What is Life?

A machine defining an inside and an outside, which reproduces and allows the expression of

A program (a "cookbook"), which replicates, and

A set of coupling processes, metabolism, which manages the flow of matter and
energy and regulates information recursively from the program's expression.

Replication First Cairns-Smith (1980) Slide 2

- Surface chemistry
  - Metallic surface attracts negative ions-phosphate
    - Polymerization by eliminating water (concentration)
      - Polyphosphates (monomer)
  - Replicating unit catalyzes monomer formation
• More efficient replicator/catalyst appears
  o No trace of former replicator

Information for A. Danchin’s Scenario (slide 3)

• **Molecular fossils are any contemporary structure or function which is ancient in origin and provides us with clues about the history of life**
  o Comparative Genomics
    ▪ Orthologs
      ▣ Minimal genomes
    ▪ Persistent Genes
      ▣ Horizontal Gene Transfer of gene/function networks
      ▣ Family genes defining a minimal set of functions required for the development of life
  • Function space re-defined
Network of conserved gene functions and arrangements

- RNA-mediated information transfer -connected
  - Ribosome, transcription (DNA into RNA), cell maintenance

- RNA metabolism -less connected
  - RNA wielding enzymes, tRNA synthetases
    - Cell-division

- Building Blocks genes –No longer connected
  - Nucleotides
  - Catalytic cores
    - Fe S centers, other metallo cores

- Amino acids, Lipid bilayers
  - Not translation-cell compartments
    - Thioesters
  - New Knowledge of Inorganic Chemistry
  - Features of Contemporary Biochemistry
- Insight into Nitrogen Reduction ($N_2$ to $NH_3$)
- Insight into Molecular Biology of RNA

Pre-biotic Surface Chemistry – Wächtershäuser Hypothesis (Slides 4 & 5)

- $FeS + H_2S \rightarrow FeS_2$ (iron pyrite) $+ H_2$
- Discovered by Wächtershäuser
- Happens anaerobically
  - Deep ocean smokers
    - High temperatures
    - Little to no oxygen
    - Gradient within smoker
      - Temperature
      - Oxygen
      - Surfaces for chemistry
    - Earliest organism-thermophilic
- Autotroph hypothesis –CO₂ polymer (reduction) coupled to energy

Two Dimensional Chemistry

- HCO₃⁻ + FeS + H₂S ⇒ HCOO⁻ + H₂O
  - Positive charge on surface attracts -PO₃, -COO⁻, -S⁻
  - Surface chemistry favors polymerization
- Contemporary fixation of carbon dioxide in a thermophilic archea
- Metal-sulfur origins of carbon fixation
- ACS/CODH uses FeS, Ni, Co coenzyme and Cu
- Reduces CO$_2$ to CO
- Channels CO to methane site
- Acetyl CoA can be produced
- Enzyme widely distributed
- Pyruvate synthase fixes another mole of CO$_2$
- FeS, ferredoxin
- Universal distribution of enolase
- Product 2-phospho-D-glycerate-first sterospecific intermediate
• RNA World Hypothesis

• Nitrogen fixation: Mo requirement
  - Mo pterin cofactor
  - Nucleotide synthesis: by product of nitrogen fixation
    - GTP cyclohydrolase reverse reaction
  - Fixation occurring on peptides (Platforms)
    - Sequestered in membranes
    - D-amino acids
• Oligonucleotides replacing peptides as surfaces (RNA metabolism era)
  o Membranes form
• RNA folds in three dimensions (RNA replication era)
  o Can be replicated
  o Division into catalytic and replicative molecules
    ▪ CCA signal
      ▫ tRNA and Ribosomes
• Degraded for energy (DNA era)
  o Polynucleotide phosphorylase
  o Di-nucleotides lead to deoxyribonucleotides
    ▪ Ferredoxin reduction
    ▪ Invention of thymine

Origin of Life A. Danchin