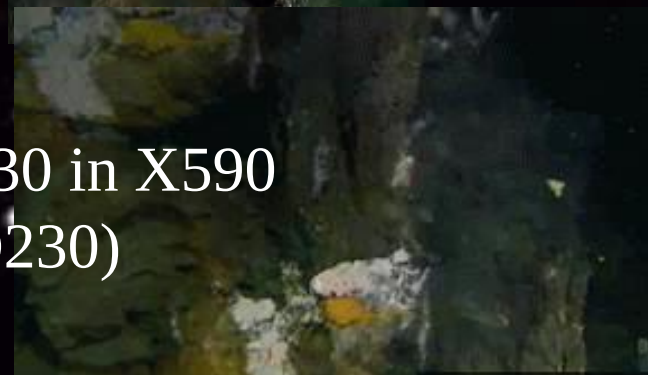
ASTR/GEOL-2040: Search for life in the Universe, Lecture 5

Astrobiology

Pages 11-17 in RGS



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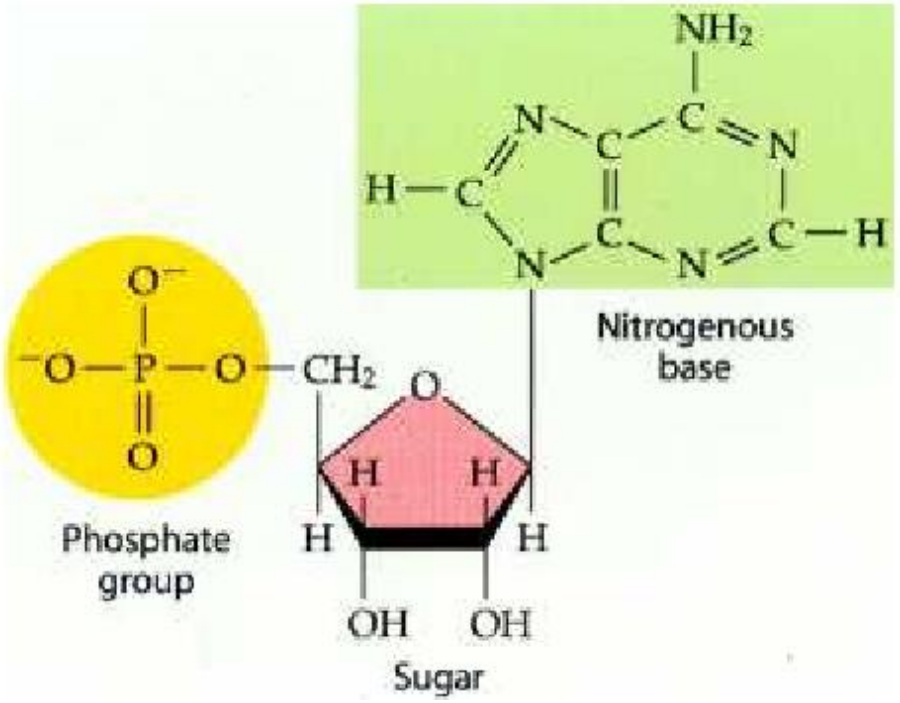
(Office hours: Mondays 2:30 – 3:30 in X590
and Wednesdays 11-12 in D230)

Last time

- The 4 building blocks
  - Lips, carbohydrates, proteins, DNA&RNA
- Their roles
  - Cell walls, energy & structual support, catalysts (enzymes), information

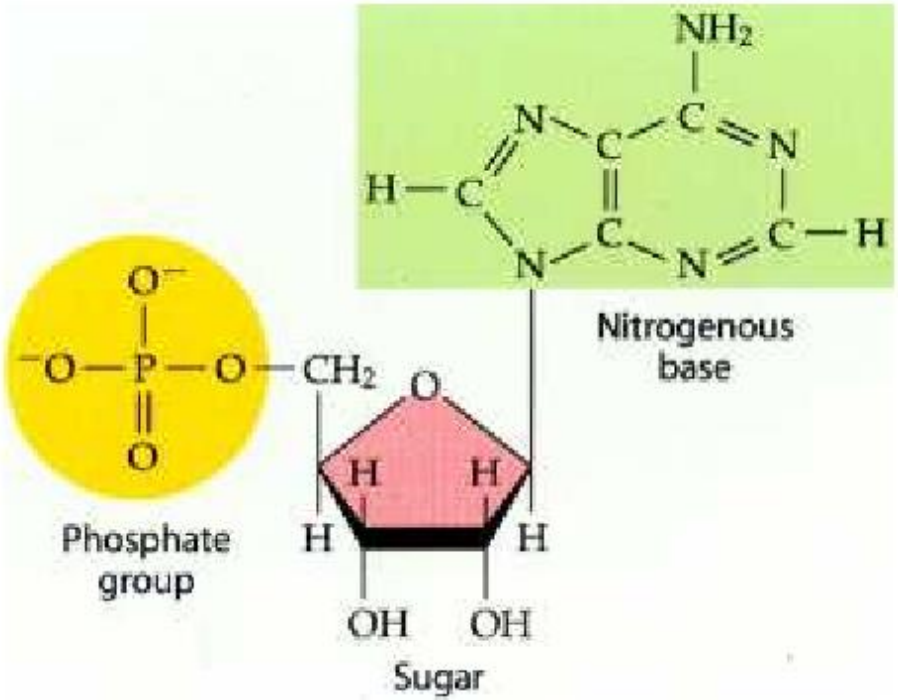
What kind of molecule?



A. Lipid
B. Carbohydrate
C. Hydrocarbon
D. Amino acid
E. Nucleotide

Hint: find the answer by elimination

What kind of molecule?



A. Lipid

B. Carbohydrate

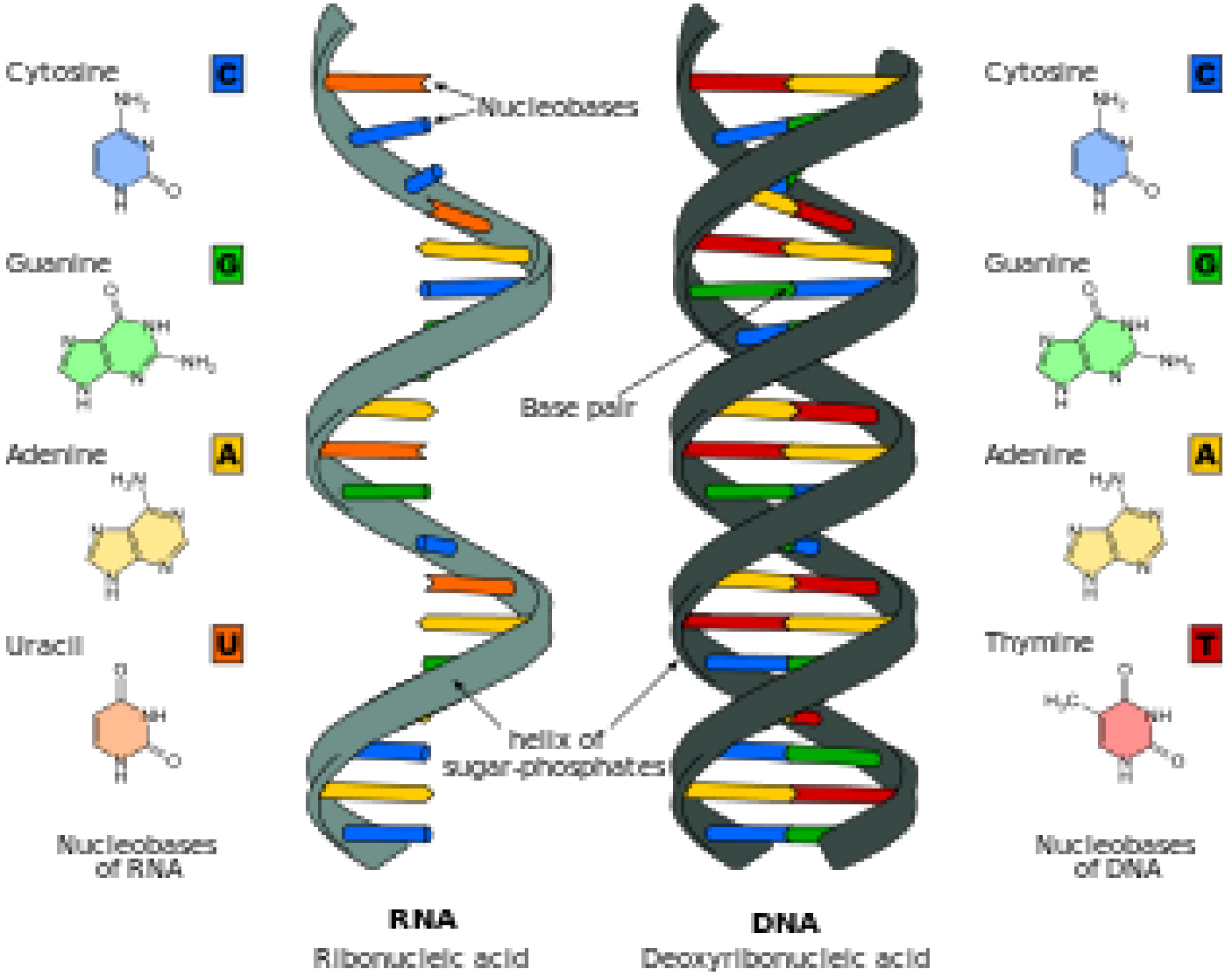
C. Hydrocarbon

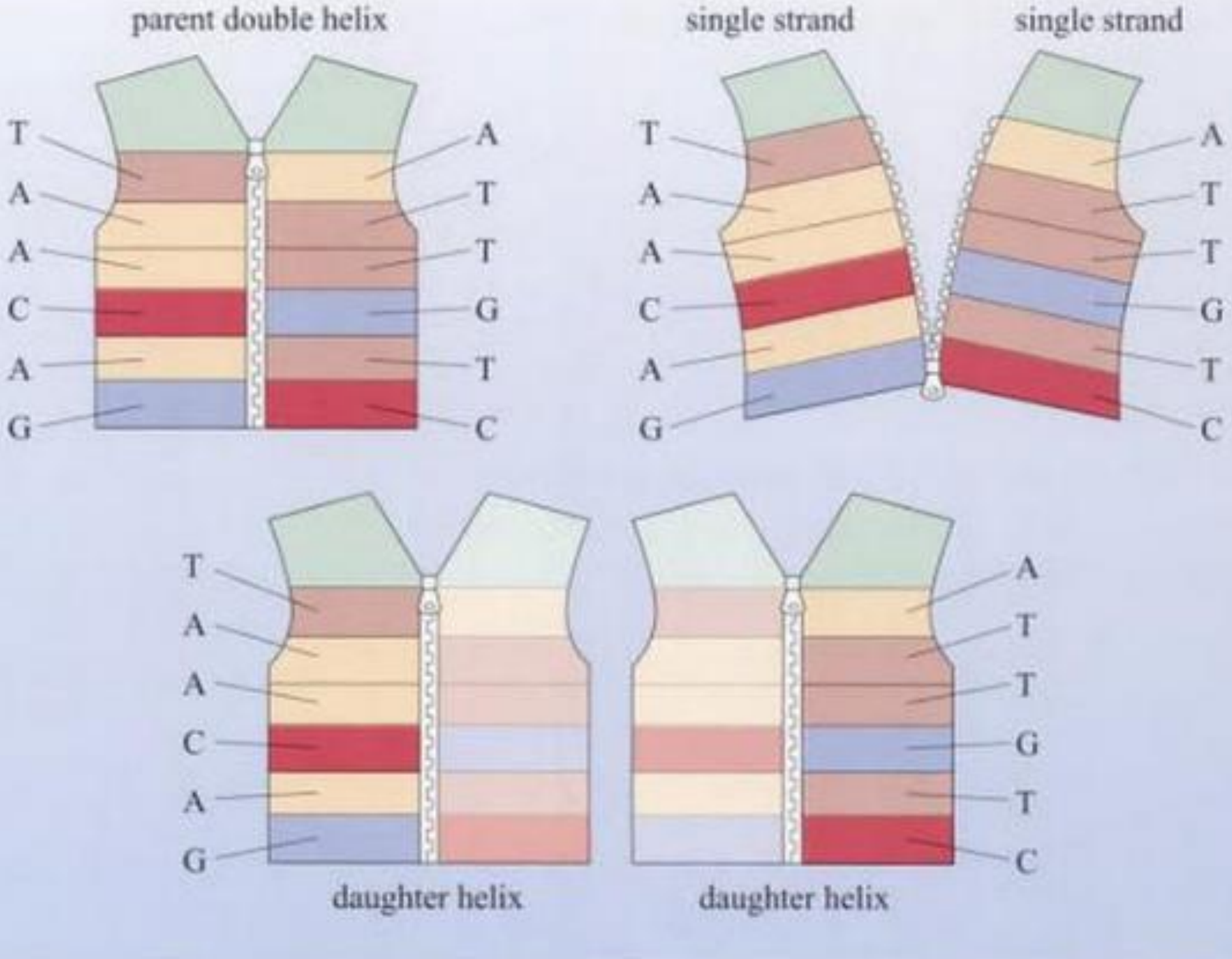
D. Amino acid

E. Nucleotide

… as in deoxyribonucleic acid

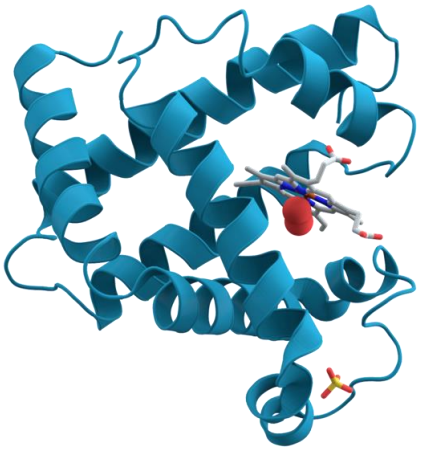
Nucleic acid staircase




parent double helix
T
A
A
C
A
G
A
T
T
G
T
C
single strand
single strand
T
A
A
C
A
G
A
T
T
G
T
C
T
A
A
C
A
G
daughter helix
A
T
T
G
T
C
daughter helix

DNA → RNA → Proteins

- Proteins assembled based on information in DNA
- Are catalysts (enzymes)
  - Some for helices
  - Others form sheets



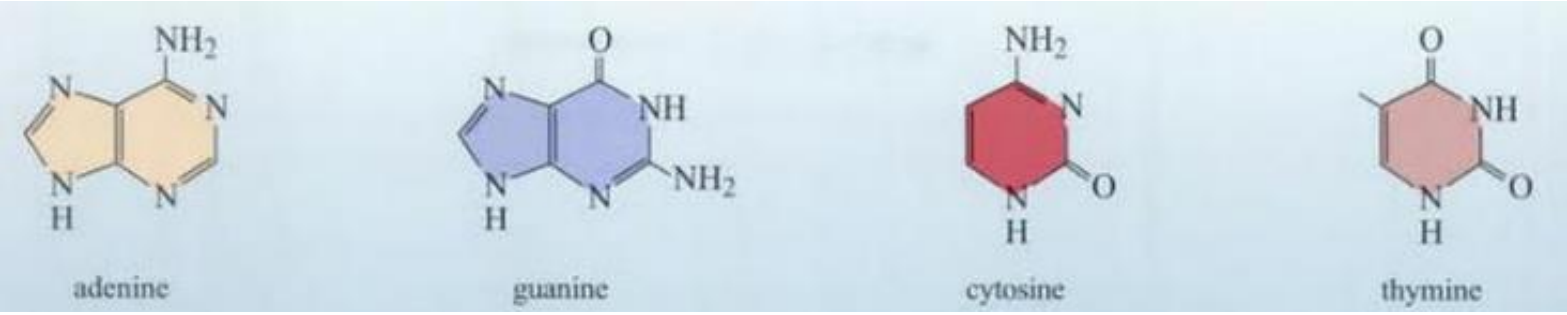
Different bases

- Two groups of bases:
  - pyrimidines T,C
  - purines A,G

T in DNA
U in RNA

- These two groups pair in specific ways
  - T-A and A-T
  - C-G and G-C

A-U pair
for RNA



Genetic code

- Alphabet of 4 letters
- Words with 3 letters
- Each word → a particular amino acid
- Gene → a particular protein

Second Letter

1st letter	U	C	A	G	3rd letter
U	UUU Phe UUC UUA Leu UUG	UCU UCC Ser UCA UCG	UAU Tyr UAC UAA Stop UAG Stop	UGU Cys UGC UGA Stop UGG Trp	U C A G
C	CUU CUC Leu CUA CUG	CCU CCC Pro CCA CCG	CAU His CAC CAA Gln CAG	CGU CGC Arg CGA CGG	U C A G
A	AUU AUC Ile AUA AUG Met	ACU ACC Thr ACA ACG	AAU Asn AAC AAA Lys AAG	AGU Ser AGC AGA Arg AGG	U C A G
G	GUU GUC Val GUA GUG	GCU GCC Ala GCA GCG	GAU Asp GAC GAA Glu GAG	GGU GGC Gly GGA GGG	U C A G

Examples

- ACC, ACA, ACT, ACG → threonine
- Why?

1st letter	Second Letter: U	Second Letter: C	Second Letter: A	Second Letter: G	3rd letter
U	UUU Phe UUC UUA Leu UUG	UCU UCC Ser UCA UCG	UAU Tyr UAC UAA Stop UAG Stop	UGU Cys UGC UGA Stop UGG Trp	U C A G
C	CUU CUC Leu CUA CUG	CCU CCC Pro CCA CCG	CAU His CAC CAA Gln CAG	CGU CGC Arg CGA CGG	U C A G
A	AUU AUC Ile AUA AUG Met	ACU ACC Thr ACA ACG	AAU Asn AAC AAA Lys AAG	AGU Ser AGC AGA Arg AGG	U C A G
G	GUU GUC Val GUA GUG	GCU GCC Ala GCA GCG	GAU Asp GAC GAA Glu GAG	GGU GGC Gly GGA GGG	U C A G

Other examples

- TGT, TGC → cysteine
- TGA ”stop”
- TGG tryptophan

1st letter	Second Letter: U	Second Letter: C	Second Letter: A	Second Letter: G	3rd letter
U	UUU Phe	UCU Ser	UAU Tyr	UGU Cys	U
	UUC Phe	UCC Ser	UAC Tyr	UGC Cys	C
	UUA Leu	UCA Ser	UAA Stop	UGA Stop	A
	UUG Leu	UCG Ser	UAG Stop	UGG Trp	G
C	CUU Leu	CCU Pro	CAU His	CGU Arg	U
	CUC Leu	CCC Pro	CAC His	CGC Arg	C
	CUA Leu	CCA Pro	CAA Gln	CGA Arg	A
	CUG Leu	CCG Pro	CAG Gln	CGG Arg	G
A	AUU Ile	ACU Thr	AAU Asn	AGU Ser	U
	AUC Ile	ACC Thr	AAC Asn	AGC Ser	C
	AUA Ile	ACA Thr	AAA Lys	AGA Arg	A
	AUG Met	ACG Thr	AAG Lys	AGG Arg	G
G	GUU Val	GCU Ala	GAU Asp	GGU Gly	U
	GUC Val	GCC Ala	GAC Asp	GGC Gly	C
	GUA Val	GCA Ala	GAA Glu	GGA Gly	A
	GUG Val	GCG Ala	GAG Glu	GGG Gly	G

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?

How many words possible?

A. $4x3=12$

B. $4x3x2x1=24$

C. $4^3=64$

D. $3^4=81$

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Redundancy

In most cases: first 2 letters alone determine which amino acid

How many words possible?

3. The biochemistry on the early Earth (or on another world) could easily be slightly different from the biochemistry as we know it.

(i) Briefly explain why it is plausible that the early genetic code might have been a binary code with just two base pairs. Make reference to related modern findings mentioned during the lecture.

(ii) How many different amino acids would an early protein contain if it was the result of such a binary code?

(iii) Suppose the early genetic code used just G bases (guanine) and C bases (cytosine), and suppose further that the words (=codons) of the early genetic code contained already three letters (similar to the modern one; see below), which amino acids would you expect in such early proteins?

(iv) Is it reasonable that the early code contained glycine (Gly)?

Properties of nucleic acids

- In DNA: pentose sugar deoxyribose
  - Very stable
  - Double-stranded
  - Replicate
- RNA
  - Less stable
  - Singly stranded

Evolution

- Mutations
  - Most are lethal
  - Many have no effect
  - A few can carry benefits

Use of nucleobases

- The sequence contains genetic information
- The sequence can be copied
  - TAA CAG
  - ATT GTC
- One word (codon) → one amino acid
  - TAA → stop (also nonsence or junk DNA)
  - CAG → Gln (=Glutamine)
- In RNA, base U (=uracil) ←→ base T

thymine

Second Letter

1st letter	U	C	A	G	3rd letter
U	UUU Phe UUC UUA Leu UUG	UCU UCC Ser UCA UCG	UAU Tyr UAC UAA Stop UAG Stop	UGU Cys UGC UGA Stop UGG Trp	U C A G
C	CUU CUC Leu CUA CUG	CCU CCC Pro CCA CCG	CAU His CAC CAA Gln CAG	CGU CGC Arg CGA CGG	U C A G
A	AUU AUC Ile AUA AUG Met	ACU ACC Thr ACA ACG	AAU Asn AAC AAA Lys AAG	AGU Ser AGC AGA Arg AGG	U C A G
G	GUU GUC Val GUA GUG	GCU GCC Ala GCA GCG	GAU Asp GAC GAA Glu GAG	GGU GGC Gly GGA GGG	U C A G

Mutations

- Example of adding one letter
  - the cat ate the rat
  - the aca tat eth era t
- One word (codon) → one amino acid
  - TAA → stop (also nonsence or junk DNA)
  - CAG → Gln (=Glutamine)
- In RNA, base U (=uracil) ←→ base T

thymine

*Which of the following mutations has the **greatest** effect?*

A. One that changes a single base in a region of non-coding DNA;

B. one that changes the third letter;

C. one that deletes one base in the middle of a gene?

Check with your neighbors

***Greatest** effect?*

A. One that changes a single base in a region of non-coding DNA;

→ Has a chance in not doing much damage

B. one that changes the third letter;

→ has no effect in many cases

C. one that deletes one base in the middle of a gene?

→ see example with the cat!

Next time

- Transfer of genetic information
- Biomarkers, biosignatures
- Origin of biomolecules
  - RGS pp. 13-15, Lon pp. 214-218
  - BS pp. 204-212