

# Extra Material: Biomolecules

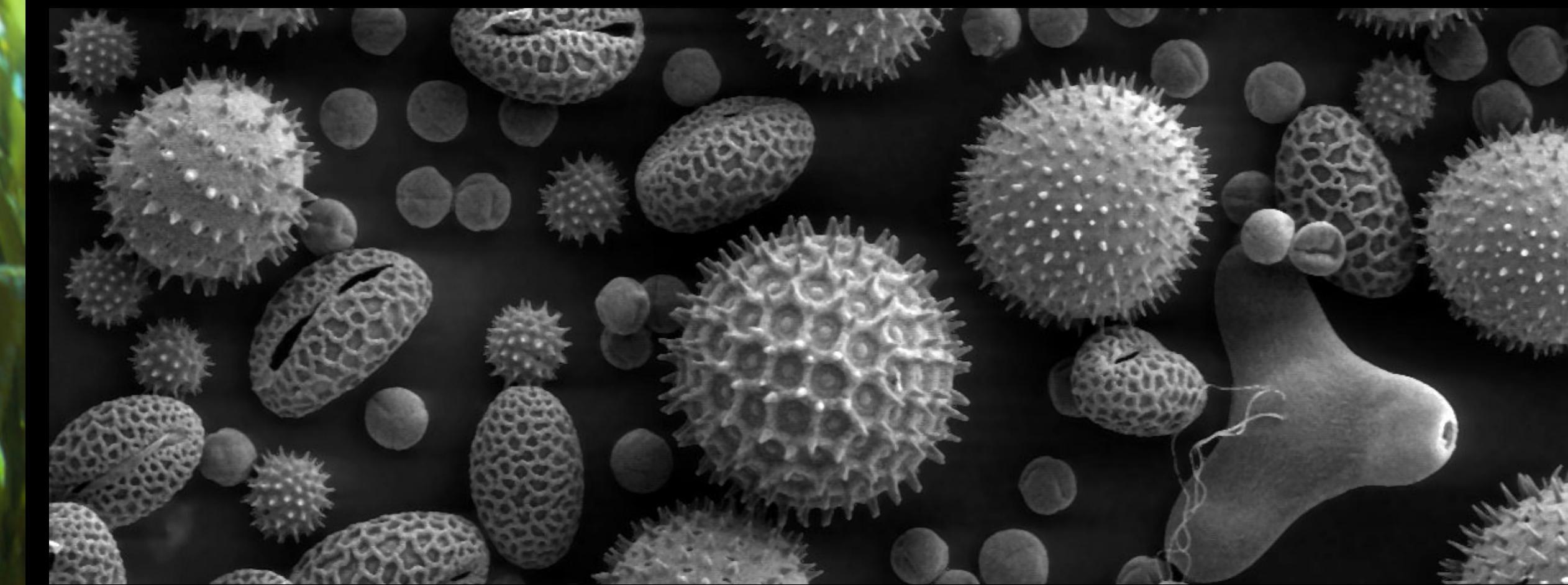
*The stuff that makes up living stuff*

Biomolecules make up  
living matter

# living matter



From: <https://e360.yale.edu/features/as-oceans-warm-the-worlds-giant-kelp-forests-begin-to-disappear#>



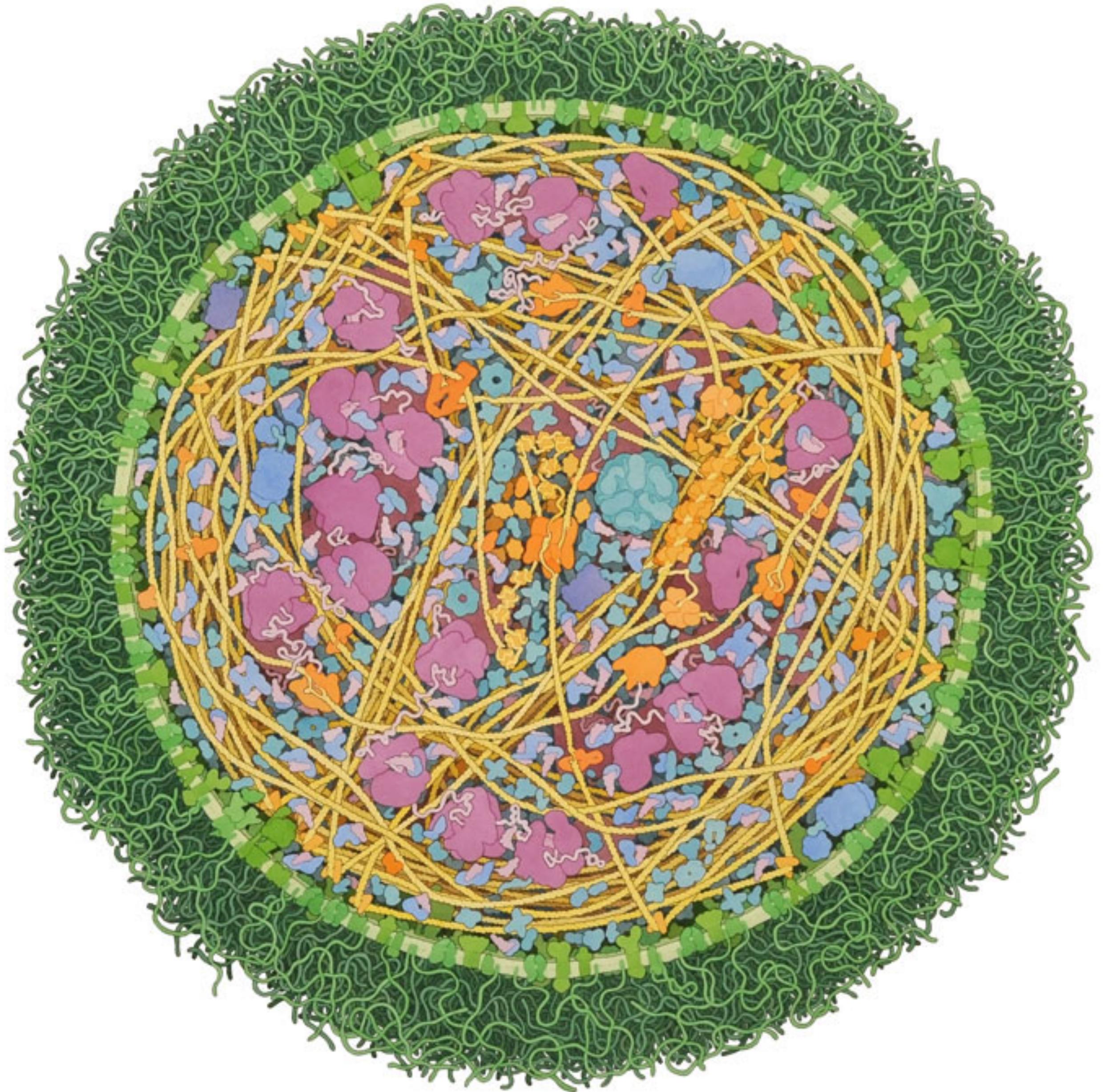
<https://svs.gsfc.nasa.gov/10394>



From: <https://cheezburger.com/6771324928>

# *Mycoplasma mycoides*

(David Goodsell, 2011)



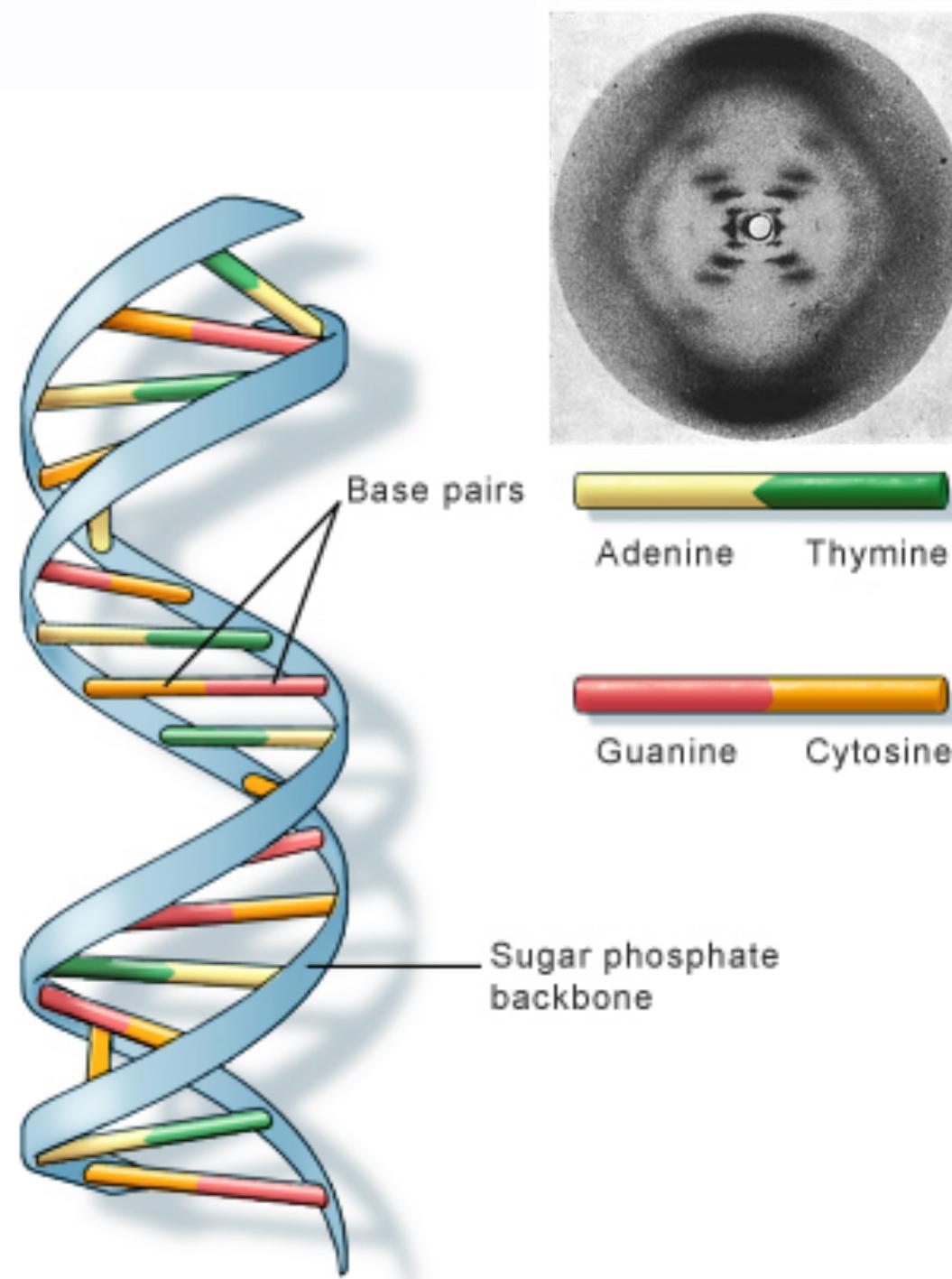
# Most biomolecules fall into four classes

nucleic acids

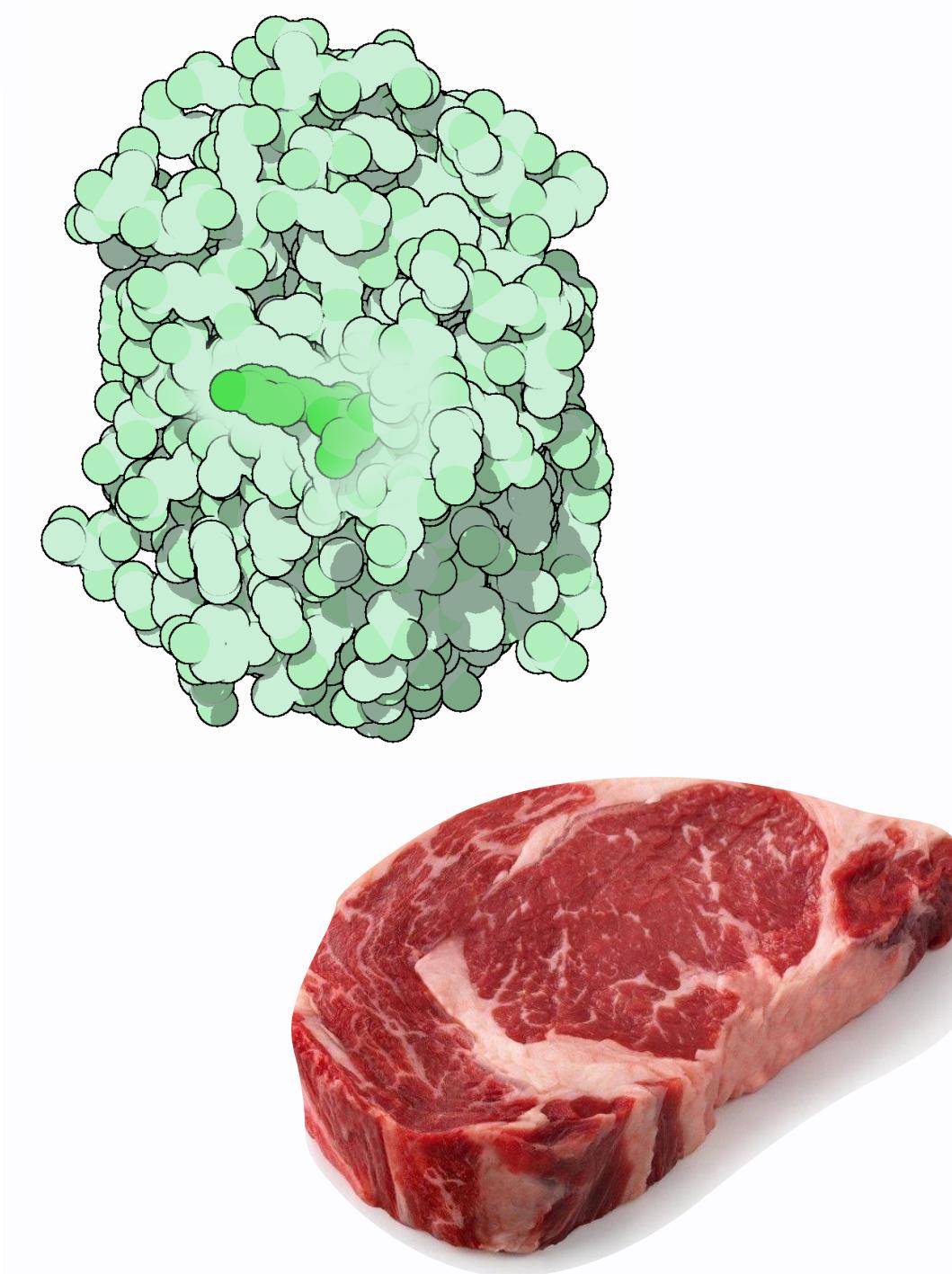
proteins

saccharides

lipids



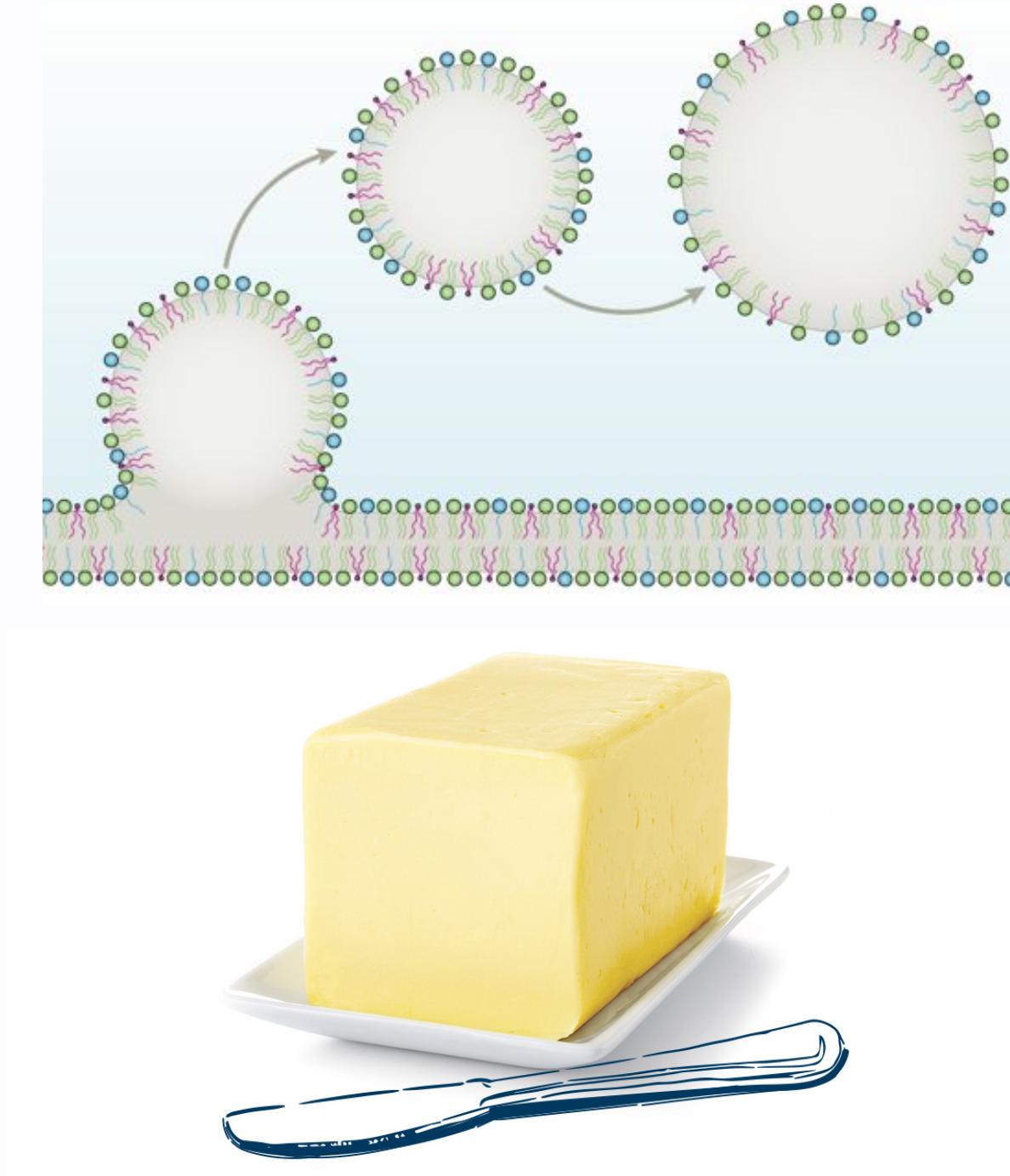
From: NIH (<https://ghr.nlm.nih.gov/primer/basics/dna>)



From: David Goodsell (<https://pdb101.rcsb.org/motm/42>) and Google

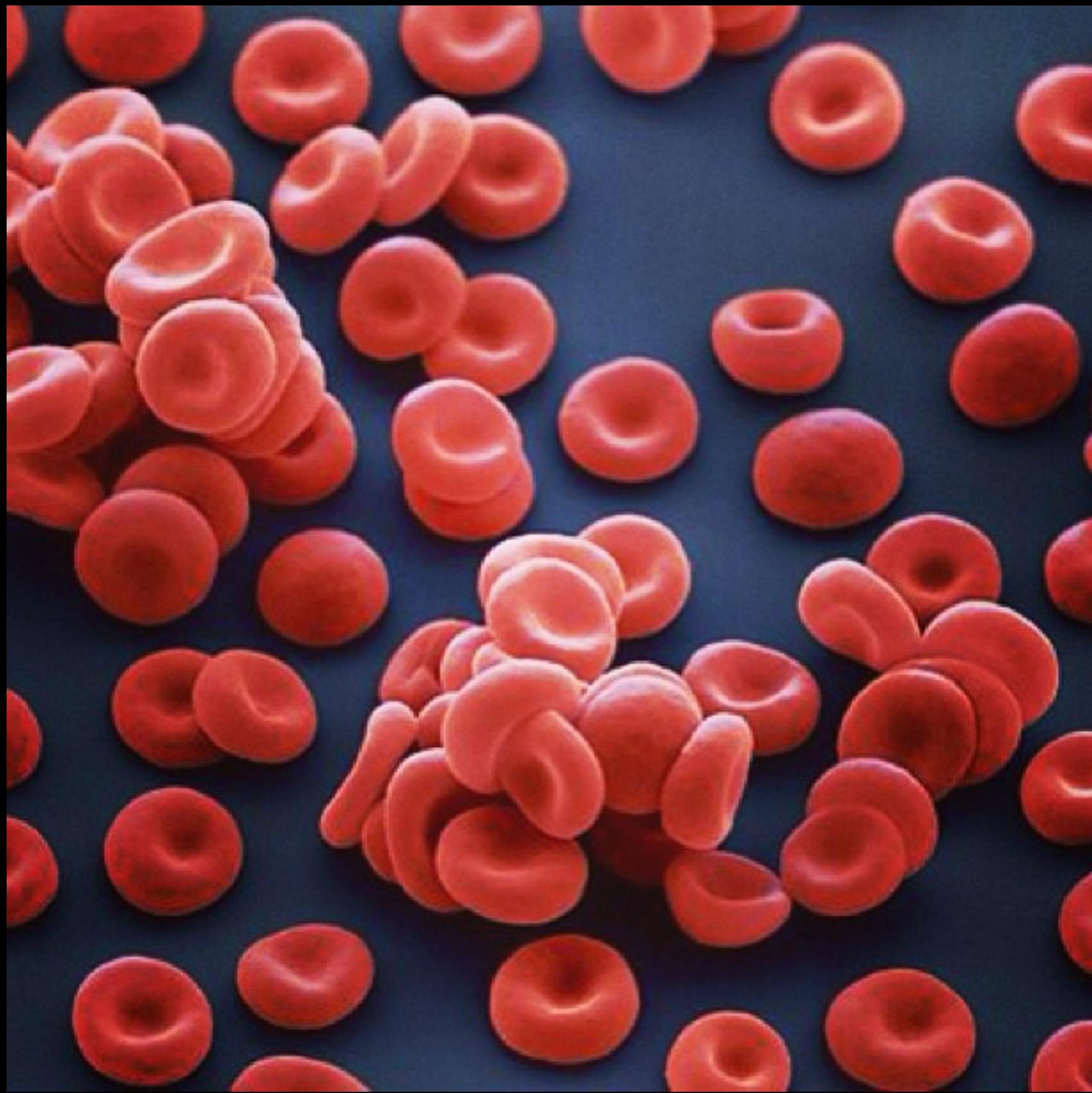


From: SF Chronicle (<https://www.sfchronicle.com/environment/article/Biggest-private-sequoia-grove-to-be-preserved-in-14444748.php>) and Google

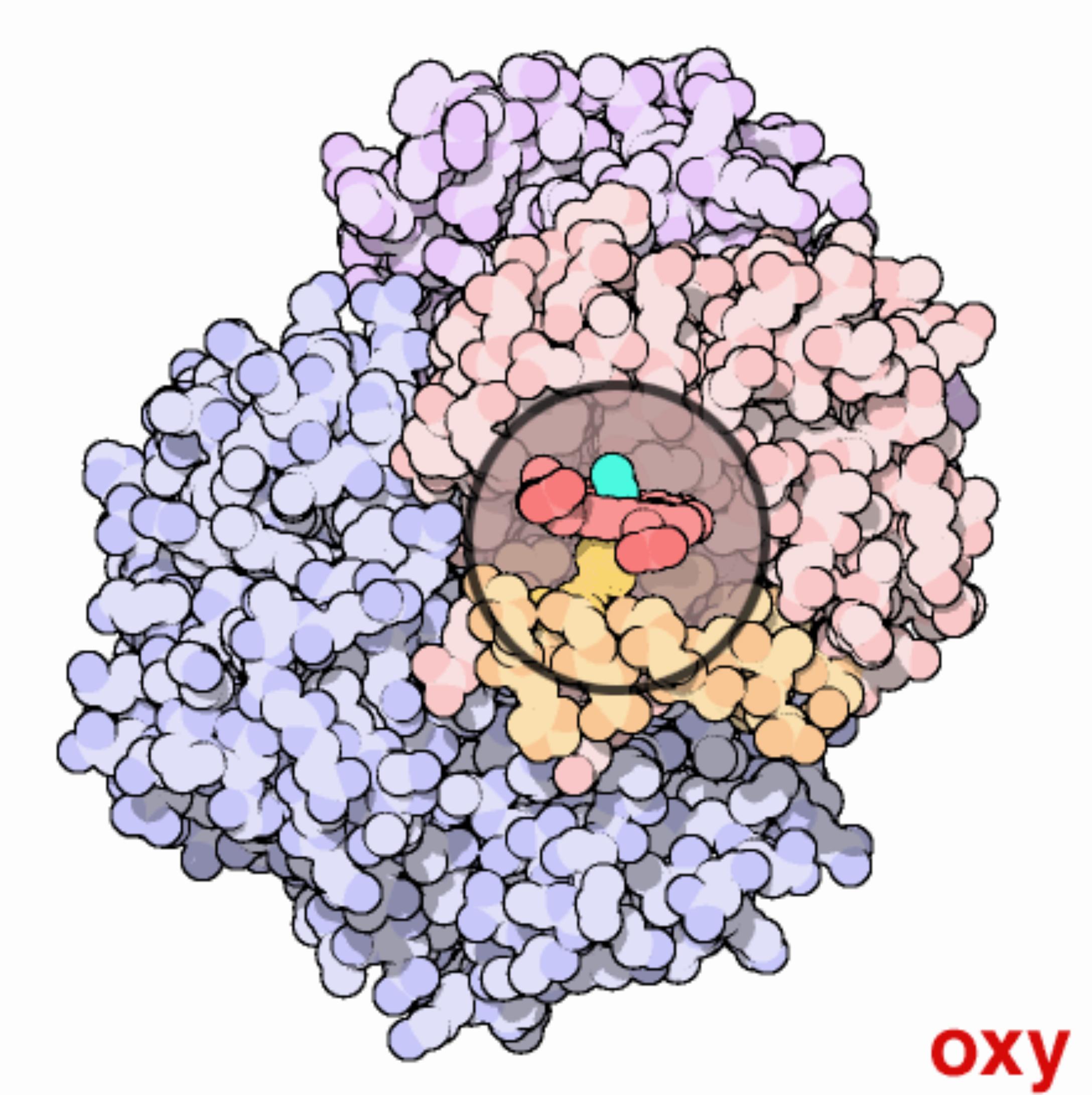


From: Nature ([doi.org/10.1038/s41580-018-0037-7](https://doi.org/10.1038/s41580-018-0037-7)) and Google

Biomolecules perform the  
*basic tasks* of biology



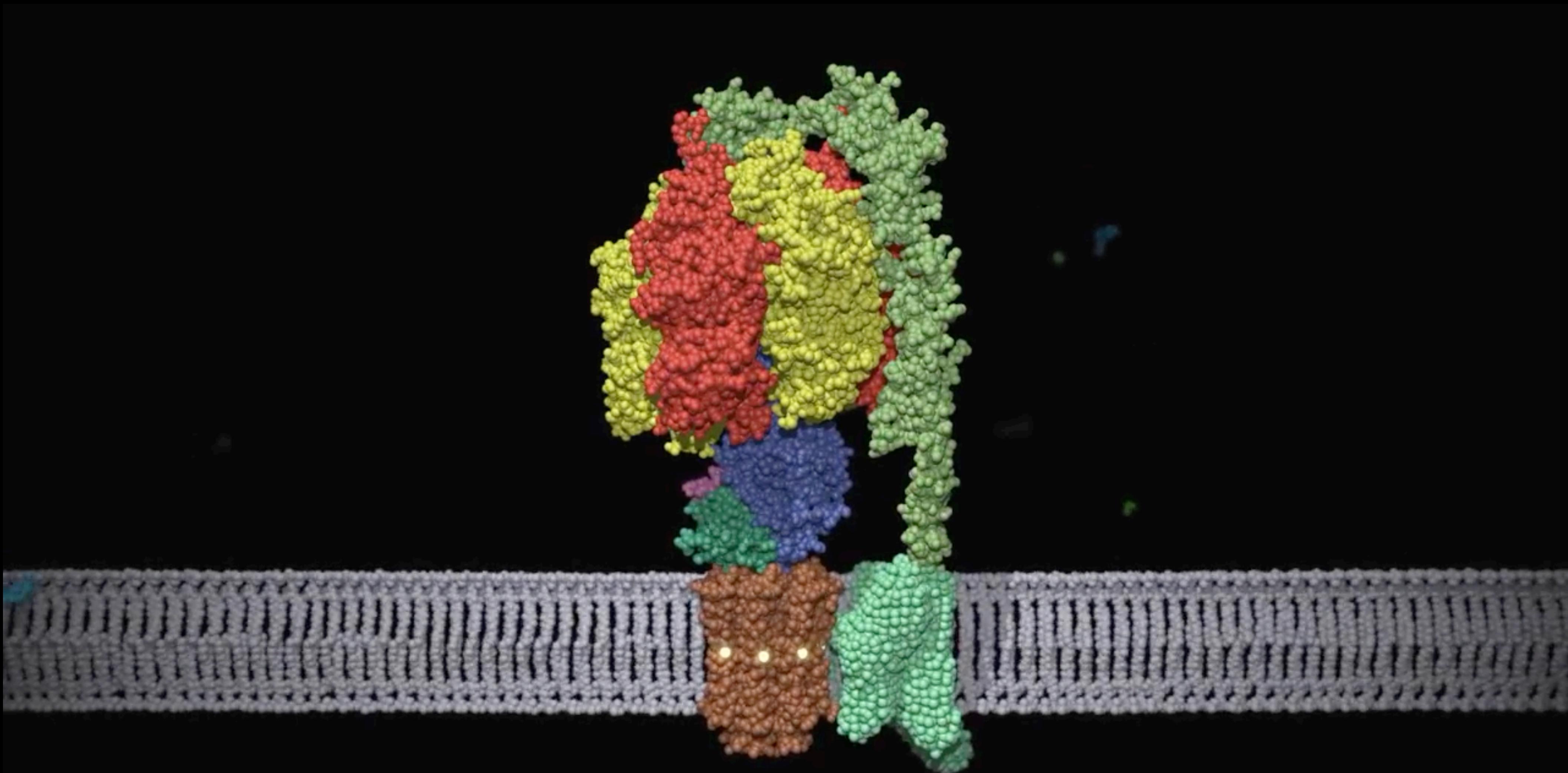
Red blood cells catch oxygen  
with a protein called  
hemoglobin



From: PDB ([https://pdb101.rcsb.org/  
motm/41](https://pdb101.rcsb.org/motm/41)) and Flickr

**Oxy**

# ATP Synthase (complex of proteins) powers cells



From: Stuart Lab ([https://www.youtube.com/watch?v=b\\_cp8MsnZFA&feature=youtu.be&t=53](https://www.youtube.com/watch?v=b_cp8MsnZFA&feature=youtu.be&t=53))

# DNA replicase (complex of proteins) copies DNA

wehi.edu.au



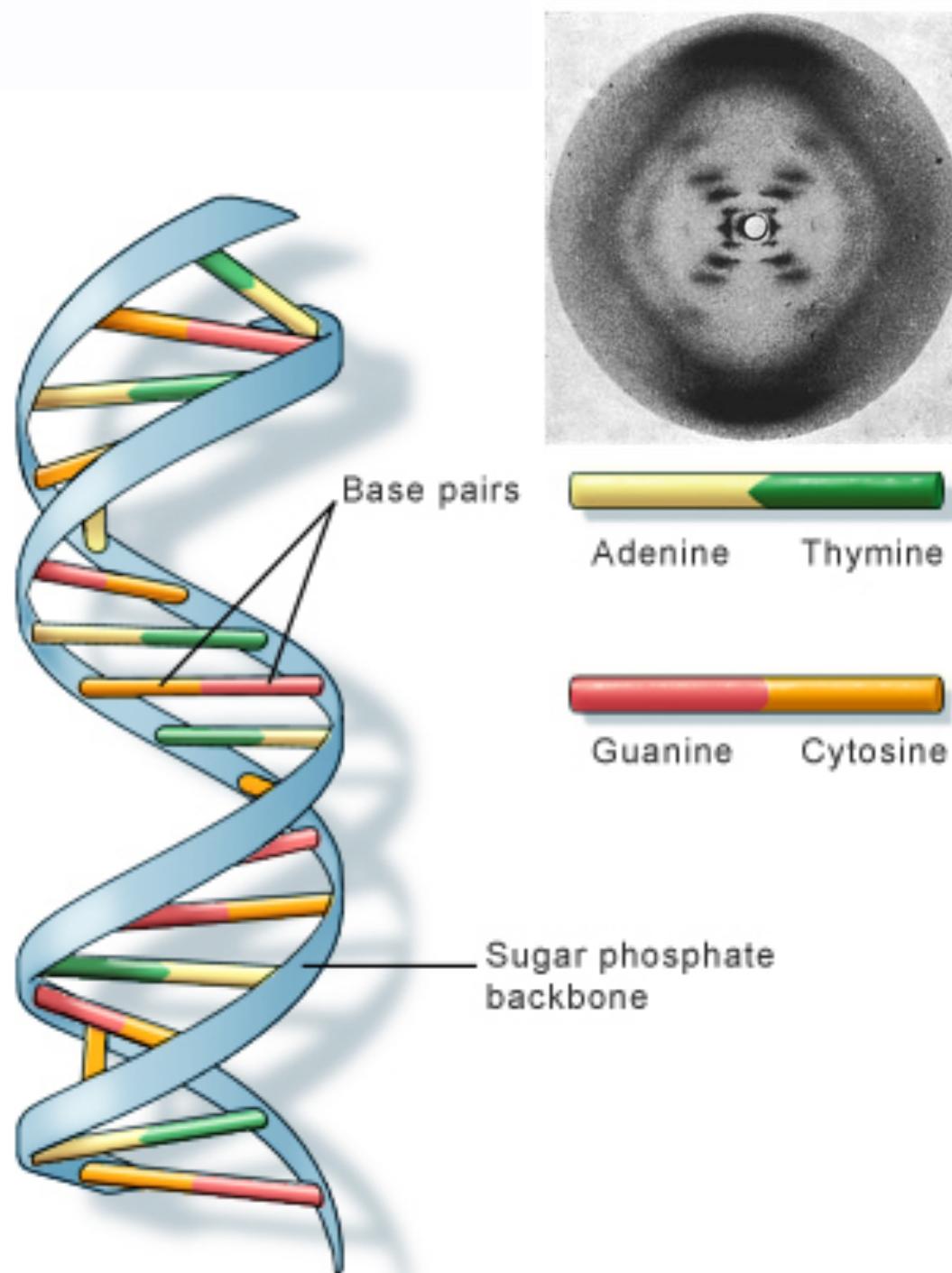
Billions of bio-molecular machines copy your DNA every second

What are biomolecules *made of*?

# Most biomolecules are polymers



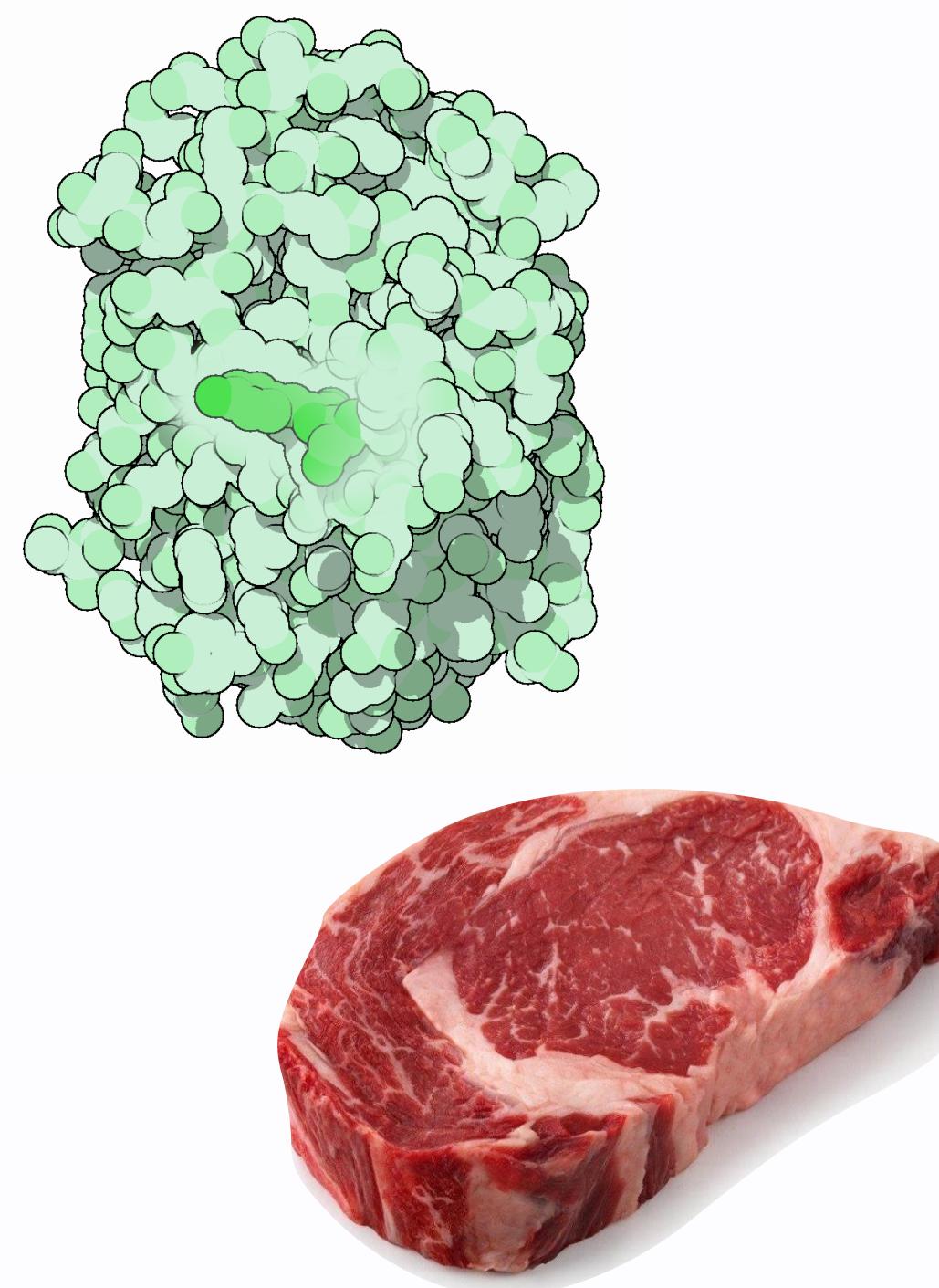
nucleic acids



From: NIH (<https://ghr.nlm.nih.gov/primer/basics/dna>)



proteins



From: David Goodsell (<https://pdb101.rcsb.org/motm/42>) and Google



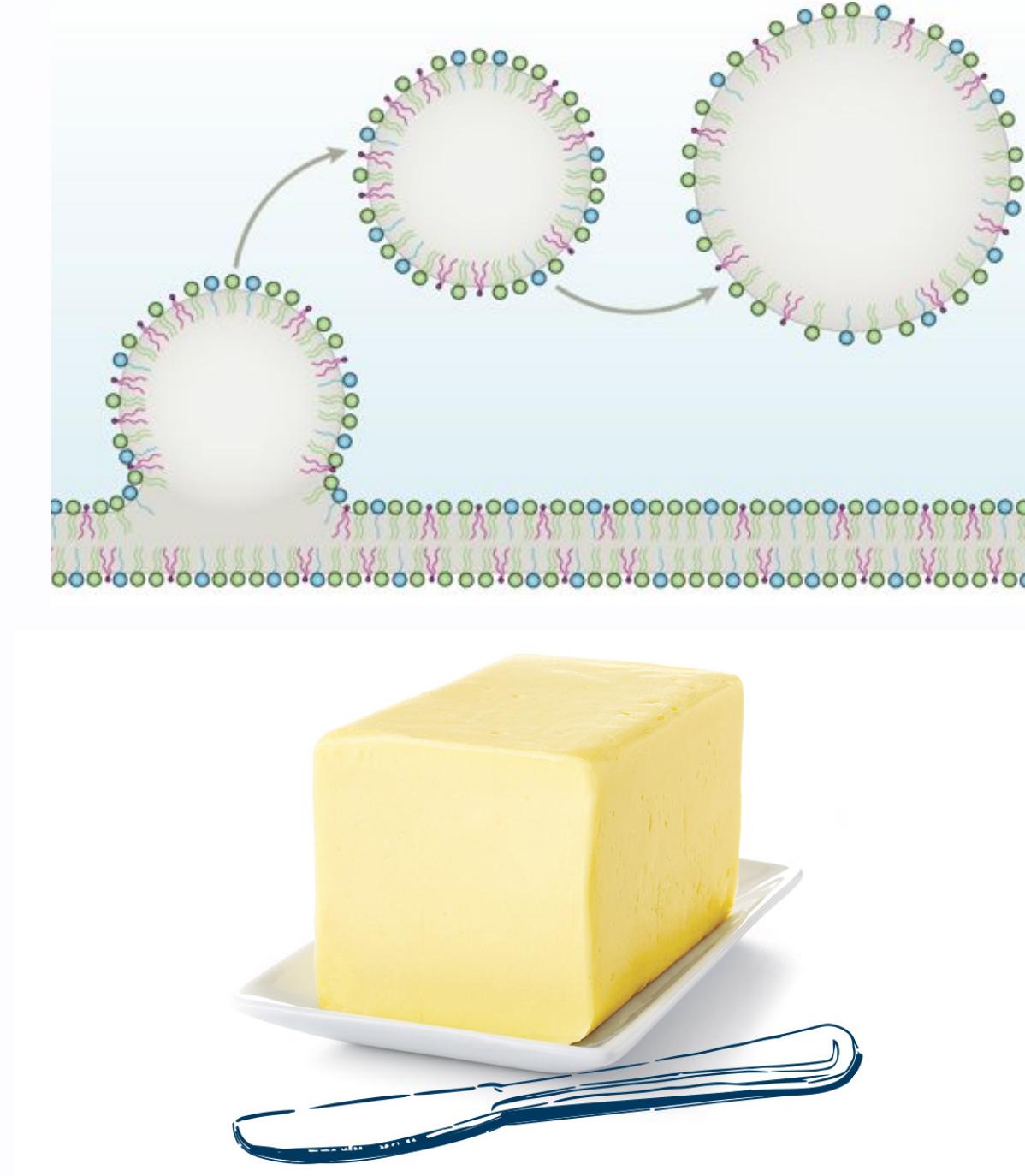
saccharides



From: SF Chronicle (<https://www.sfchronicle.com/environment/article/Biggest-private-sequoia-grove-to-be-preserved-in-14444748.php>) and Google

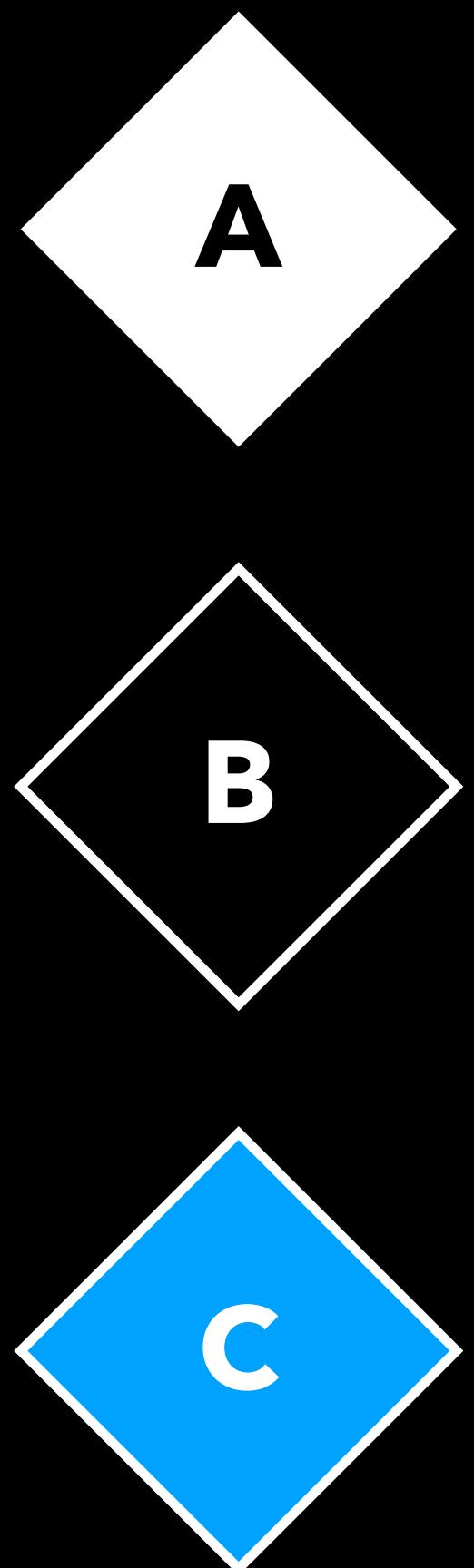


lipids

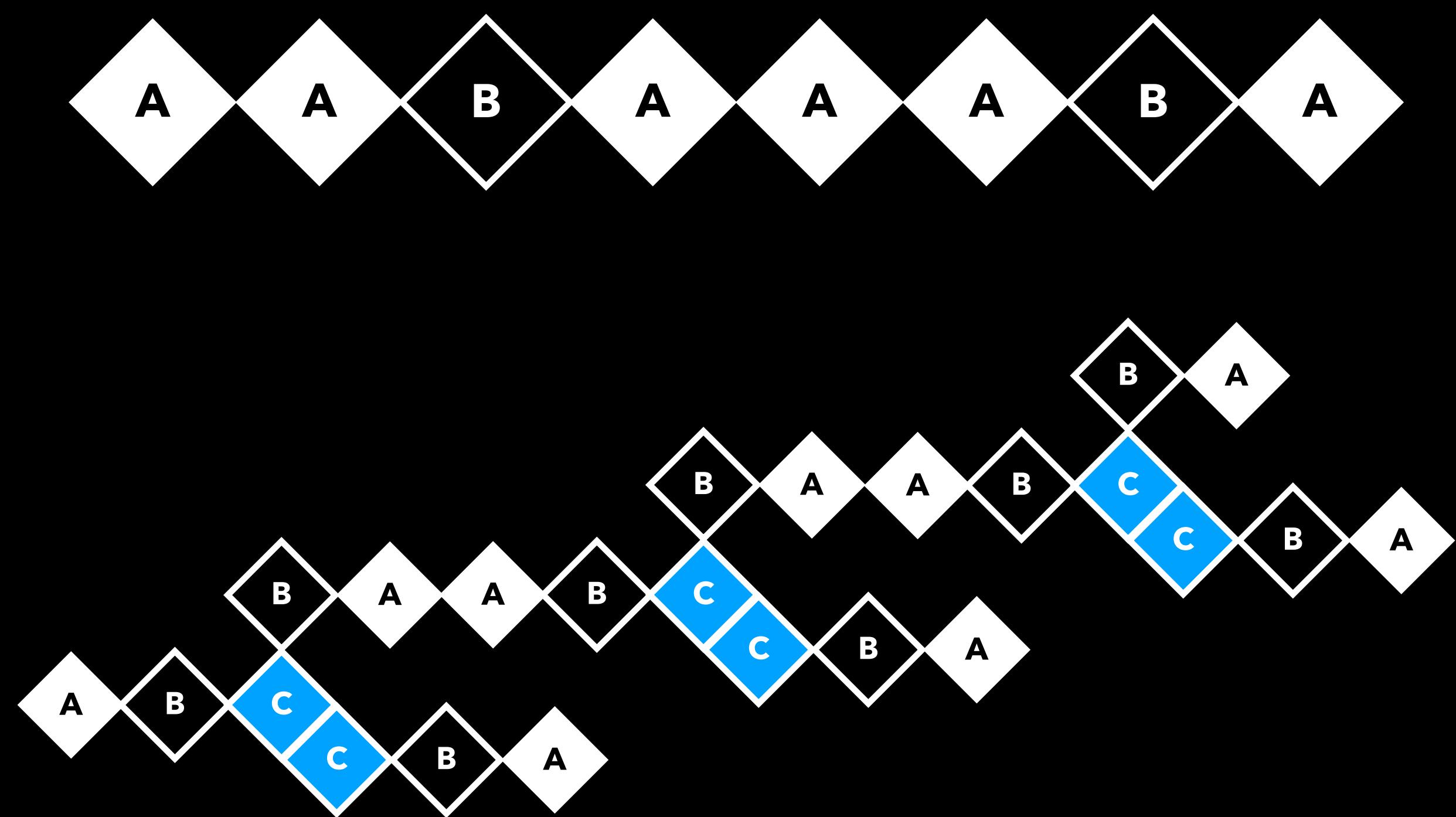


From: Nature (doi.org/10.1038/s41580-018-0037-7) and Google

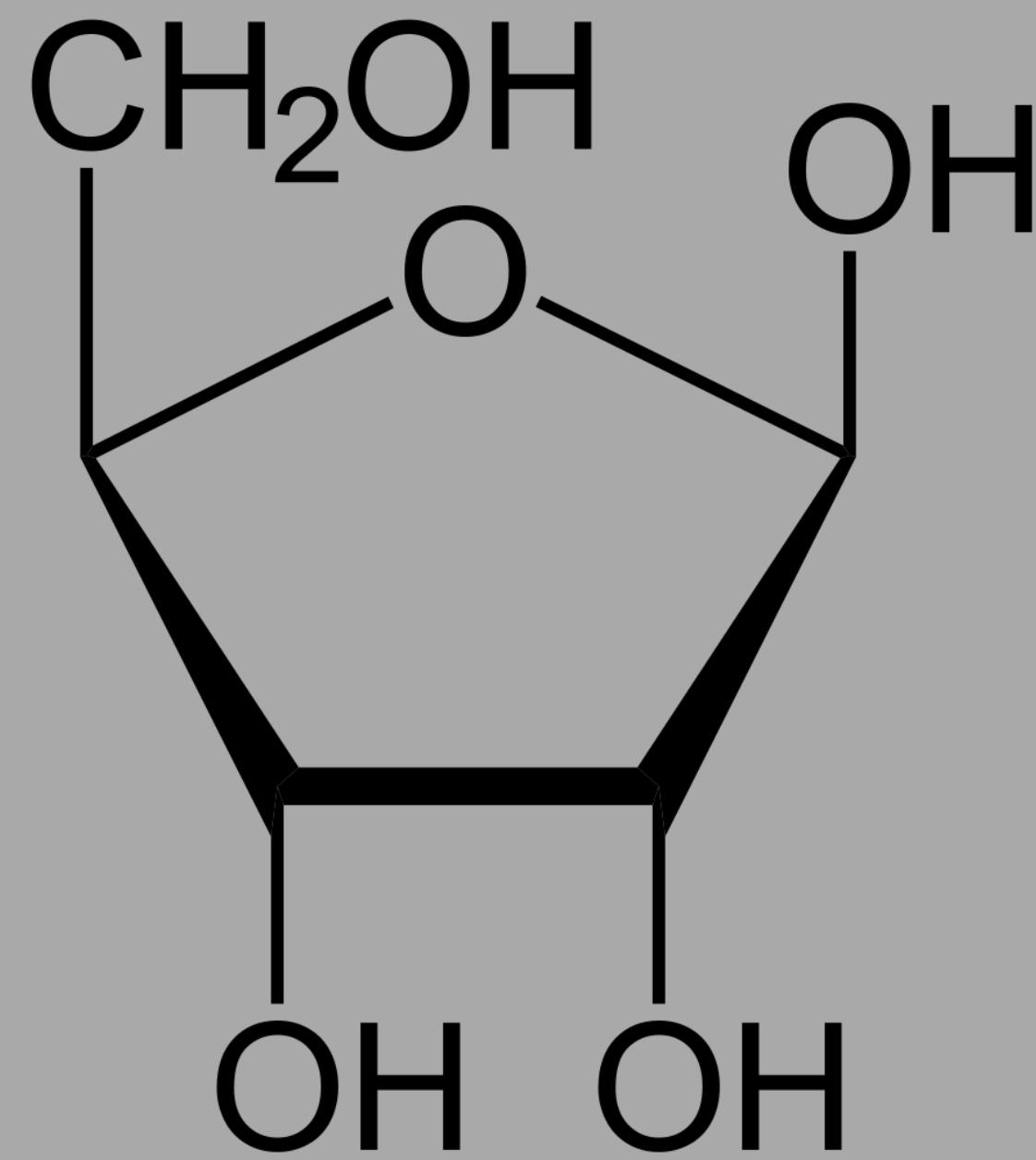
# monomers



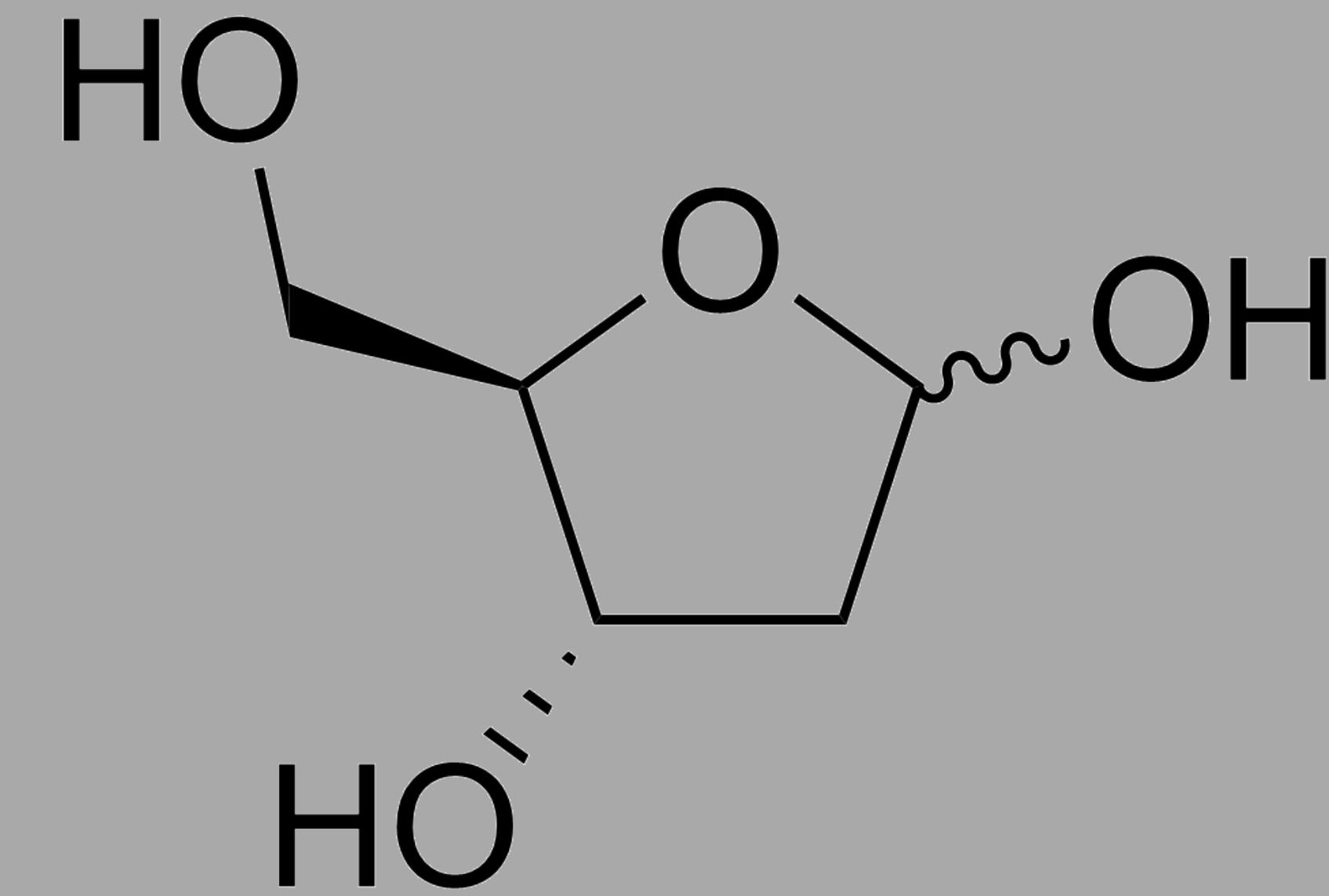
# polymers



Polysaccharides are made of monosaccharides

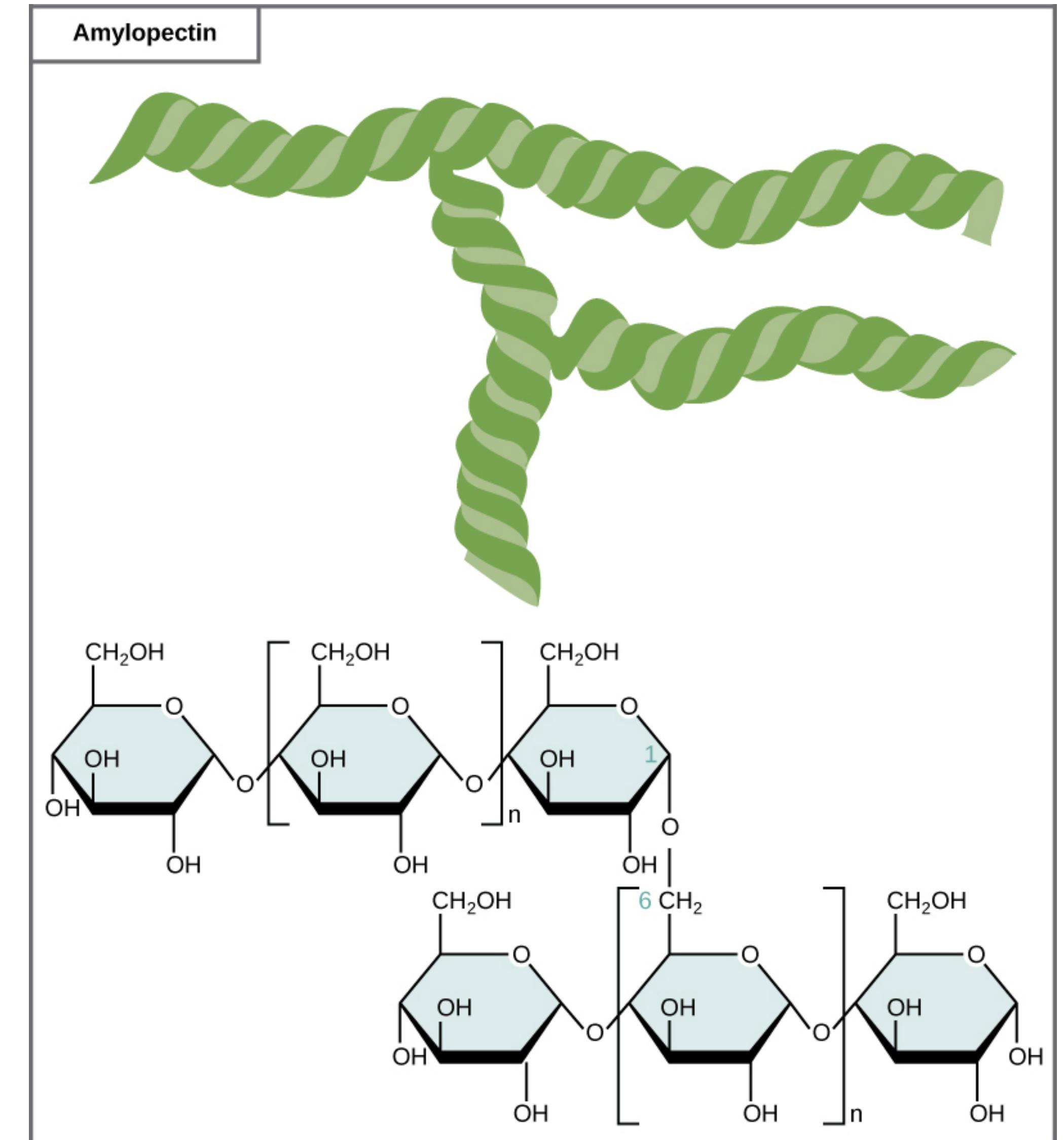
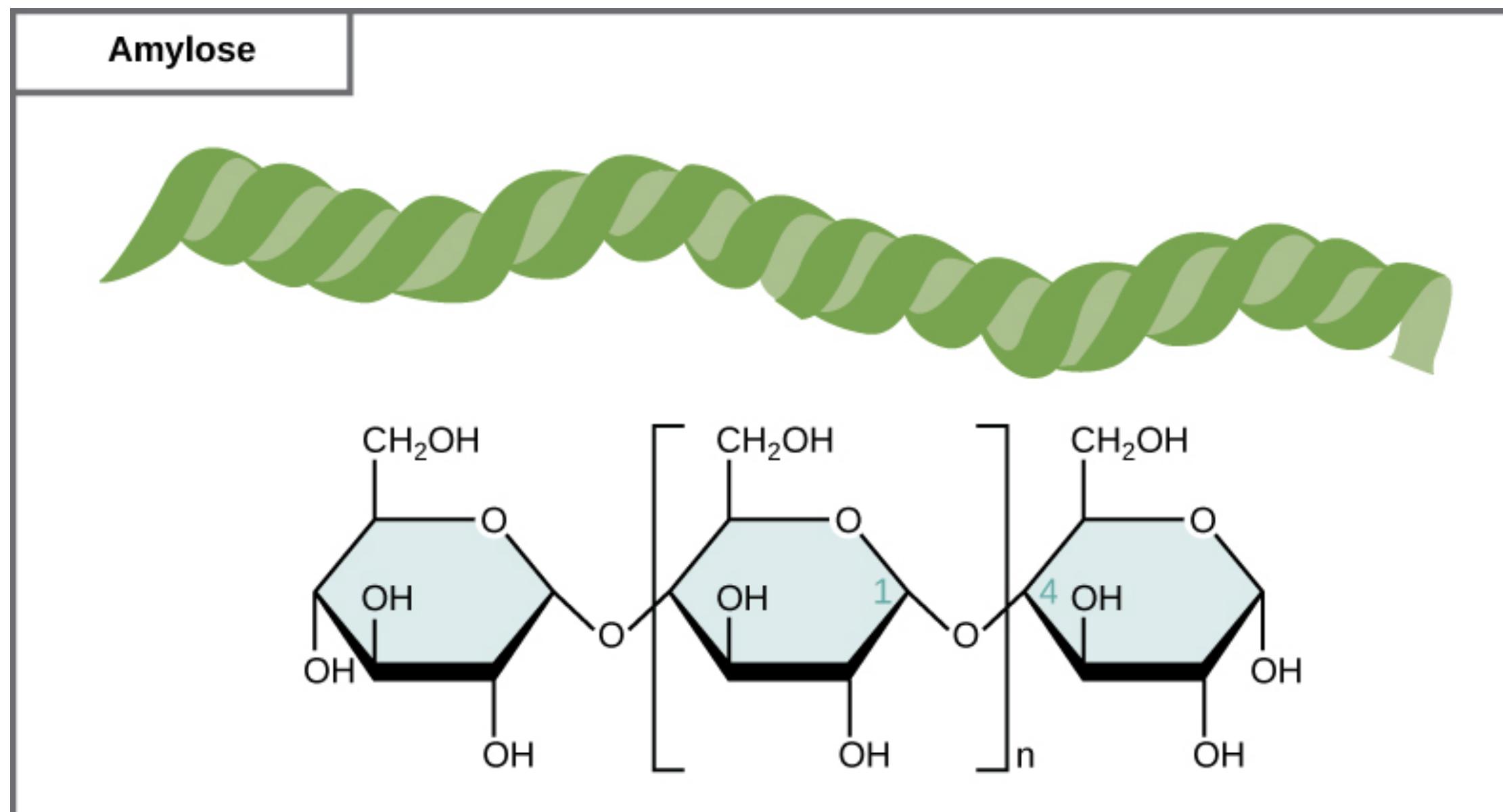


Ribose

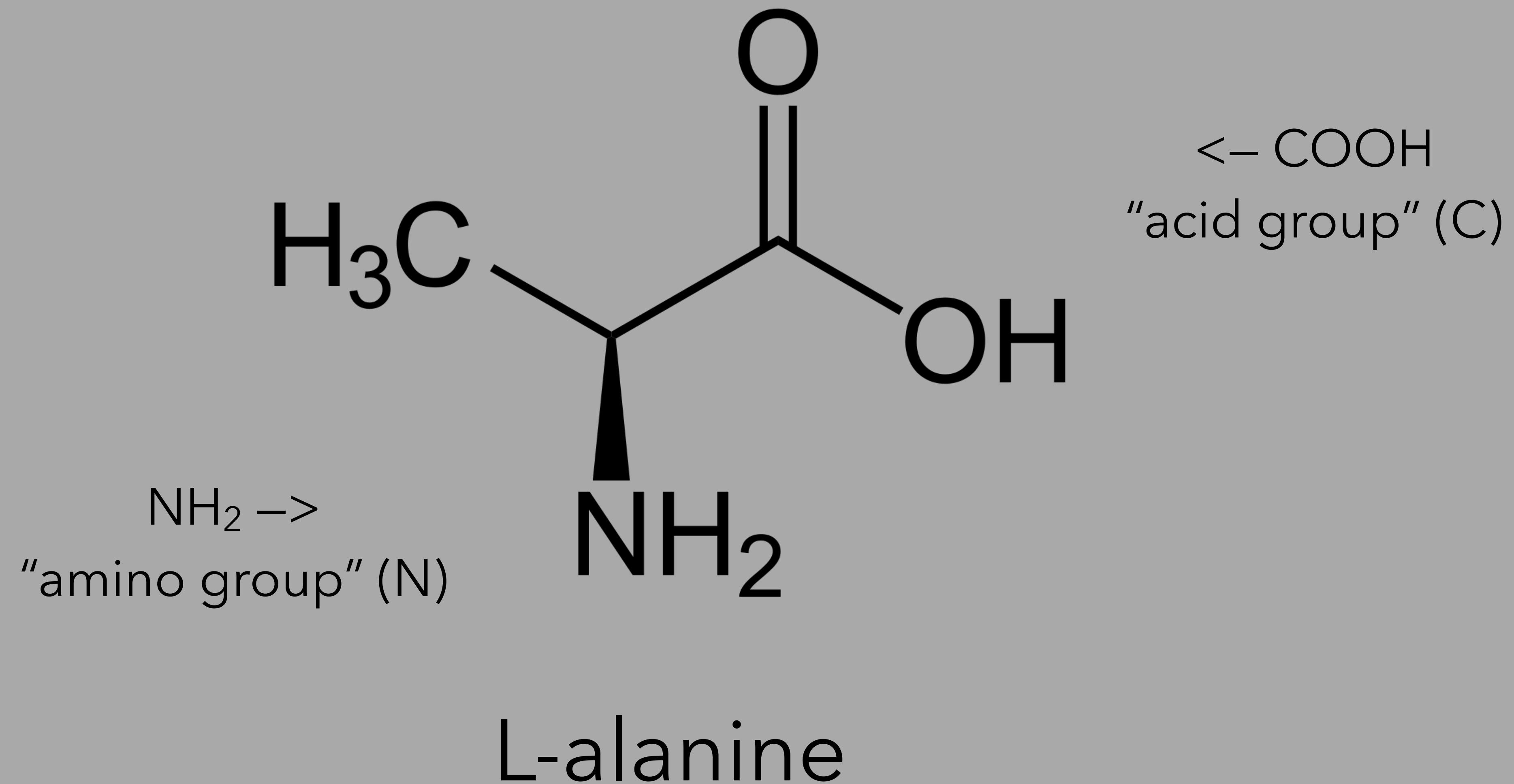


Deoxyribose

Polysaccharides form  
*straight or branched chains*



# Proteins are made of amino acids



There are  
20 amino acids\*

\*(kinda, biology makes more kinds of amino acids by modifying these twenty)

From: Biological Science, 2nd Ed (grabbed from <https://sites.google.com/a/providenceday.org/apbiology/codon-charts-periodic-table>)

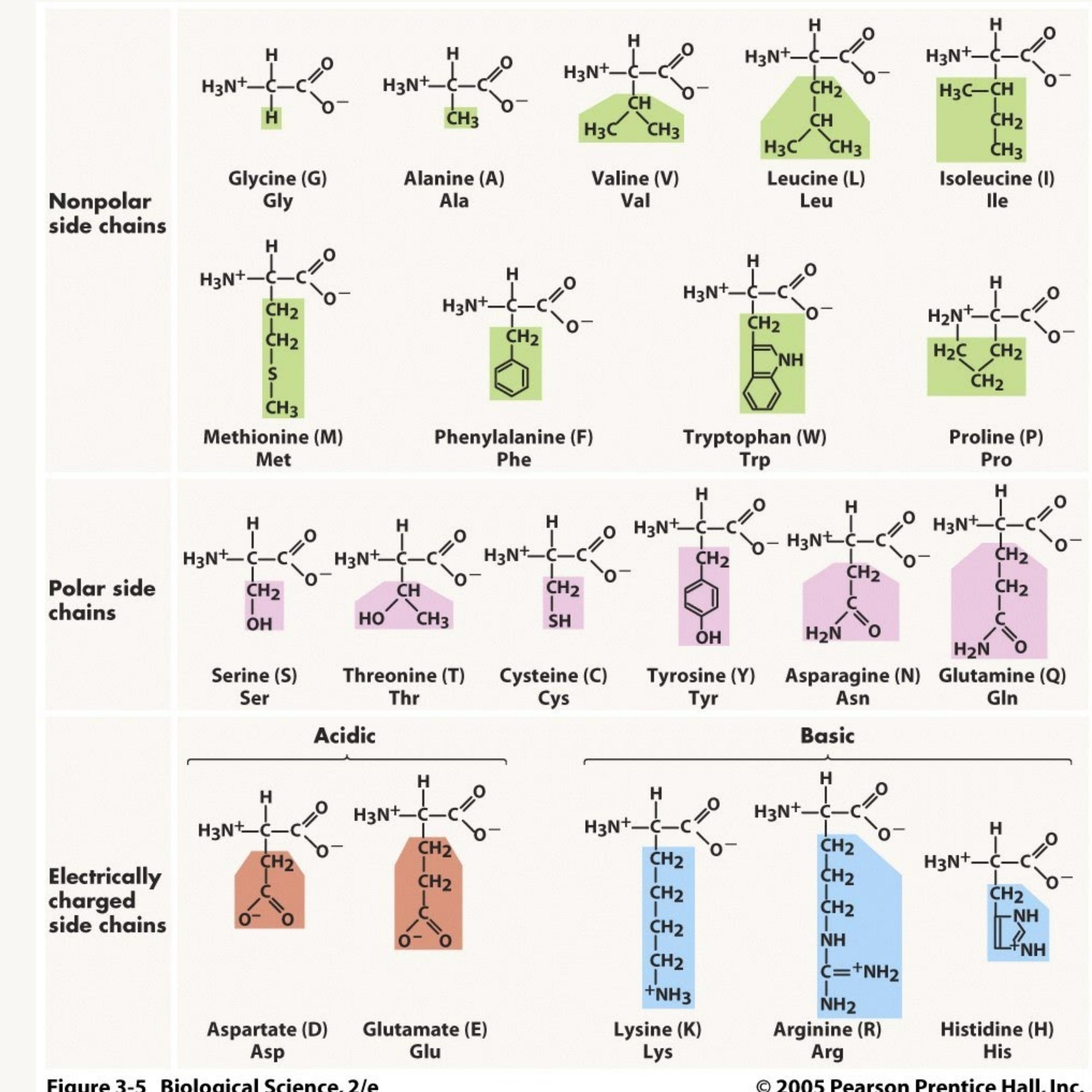
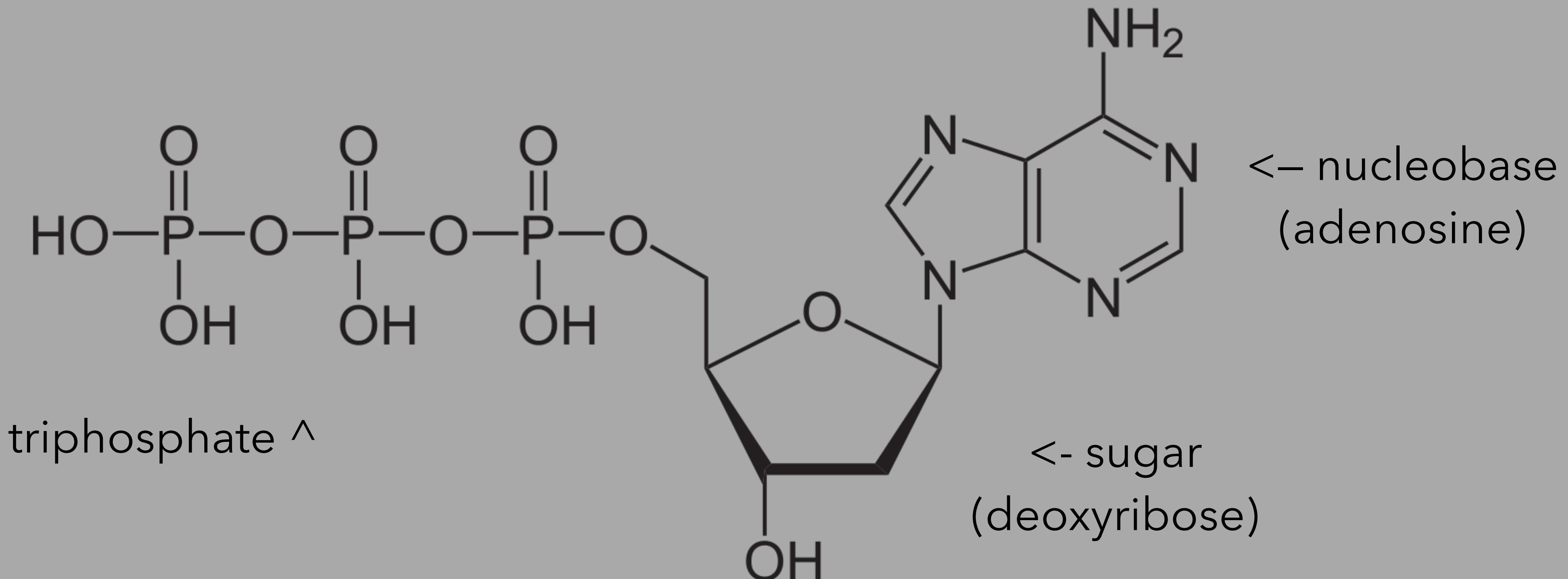


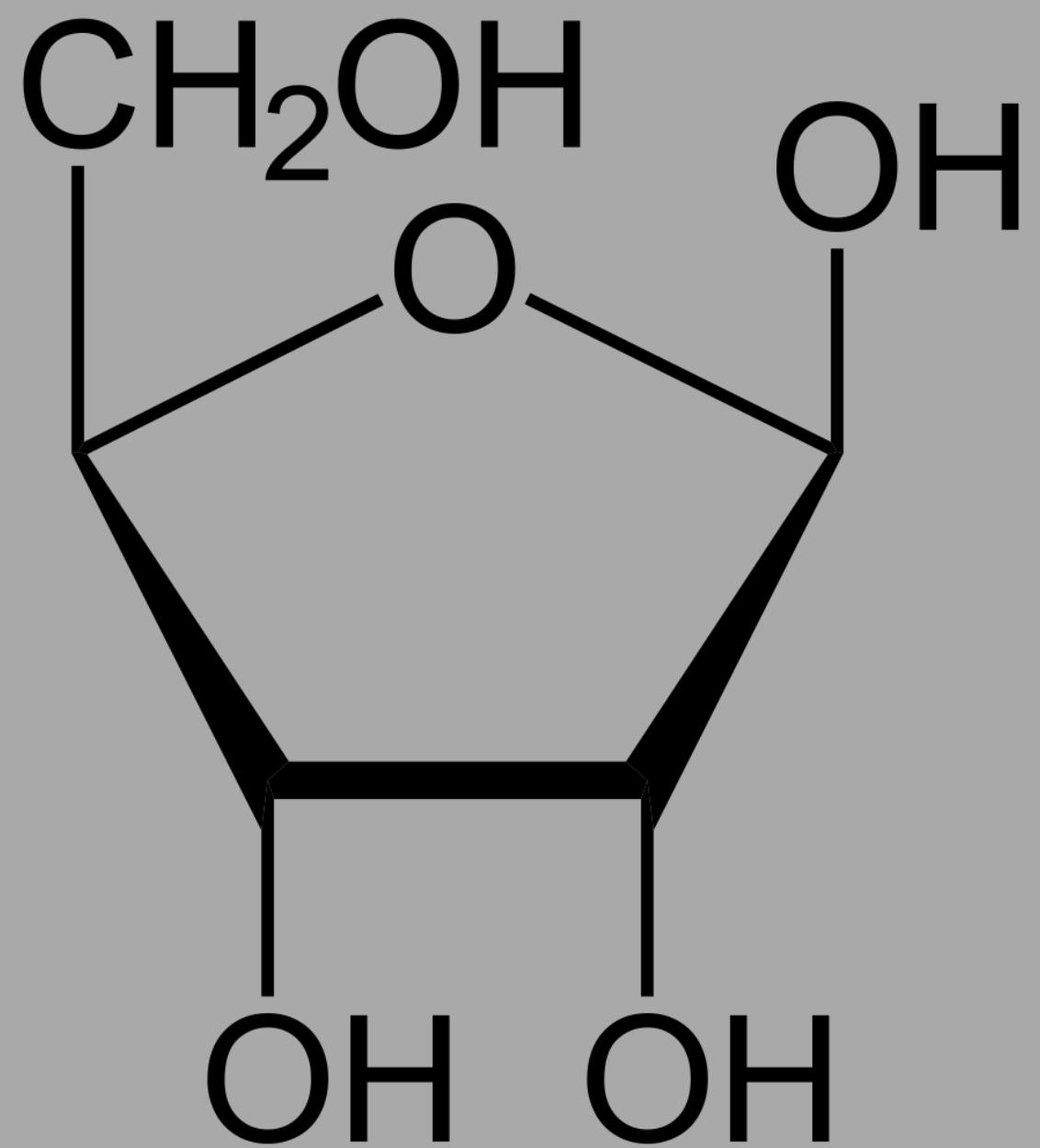
Figure 3-5 Biological Science, 2/e

# Nucleic acids are made of nucleotides



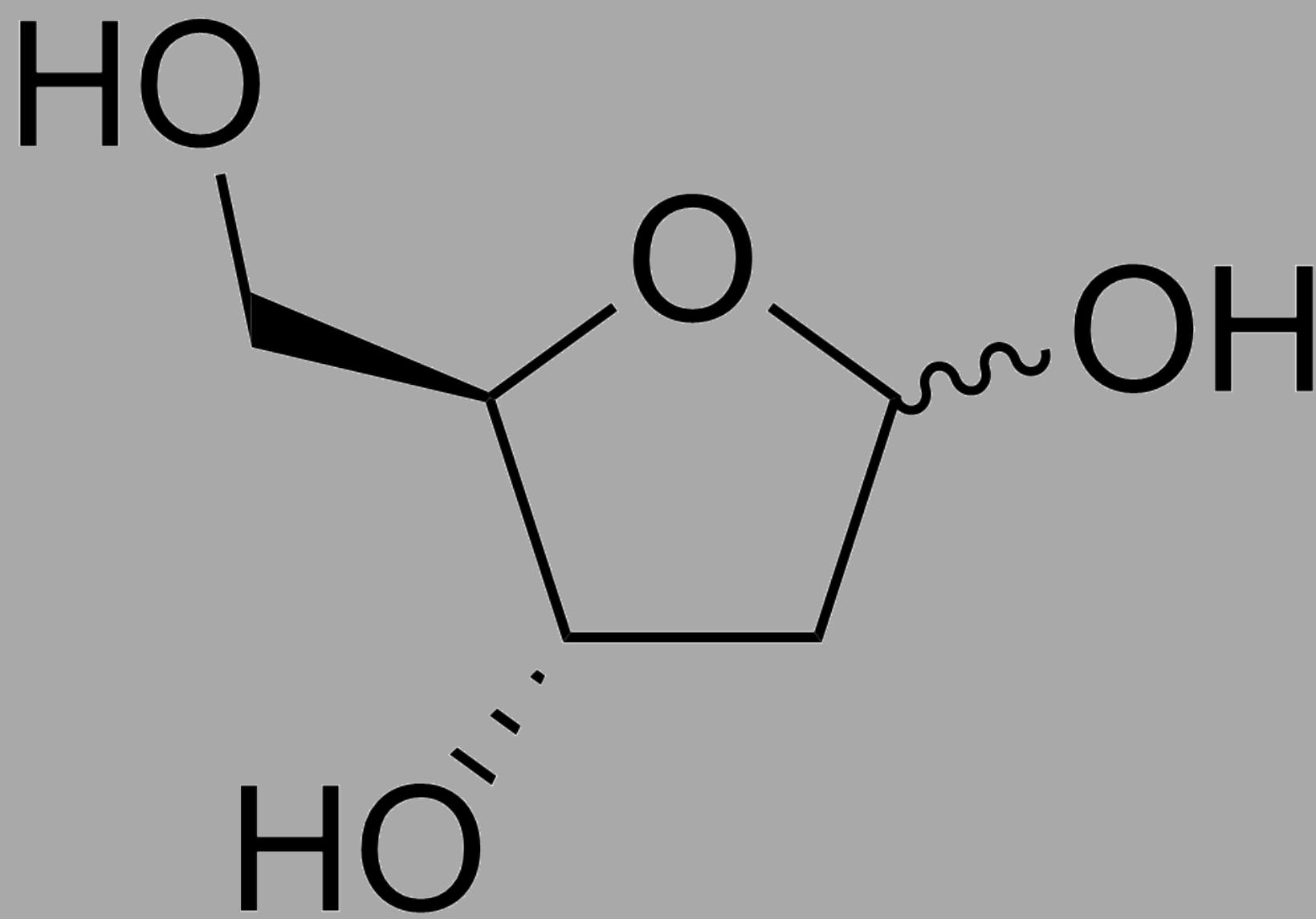
Deoxyadenosine triphosphate  
(dATP)

RNA  
(ribonucleic acid)



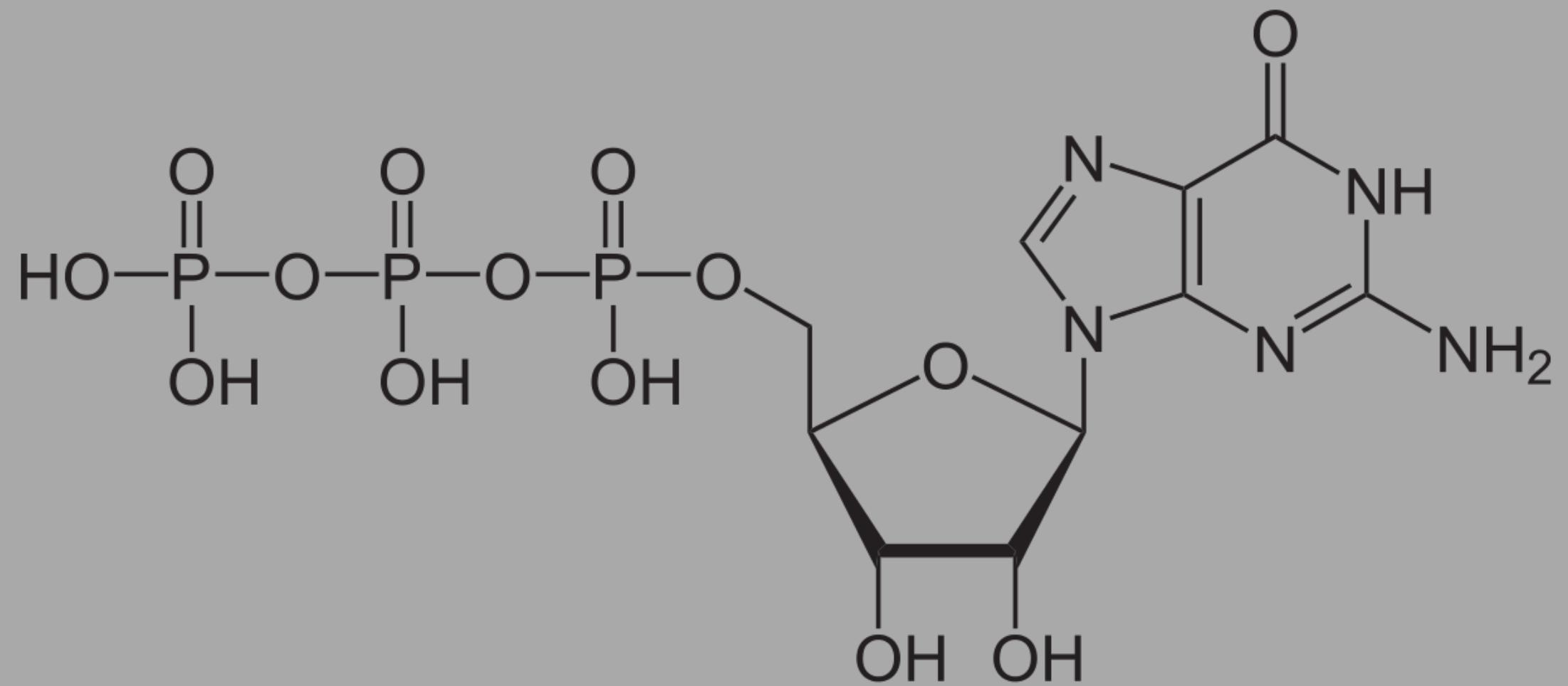
Ribose

DNA  
(deoxyribonucleic acid)



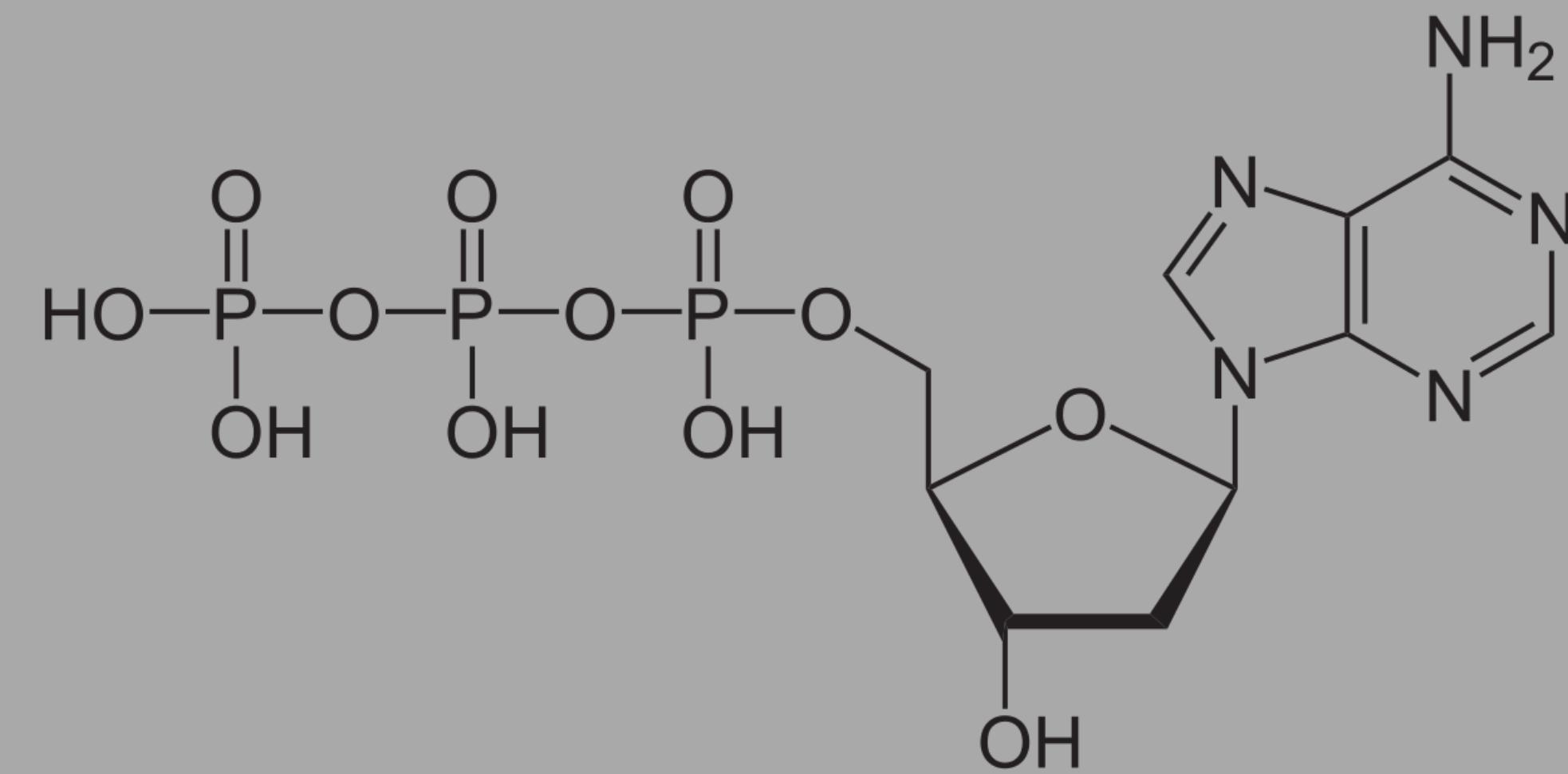
Deoxyribose

RNA  
(ribonucleic acid)

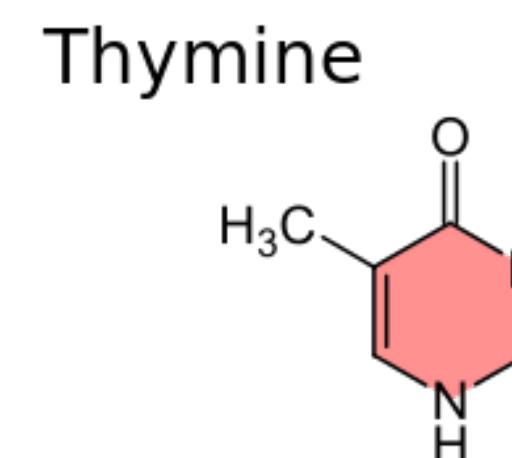
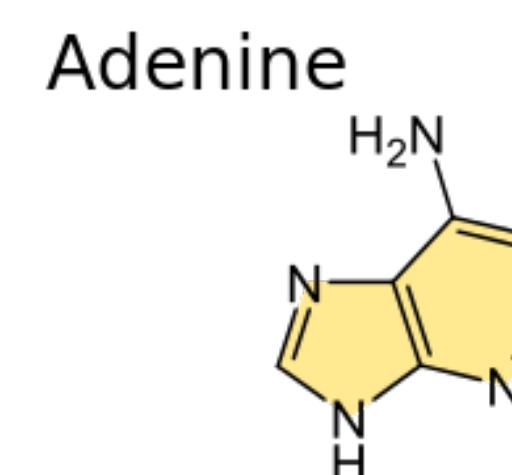
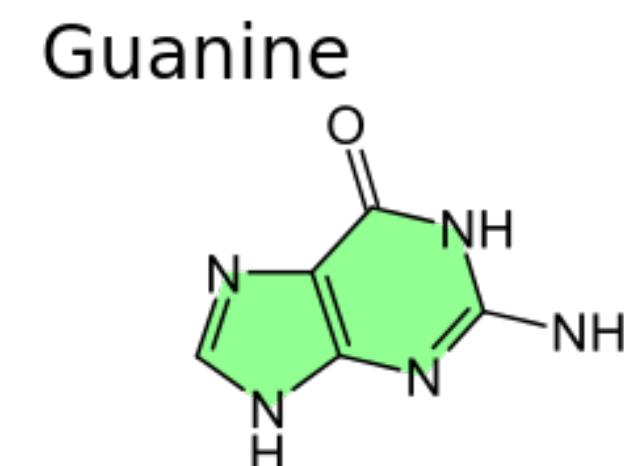
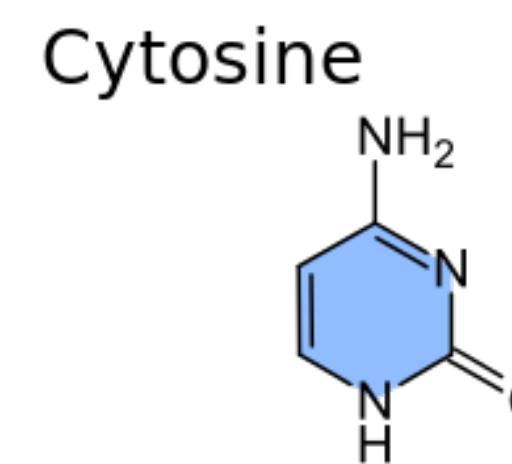
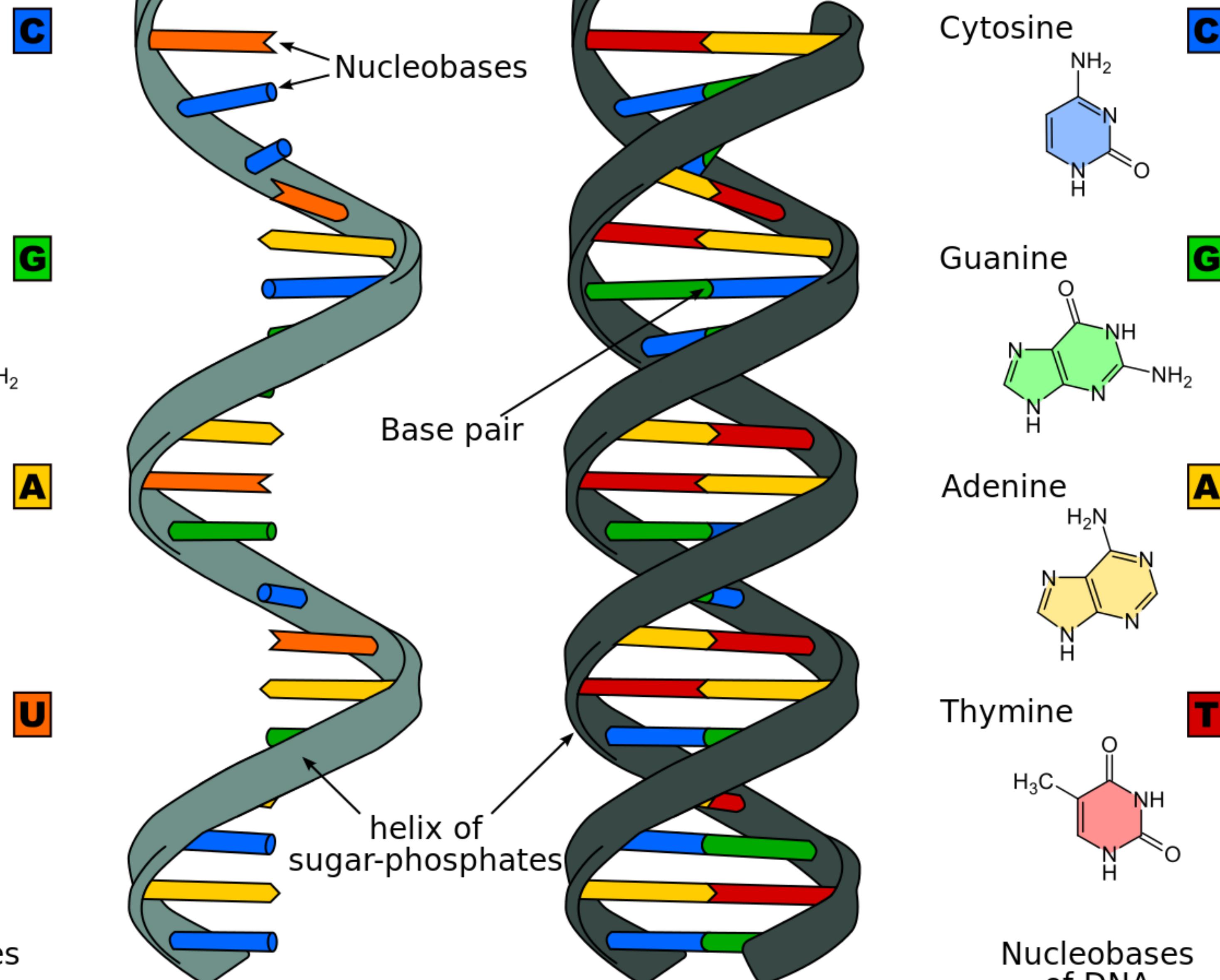
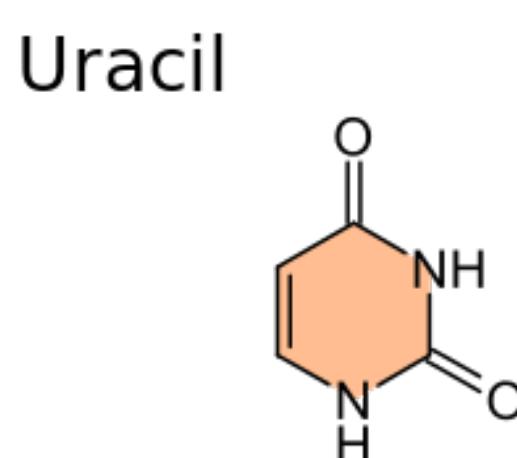
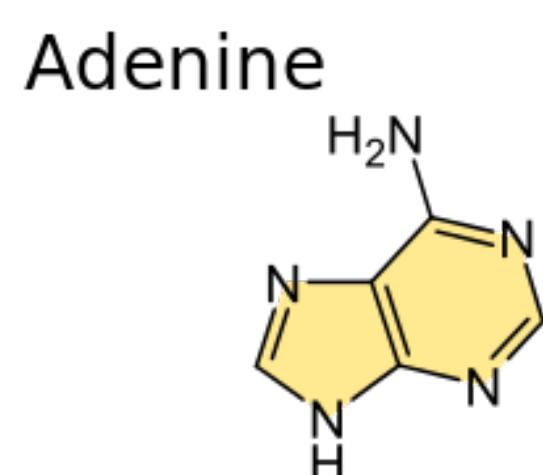
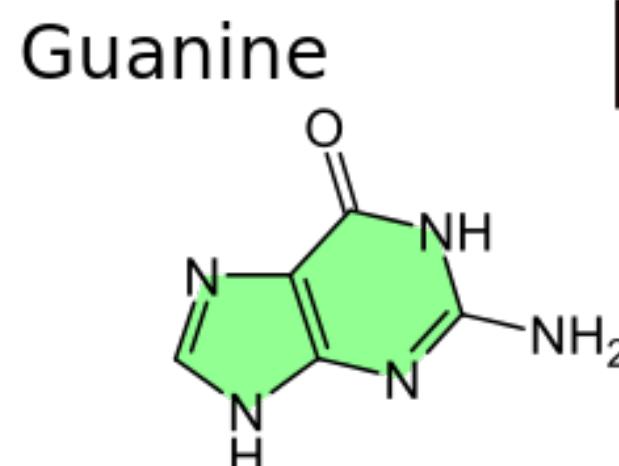
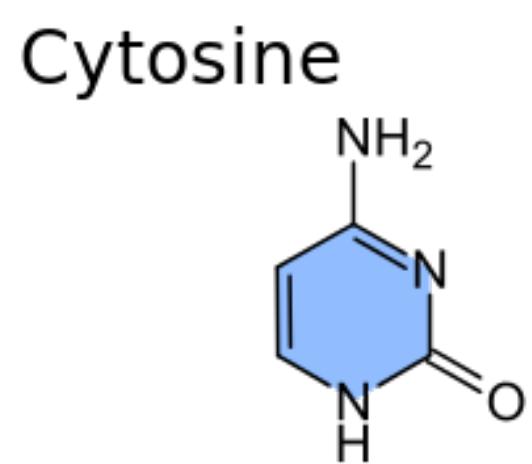


rGTP

DNA  
(deoxyribonucleic acid)



dATP

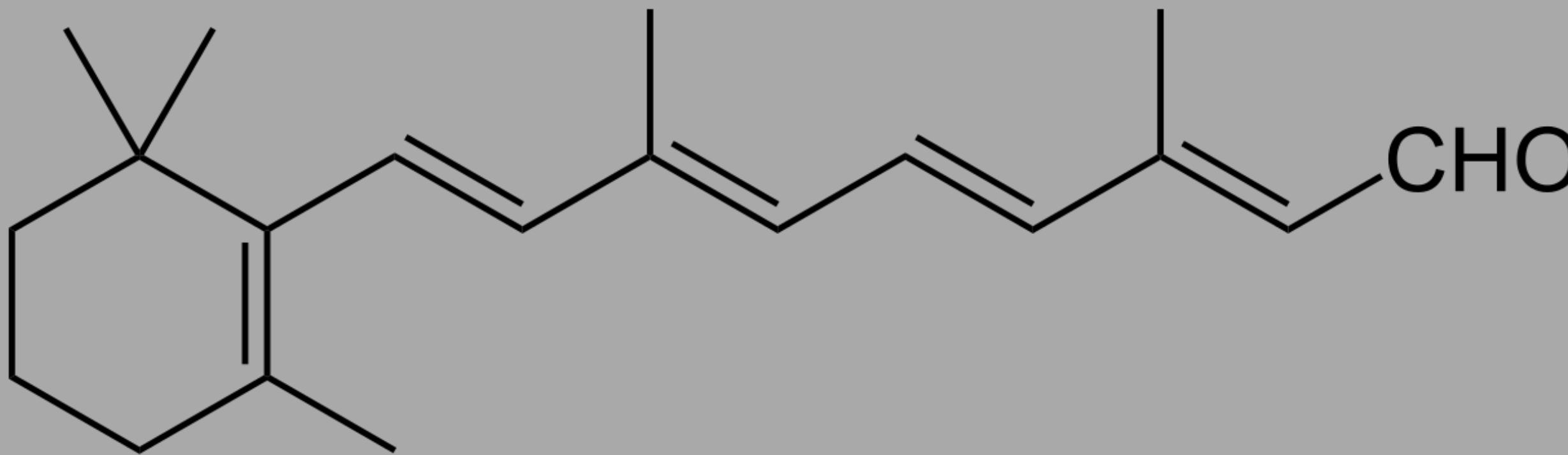


## **RNA**

# DNA

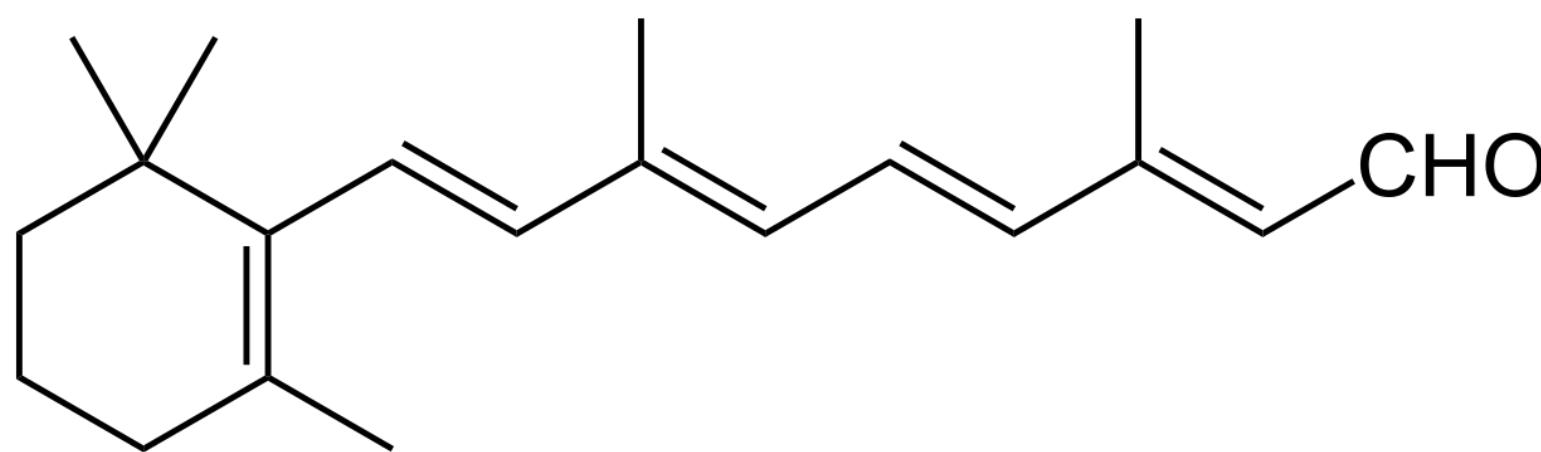
From: Wikimedia Commons ([https://commons.wikimedia.org/wiki/File:Difference\\_DNA\\_RNA-EN.svg](https://commons.wikimedia.org/wiki/File:Difference_DNA_RNA-EN.svg))

# Lipids take on a variety of forms

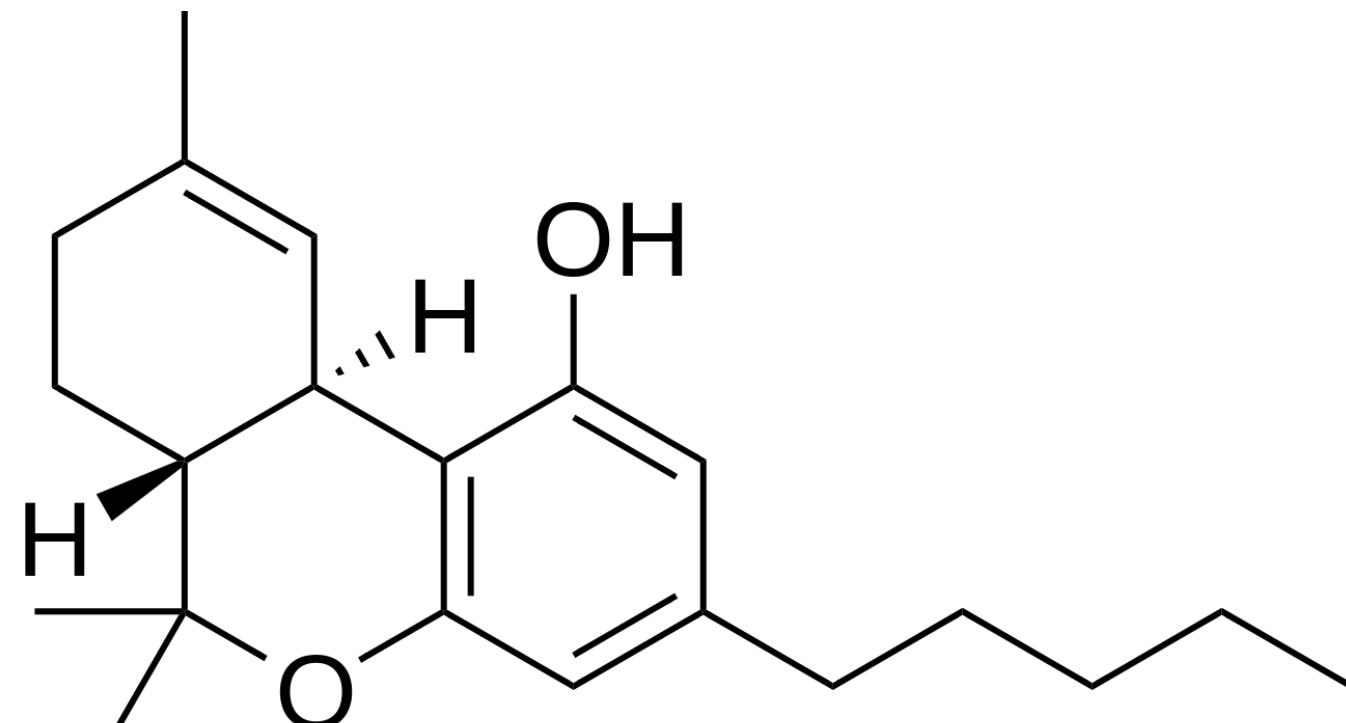


*trans*-Retinal

# Lipids take on a variety of forms



*trans*-Retinal

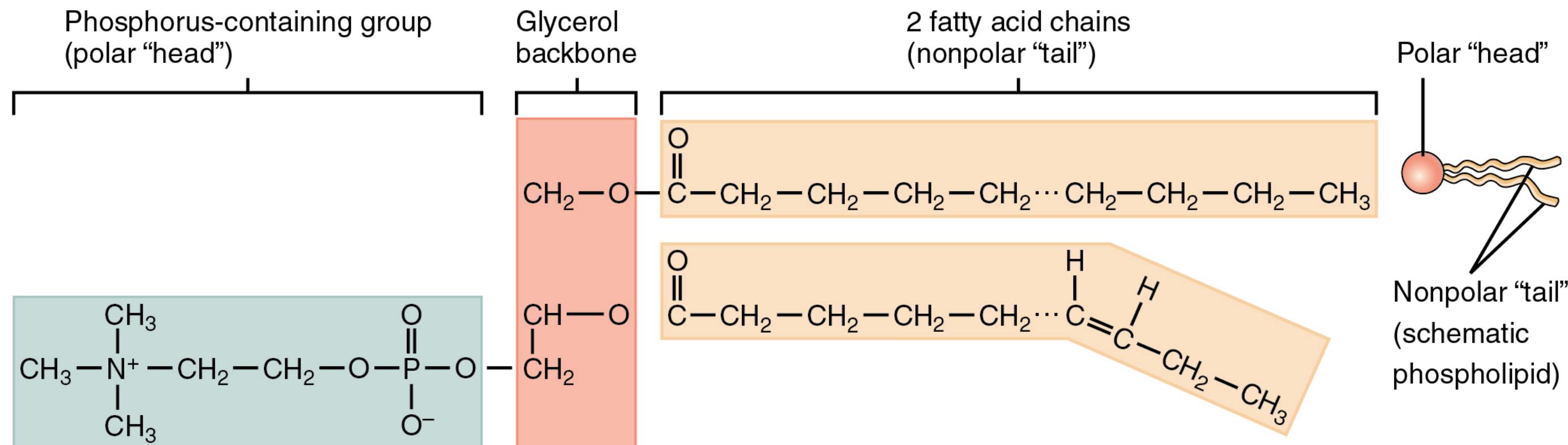


tetrahydrocannabinol

## (a) Phospholipids

Two fatty acid chains and a phosphorus-containing group are attached to the glycerol backbone.

*Example:* Phosphatidylcholine

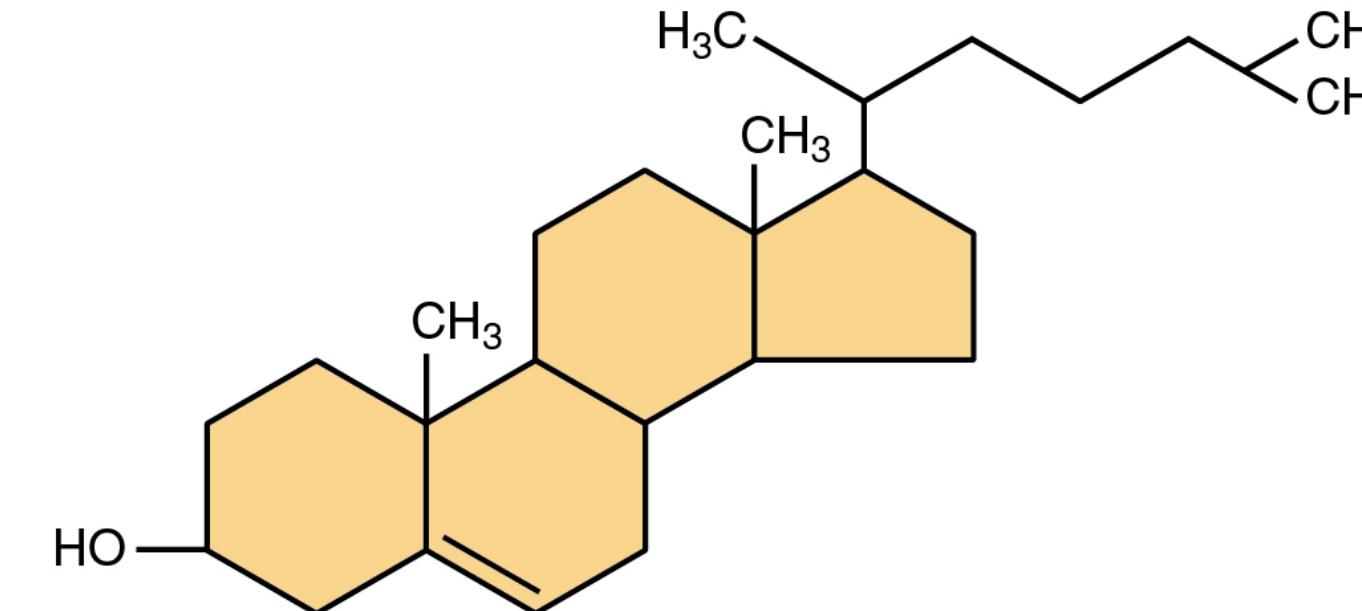


Polar "head"  
Nonpolar "tail"  
(schematic phospholipid)

## (b) Sterols

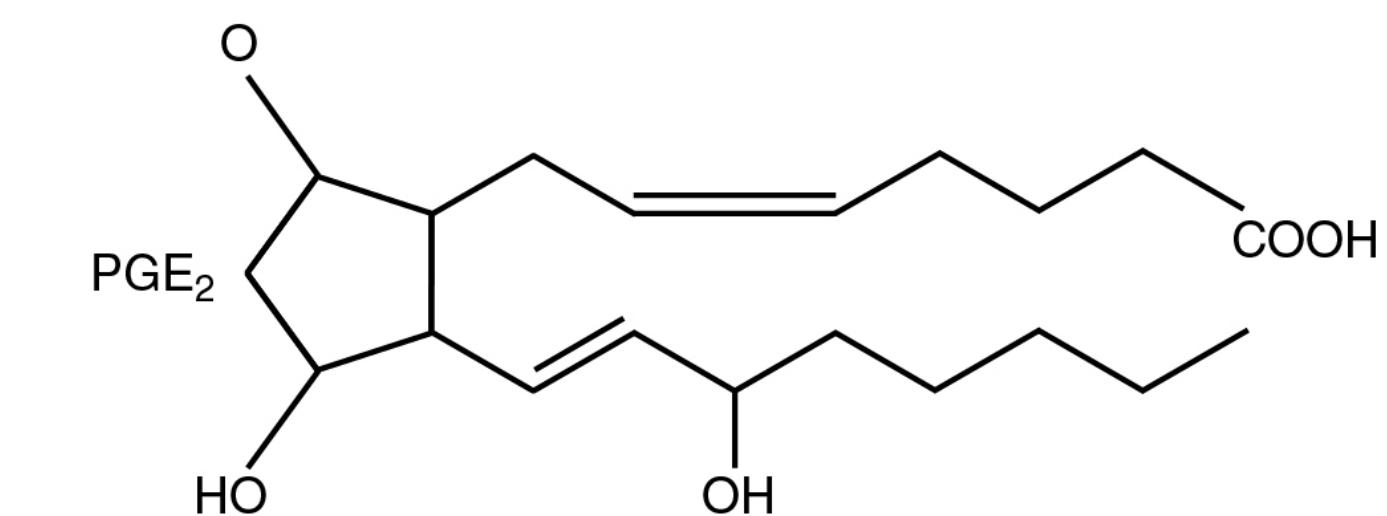
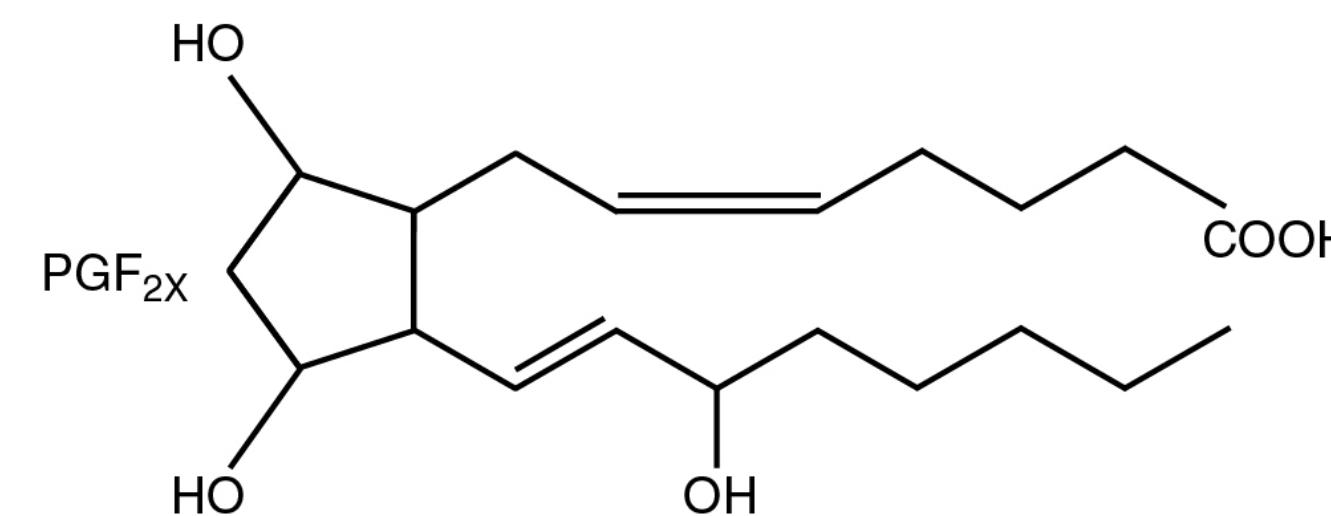
Four interlocking hydrocarbon rings from a steroid.

*Example:* Cholesterol (cholesterol is the basis for all steroids formed in the body)



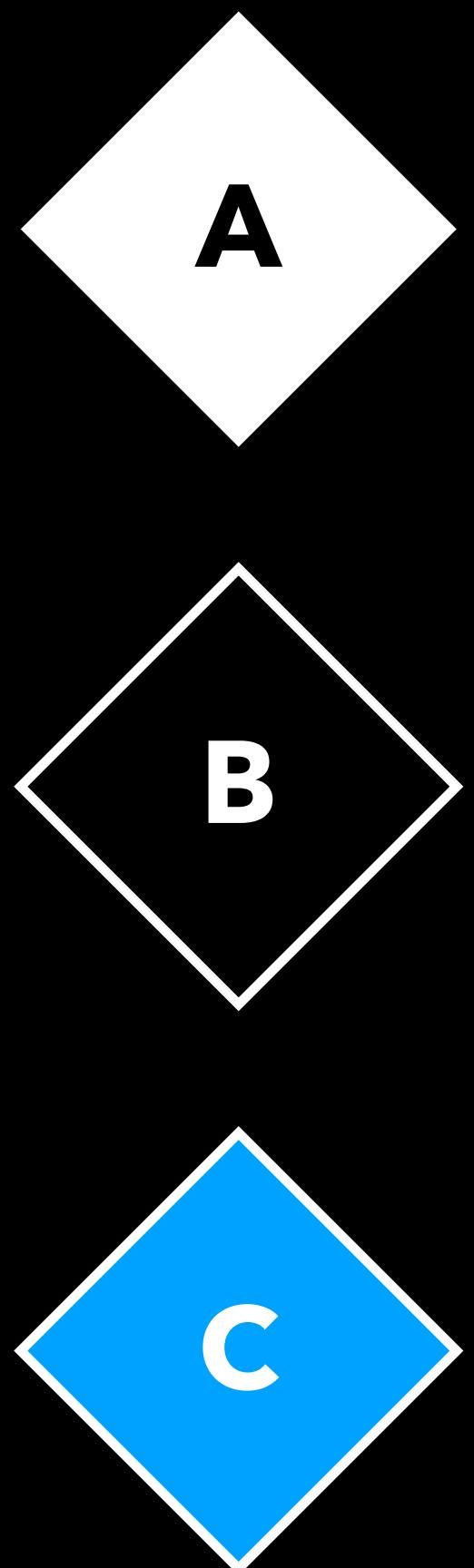
From: Wikimedia Commons ([https://commons.wikimedia.org/wiki/File:222\\_Other\\_Important\\_Lipids-01.jpg](https://commons.wikimedia.org/wiki/File:222_Other_Important_Lipids-01.jpg))

## (c) Prostaglandins

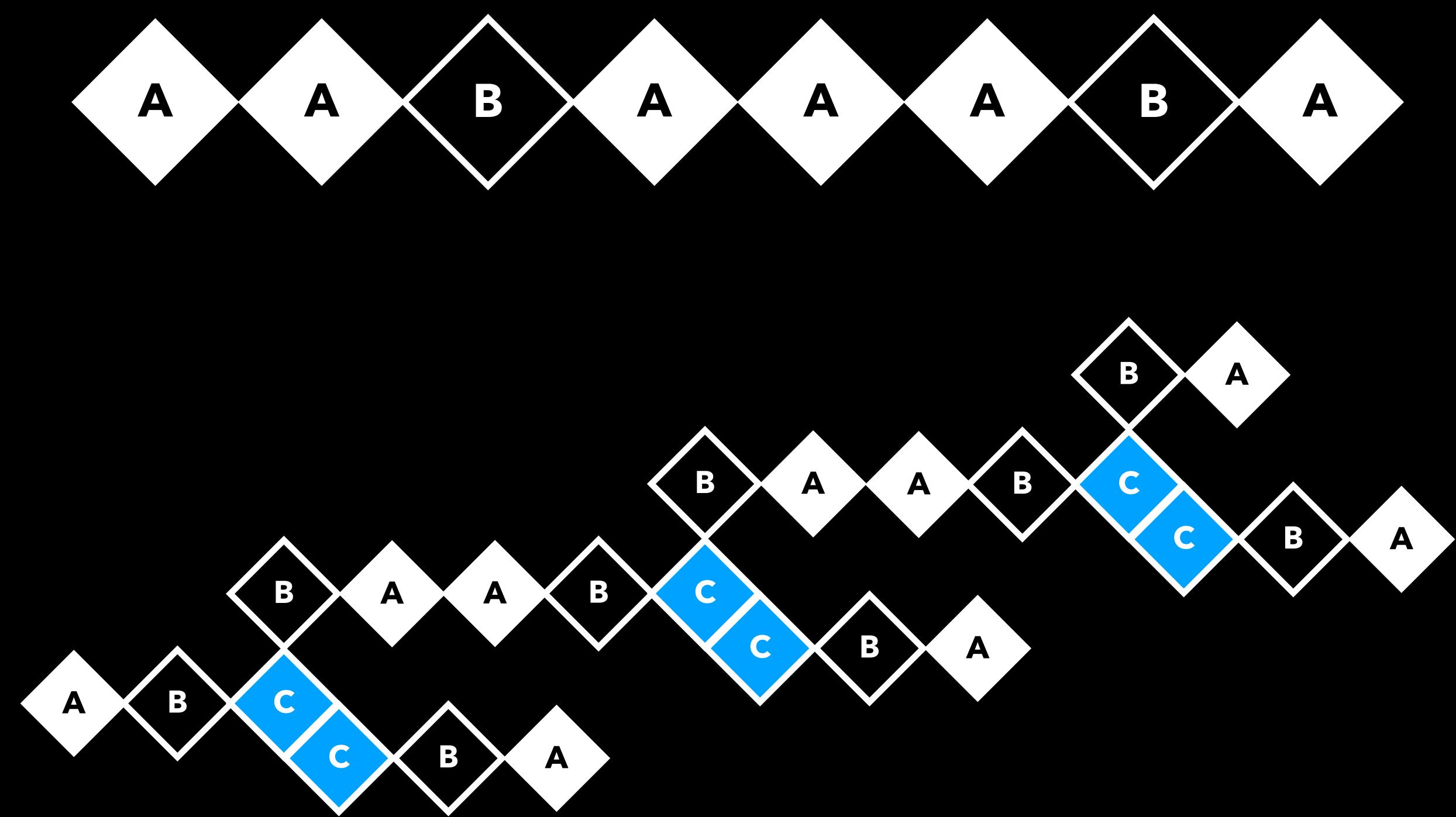


Biopolymers are  
*programmable* materials

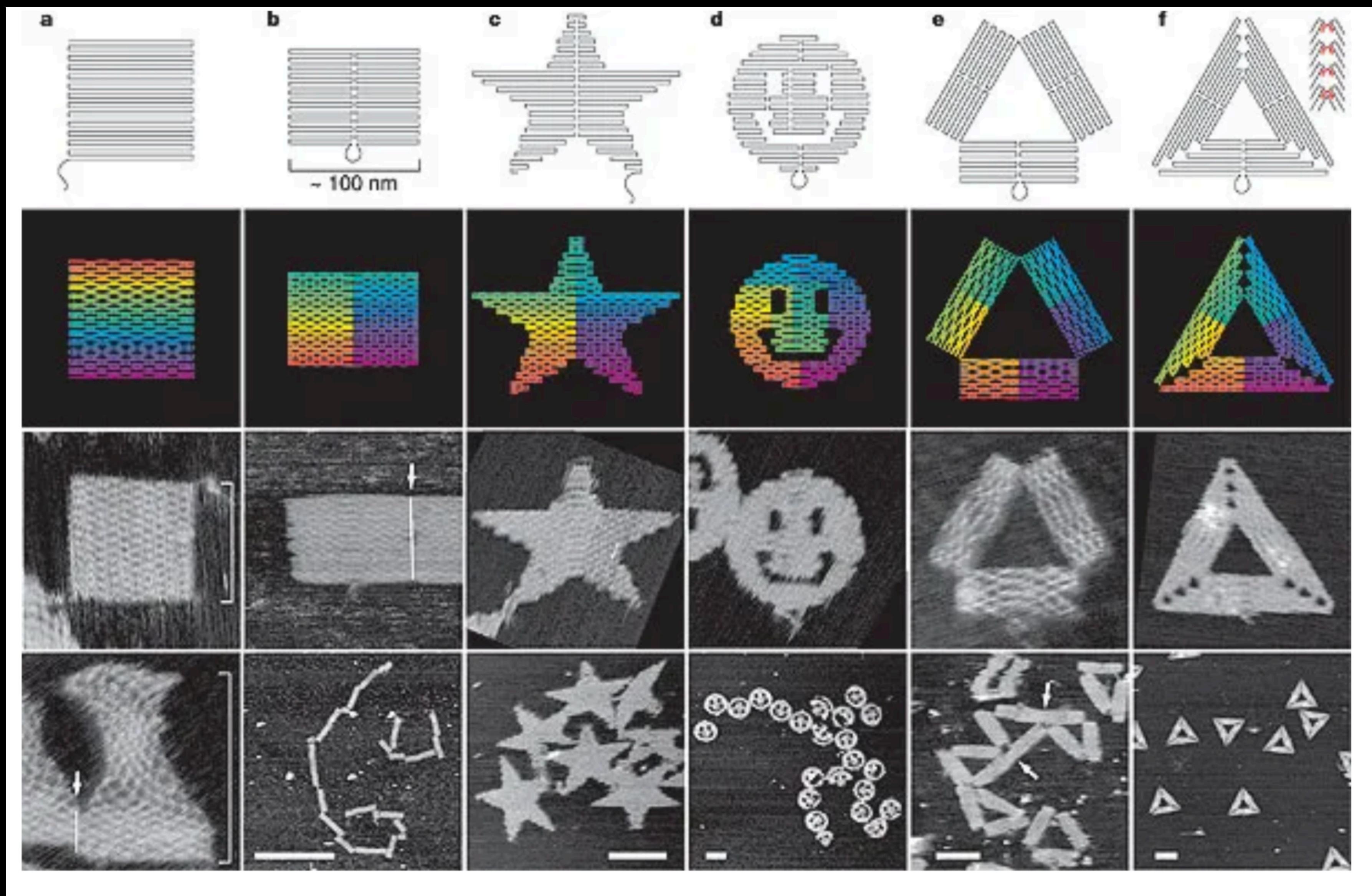
# monomers



# polymers



# *programmable* materials: e.g., DNA origami



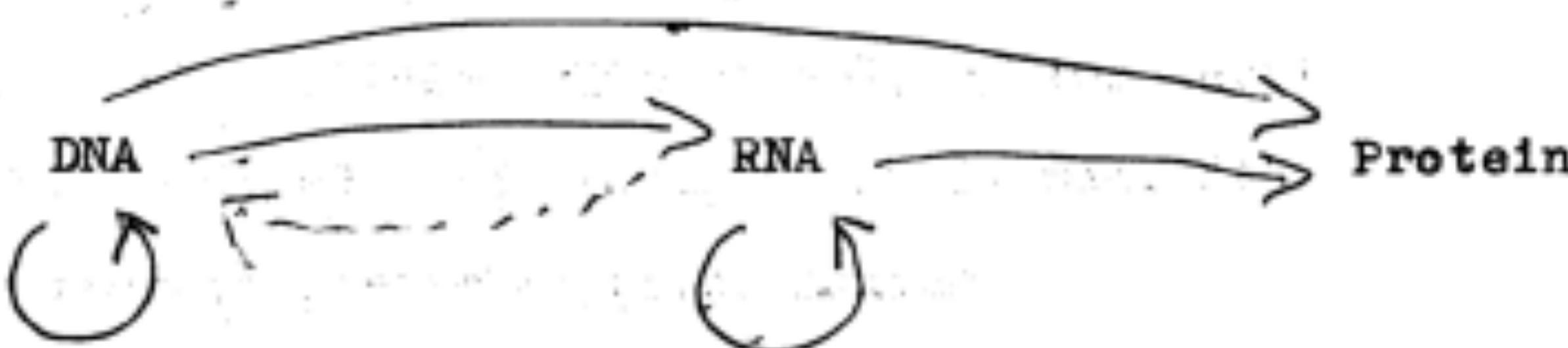
From: Rothemund,  
P.W.K, 2006  
([doi.org/10.1038/nature04586](https://doi.org/10.1038/nature04586))

## Ideas on Protein Synthesis (Oct. 1956)

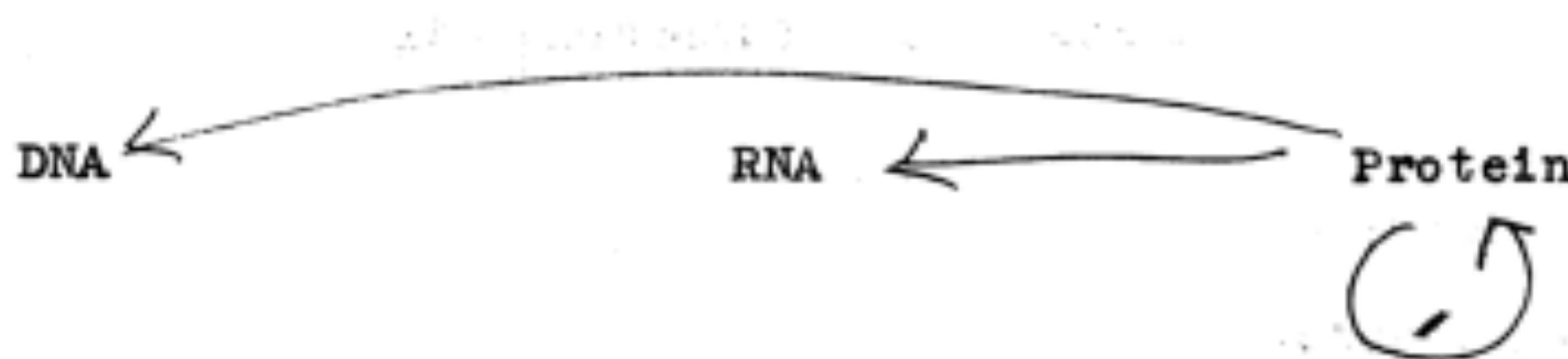
The Doctrine of the Triad.

The Central Dogma: "Once information has got into a protein it can't get out again". Information here means the sequence of the amino acid residues, or other sequences related to it.

That is, we may be able to have

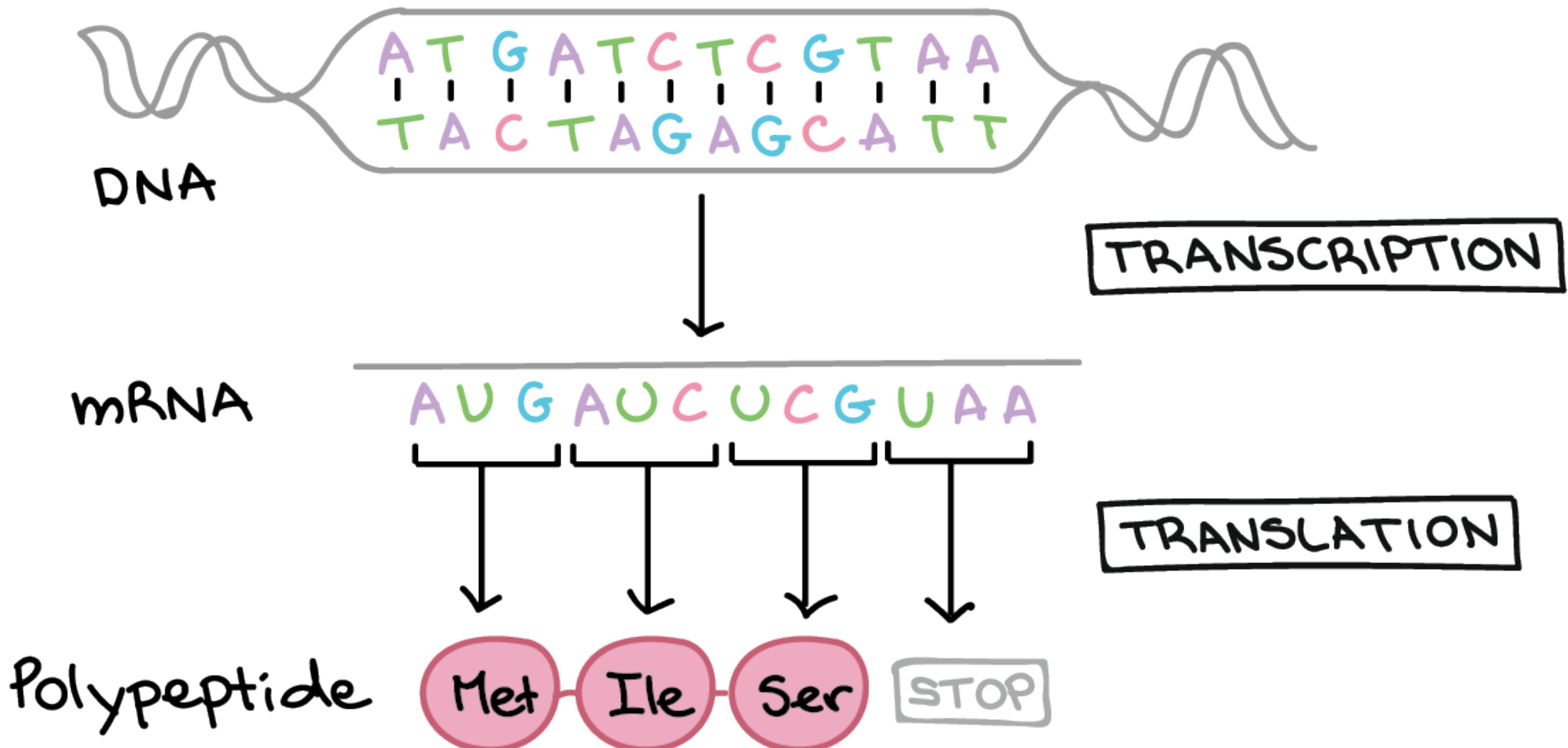


but never



where the arrows show the transfer of information.

# THE CENTRAL DOGMA

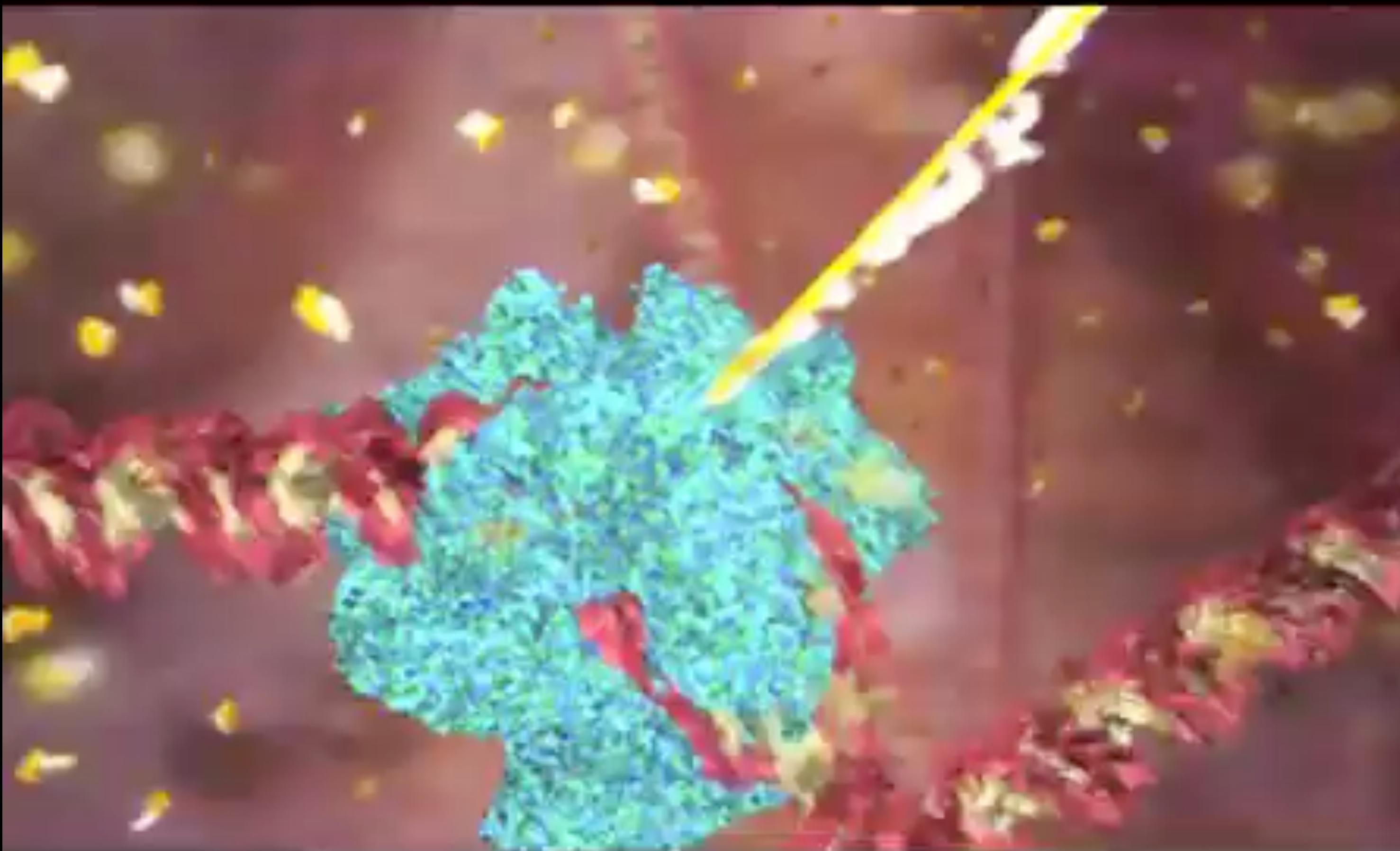


How does *information*  
get converted from DNA to proteins?

How do *atoms*  
get converted from DNA to proteins?

# Atoms: RNA polymerase reads DNA, writes RNA

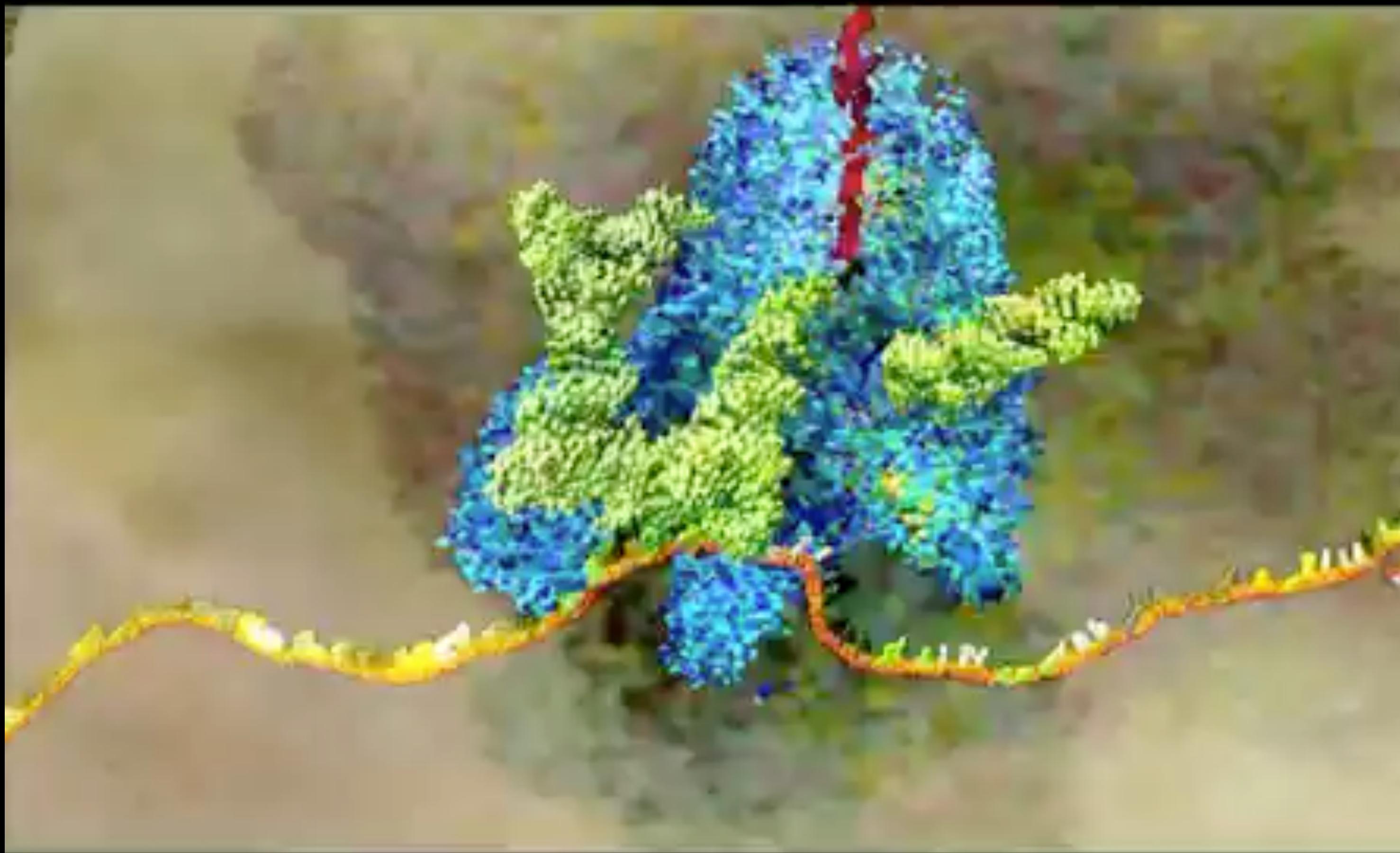
wehi.edu.au



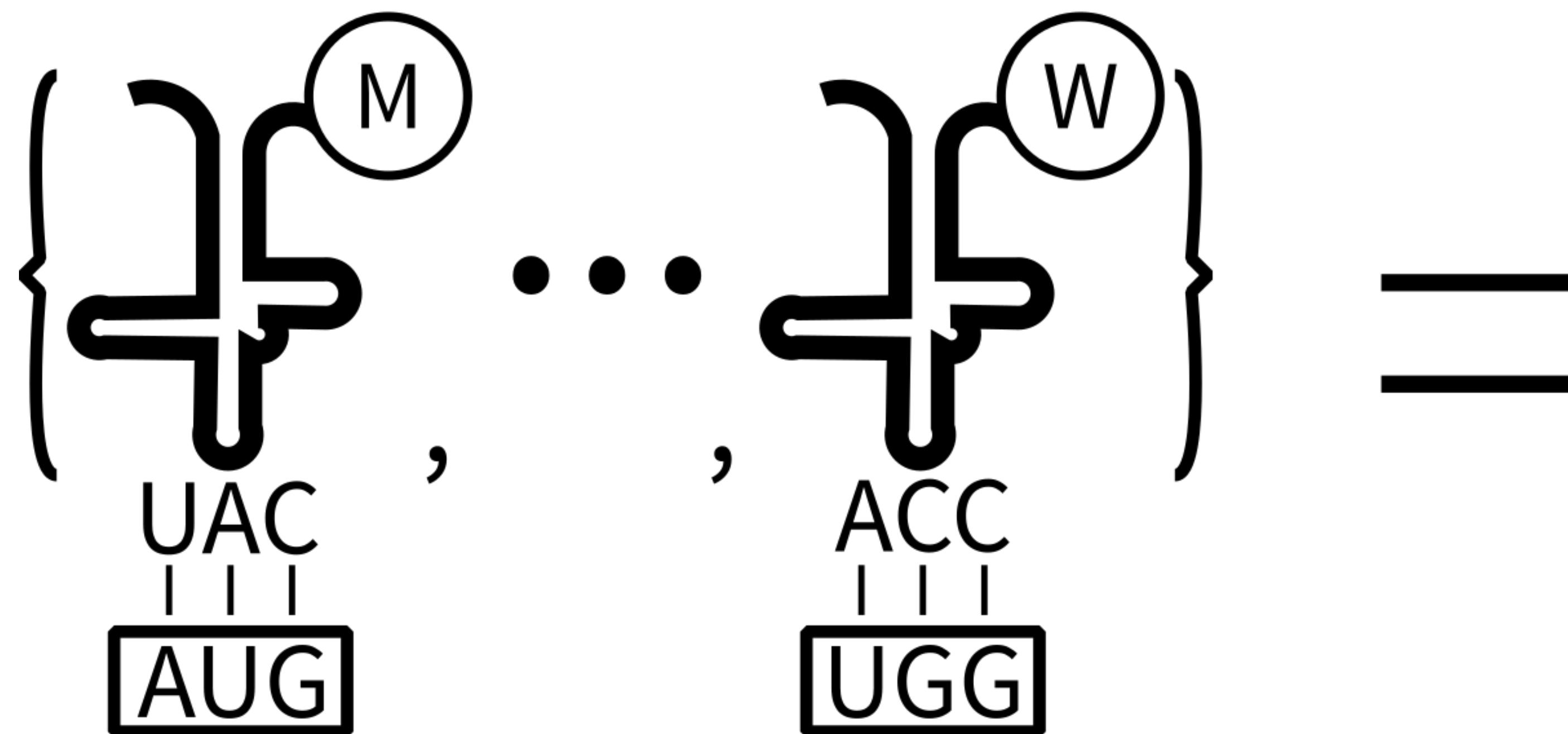
Transcription of a gene

# Atoms: the Ribosome reads RNA, writes protein

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# Information: the Genetic Code maps RNA to Protein



Second Position				Third Position
U	C	A	G	
U	UUU : F UUC : F UUA : L UUG : L	UCU : S UCC : S UCA : S UCG : S	UAU : Y UAC : Y UAA : * UAG : *	UGU : C UGC : C UGA : * UGG : W
C	CUU : L CUC : L CUA : L CUG : L	CCU : P CCC : P CCA : P CCG : P	CAU : H CAC : H CAA : Q CAG : Q	CGU : R CGC : R CGA : R CGG : R
A	AUU : I AUC : I AUA : I AUG : M	ACU : T ACC : T ACA : T ACG : T	AAU : N AAC : N AAA : K AAG : K	AGU : S AGC : S AGA : R AGG : R
G	GUU : V GUC : V GUA : V GUG : V	GCU : A GCC : A GCA : A GCG : A	GAU : D GAC : D GAA : E GAG : E	GGU : G GGC : G GGA : G GGG : G

# Information: the Genetic Code maps RNA to Protein

mRNA



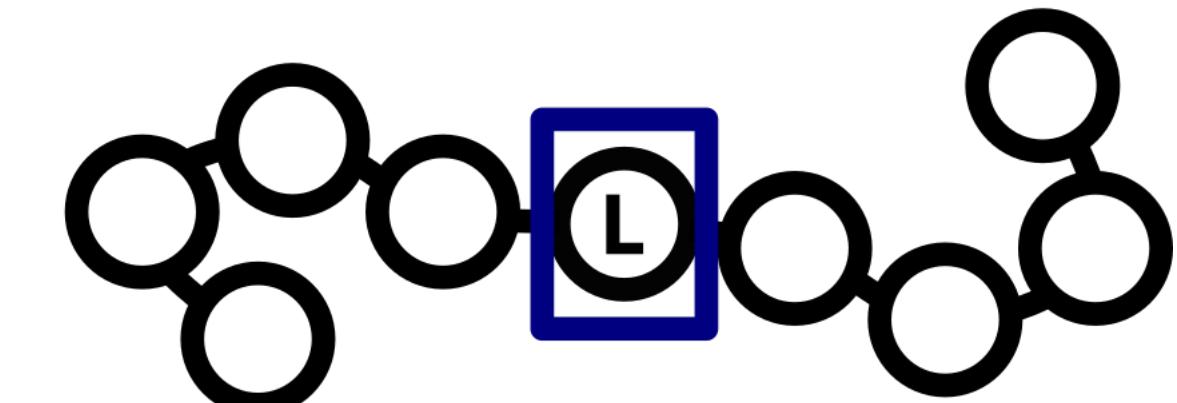
Protein

UUA



Second Position			
U	C	A	G
UUU : F	UCU : S	UAU : Y	UGU : C
UUC : F	UCC : S	UAC : Y	UGC : C
<b>UUA : L</b>	<b>JCA : S</b>	UAA : *	UGA : *
UUCG : F	UCCG : S	UAG : *	UGG : W
C	CUU : L	CCU : P	CAU : H
CUC : L	CCC : P	CAC : H	CGC : R
CUA : L	CCA : P	CAA : Q	CGA : R
CUG : L	CCG : P	CAG : Q	CGG : R
AUU : I	ACU : T	AAU : N	AGU : S
AUC : I	ACC : T	AAC : N	AGC : S
AUA : I	ACA : T	AAA : K	AGA : R
AUG : M	ACG : T	AAG : K	AGG : R
G	GUU : V	GCU : A	GAU : D
GUC : V	GCC : A	GAC : D	GGC : G
GUA : V	GCA : A	GAA : E	GGA : G
GUG : V	GCG : A	GAG : E	GGG : G

Leucine



# Some awesome links for extra info

XBio (e-book)

Cell Biology by the Numbers (e-book)

Protein Data Bank (web page)

Khan Academy - Biomolecules (videos)

Khan Academy - Central Dogma (videos)