# ASTR/GEOL-2040: Search for life in the Universe: Lecture 9


- Metabolism first vs replication first
- Chemotrophs

# *On Wednesday (Sep 20)*

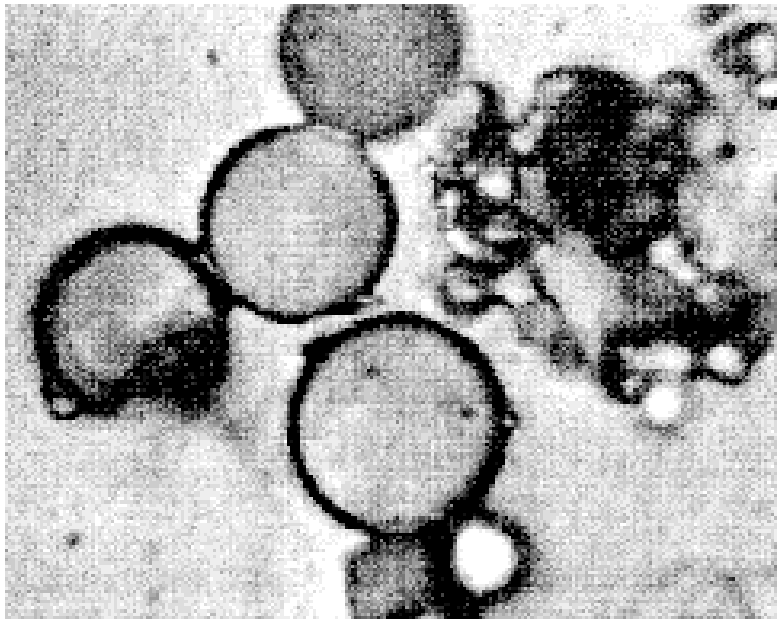
- Lecture 10:00 – 10:15
  - Giving out HW3, review, Q/A
- Quiz 10:20 – 10:50 (closed book)
  - 3 pages (1p multiple choice)
  - RGS pp. 1-34 + lecture notes
- Special accommodations
  - I have emailed those who contacted me
  - If you didn't, make sure you do

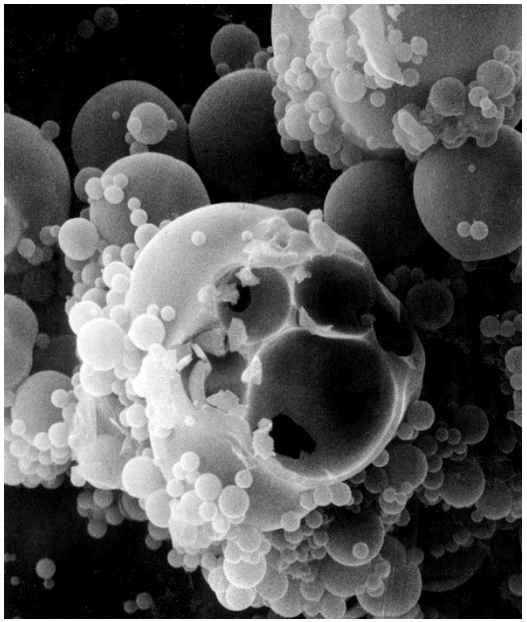
# Today

- 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*

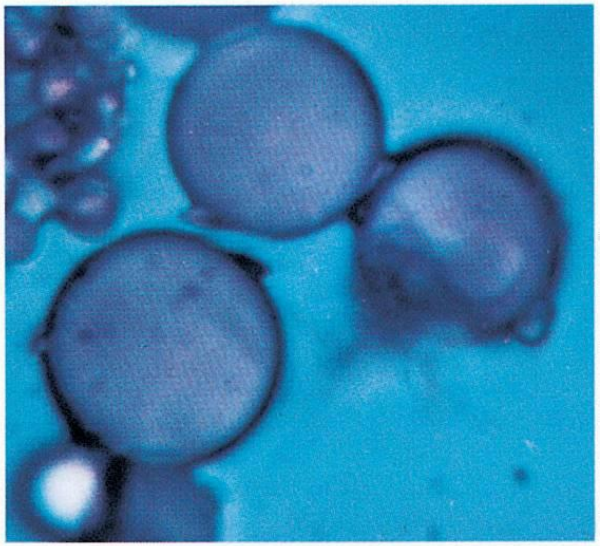
- Lipid bilayers
- Protein droplets (Oparin 1924)
- Dehydration – rehydration (S Fox 1958)

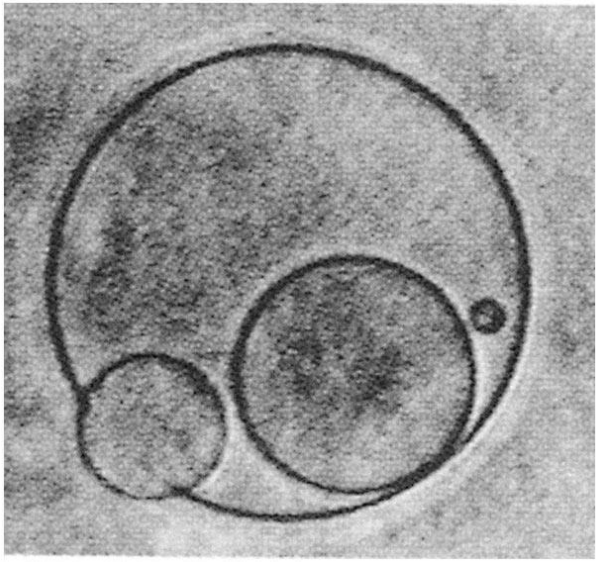


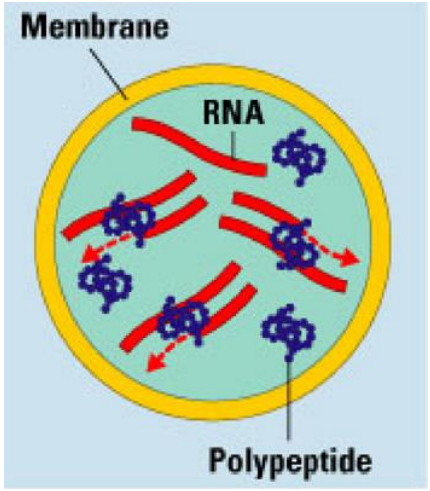


# Properties of protocells

- 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.





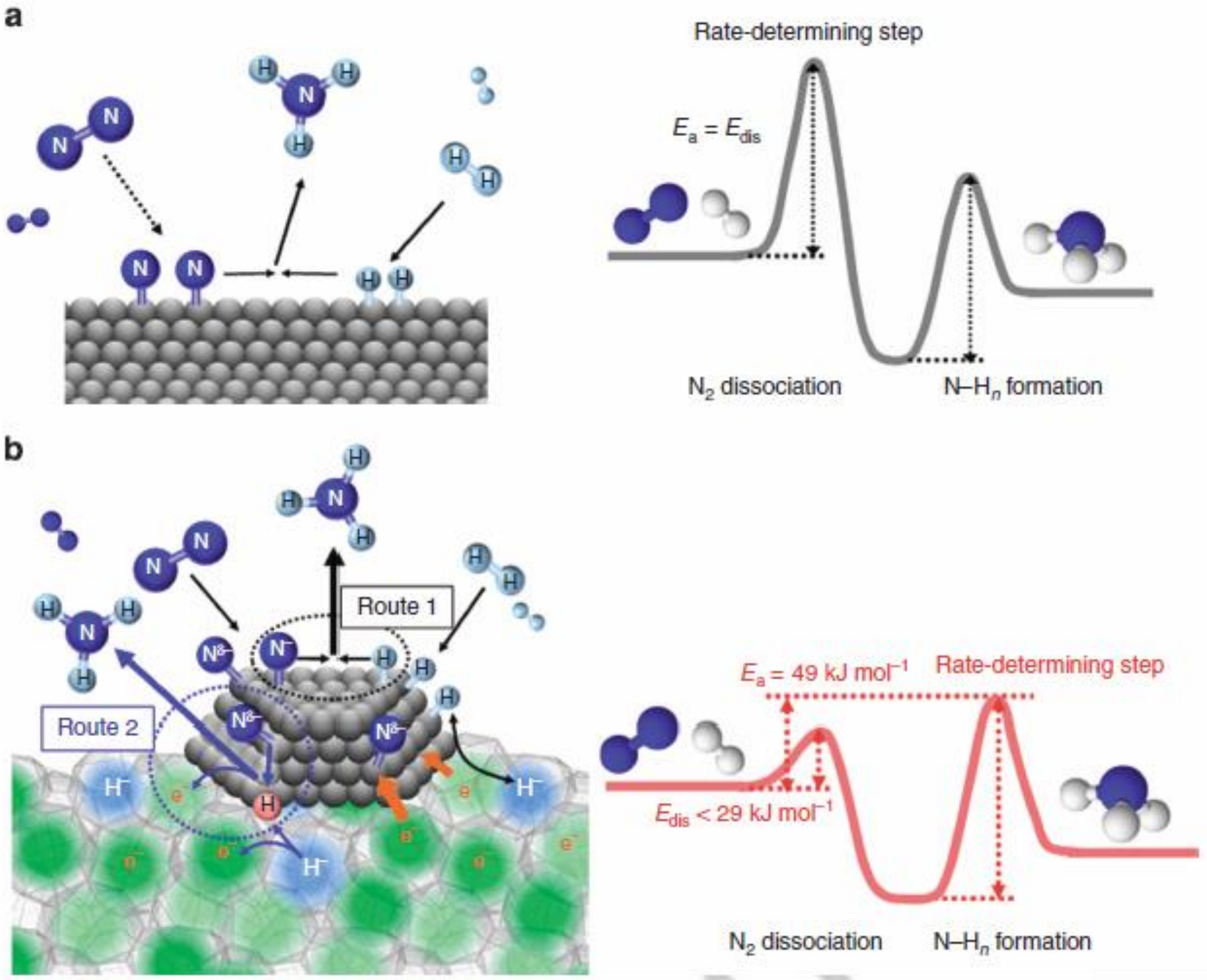


# *Abiotic "cells"*

- 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
  - $N_2$ to $N_3H$ via metalic surfaces
  - Suitable in hydrothermal vents


a
Rate-determining step
$E_a = E_{dis}$
$N_2$ dissociation
N–$H_n$ formation
b
Route 1
Route 2
$E_a$ = 49 kJ mol$^{-1}$
Rate-determining step
$E_{dis}$ < 29 kJ mol$^{-1}$
$N_2$ dissociation
N–$H_n$ formation

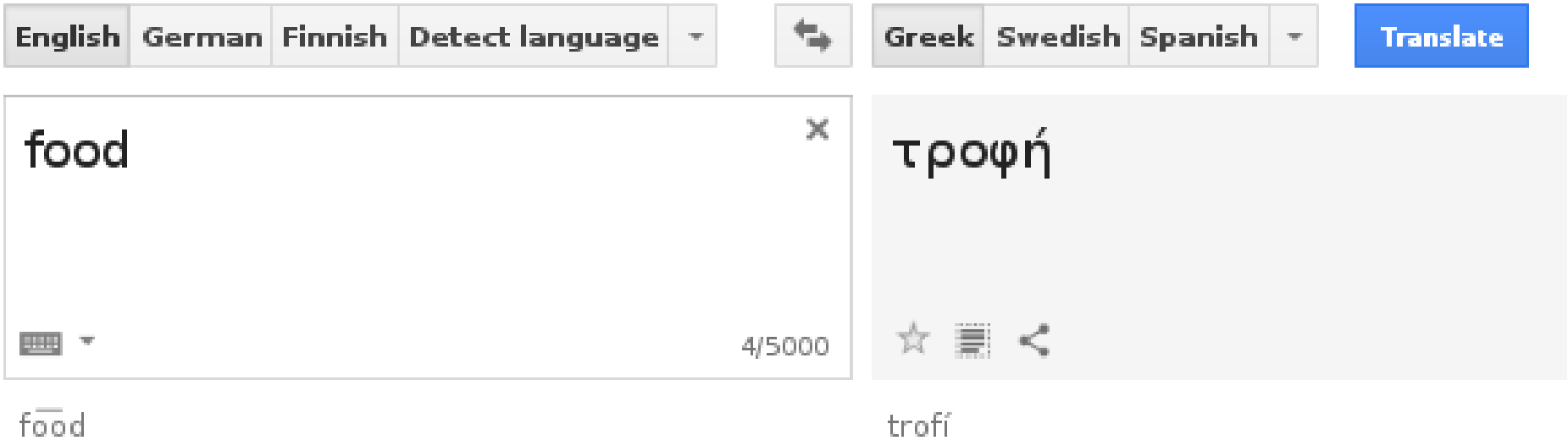
# *Metabolism*

- How to make a living (Longstaff 193)
- Use of catalysts
  - Speeds up reaction
  - Regardless of direction (!)
- Two types
  - Proteins
  - RNA catalysts (=ribozyme)

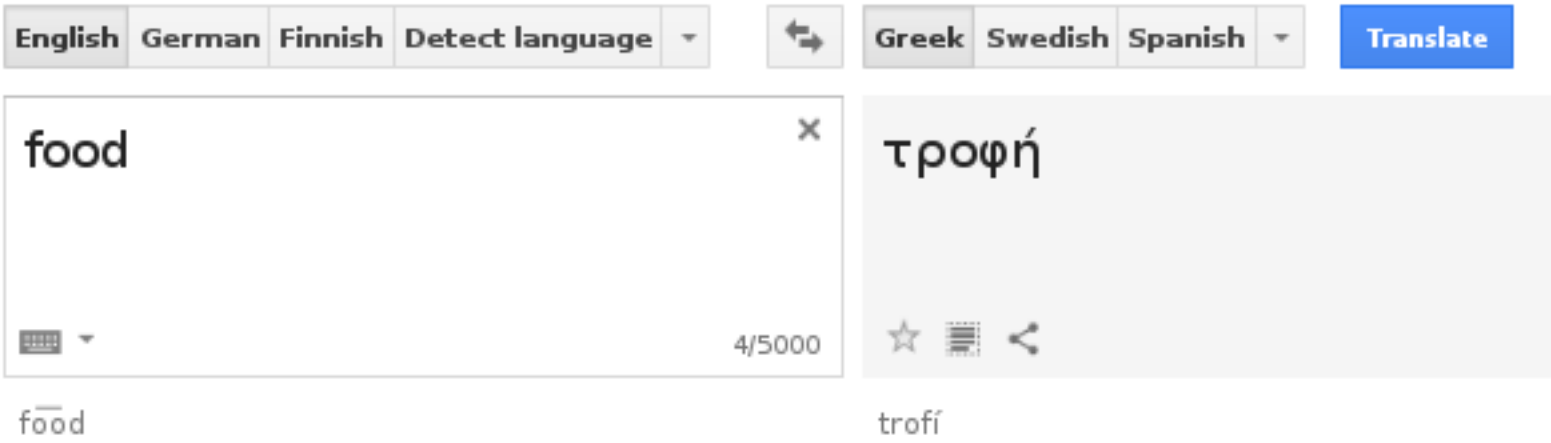
# *Three requirements*

- Source of carbon ($CO_2$ or $CH_2O$)
- 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?



# *Troph (Greek) = food*




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

- Photoautotroph
- Chemoautotroph
- Photoheterotroph
- Chemoheterotroph

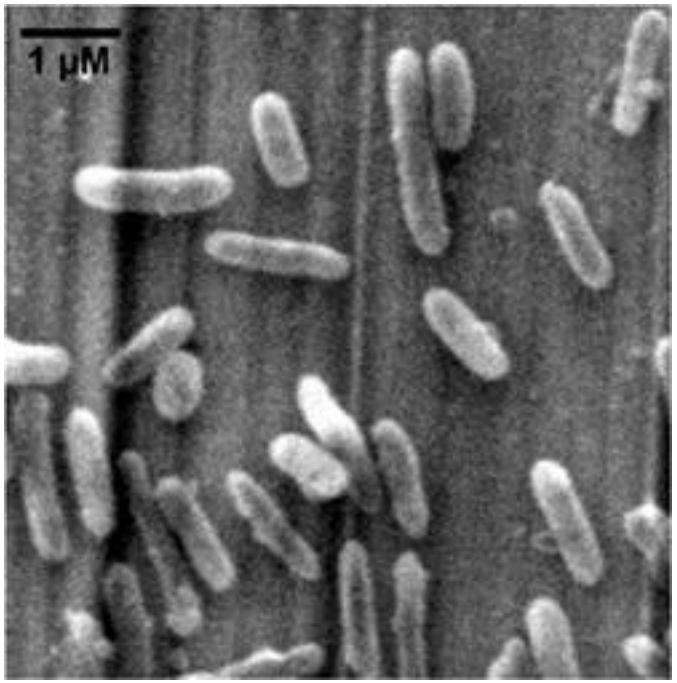
# Range of possibilities

| | | | | | |
|---|---|---|---|---|---|
| Energy source | Sunlight | Photo- | | | -troph |
| | Molecules | Chemo- | | | |
| Electron donor | Organic | | Organo- | | |
| | Inorganic | | Litho- | | |
| Carbon source | Organic | | | Hetero- | |
| | Inorganic | | | Auto- | |

- e.g.: Chemolithoheterotroph
- Altogether 8 possibilities!

# *Thiobacillus denitrificans*

- Discovered 1904
  - $0.5 \times 1 \times 3\ \mu m^3$
- Soil & mud
  - Oxidize U(IV)→U(VI)
- Chemolithoautotroph or chemoautotroph
  - $H_2S + CO_2 \rightarrow CH_2O + 2S$



# *Gray bacterium in rock spaces*

Always found to be growing
Excreting $CO_2$
Rocks mineral structure depleted in Fe

A. Chemoautotroph
B. Lithoautotroph
C. Photoautotroph
D. Lithoheterotroph

# *Gray bacterium in rock spaces*

Always found to be growing
Excreting $CO_2$
Rocks mineral structure depleted in Fe

A. Chemoautotroph

B. Lithoautotroph

C. Photoautotroph

D. Lithoheterotroph

# *Blue-green in petri dish*

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

A. Chemoautotroph
B. Lithoautotroph
C. Photoautotroph
D. Lithoheterotroph

# *Blue-green in petri dish*

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

A. Chemoautotroph
B. Lithoautotroph
C. Photoautotroph
D. Lithoheterotroph

# 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 → 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