• Metabolism first vs replication first
• Chemotrophs
On Wednesday (Sep 20)

• Lecture 10:00 – 10:15
  – Giving out HW3, review, Q/A

• Quiz 10:20 – 10:50 (closed book)
  – 3 pages (1p multiple choice)
  – RGS pp. 1-34 + lecture notes

• Special accommodations
  – I have emailed those who contacted me
  – If you didn’t, make sure you do
Today

• Replication first vs Metabolism first
• Early cells
• RNA world
• LUCA
• Reading:
  – RGS pp. 30-34
  – Lon pp. 193-195
  – BS pp. 172-176, 206-208
Primitive cells

- Lipid bilayers
- Protein droplets (Oparin 1924)
- Dehydration – rehydration (S Fox 1958)
Properties of protocells

- Confinement of organics within cells is advantageous:
  - Facilitates chemical reactions.
  - Cooperative relationships evolve.
- Membrane-like spheres easily made in lab experiments!
  - Cooled amino acids solutions.
  - Lipids in water.
- First “cell” may have been RNA replicating within simple membrane.
**Abiotic “cells”**

- Volcanic rock (pumice)
  - Small air pockets
  - Tiny compartments
  - Could house small chemical mixtures
  - First steps toward life (?)
Role of minerals

• Support
  – Amino acids polymerize on surfaces

• Selection
  – Different crystal faces select left/right
  – Both possible → natural selection chose one

• Catalysis
  – $\text{N}_2$ to $\text{N}_3\text{H}$ via metallic surfaces
  – Suitable in hydrothermal vents
• **Support** – Amino acids polymerize on surfaces

• **Selection** – Different crystal faces select left/right – Both possible \[\rightarrow\] natural selection chose one

• **Catalysis** – $N_2$ to $N_3H$ via metalic surfaces
Metabolism

• How to make a living (Longstaff 193)

• Use of catalysts
  – Speeds up reaction
  – Regardless of direction (!)

• Two types
  – Proteins
  – RNA catalysts (=ribozyme)
Three requirements

- **Source of carbon** (CO$_2$ or CH$_2$O)
- **Source of energy**
  - To reduce inorganic to org macromolecule
  - Electron donor (e.g. H$_2$)
- **An oxidant**
  - To harness chemical potential energy
  - Electron acceptor (e.g. O$_2$)
“Food” in Greek?

food

τροφή
**Troph (Greek) = food**

- auto – hetero
- photo – chemo
- litho – organo

- Photoautotroph
- Chemoautotroph
- Photoheterotroph
- Chemoheterotroph
### Range of possibilities

<table>
<thead>
<tr>
<th>Energy source</th>
<th>Sunlight</th>
<th>Photo-</th>
<th>Chemo-</th>
<th>Electron donor</th>
<th>Organic</th>
<th>Inorganic</th>
<th>Organo-</th>
<th>Litho-</th>
<th>Carbon source</th>
<th>Organic</th>
<th>Inorganic</th>
<th>Hetero-</th>
<th>Auto-</th>
</tr>
</thead>
</table>

- e.g.: Chemolithoheterotroph
- Altogether 8 possibilities!
**Thiobacillus denitrificans**

- Discovered 1904
  - 0.5x1x3 μm³
- Soil & mud
  - Oxidize U(IV) → U(VI)
- Chemolithoautotroph or chemoautotroph
  - H₂S + CO₂ → CH₂O + 2S
Gray bacterium in rock spaces

Always found to be growing
Excreting CO₂
Rocks mineral structure depleted in Fe

A. Chemoautotroph
B. Lithoautotroph
C. Photoautotroph
D. Lithoheterotroph
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Blue-green in petri dish

Cells grow when exposed to sunlight
Excrete $O_2$
Grow and produce $O_2$ as long as in sunlight

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**Blue-green in petri dish**

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Metabolism/replication first?

• Organism needs 2 things
  – Replication (otherwise not self-sustaining)
• Turn disorder to ordered chem reactions to extract energy from surroundings
  → metabolism, needed to control flow of energy
Advantage of RNA over DNA?

A. More stable?

B. Less stable?
Advantage of RNA over DNA?

A. More stable?
B. Less stable?
DNA transcription

• DNA $\rightarrow$ messenger RNA (mRNA, transient)
• mRNA read out by ribosome (rRNA)
  – Ribosomes contain their own type of RNA
  – Amino acids + RNA (tRNA, small)
• Ribosome synthesizes proteins (incoming tRNA)
  – Forges peptide bonds between amino acids
  – tRNA liberated, captures new amino acids
  – 10-20 amino acids/second
RNA world before DNA/protein

- Nucleotides in RNA easier made
- RNA evolved to DNA (greater stability)
- No scenario for protein replication w/o RNA
- Natural selection outcompeted DNA+protein
On Friday

- RNA world (RGS pp. 35)
  - Last common ancestor (LUCA)

- Top-down approach
  - RGS pp. 37-41
  - BS pp. 172-176