ASTR/GEOL-2040: Search for life in the Universe, Lecture 4

Pages 6-10 in RGS
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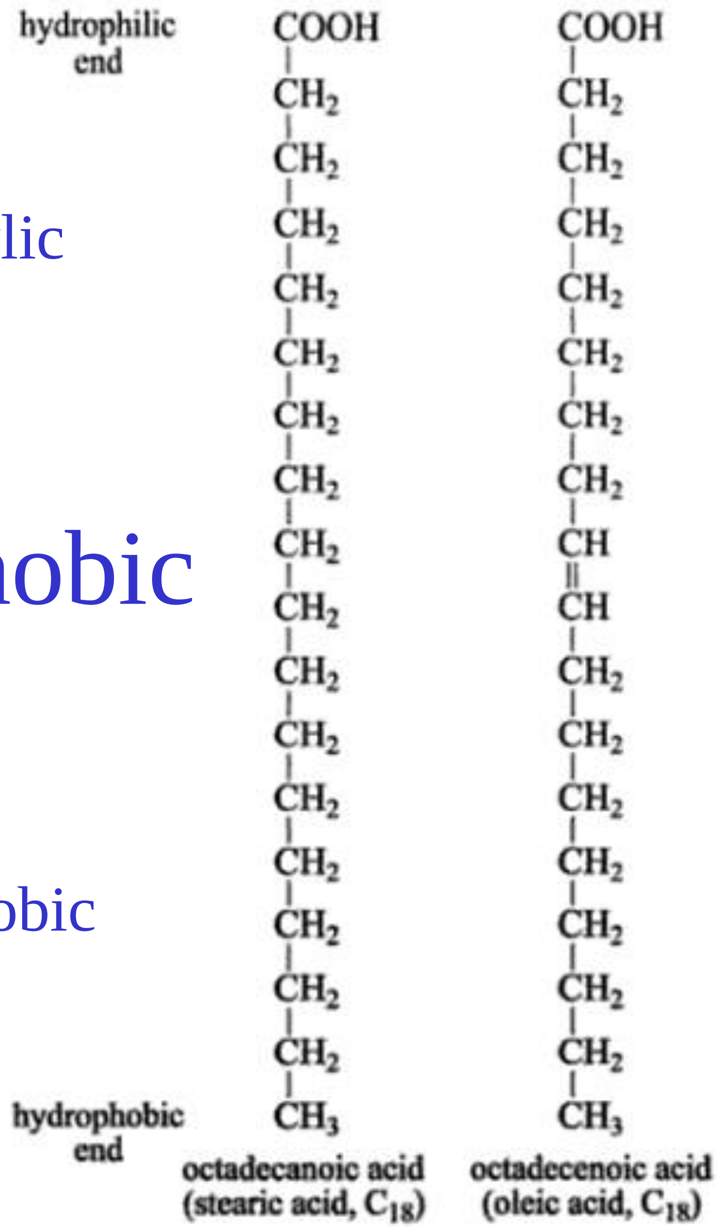
(Office hours: Mondays 2:30 – 3:30 in X590
and Wednesdays 11-12 in D230)

Cells are made of lipids

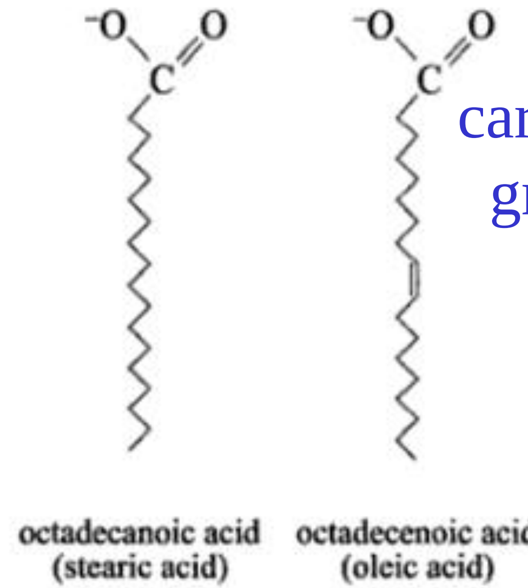
hydrophylic

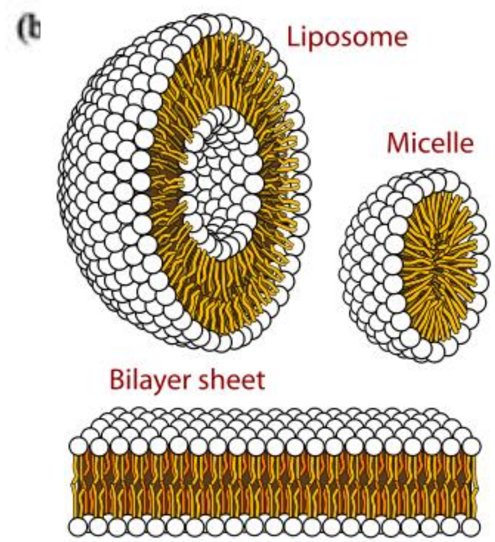
→ amphobic

hydrophobic



carboxyl group





Common carbon compounds

- carbohydrates
- hydrocarbons

Sugars are

A. Hydrocarbons
B. Carbohydrates
C. Hydroxyls
D. Carboxyls

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A. Hydrocarbons
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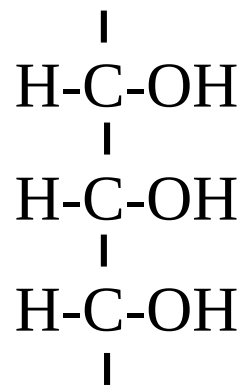
Common carbon compounds

- Hydrocarbons: made up entirely of hydrogen & carbon

  $CH_3\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}CH_3$

- Carbohydrates: made up of hydrogen, carbon, & oxygen

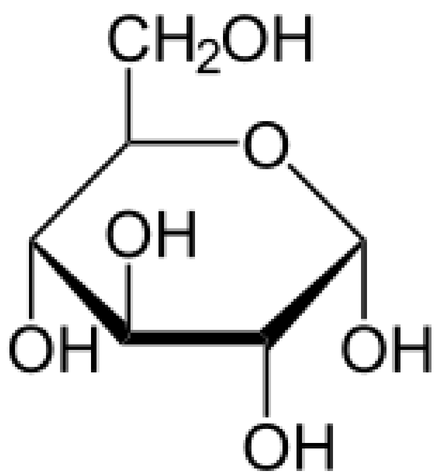
  $C_m(H_2O)_n$

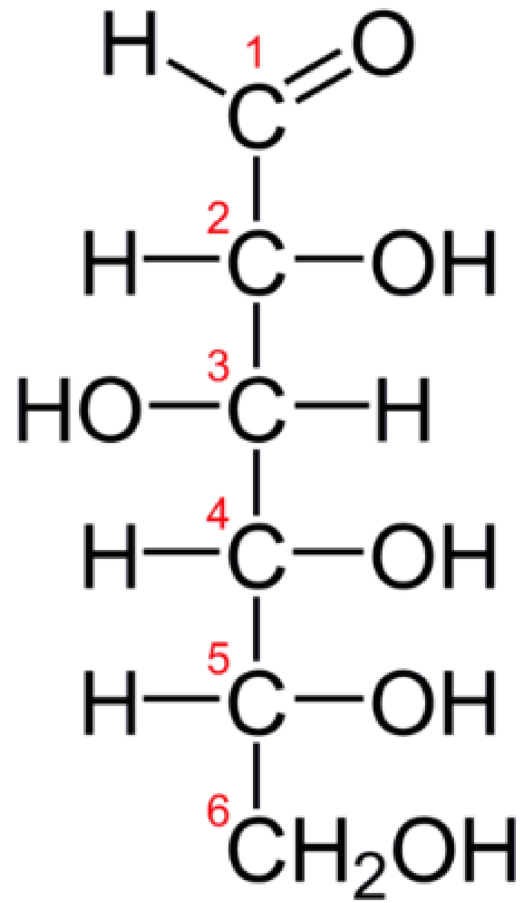


Glucose

- Glucose=hexose =monosaccharide = $C_6H_{12}O_6$

chemists drop C & H

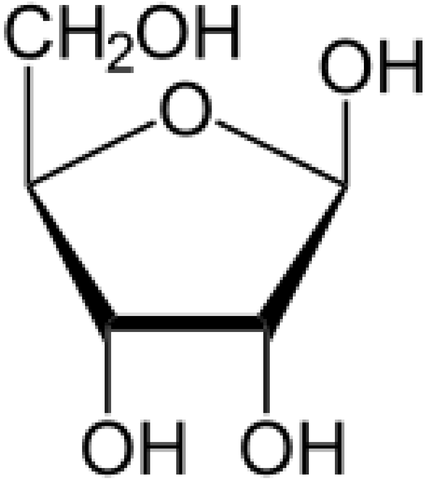


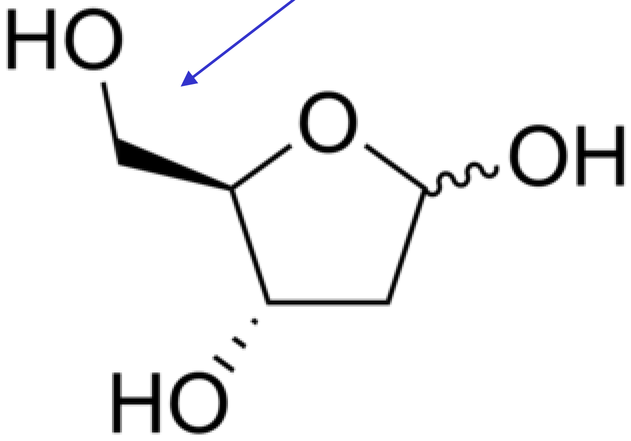


Another important sugar

- Ribose = pentose = $C_5H_{10}O_5$
- deoxyribose=$C_5H_{10}O_4$

again: drop
C & H





…note 3-D
perspective

Why are sugars useful?

- ……
- ………..
- …………….

→ think of carbohydrates more generally

Why are carbohydrates useful?

- Energy storage
- Structural support
- Food source for others

Two more building blocks

- Proteins
- RNA & DNA: nuclei acids

> The Central Dogma. This states that once 'information' has passed into protein it cannot get out again. In more detail, the transfer of information from nucleic acid to nucleic acid, or from nucleic acid to protein may be possible, but transfer from protein to protein, or from protein to nucleic acid is impossible. Information means here the precise determination of sequence, either of bases in the nucleic acid or of amino acid residues in the protein.

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

What are proteins?

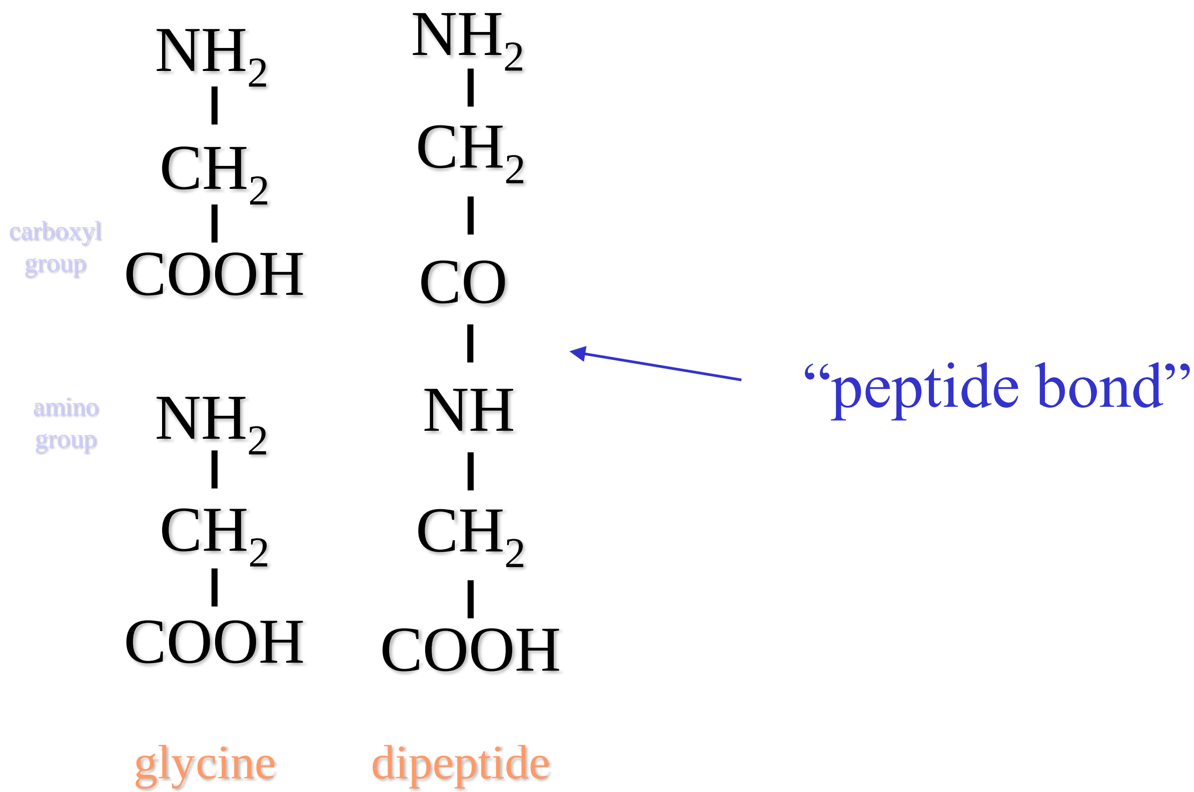
- Proteios = primary
  - Berzelius (1838) $C_{400}H_{620}N_{100}O_{120}P_{1}S_{1}$
- Are the most complex macromolecules in living systems
- Polymers of amino acids
- ”peptides” are shorter polymers

What are amino acids?

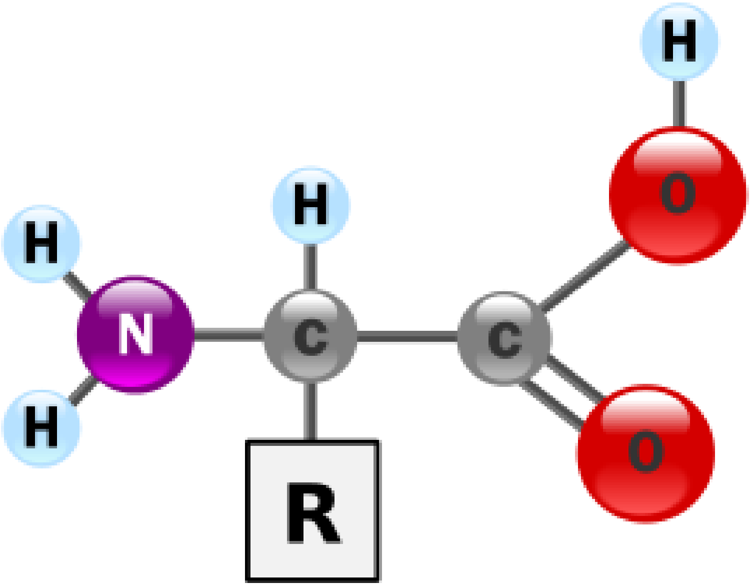
- amino: $-NH_2$
- acid: -COOH
- and a C
- and an H
- and possibly another H

$$
\begin{array}{c}
NH_2 \\
| \\
H\text{-}C\text{-}H \\
| \\
COOH
\end{array}
$$

Polymerization
→ polycondensation



Other amino acids



- if R=CH_3: alanine
- valine, proline, sarcosine, ...

Recognize 3 of the 4 endings?

– COOH carboxyl group
– OH hydroxyl group
– CH_3 methyl group
– NH_2 amino group (=amine group)

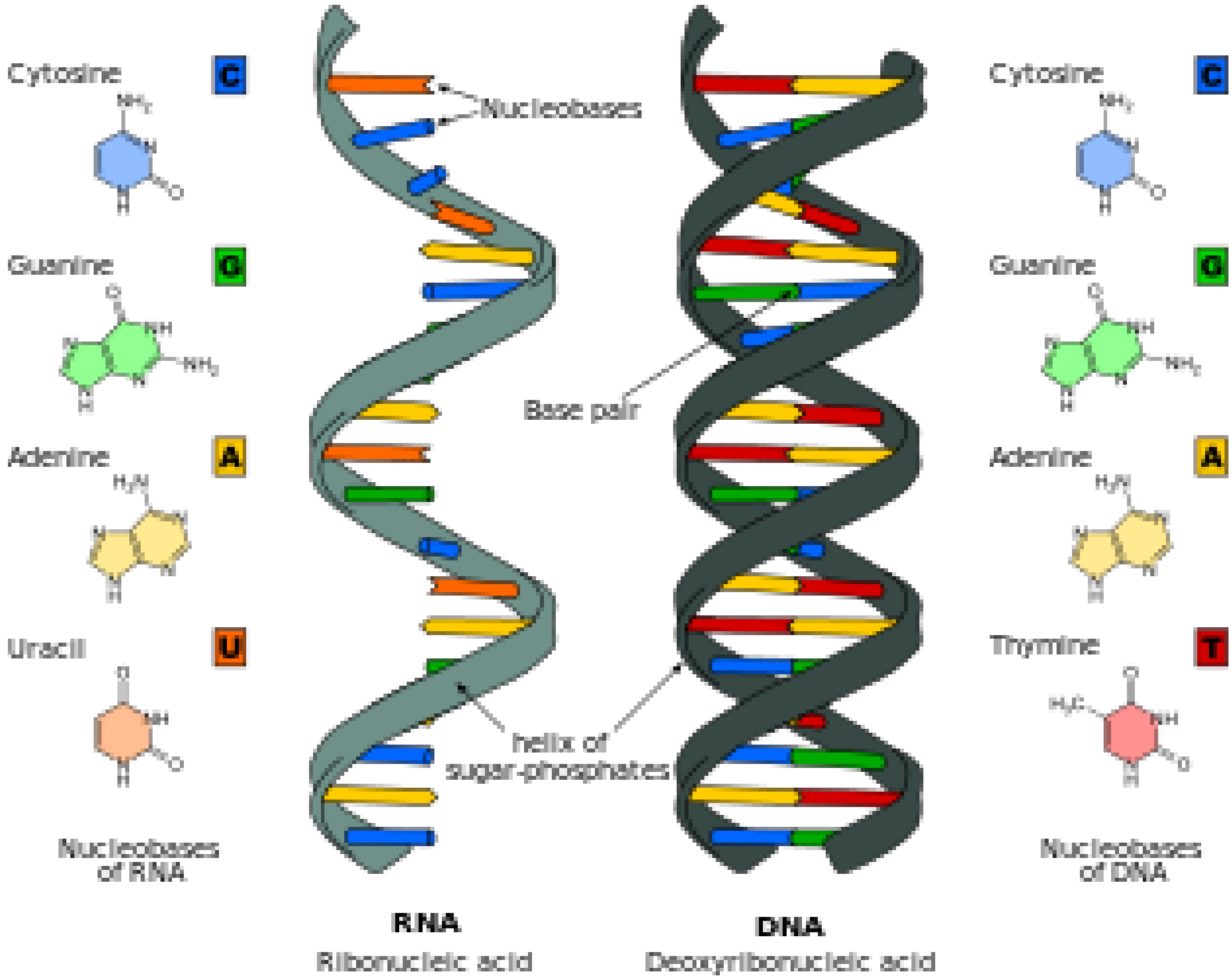
Why are proteins important?

- Structural support (e.g., finger nails)
- Act as catalysts (=enzymes)
  - Facilitates/accelerates reactions
  - Not used up or involved in reaction
  - Can be reused many times!
- Their exact role depends on sequence

So many different ones

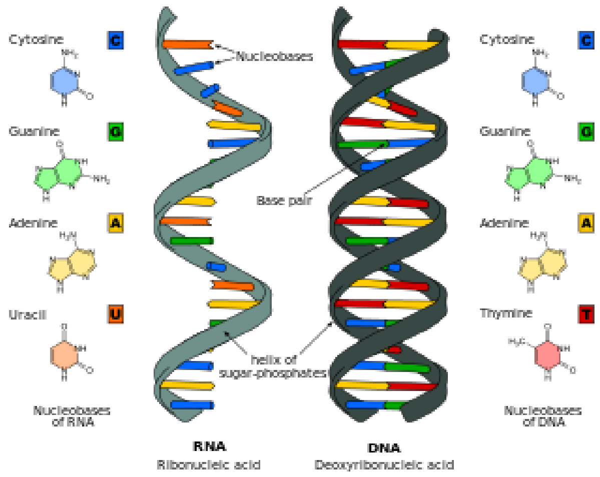
- Only 20 amino acids in proteins
  - Although 70 have been identified
  - 2 (+) of them used in rare cases microbes
- Folding
  - Depends on amino acid sequence
  - Determines how they work.

Finally: nucleic acids



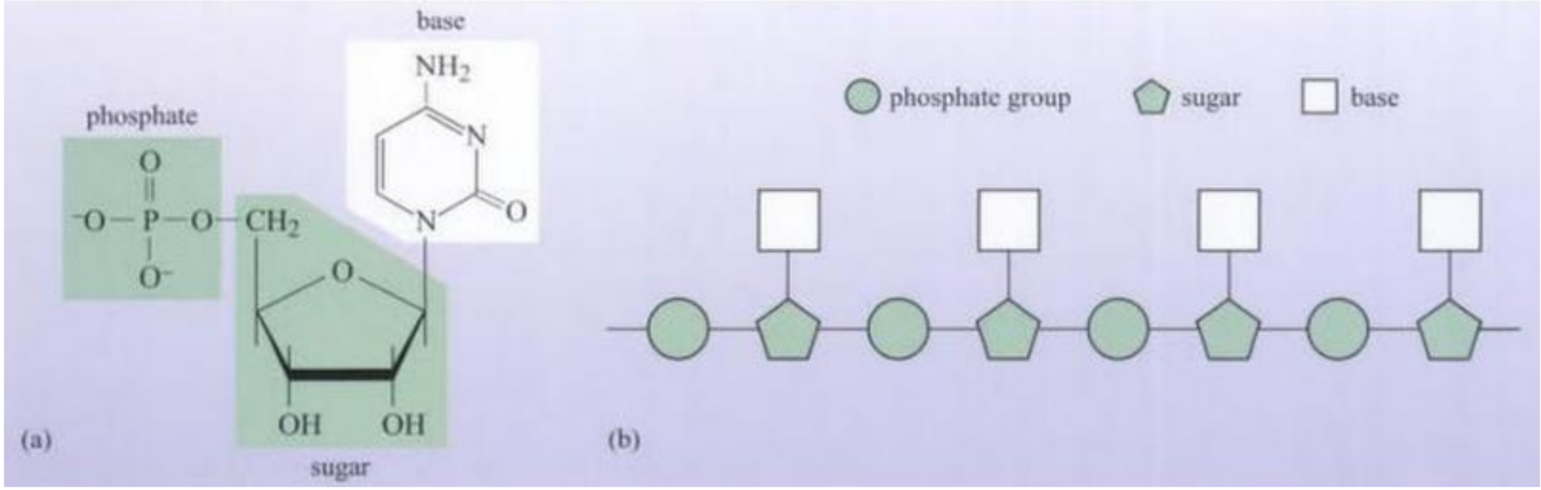
Inventory

- Polymers of nucleotides
- Backbone
  - DNA (*d*eoxyribo*n*ucleic *a*cid)
  - or RNA (*r*ibo*n*ucleic *a*cid)
  - Pentose sugar (5 carbons)
  - Phosphate group
- Nitrogen-containing base
  - four different ones
- Form a spiral



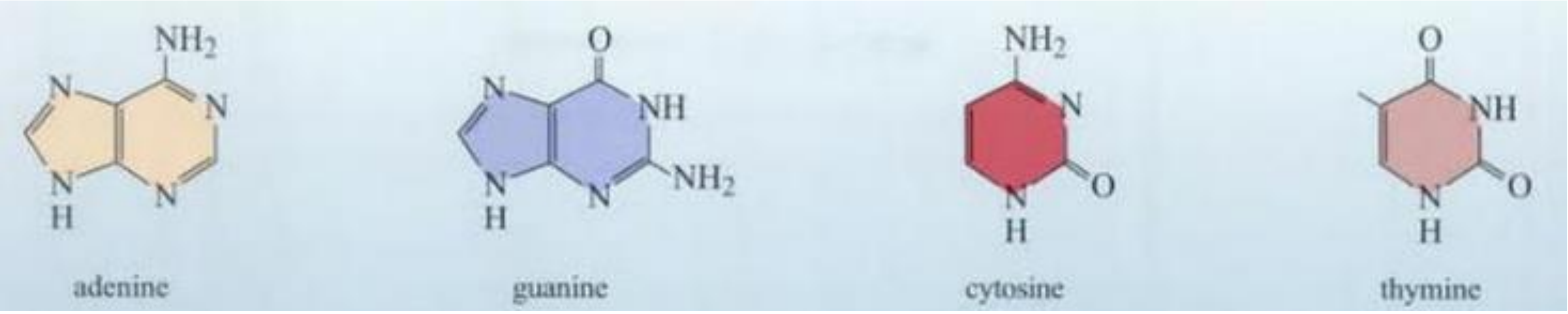
Inventory

- Backbone
  - *d*eoxyribo*n*ucleic *a*cid, *r*ibo*n*ucleic *a*cid
  - Pentose sugar (5 carbons)
  - Phosphate group
- Nitrogen-containing base



Different bases

- Two groups of bases:
  - pyrimidines T,C
  - purines A,G
- These two groups pair in specific ways
  - T-A and A-T
  - C-G and G-C



In which ways could life elsewhere be different?

- Different backbones
- Different base pairs

An enzyme consists of a chain of

A. Carbohydrates
B. Amino acids
C. nucleotides

Two more bases synthesized in 2014

LETTER

doi:10.1038/nature13314

A semi-synthetic organism with an expanded genetic alphabet

Denis A. Malyshev[1], Kirandeep Dhami[1], Thomas Lavergne[1], Tingjian Chen[1], Nan Dai[2], Jeremy M. Foster[2], Ivan R. Corrêa Jr[2] & Floyd E. Romesberg[1]

Organisms are defined by the information encoded in their genomes, and since the origin of life this information has been encoded using a two-base-pair genetic alphabet (A–T and G–C). *In vitro*, the alphabet has been expanded to include several unnatural base pairs (UBPs)[1–3]. We have developed a class of UBPs formed between nucleotides bearing hydrophobic nucleobases, exemplified by the pair formed between d5SICS and dNaM (d5SICS–dNaM), which is efficiently PCR-amplified[1] and transcribed[4,5] *in vitro*, and whose unique mechanism of replication has been characterized[6,7]. However, expansion of an organ-

suggest that decomposition is mediated by phosphatases. As no degradation was observed upon incubation in spent media, decomposition seems to occur within the periplasm. No increase in stability was observed in cultures of single-gene-deletion mutants of *E. coli* BW25113 lacking a specific periplasmic phosphatase[19] (as identified by the presence of a Sec-type amino-terminal leader sequence), including *phoA*, *ushA*, *appA*, *aphA*, *yjjX*, *surE*, *yfbR*, *yjjG*, *yfaO*, *mutT*, *nagD*, *yggV*, *yrfG* or *ymfB*, suggesting that decomposition results from the activity of multiple phosphatases. However, the extracellular stability of [α-^{32}P]-dATP was sig-

Think about other worlds

- Large impacts can blast rocks into space
  - Life (spores) might survive in rocks
- Suppose life on Mars is found with
  - Different sets of amino acids
  - Right-handed versions of amino acids
- Does this support/contradict hypothesis that life migrated from Mars?

What we talked about

- The 4 different building blocks
  - Lipids, carbohydrates, proteins, nucleic acids
  - Their usefulness
- Next time
  - How they propagrate genetic information
  - Genetic code
  - Biomarkers, biosignatures
  - pp. 11-17 of RGS