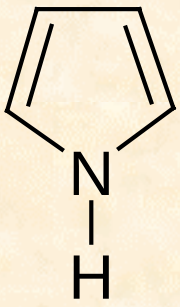
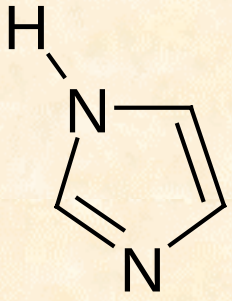
Chemistry of nucleic acids

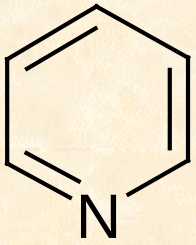
1. Basic properties of heterocycles



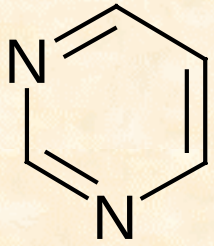
Pyrrole
(Azole)



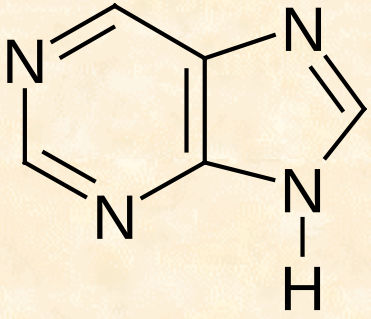
Imidazole
(1,3-Diazole)



Pyridine
(Azine)



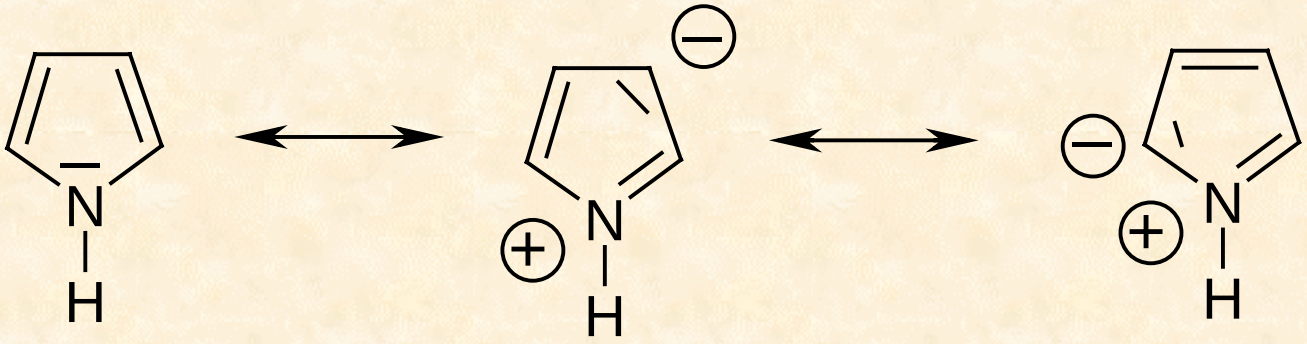
Pyrimidine
(1,3-Diazine)

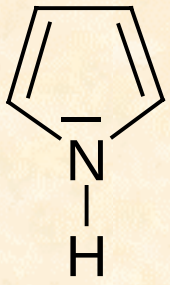


Purine

Pyrrole

Pyrrole: Aromatic system (6 π-Electrons)



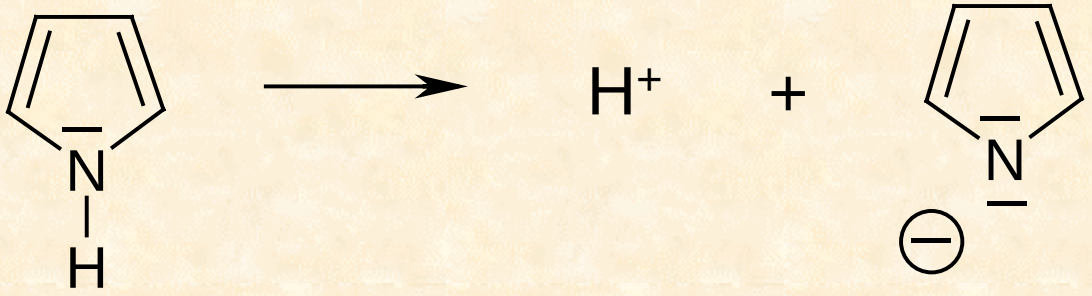


107.6 ppm

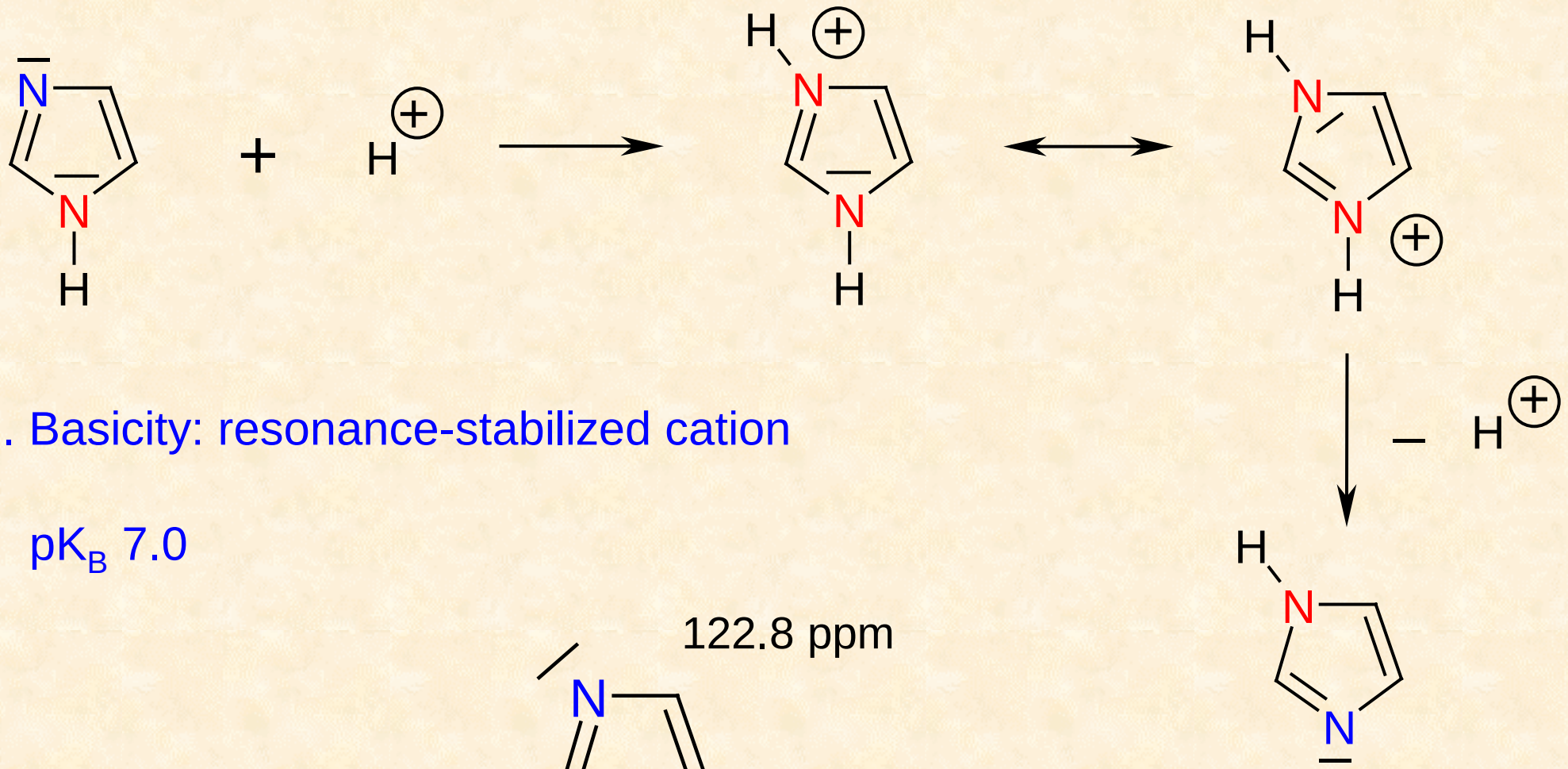
117.3 ppm

Resonance structures:
Electron rich system

N: lack of basicity

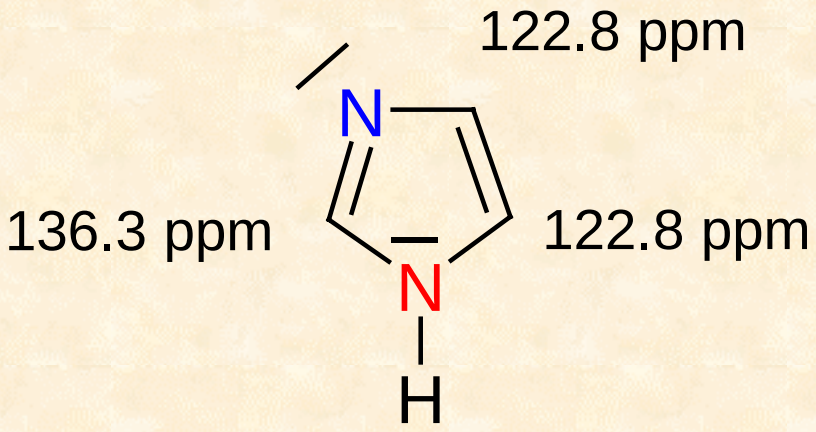


Imidazole

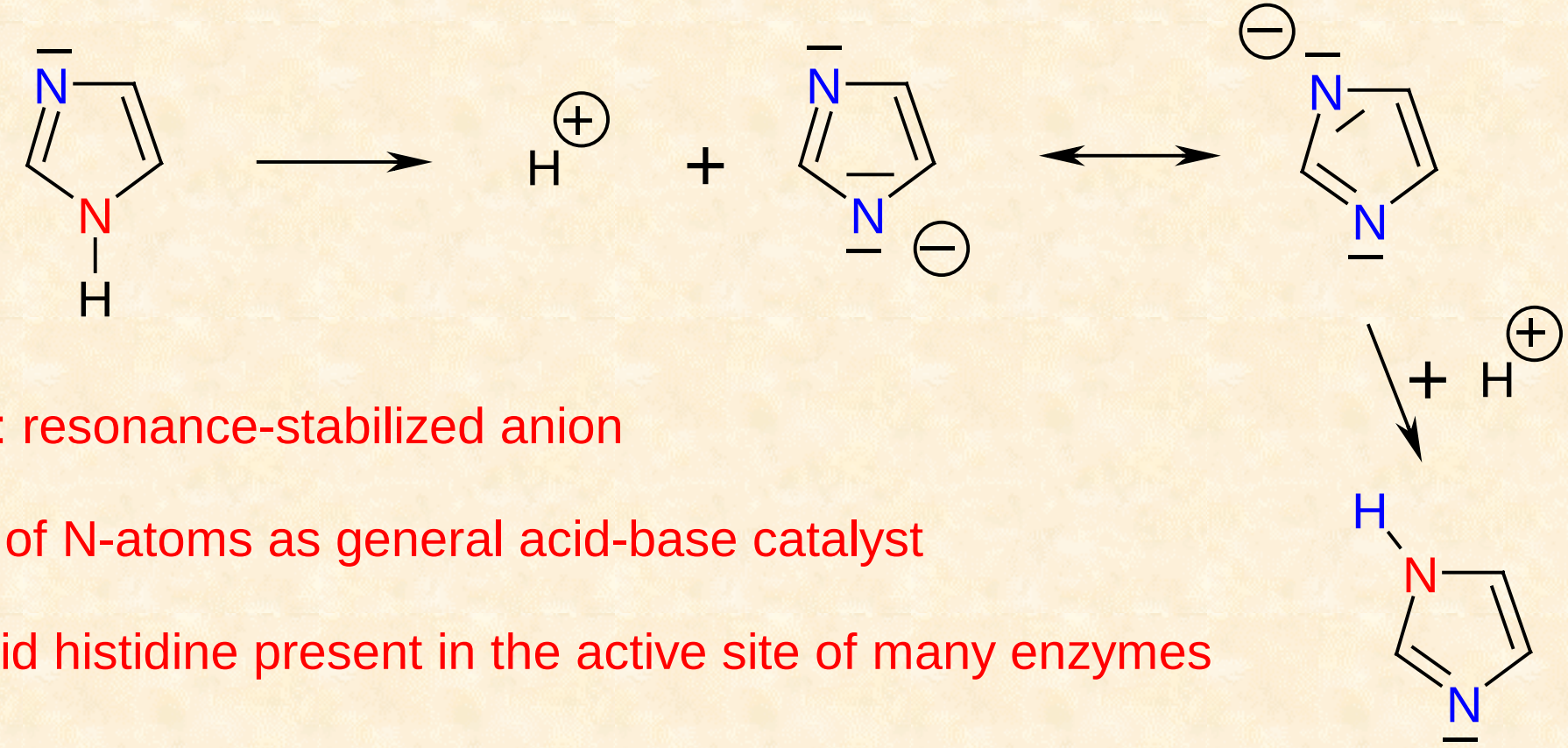


1. Basicity: resonance-stabilized cation

pK_B 7.0



Imidazole



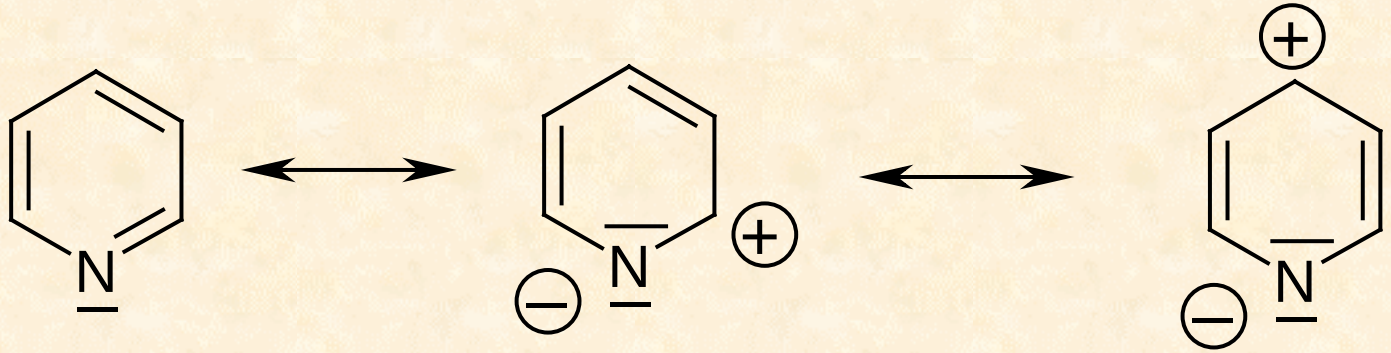
2. Acidity: resonance-stabilized anion

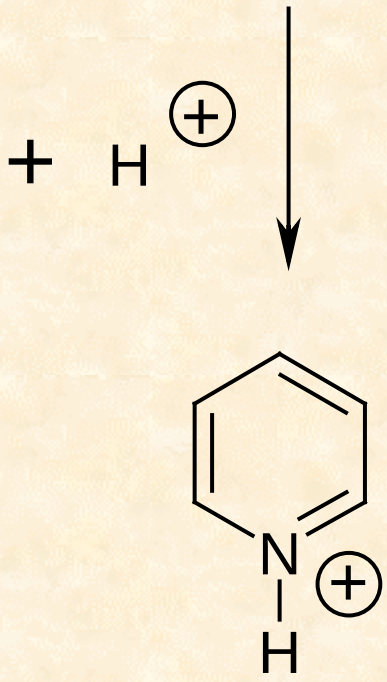
Dual role of N-atoms as general acid-base catalyst

Amino acid histidine present in the active site of many enzymes

Pyridine

Pyridine: 6 π-electrons

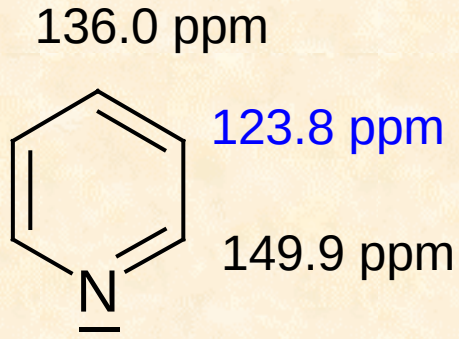




Resonance structures:
Electron-deficient aromatic system
(highest electron density at *m*-position)

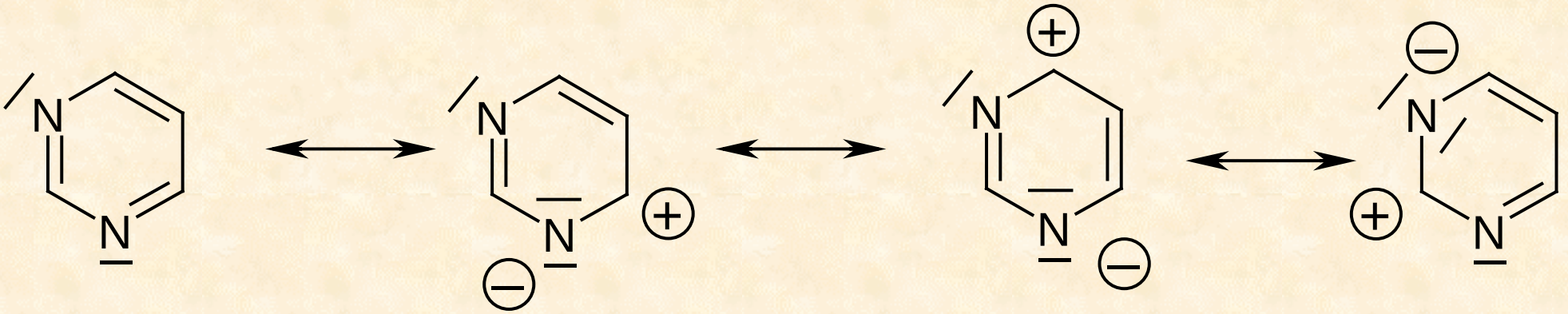
N: weak basicity

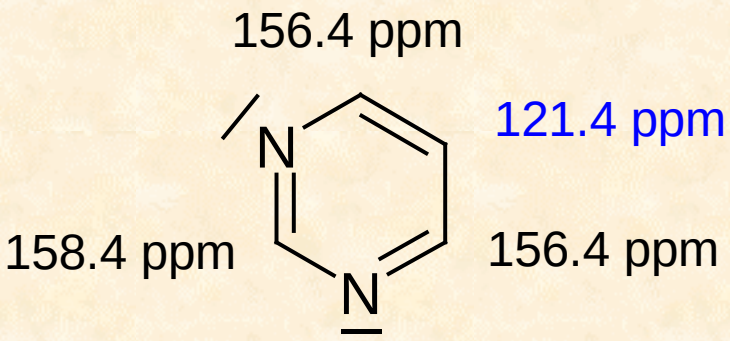
pK_B: 8.7



Pyrimidine

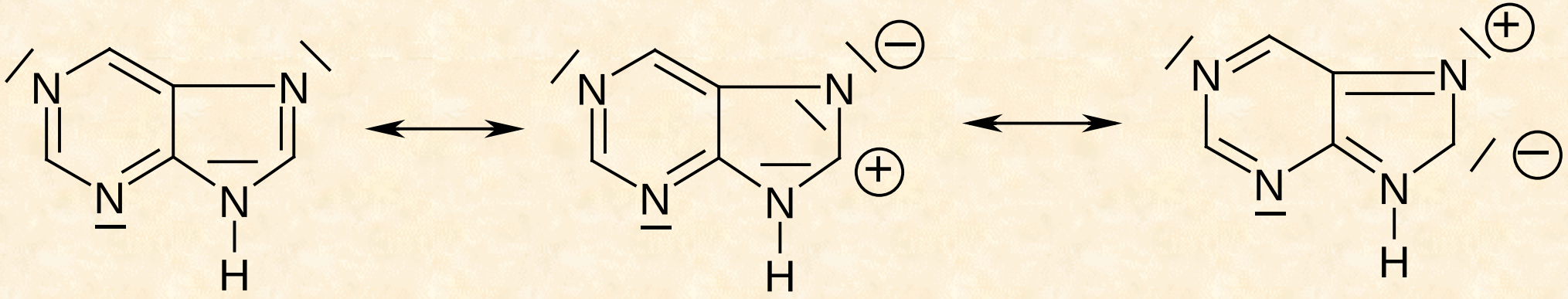
Pyrimidine: 6 π-electrons

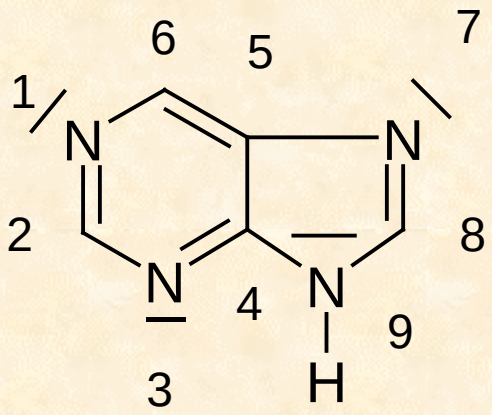




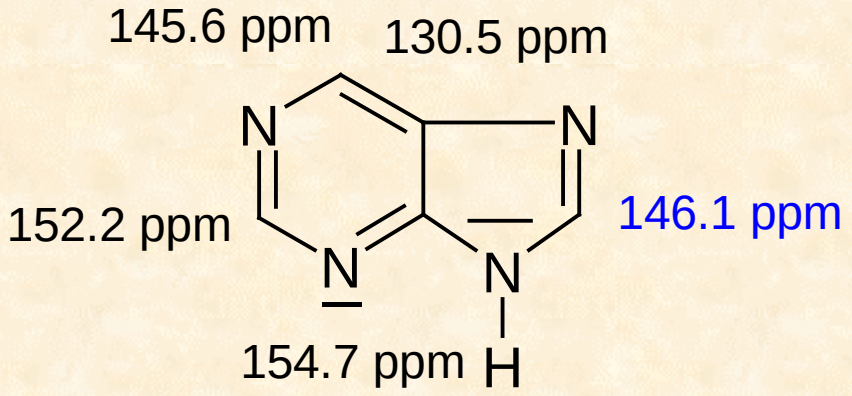
Reduced aromaticity
5-position relative high electron density

Purine



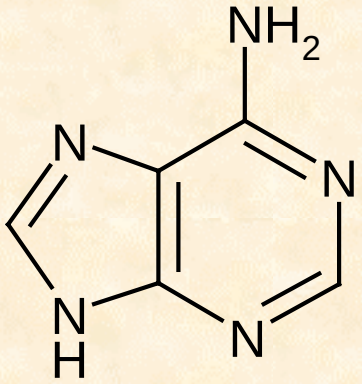


Reduced aromaticity
8-position relative high electron density

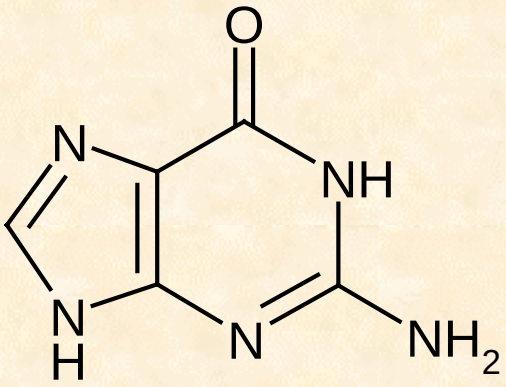


N-Bases of DNA and RNA

Purin bases

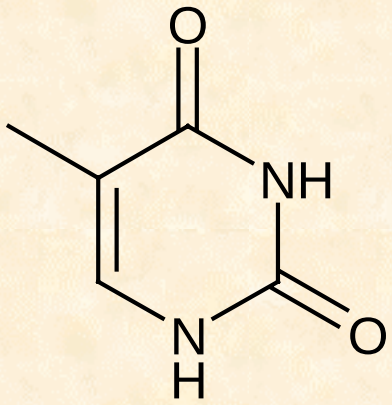


Adenine

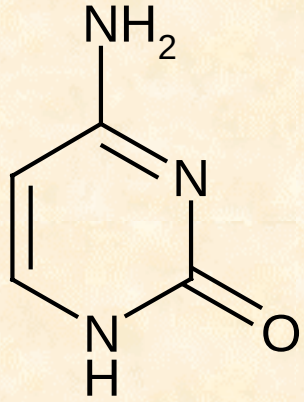


Guanine

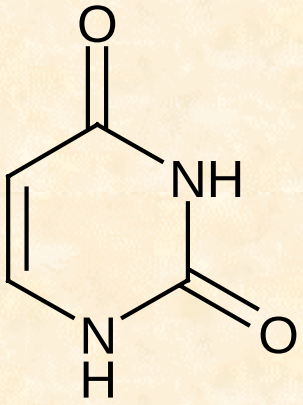
Pyrimidine bases



Thymine

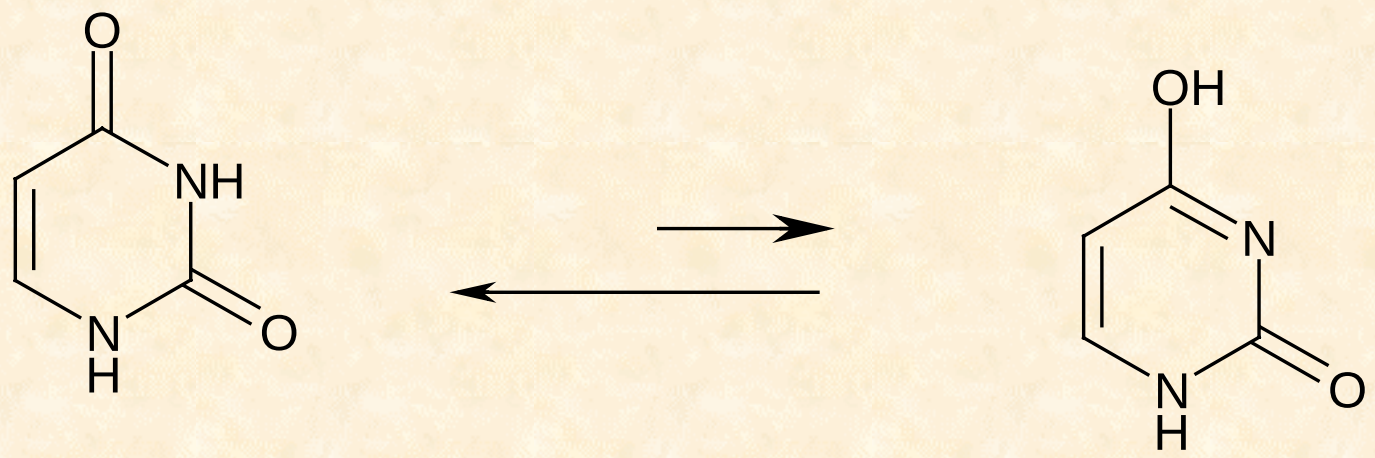


Cytosine



Uracil

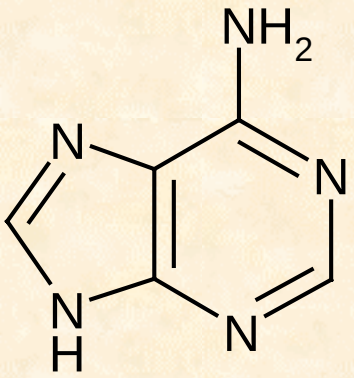
Lactame-Lactime Tautomers



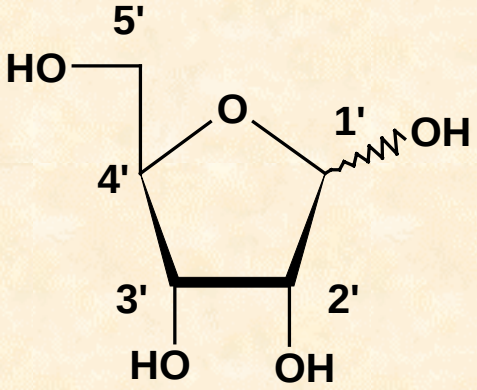
Uracil: Lactame form

Lactime form

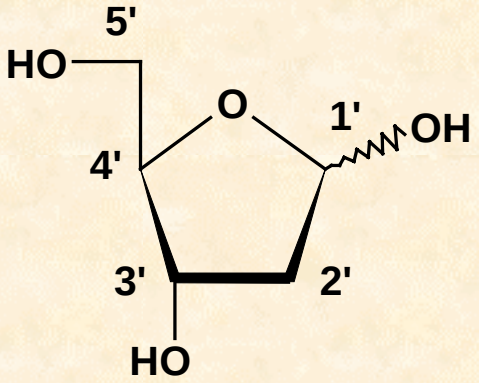
Nucleoside: *N*-Glycoside of N-bases



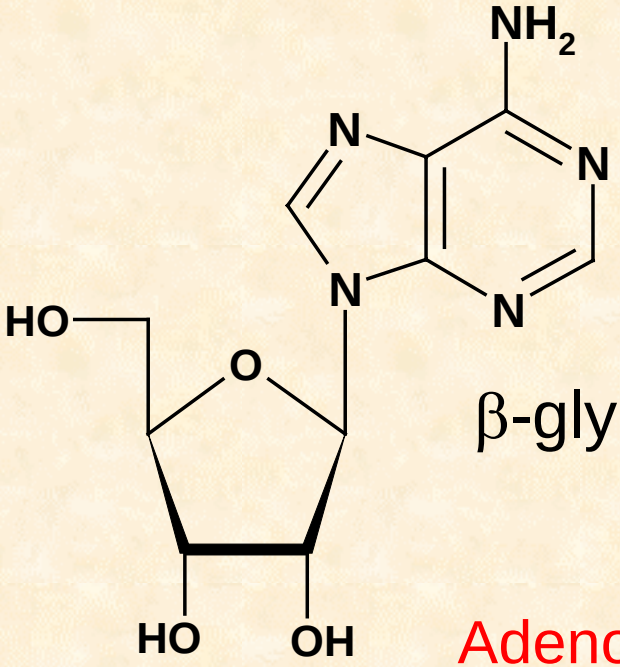
Adenine



Ribose
(Furanose)



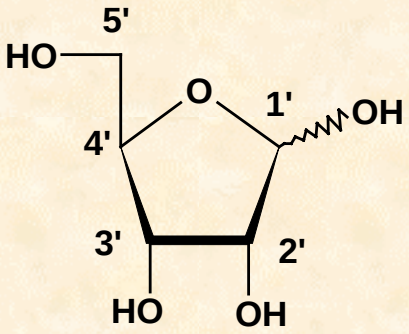
2'-Desoxyribose
(Furanose)



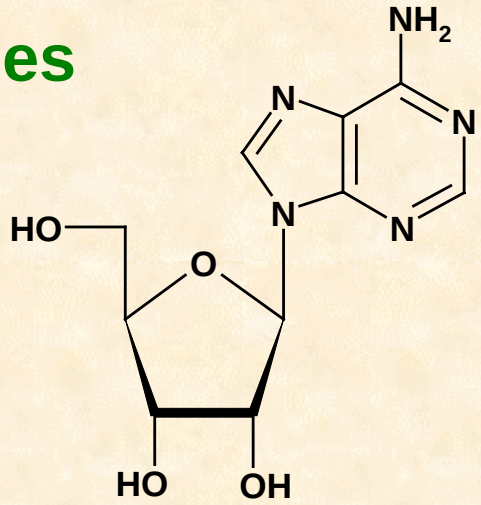
β-glycosidic bond (β-ribofuranoside)

Adenosine

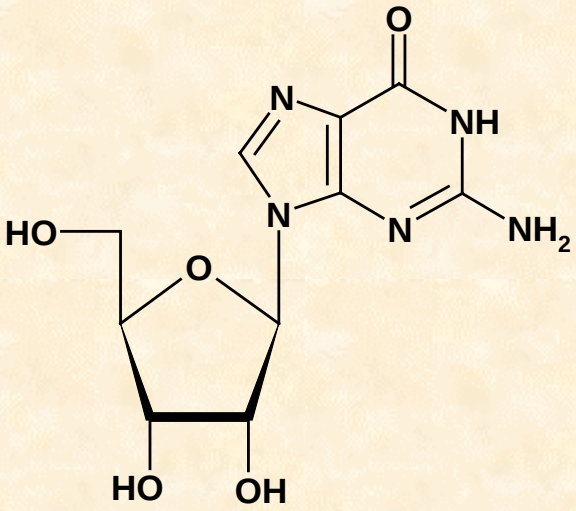
Purine nucleosides



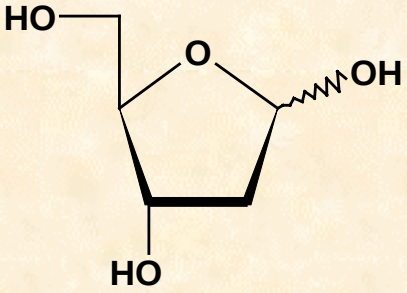
Ribose
(Furanose)



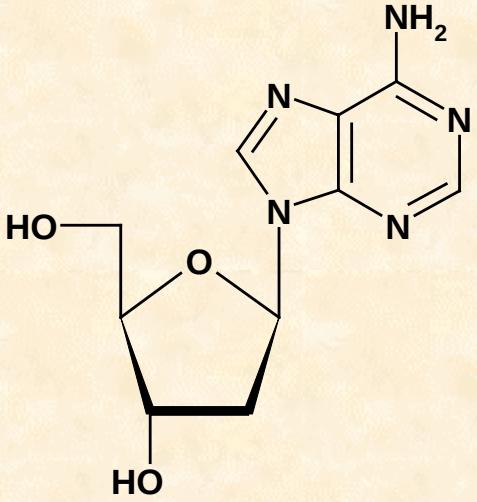
Adenosine



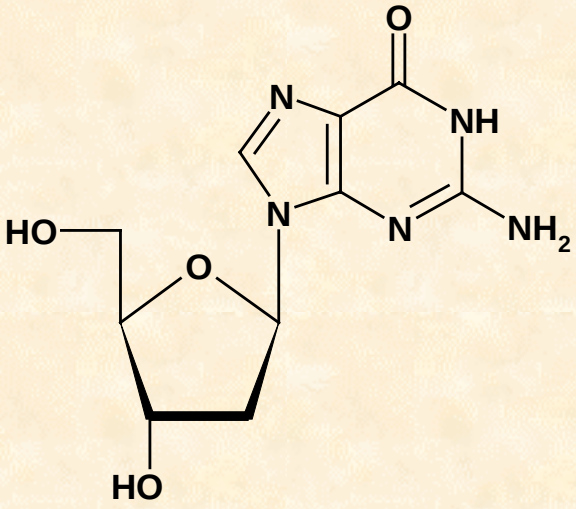
Guanosine



2'-Desoxyribose
(Furanose)

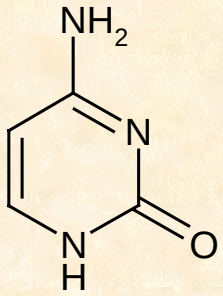


2'-desoxy-Adenosine
dA

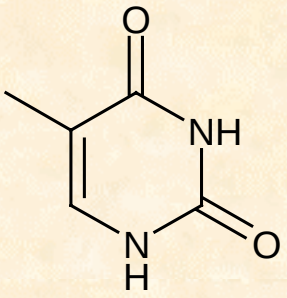


2'-desoxy-Guanosine
dG

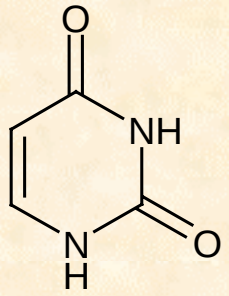
Pyrimidine nucleosides



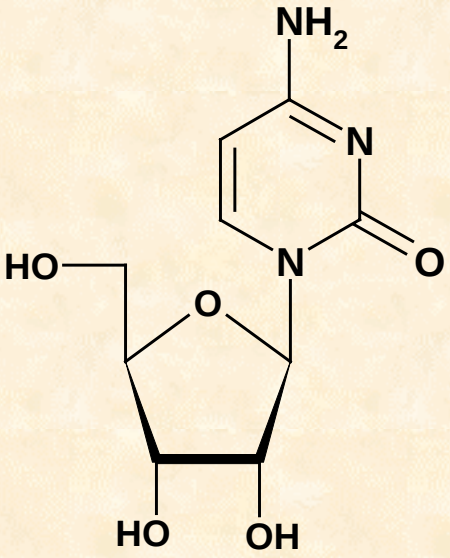
Cytosine



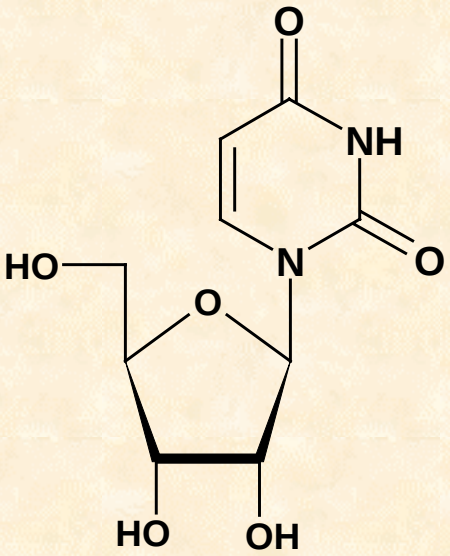
Thymine



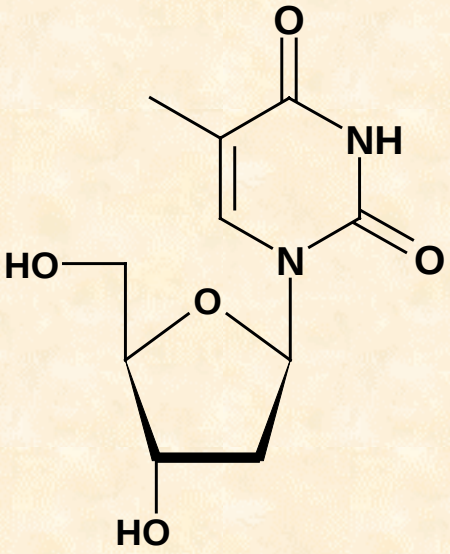
Uracil



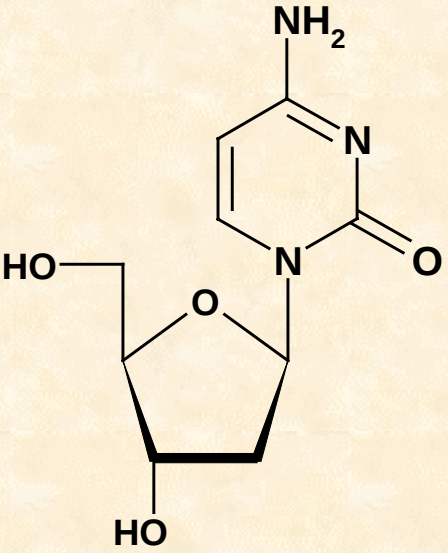
Cytidine
C



Uridine
U

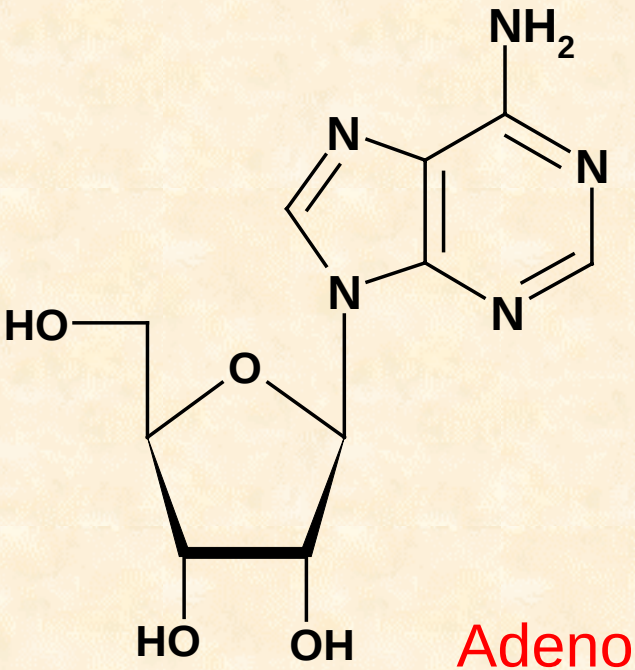


Thymidine
2'-Desoxyribosylthymine
dT

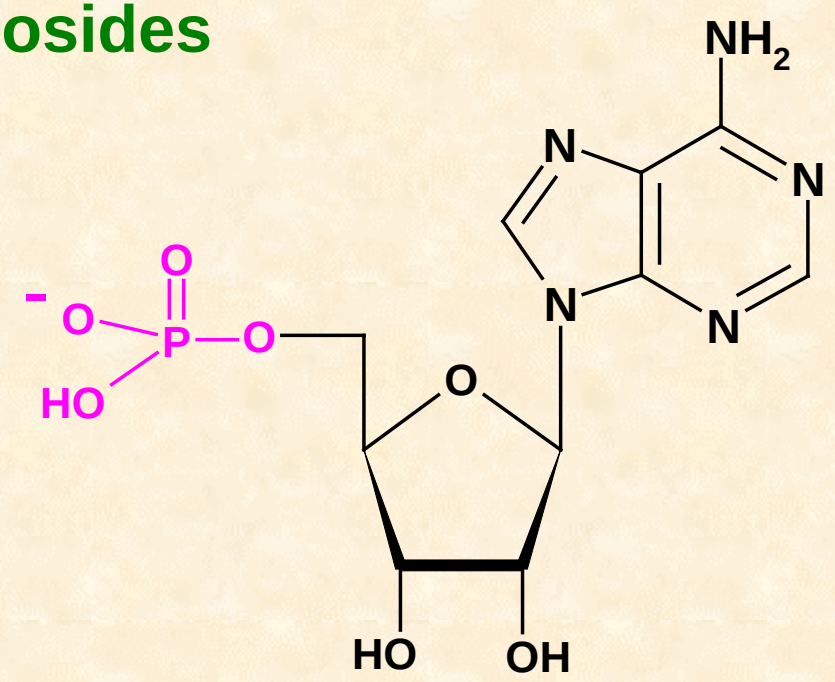


2'-desoxy-Cytidine
dC

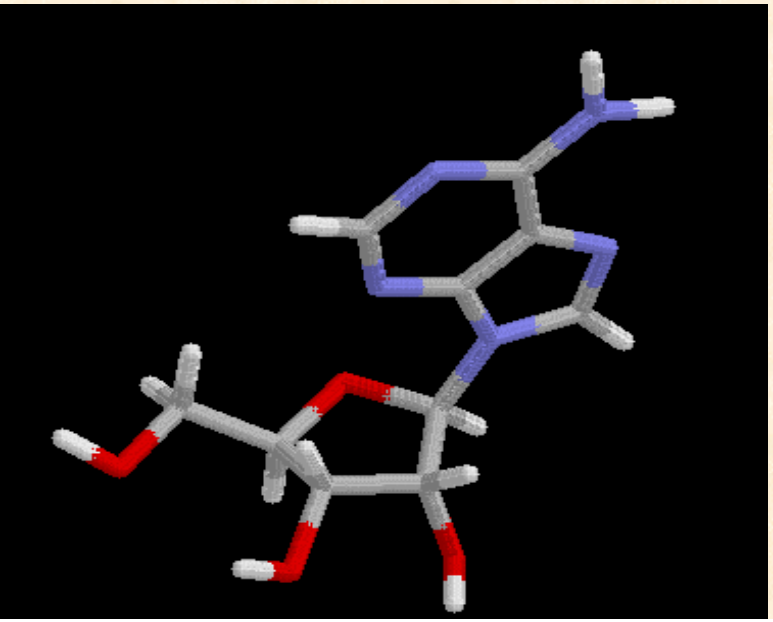
Nucleotides: phospho esters of nucleosides



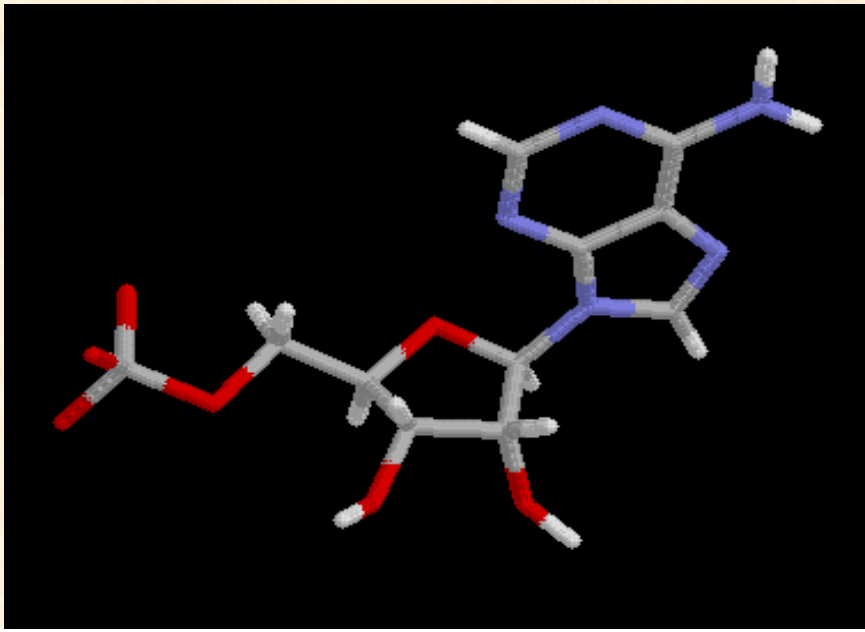
Adenosine



Adenosine 5'-monophosphate



Phosphomonoester



2. General properties

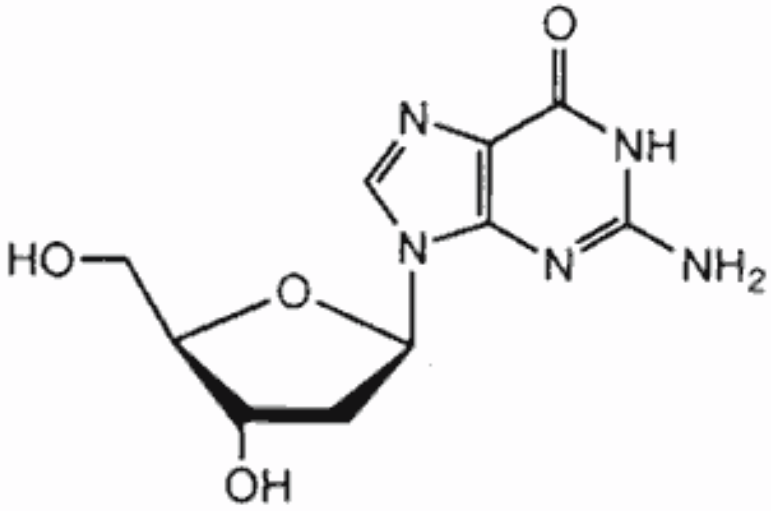
Solubility of pyrimidines and purines in water (1 g x g H_2O)

Heterocycle	x g H_2O	functional group
Pyrimidine	1	-
Uracil	280	2 OH
Thymine	250	2 OH, 1 Me
Purine.picrate	2	-
Adenine.picrate	1086	1 NH_2
Guanine.picrate	26000	1 OH, NH_2
2,8-Dihydroxyadenine	500000	1 OH, NH_2
Uric acid	39480	3 OH
Nucleosides, Nucleotides	soluble in hot, insolub. in cold water	

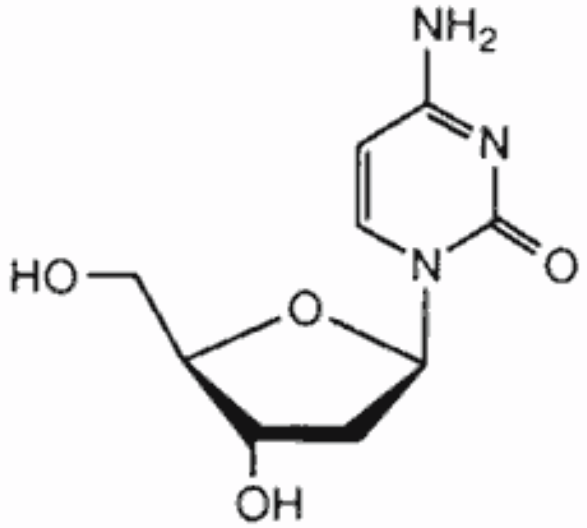
General properties

Dissociation equilibria in nucleotides

Functional group	Dissociation reaction	pK
1. Phosphate-OH	$RO\text{-}PO_3H_2 \Leftrightarrow RO\text{-}PO_3H^- + H^+$	0.7-1.6
$-NH_2$ of adenine	$R\text{-}NH_3^+ \Leftrightarrow R\text{-}NH_2 + H^+$	3.5-4.5
2. Phosphate-OH	$RO\text{-}PO_3H^- \Leftrightarrow RO\text{-}PO_3^{2-} + H^+$	5.8-6.6
Heterocycl. protons (U, T, G)	$-NH\text{-}CO- \Leftrightarrow -N{=}C(O^-)- + H^+$	9.5
-OH of ribose	$R\text{-}OH \Leftrightarrow RO^- + H^+$	12.5

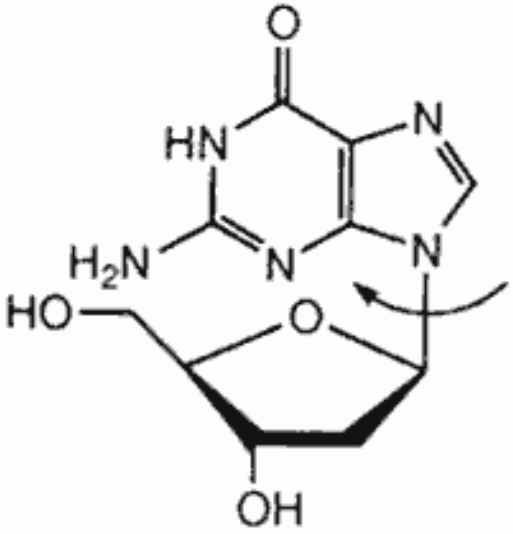


anti deoxyguanosine

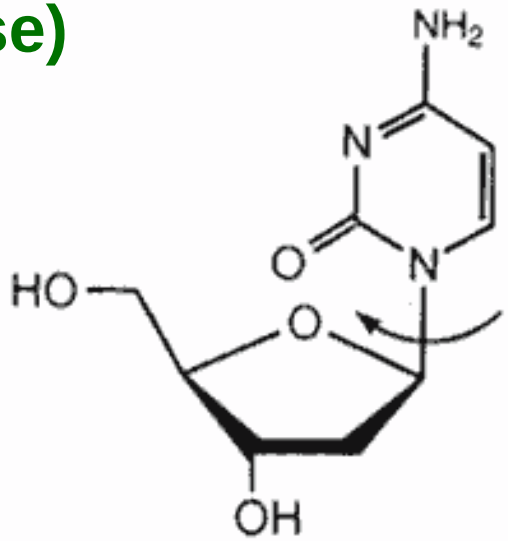


anti deoxycytidine

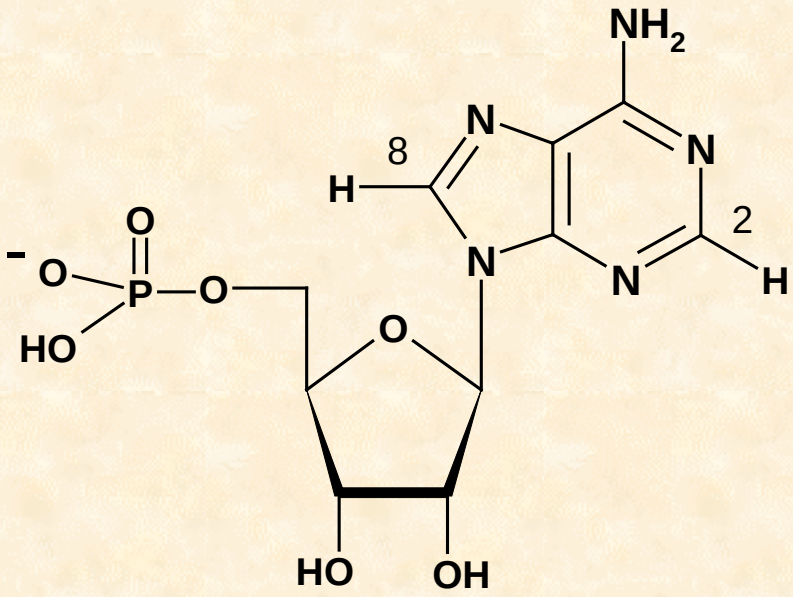
General properties
conformations of nucleosides
(Orientation of N-base)



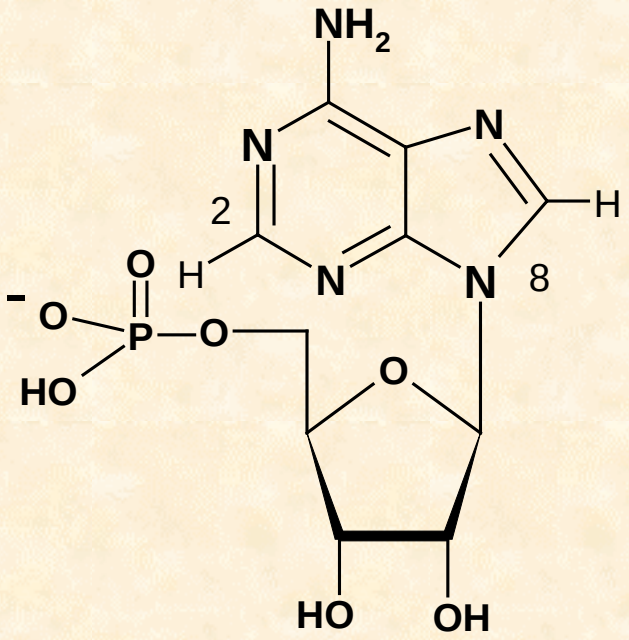
syn deoxyguanosine



Conformation of nucleotides



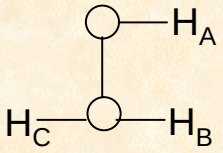
anti-conformation

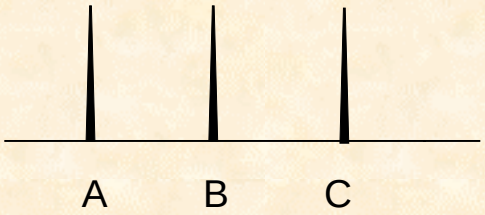


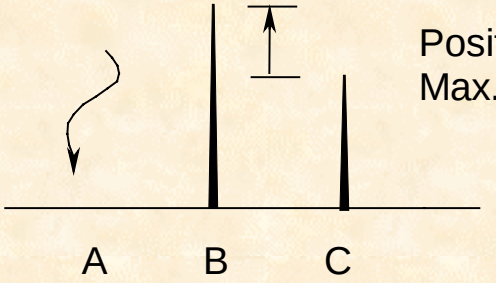
syn-conformation

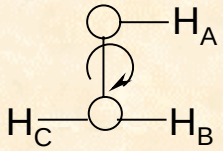
Orientation of the N-base relative to the pentose

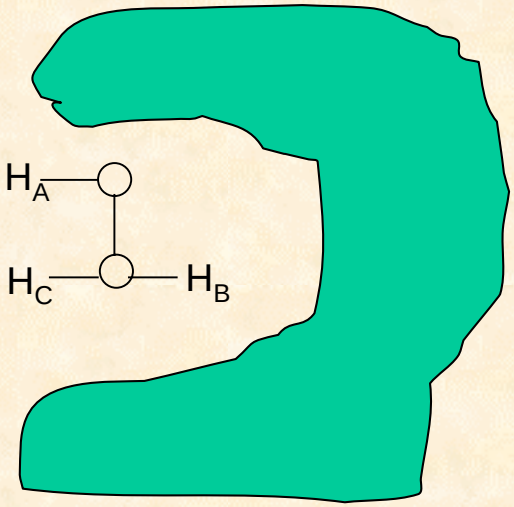
Transfer-Noe: study of conformation of a ligand in the binding site

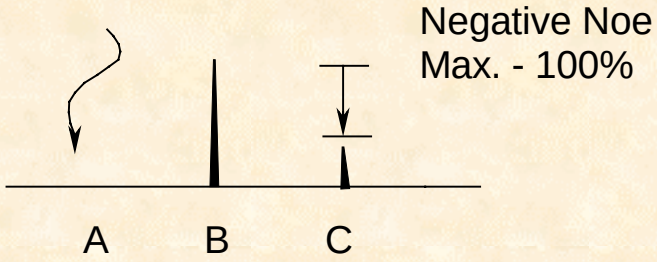












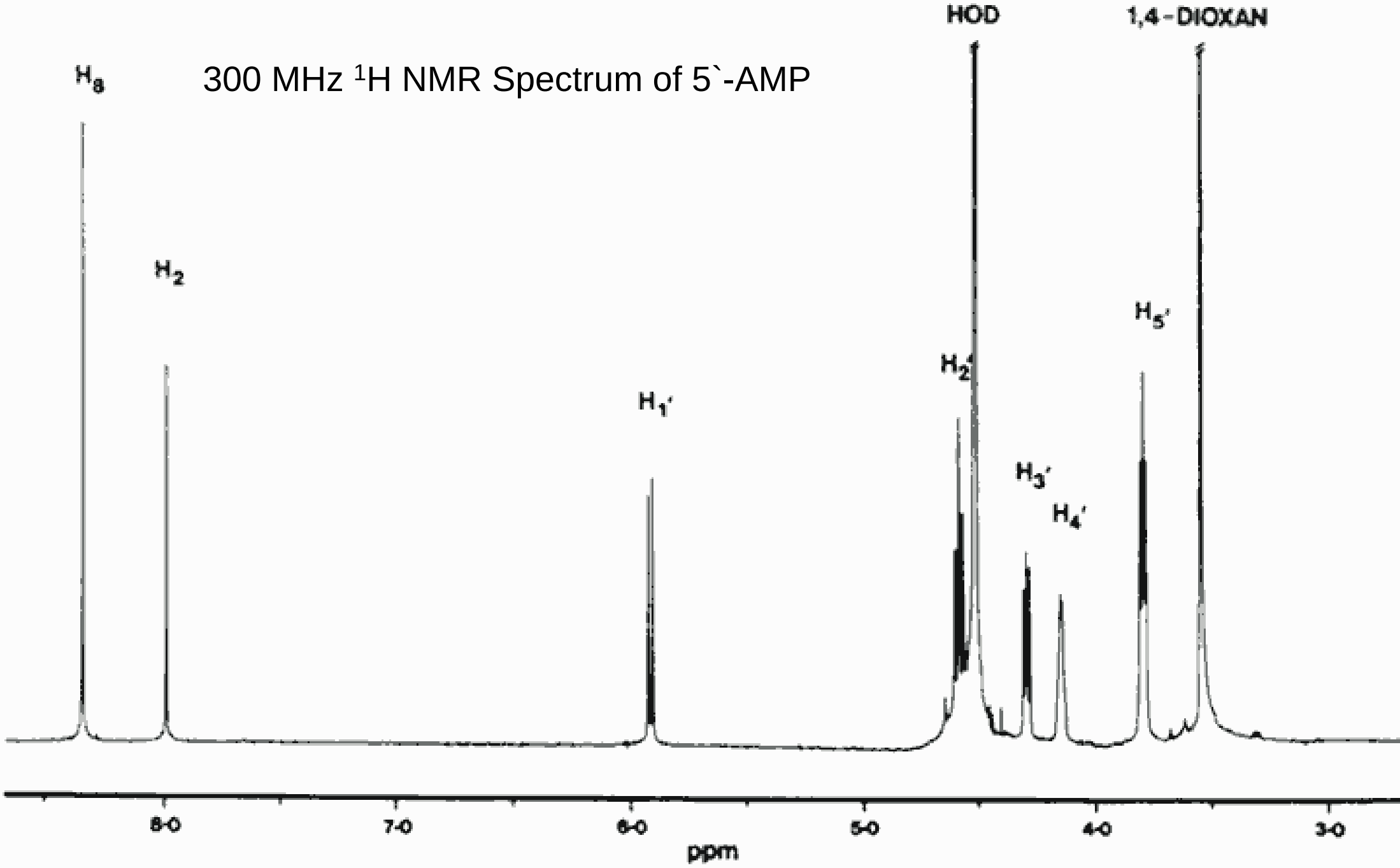
$k_D \sim \mu M$

Free ligand

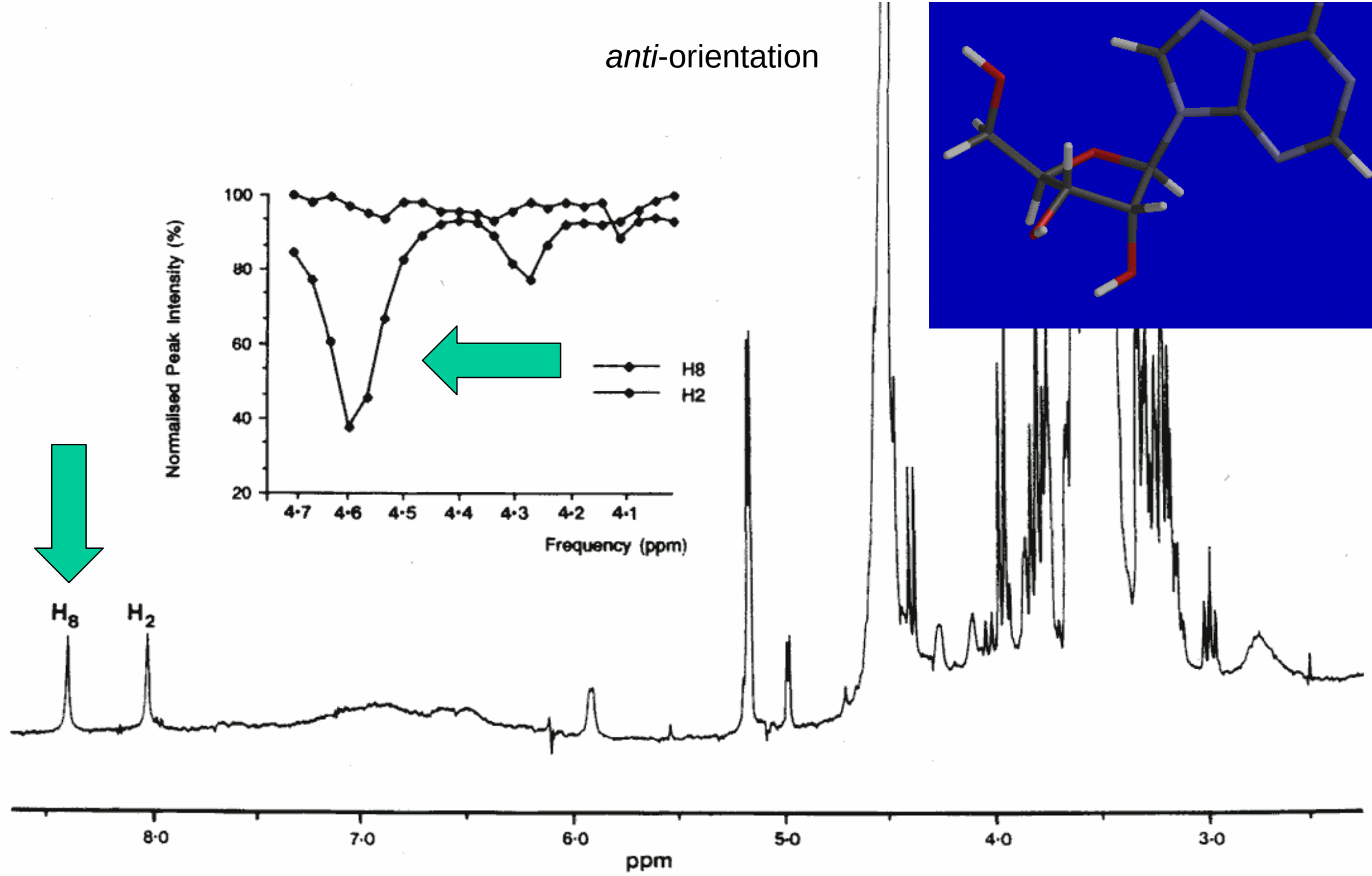
Bound ligand

ligand : protein > 10 : 1

300 MHz ^{1}H NMR Spectrum of 5`-AMP

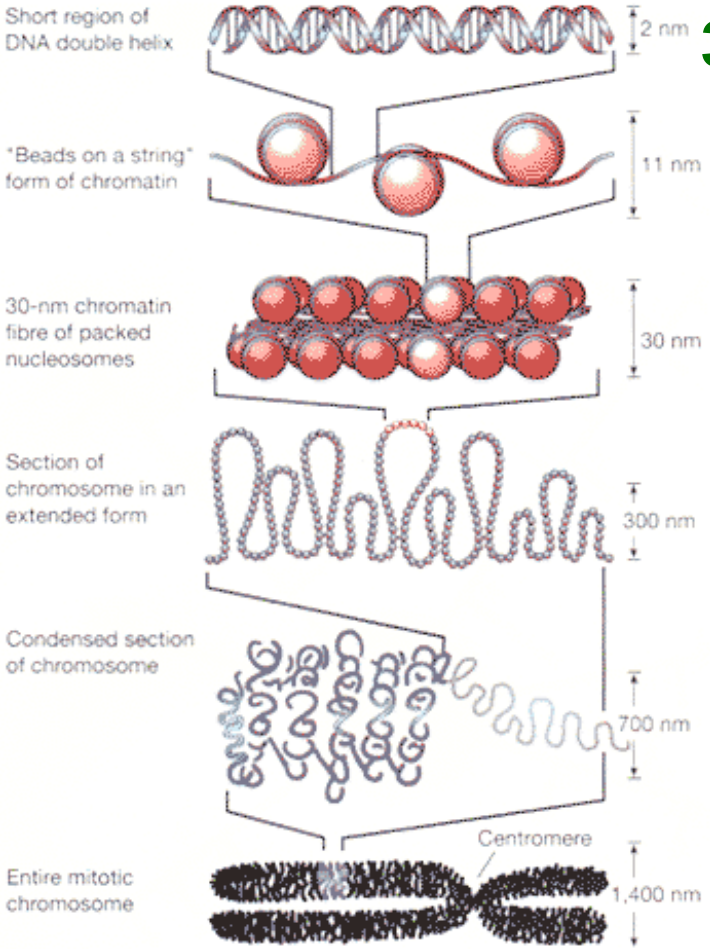


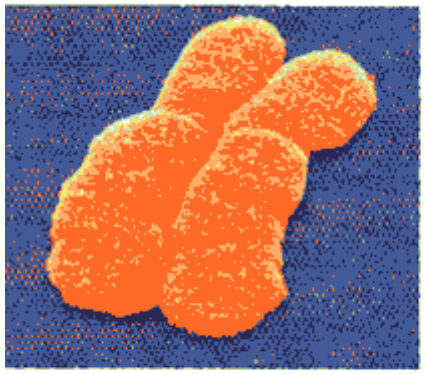
J. Chem. Ed. 1991 (68)



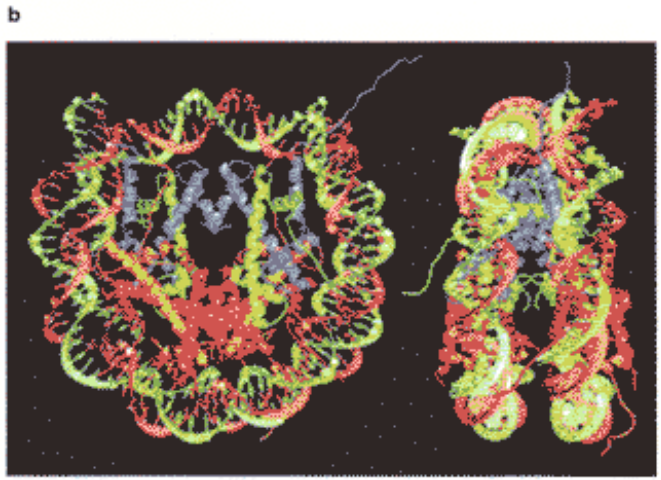
AMP (3.33 mM) as ligand of alcohol dehydrogenase (ADH, 0.1 mM);
TrNOe from H-2` and H-3´ to H-8

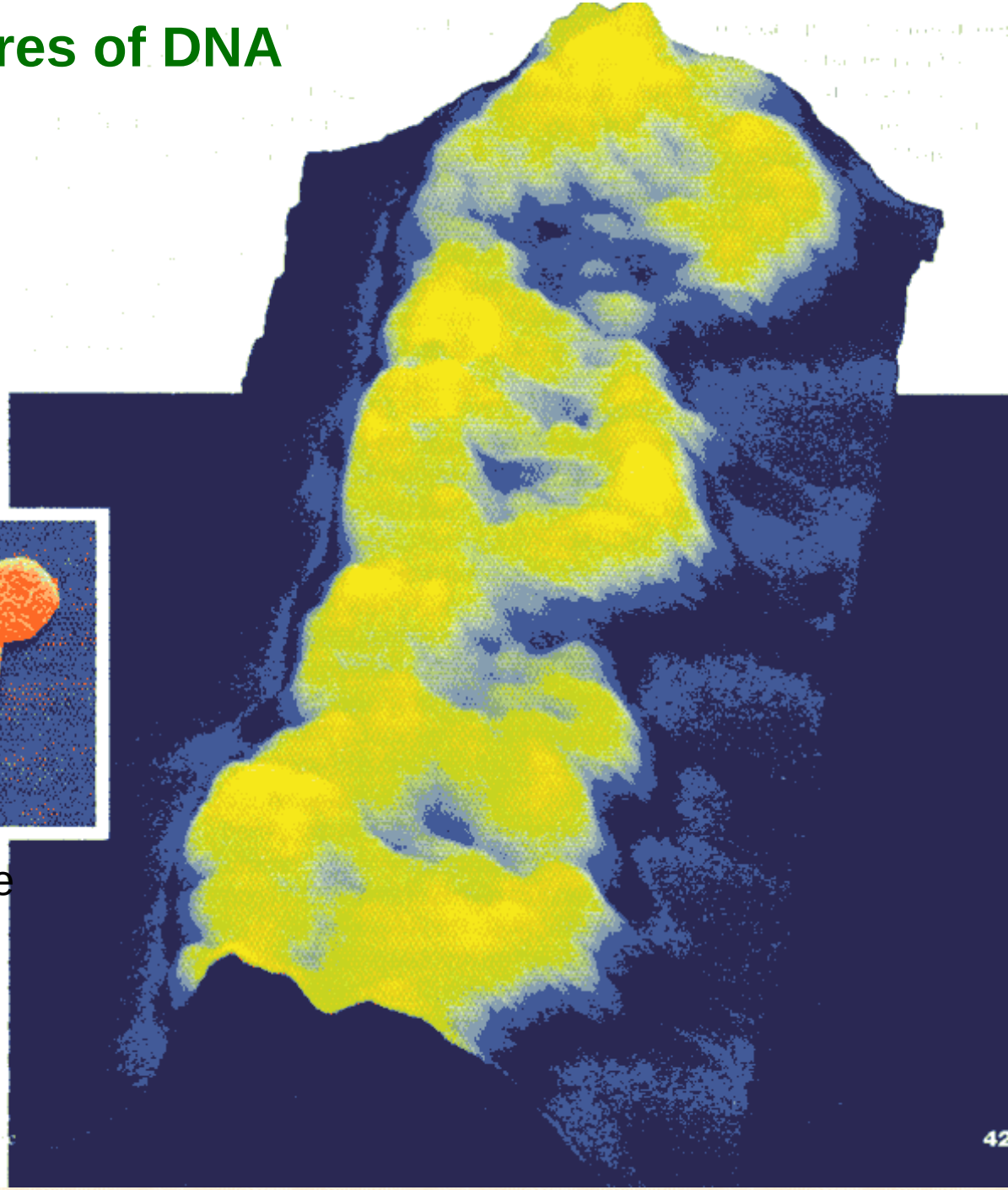
3. Structures of DNA and RNA





Chromosome





Double helix *Nature*, 412 (2003)

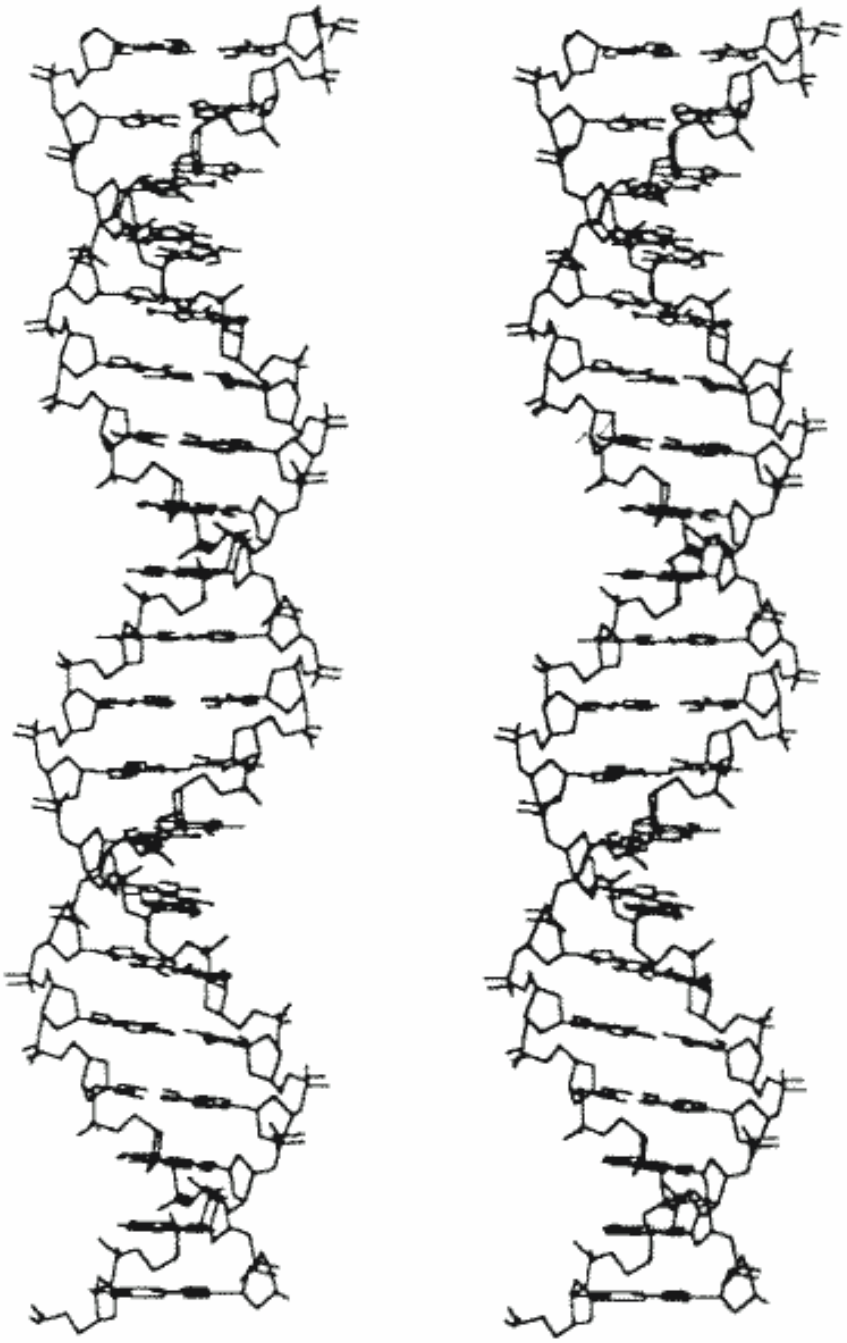
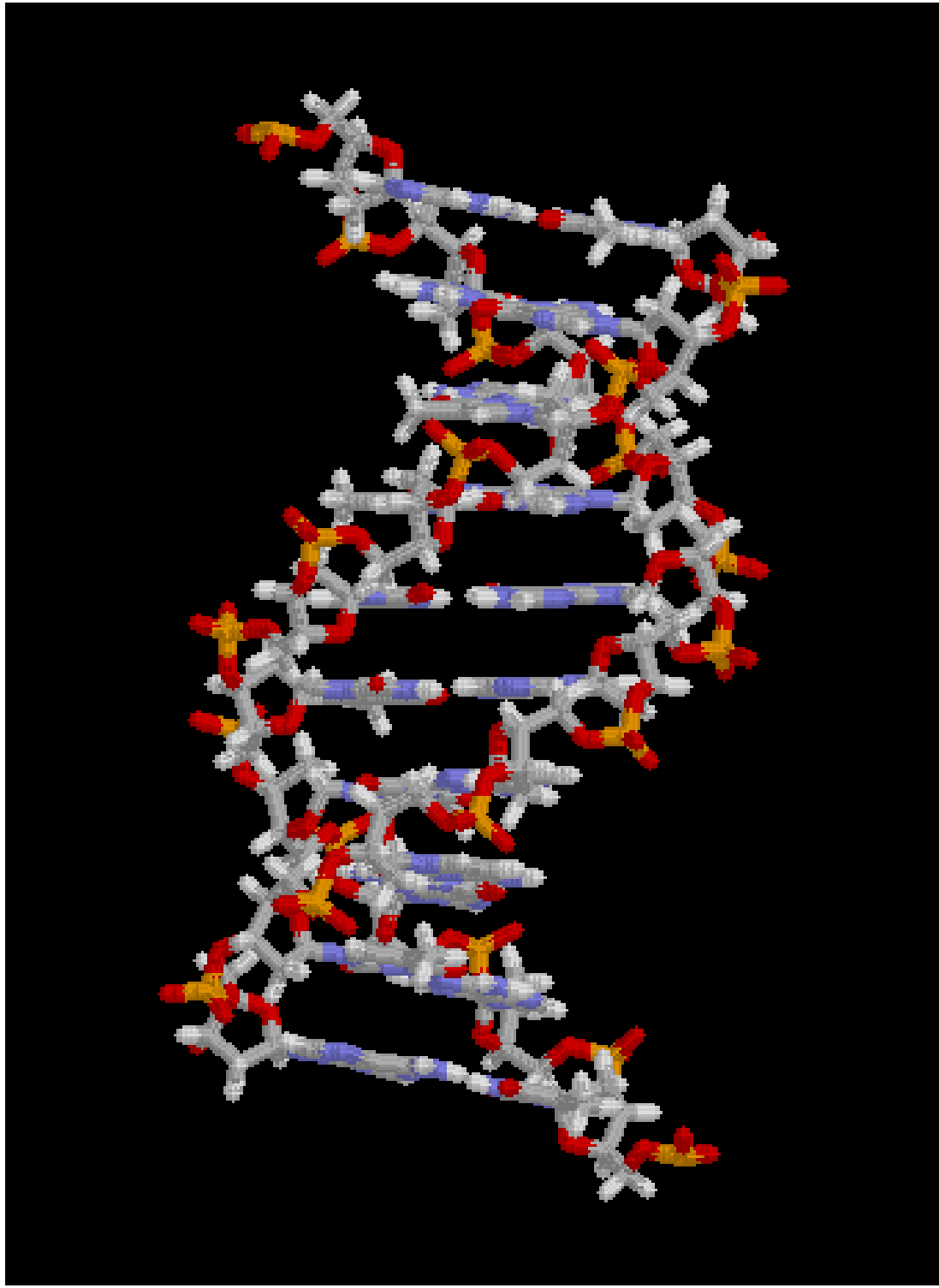
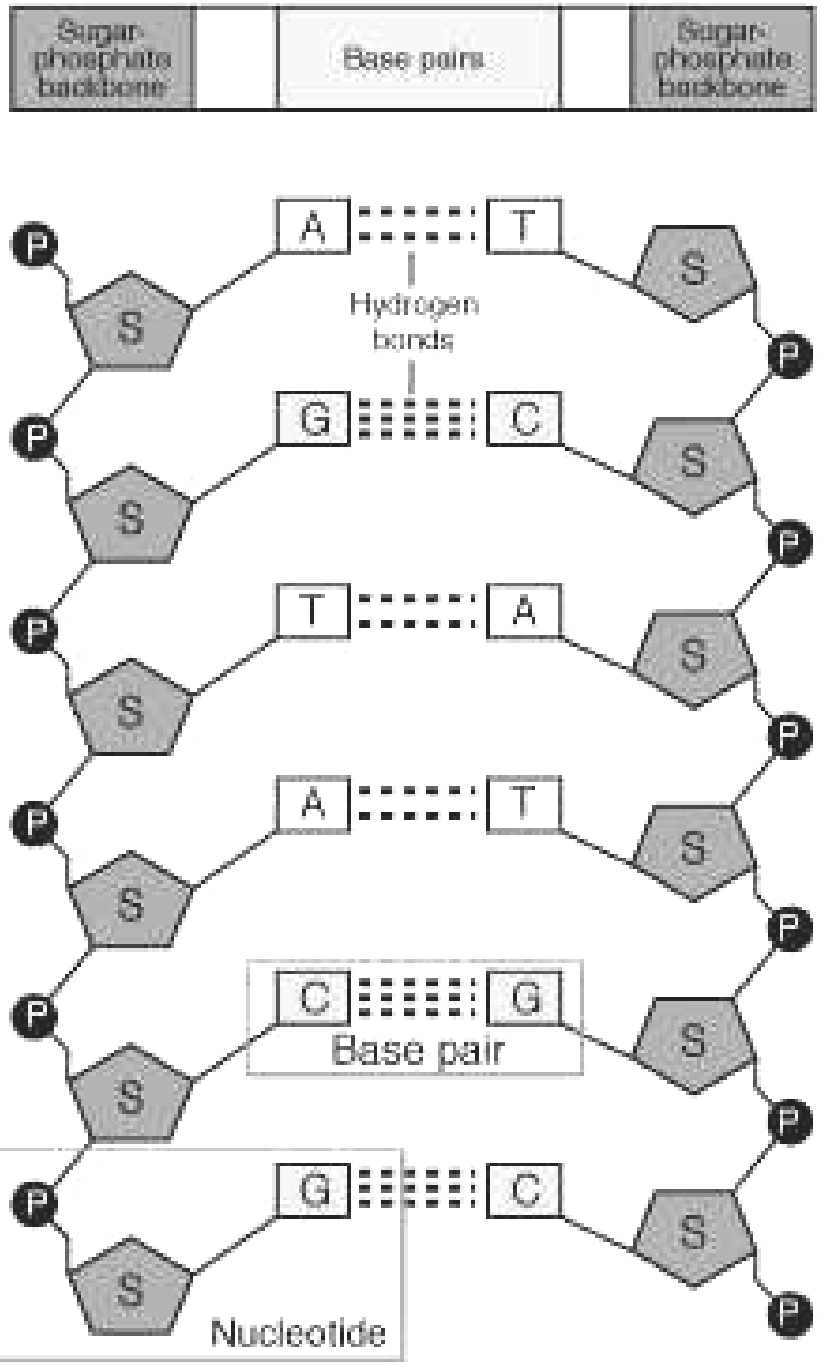


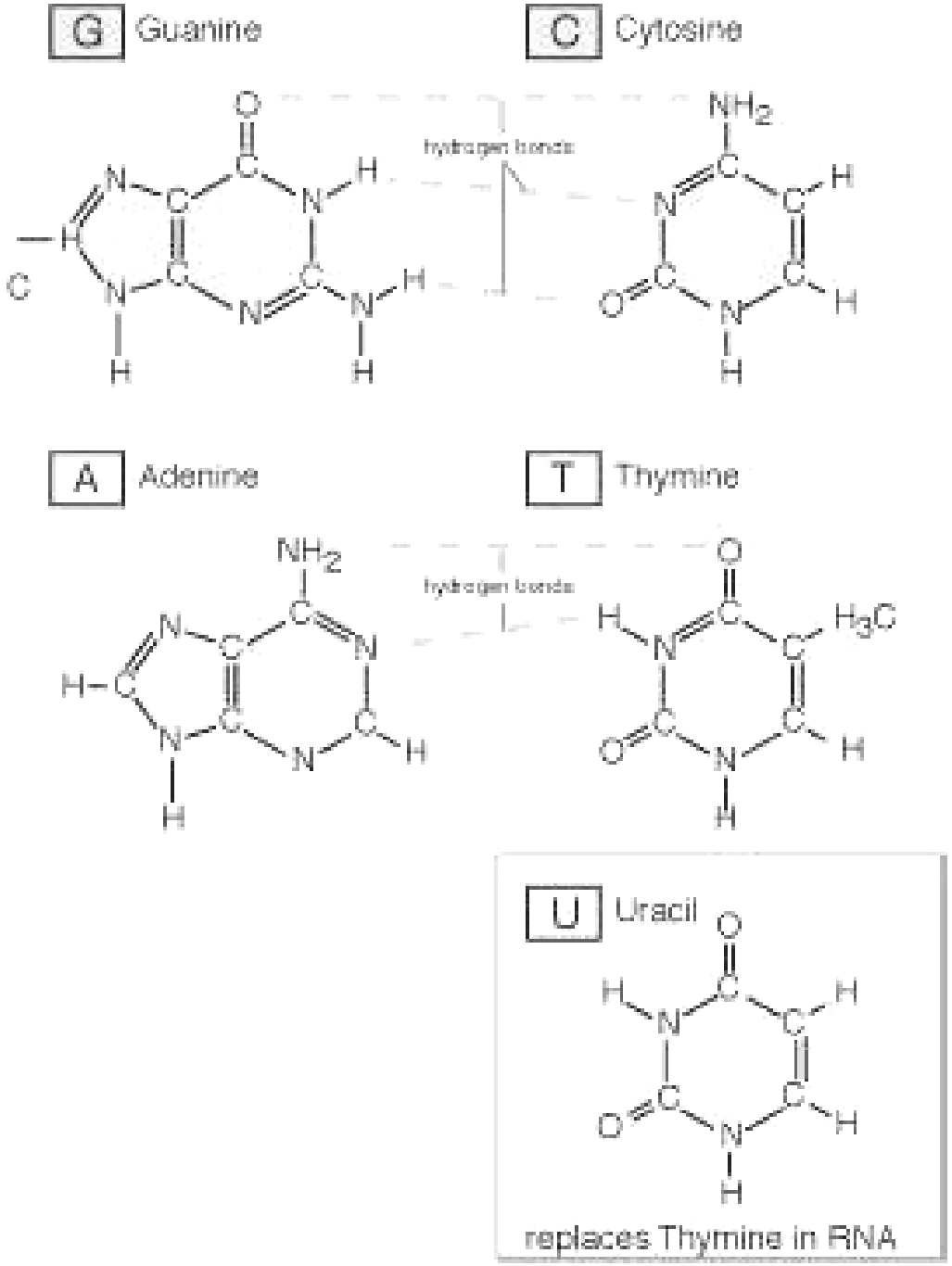
Figure 1-5. Stereoview of B-form DNA.



Deoxyribonucleic Acid (DNA)

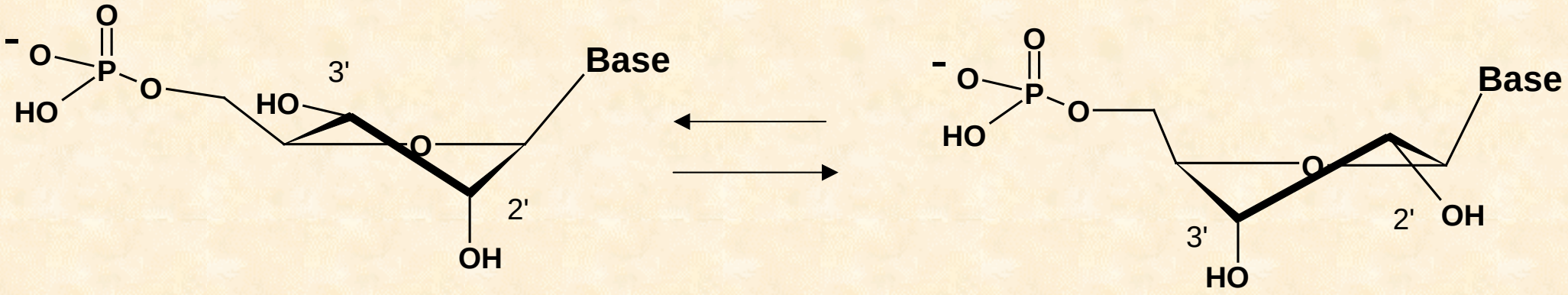


Nitrogenous Bases



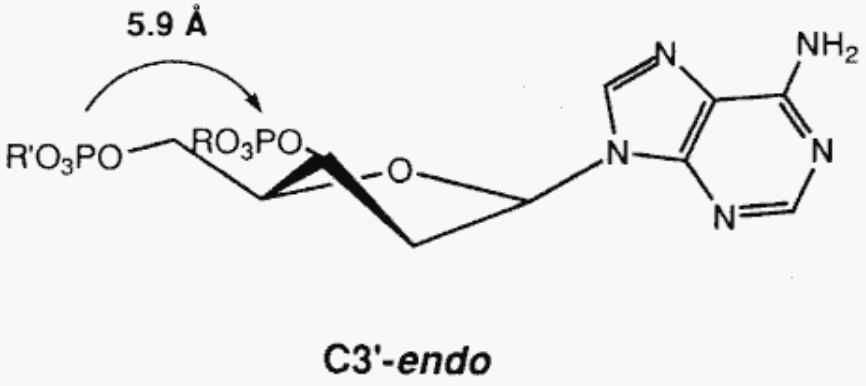
Conformations of nucleotides

Conformations of furanose rings: „Ring puckering“, Example:
exo-, *endo*- Twistkonformation

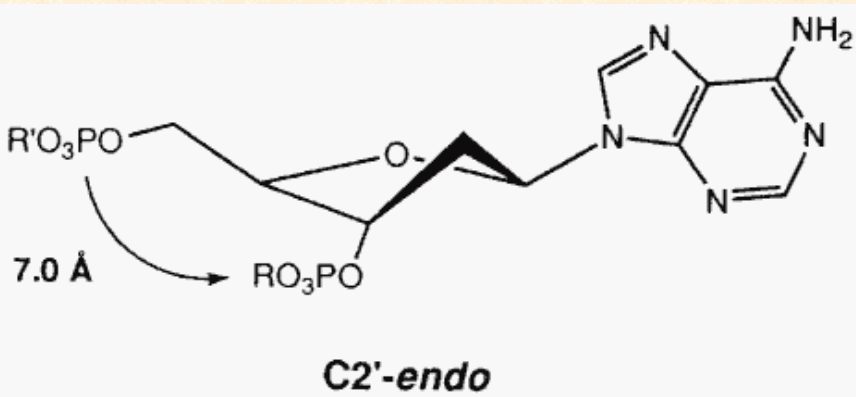


$^{3}T_{2}$ 3'-*endo*-conformation

$^{2}T_{3}$ 3'-*exo*-conformation

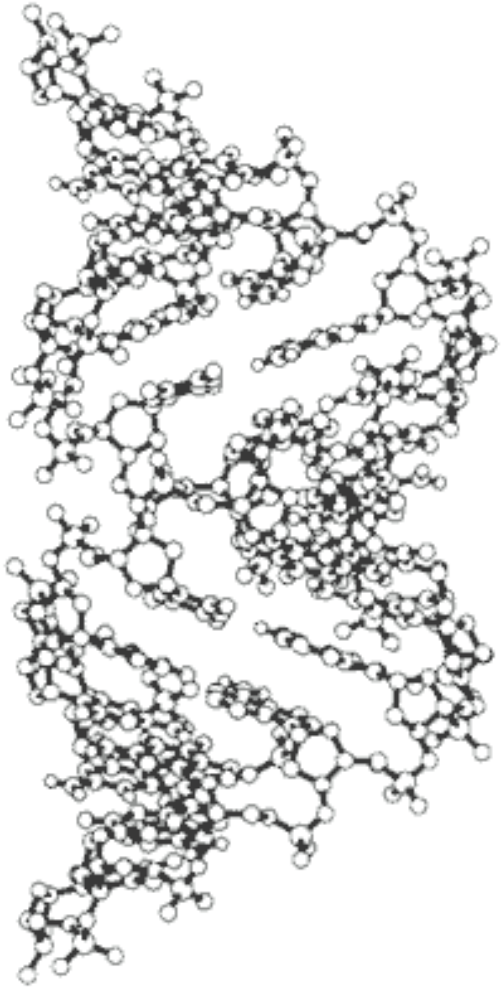


C3'-*endo*



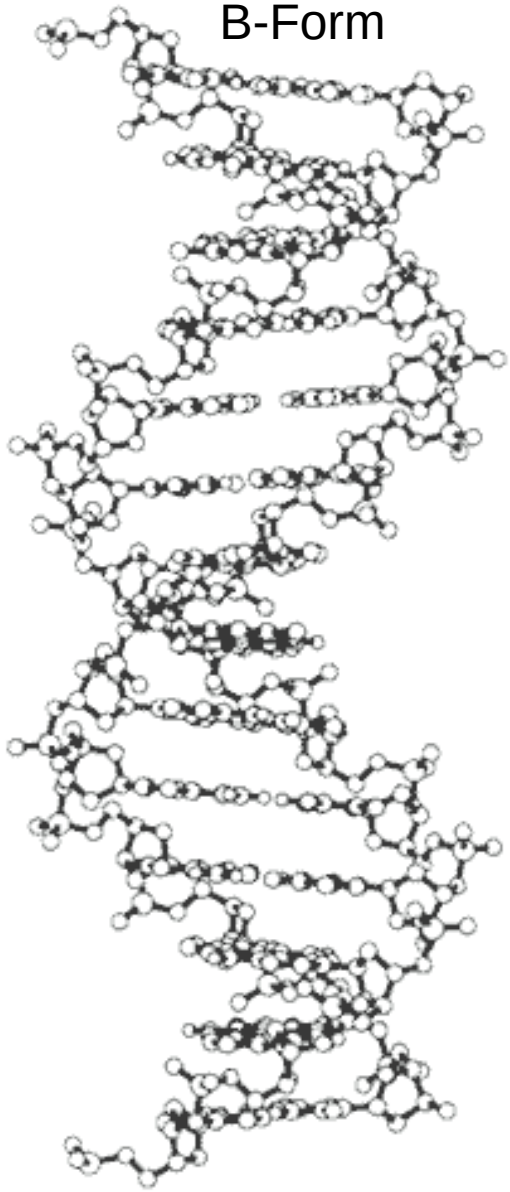
C2'-*endo*

A-Form



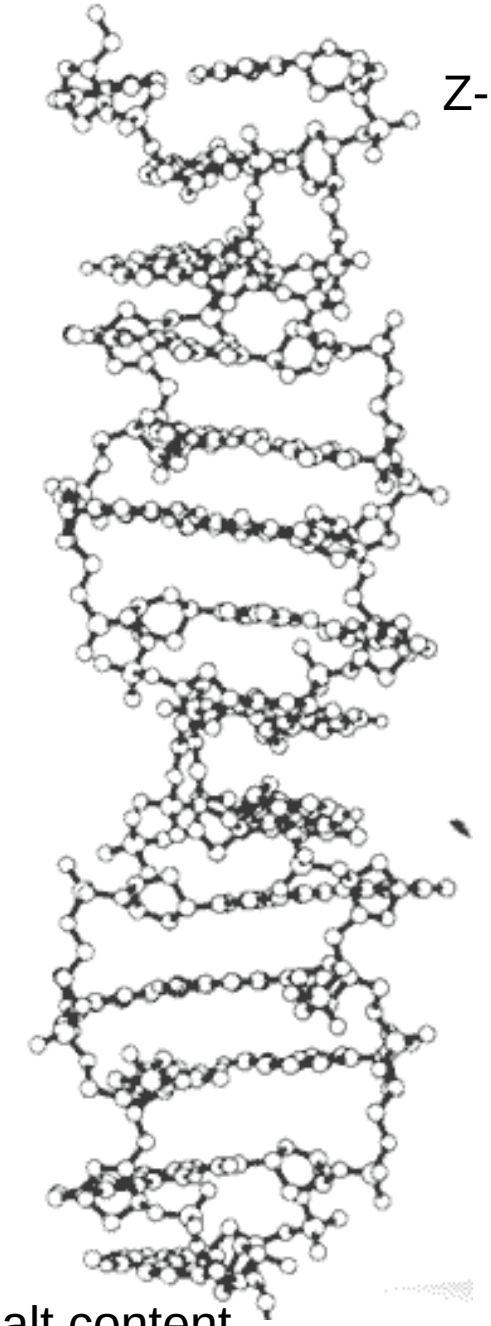
RNA, RNA-DNA
Low H_2O-content
„Tilt“ of N-bases
C3´-endo

B-Form

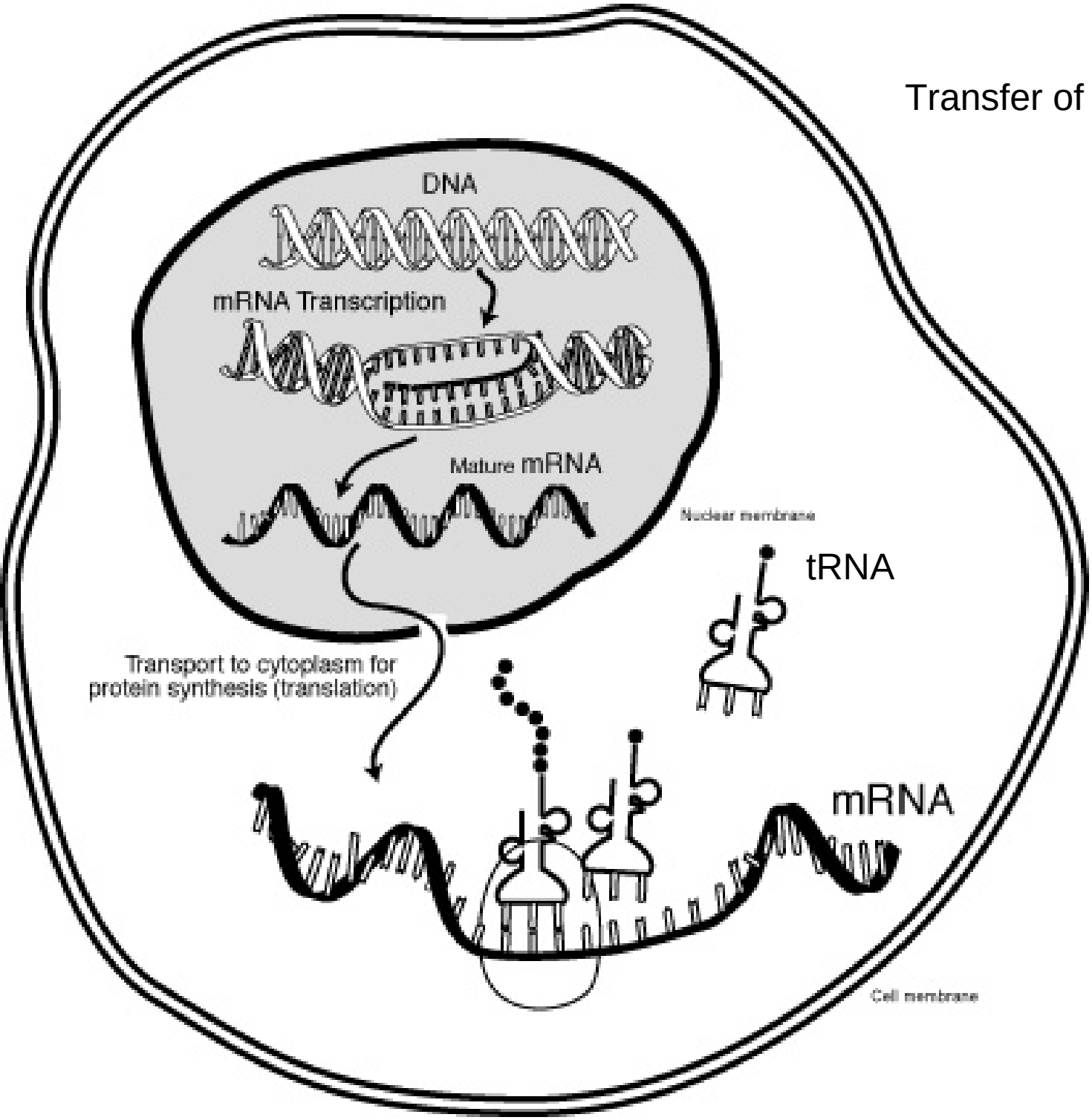


DNA
High H_2O-content
C2´-endo

Z-Form



DNA
High salt content
Alternating purine-pyrimidine
G: syn, C2´-endo; C: anti, C3´-endo



Transfer of genetic information

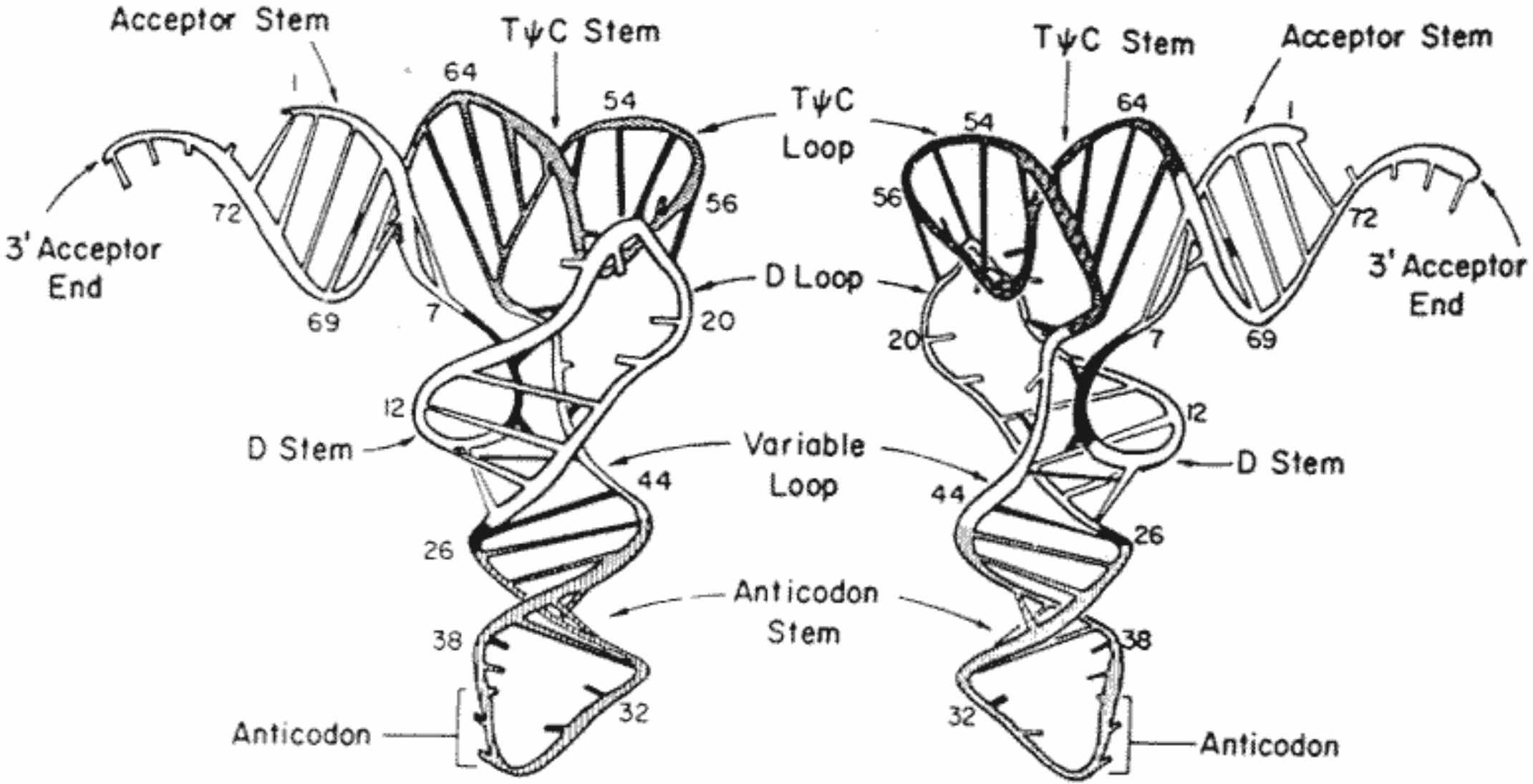
DNA

Transcription

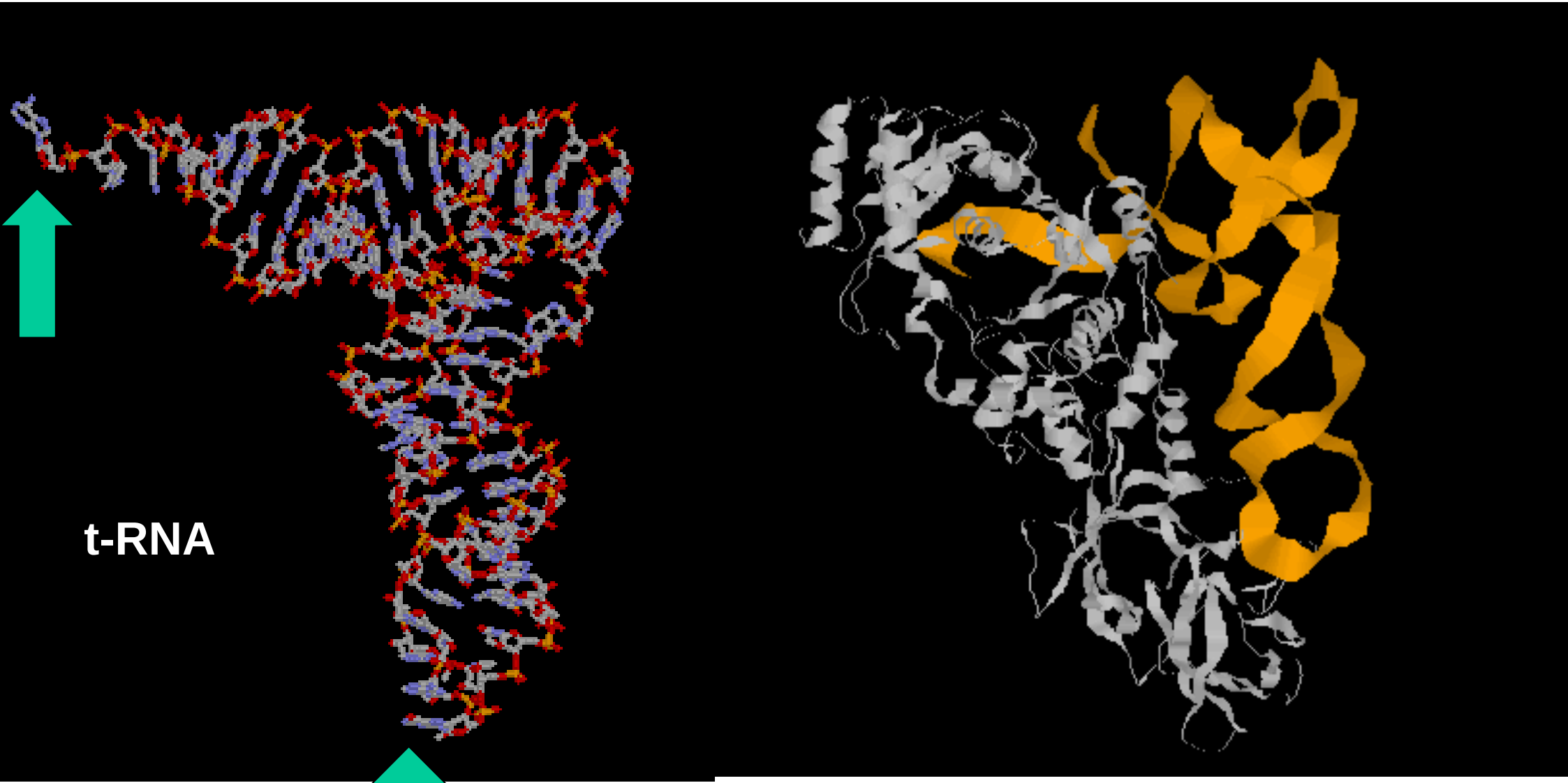
mRNA

Translation

Protein



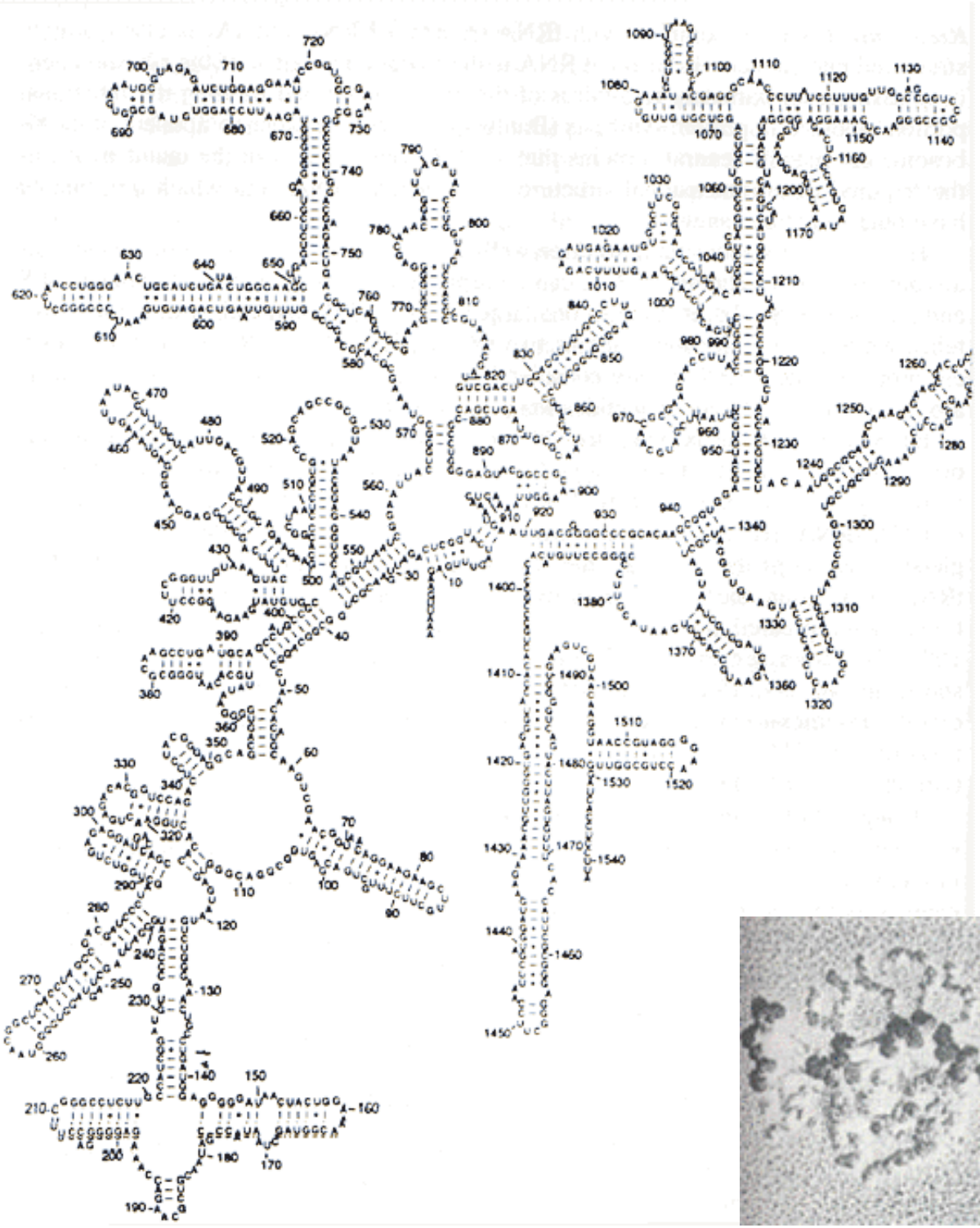
Transfer- RNA (t-RNA)



CCA-Terminus

Anticodon

Aminoacyl-tRNA-synthase
(Hyperspecific Enzyme)



16S rRNA
E. coli

Ribosome