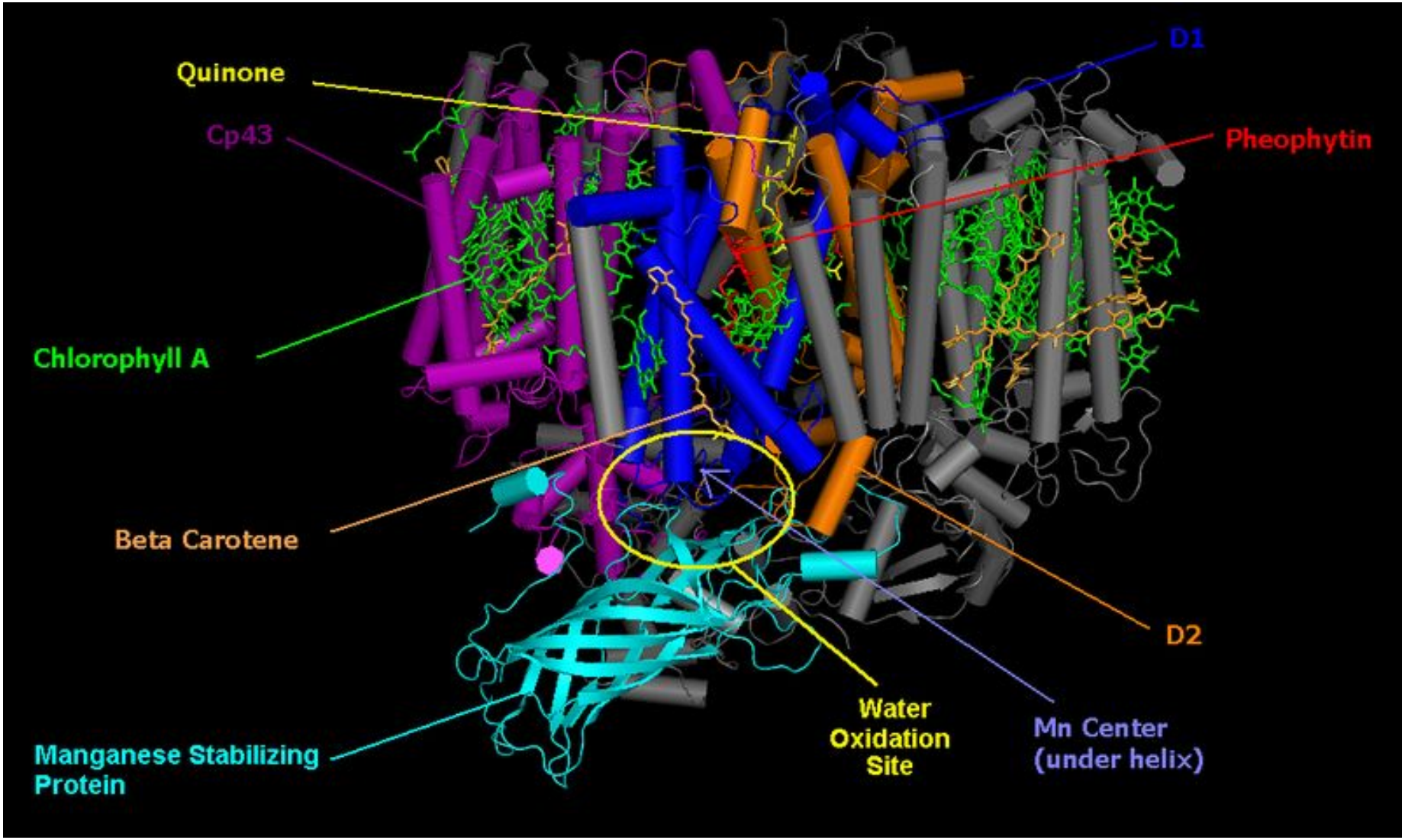


https://en.wikipedia.org/wiki/Evolution_of_metal_ions_in_biological_systems

Origin of Metabolic Pathways

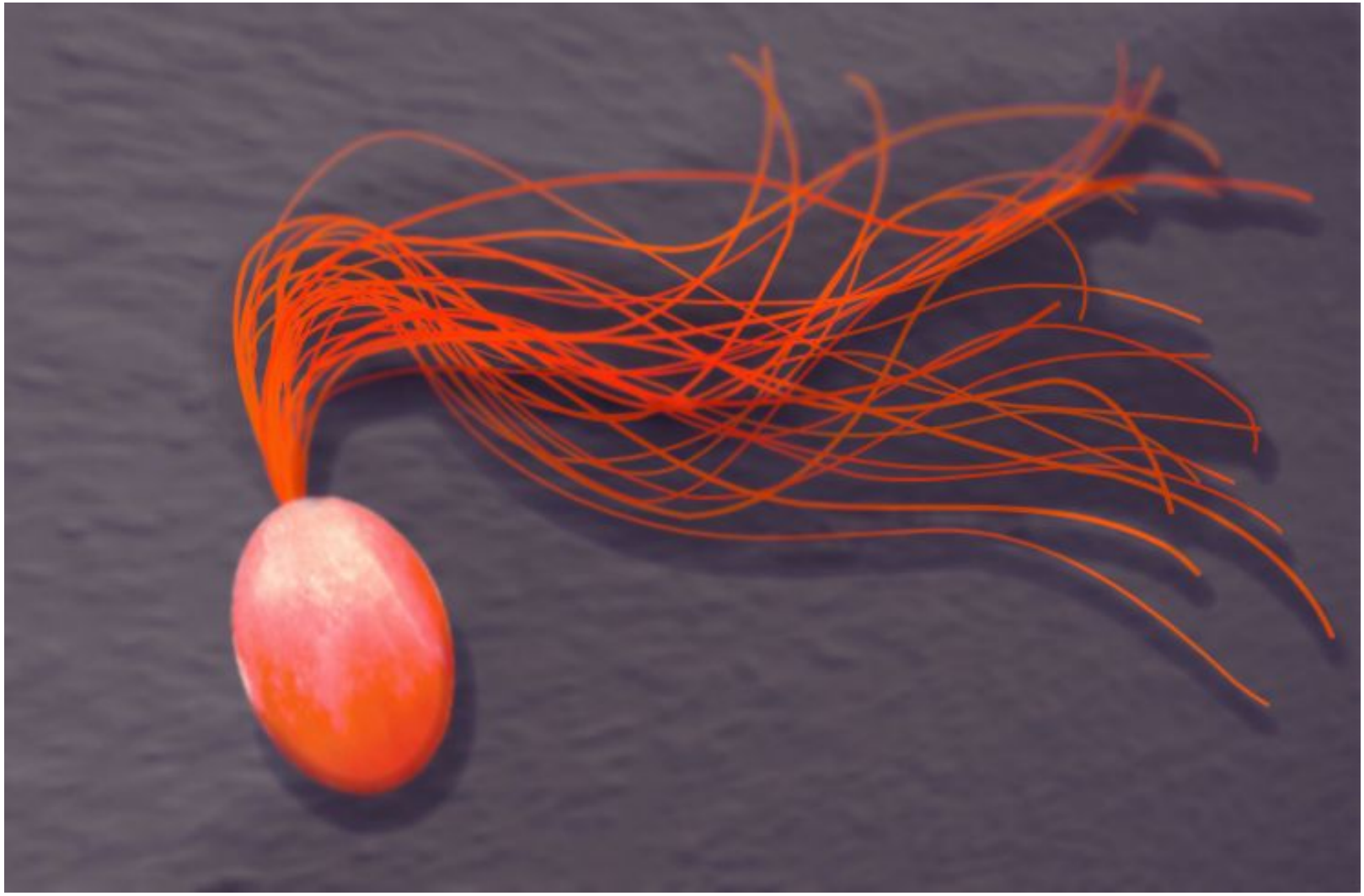
- **Iron-Sulfur World**
- **Zn-world Hypothesis**
- **Deep Sea Vent / Alkaline Hydrothermal Vent Hypothesis**
- **Thermosynthesis**

Evolution of Metals in Biology



Magnesium Center in Cyanobacterial photosystem II

Evolution of Metals in Biology



Pyrococcus furiosus – Hyperthermophillic archaea contains Tungesten (high M.P.)

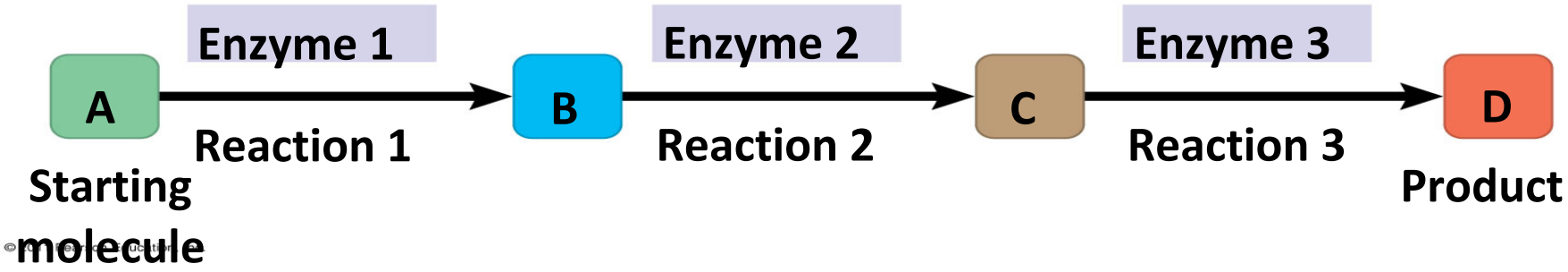
Metabolism

- **Metabolism** is the totality of an organism's chemical reactions

- Metabolism is an emergent property of life that arises from interactions between molecules within the cell

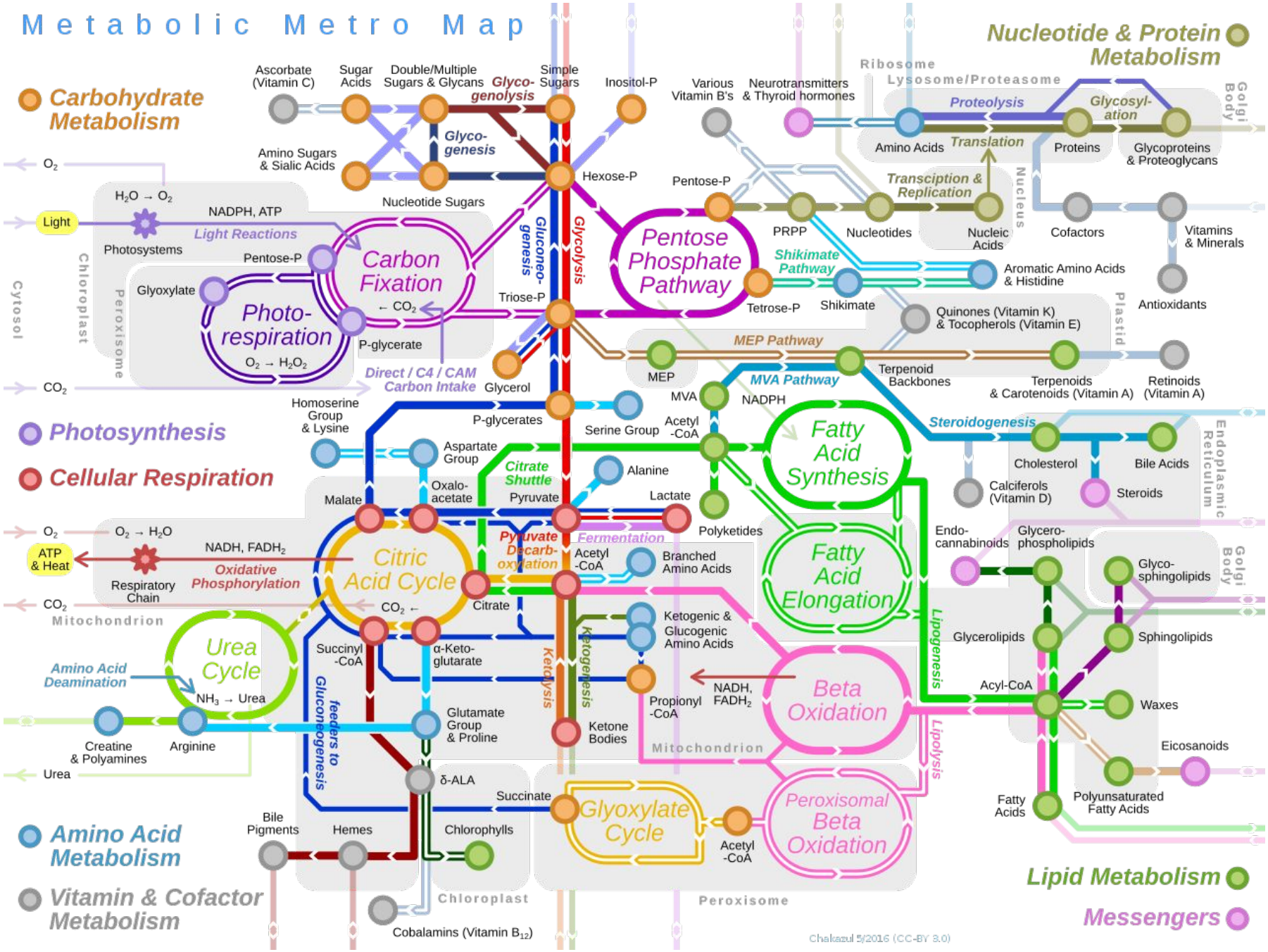
- An organism's metabolism transforms matter and energy, subject to the laws of thermodynamics

Metabolism

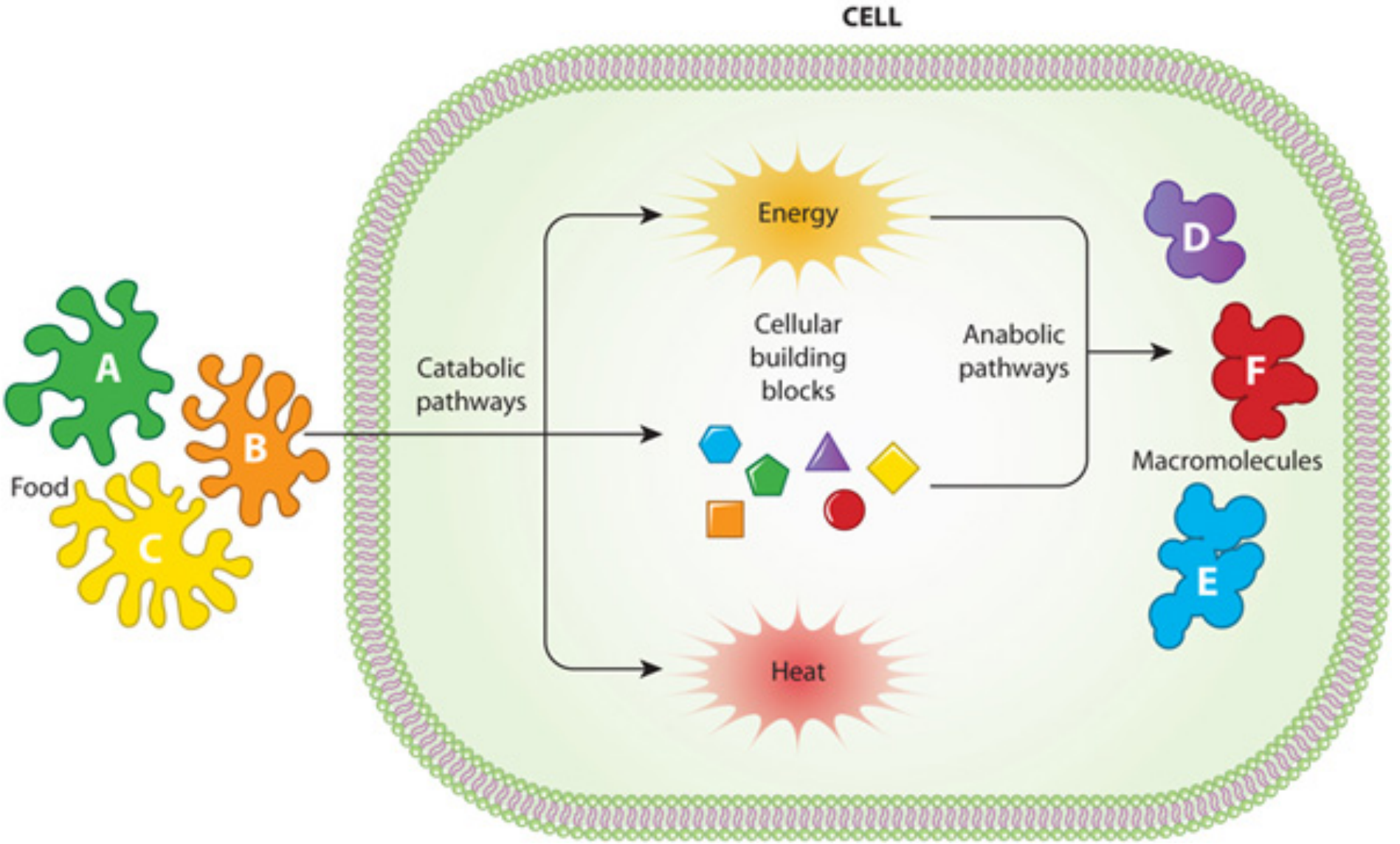


- A **metabolic pathway** begins with a specific molecule and ends with a product

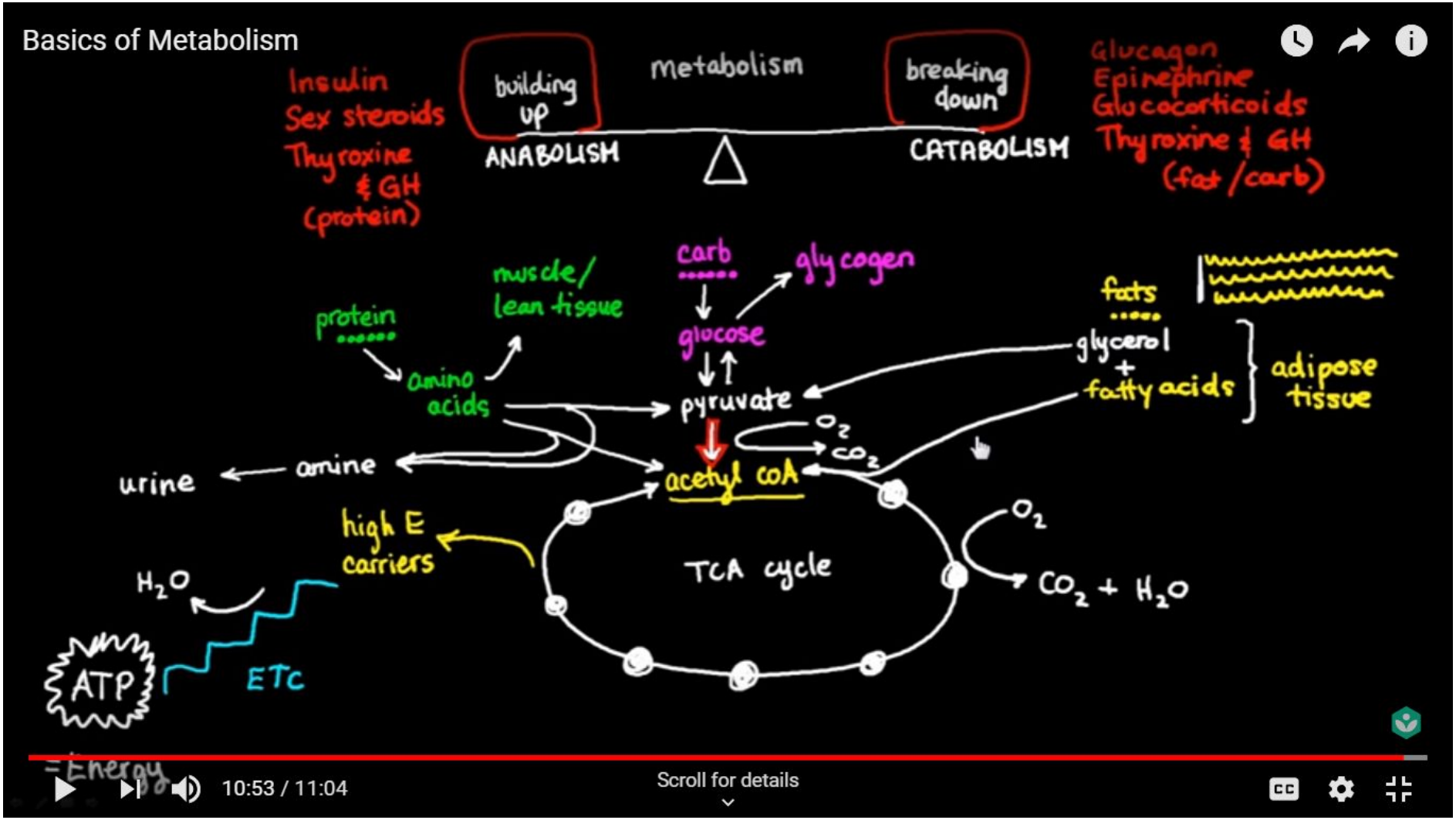
- Each step is catalyzed by a specific enzyme


Metabolic Metro Map
Carbohydrate Metabolism
Photosynthesis
Cellular Respiration
Amino Acid Metabolism
Vitamin & Cofactor Metabolism
Nucleotide & Protein Metabolism
Lipid Metabolism
Messengers
Ascorbate (Vitamin C)
Sugar Acids
Double/Multiple Sugars & Glycans
Glyco-genolysis
Simple Sugars
Inositol-P
Amino Sugars & Sialic Acids
Glyco-genesis
Hexose-P
Nucleotide Sugars
Pentose-P
Pentose Phosphate Pathway
Gluconeo-genesis
Glycolysis
Triose-P
Tetrose-P
Glycerol
Glyoxylate
Carbon Fixation
Photo-respiration
P-glycerate
Direct / C4 / CAM Carbon Intake
Light
Photosystems
Light Reactions
NADPH, ATP
Chloroplast
Peroxisome
Cytosol
Various Vitamin B's
Neurotransmitters & Thyroid hormones
Ribosome
Lysosome/Proteasome
Proteolysis
Glycosyl-ation
Amino Acids
Translation
Proteins
Glycoproteins & Proteoglycans
Golgi Body
Transciption & Replication
Nucleus
PRPP
Nucleotides
Nucleic Acids
Cofactors
Vitamins & Minerals
Shikimate Pathway
Shikimate
Aromatic Amino Acids & Histidine
Antioxidants
Quinones (Vitamin K) & Tocopherols (Vitamin E)
Plastid
MEP Pathway
MEP
Terpenoid Backbones
Terpenoids & Carotenoids (Vitamin A)
Retinoids (Vitamin A)
MVA Pathway
MVA
NADPH
Homoserine Group & Lysine
P-glycerates
Serine Group
Acetyl -CoA
Fatty Acid Synthesis
Steroidogenesis
Cholesterol
Bile Acids
Calciferols (Vitamin D)
Steroids
Endoplasmic Reticulum
Aspartate Group
Citrate Shuttle
Alanine
Malate
Oxalo-acetate
Pyruvate
Lactate
Polyketides
Pyruvate Decarb-oxylation
Fermentation
Endo-cannabinoids
Glycero-phospholipids
Glyco-sphingolipids
Golgi Body
ATP & Heat
NADH, FADH2
Oxidative Phosphorylation
Respiratory Chain
Citric Acid Cycle
Acetyl -CoA
Branched Amino Acids
Fatty Acid Elongation
Lipogenesis
Citrate
Mitochondrion
Ketogenic & Glucogenic Amino Acids
Glycerolipids
Sphingolipids
Urea Cycle
Amino Acid Deamination
Succinyl -CoA
α-Keto-glutarate
Ketolysis
Ketogenesis
Propionyl -CoA
NADH, FADH2
Beta Oxidation
Acyl-CoA
Waxes
Lipolysis
Glutamate Group & Proline
Ketone Bodies
Creatine & Polyamines
Arginine
Urea
Eicosanoids
δ-ALA
Succinate
Glyoxylate Cycle
Peroxisomal Beta Oxidation
Fatty Acids
Polyunsaturated Fatty Acids
Bile Pigments
Hemes
Chlorophylls
Cobalamins (Vitamin B12)
Chloroplast
Peroxisome
Chakazul 5/2016 (CC-BY 3.0)

Catabolism and Anabolism



Metabolism in Action



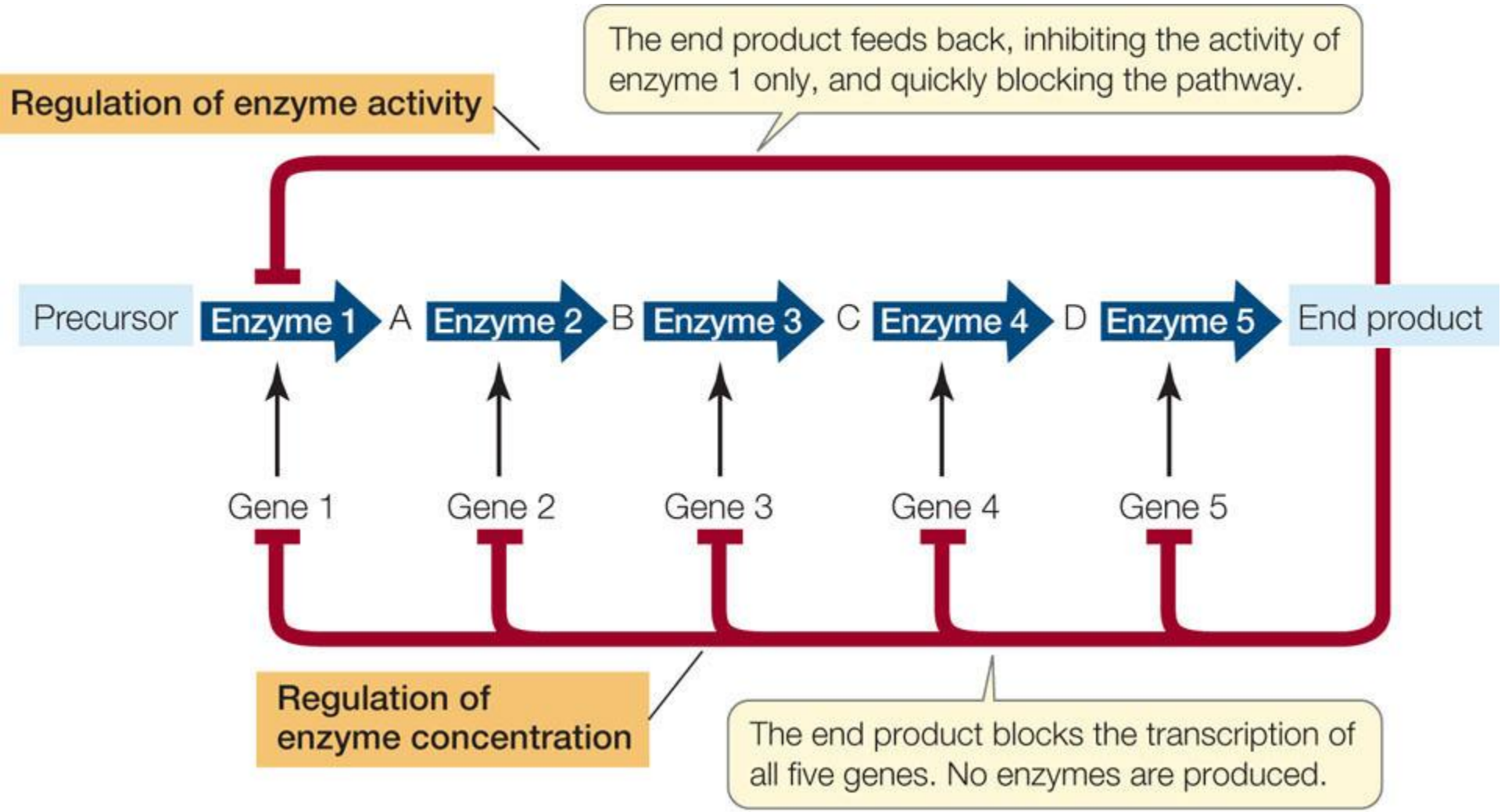
https://www.youtube.com/watch?v=wQ1QGZ6gJ8w

Regulation of Metabolism

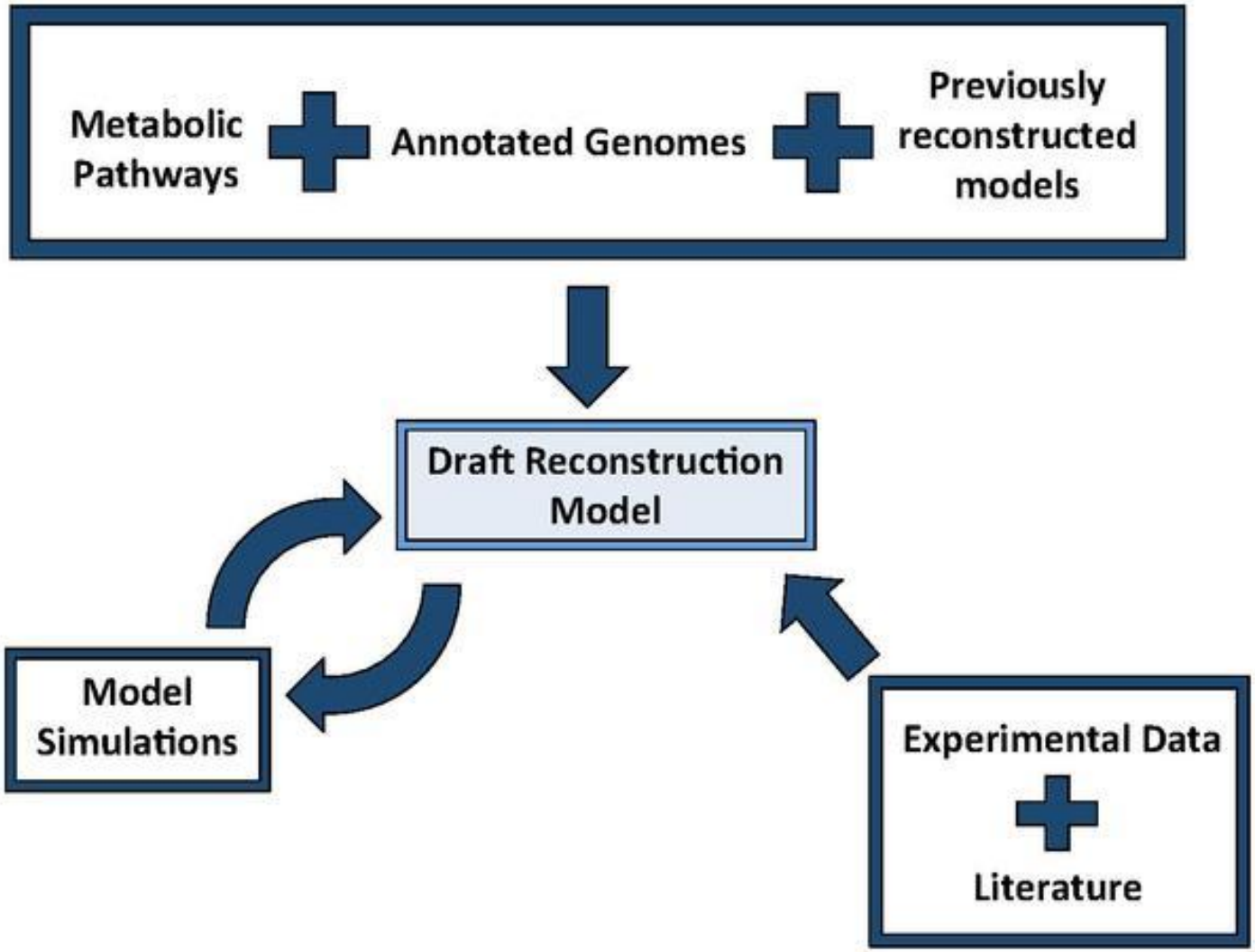
- **Rate Limiting Step: Slowest step; beginning of the pathway**
- **Covalent and Non-covalent modifications**
- **Metabolic flux is regulated by** the Stoichiometric Reaction Model*, the utilization rate of metabolites, and the translocation pace of molecules across the lipid bilayer

**Law of conservation of mass = Matter is not created or destroyed in a chemical reaction*

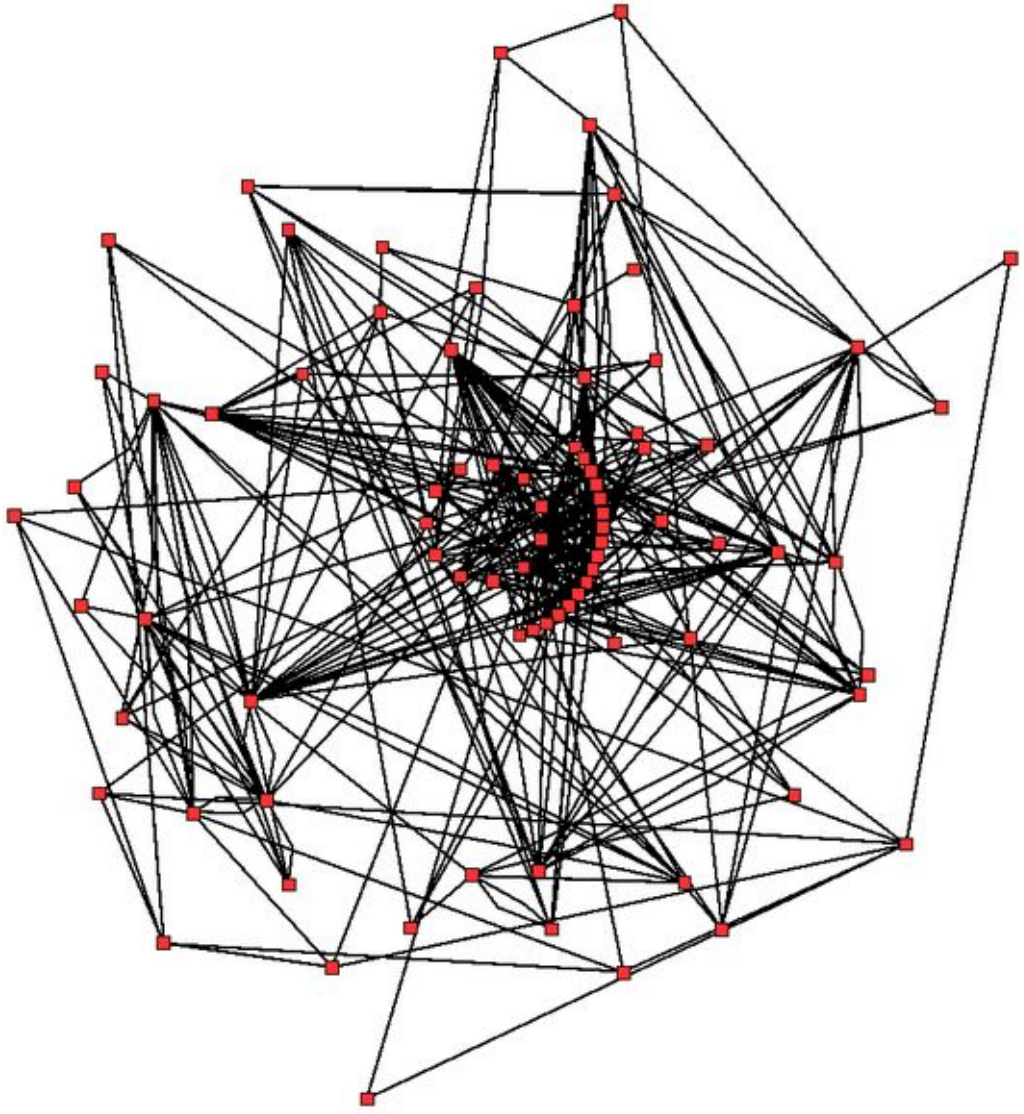
Regulation of Metabolism

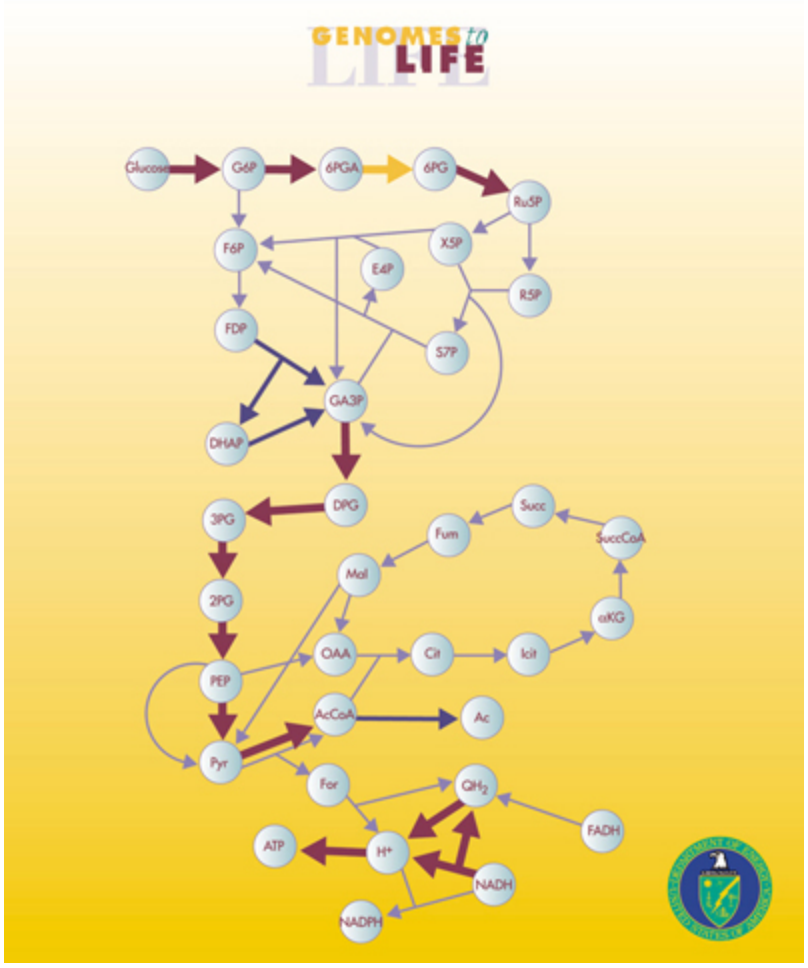


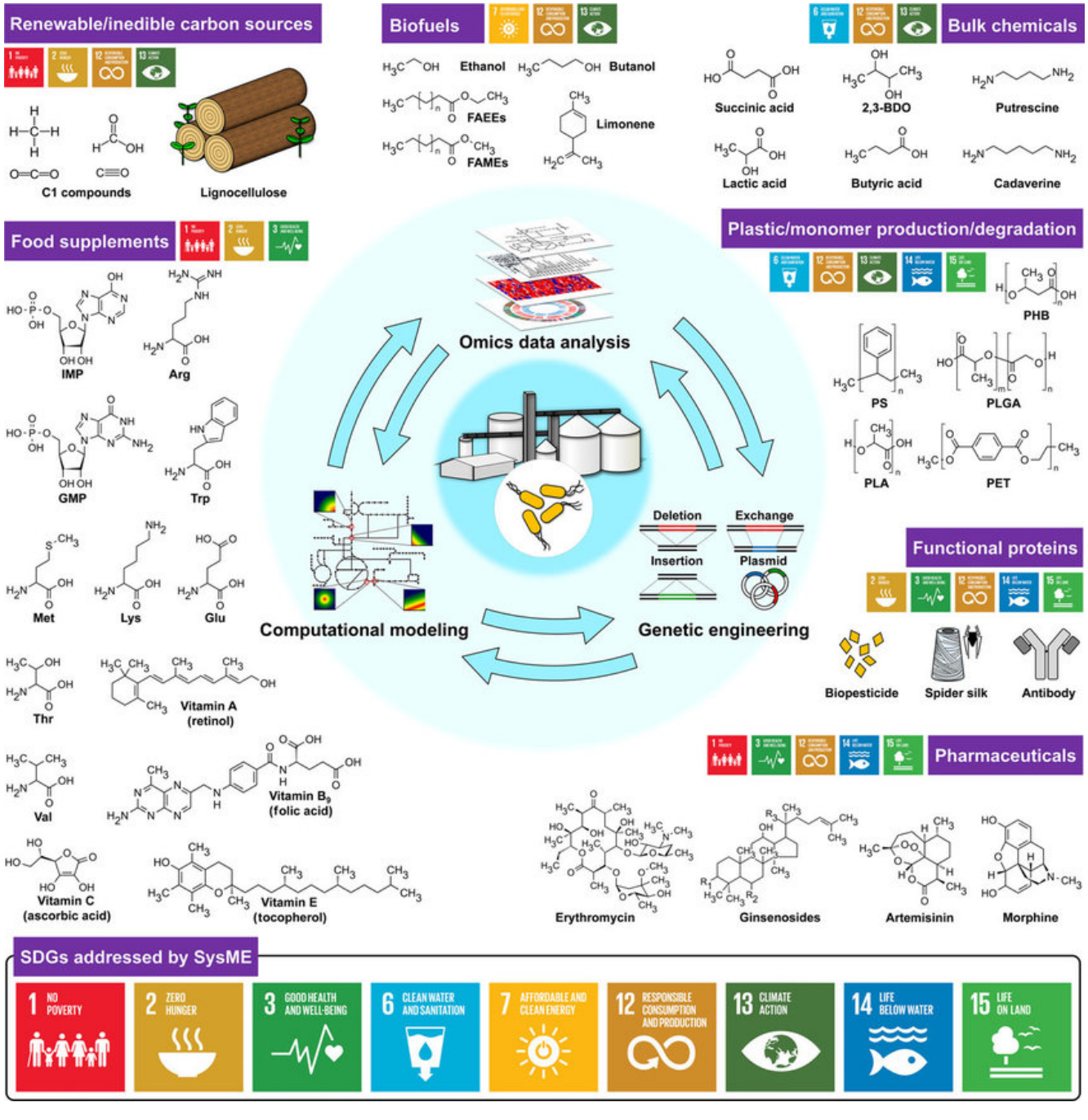
Metabolic Network Modeling



Metabolic Network Modeling







Metabolic Engineering

Synthetic Biology

- First to synthesis an oligonucleotide
- Genetic code behind Amino Acids
- Two repeating units (UCUCUCU → UCU CUC UCU) produce two alternating AAs
- Three repeating units (UACUACUA → UAC UAC UAC, or ACU ACU ACU, or CUA CUA CUA) produce three different strings of AAs

Hargobind Khorana

Synthetic Cell