Structure of DNA

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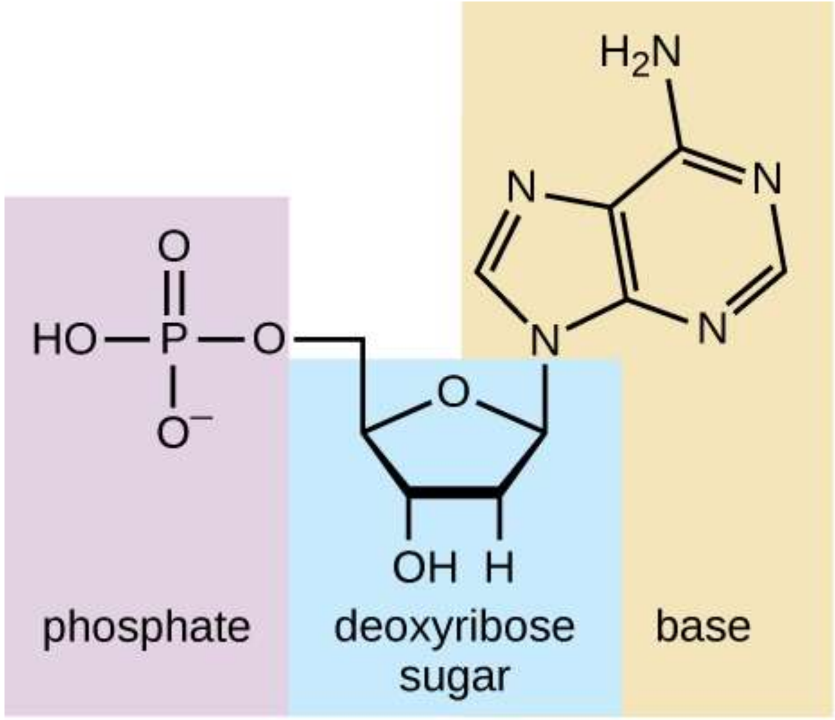
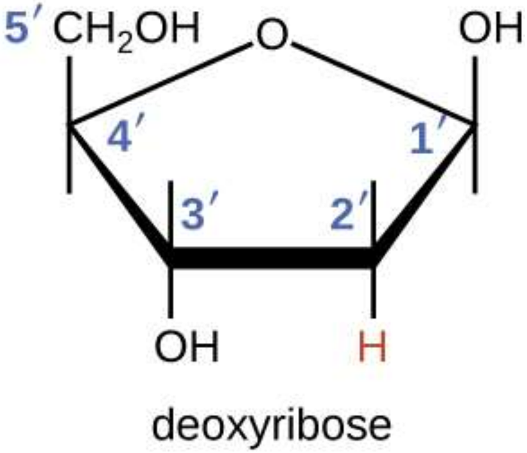
- Deoxyribonucleic Acid – Large macromolecule with mol.wt. in millions.
- Each DNA molecule is made up of a large no. of monomeric units of NUCLEOTIDES
- Nucleotide = Nucleoside + a phosphate group
- Nucleoside = A Pentose Sugar + A Nitrogenous Base

- The building blocks of nucleic acids are nucleotides.
- Nucleotides that compose DNA are called deoxyribonucleotides.
- The three components of a deoxyribonucleotide are
- a five-carbon sugar called deoxyribose,
- a phosphate group,
- and a nitrogenous base - a nitrogen-containing ring structure that is responsible for complementary base pairing between nucleic acid strands. The carbon atoms of the five-carbon deoxyribose are numbered 1', 2', 3', 4', and 5' (1' is read as "one prime").
- A nucleoside comprises the five-carbon sugar and nitrogenous base.


H2N
N
N
N
N
O
HO—P—O
O⁻
O
OH H
phosphate
deoxyribose
sugar
base

(a)


5′ CH2OH
O
OH
4′
1′
3′
2′
OH
H
deoxyribose

(b)

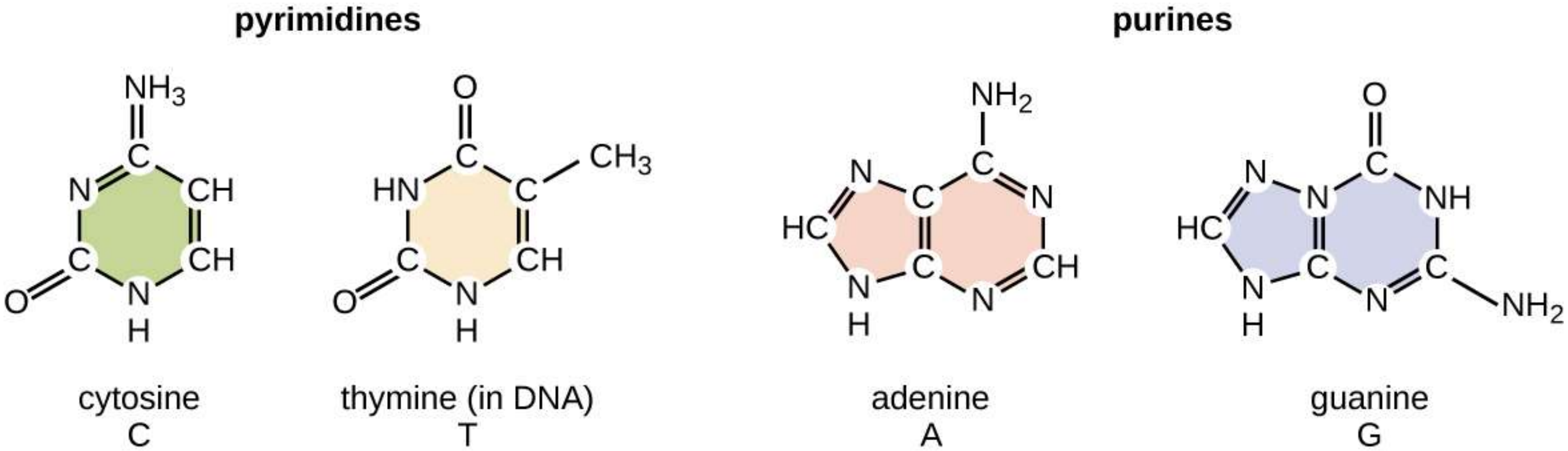
- The deoxyribonucleotide is named according to the nitrogenous bases.
- nitrogenous bases

  adenine (A) and guanine (G) are the purines;

  they have a double-ring structure with a six-carbon ring fused to a five- carbon ring.

  The pyrimidines, cytosine (C) and thymine (T), are smaller nitrogenous bases that have only a six-carbon ring structure.

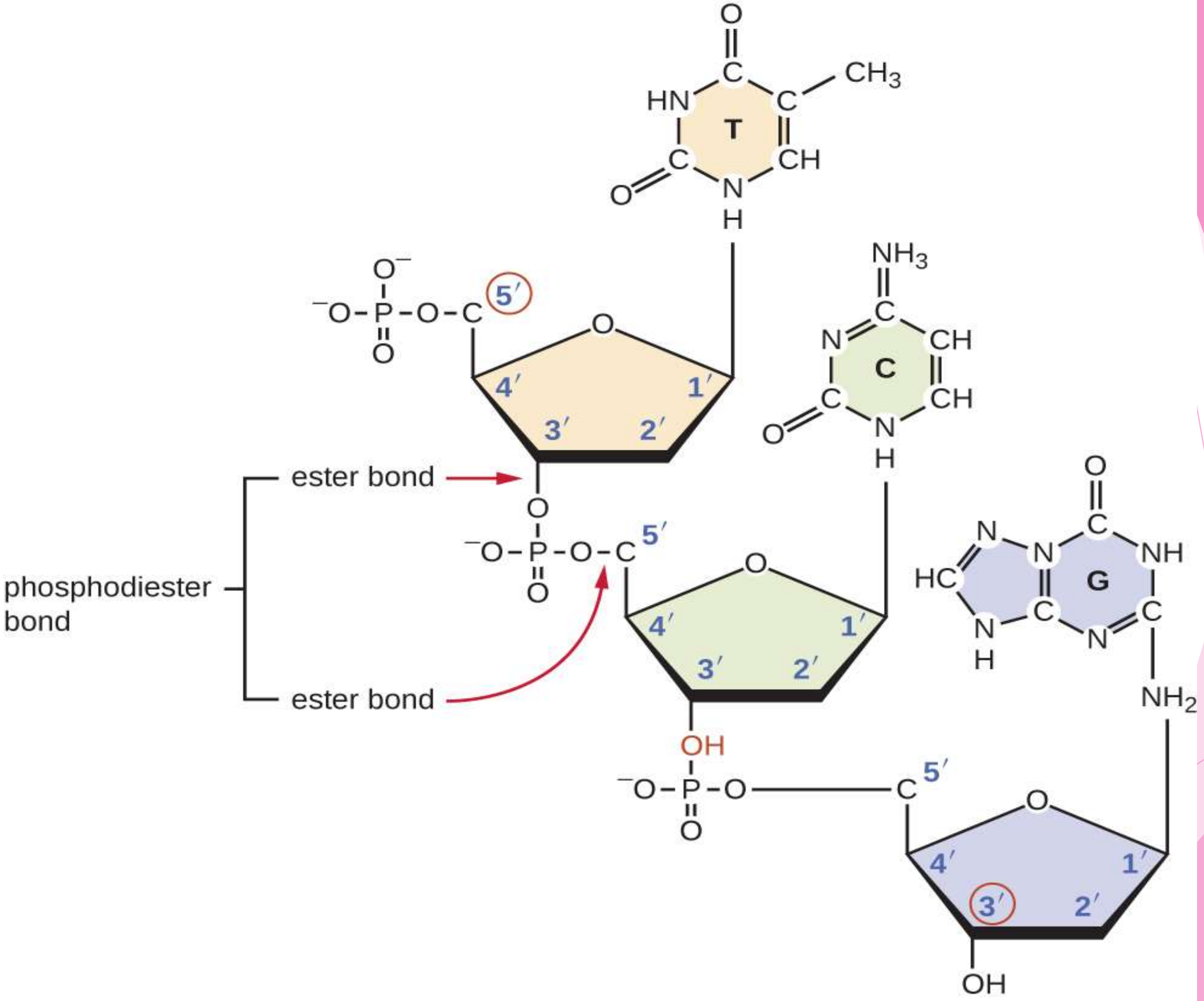
- Pyrimidines have 1 ring containing both carbon and nitrogen in the ring.
- Cytosine and thymine are both pyrimidines.
- Their rings are the same but have different functional groups attached.
- Purines have 2 rings containing carbon and nitrogen.
- Adenine and Guanine are both purines but have different arrangement of atoms as part of and attached to their rings.



pyrimidines
purines
cytosine
C
thymine (in DNA)
T
adenine
A
guanine
G

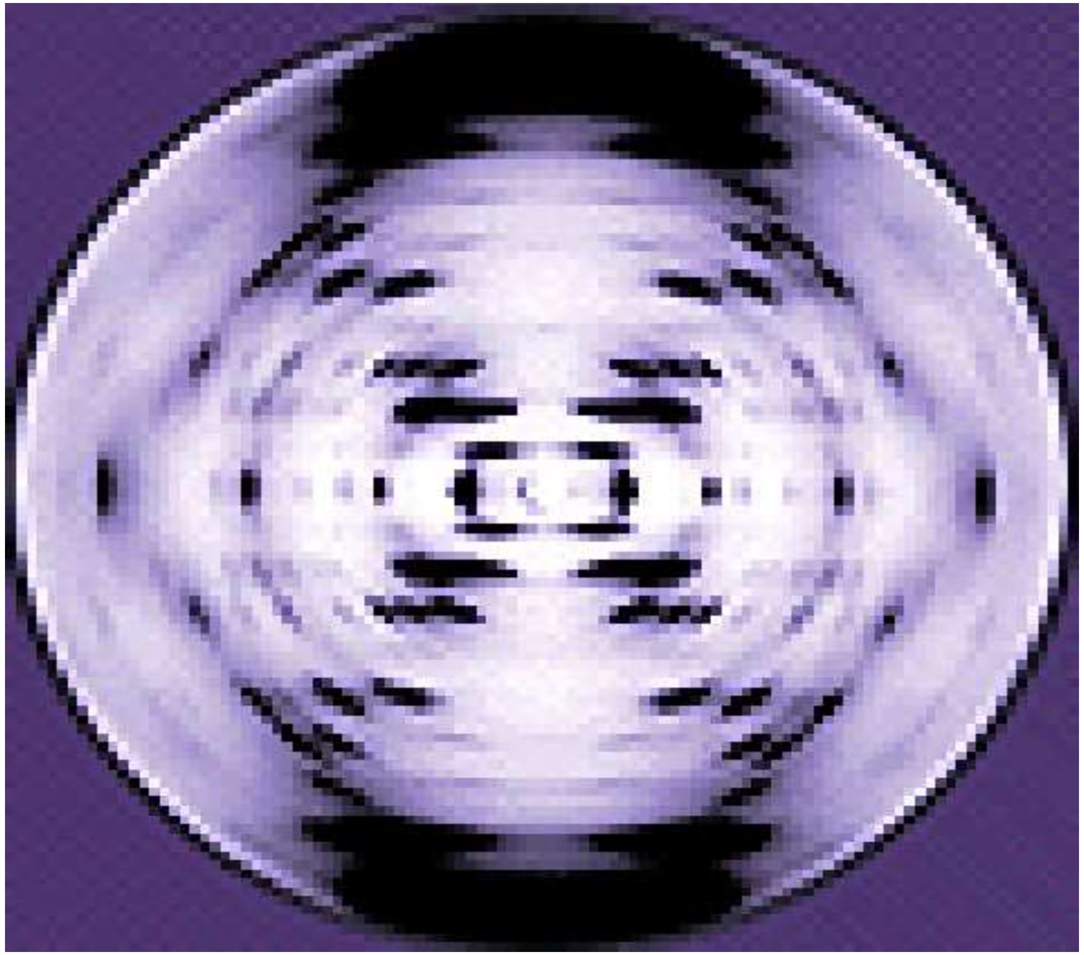
- Individual nucleoside triphosphates combine with each other by **covalent bonds** known as **5'-3' phosphodiester bonds**, or linkages
- the phosphate group attached to the 5' carbon of the sugar of one nucleotide bonds to the hydroxyl group of the 3' carbon of the sugar of the next nucleotide.
- **Phosphodiester bonding between nucleotides forms the sugar-phosphate backbone,** the alternating sugar-phosphate structure composing the framework of a nucleic acid strand.

- To construct the sugar-phosphate backbone, the two terminal phosphates are released from the dNTP as a pyrophosphate. The resulting strand of nucleic acid has a free phosphate group at the 5' carbon end and a free hydroxyl group at the 3' carbon end. The two unused phosphate groups from the nucleotide triphosphate are released as pyrophosphate during phosphodiester bond formation. Pyrophosphate is subsequently hydrolyzed, releasing the energy used to drive nucleotide polymerization.


ester bond
phosphodiester bond
ester bond
T
C
G
5′
4′
3′
2′
1′
OH
CH_3
NH_3
NH_2

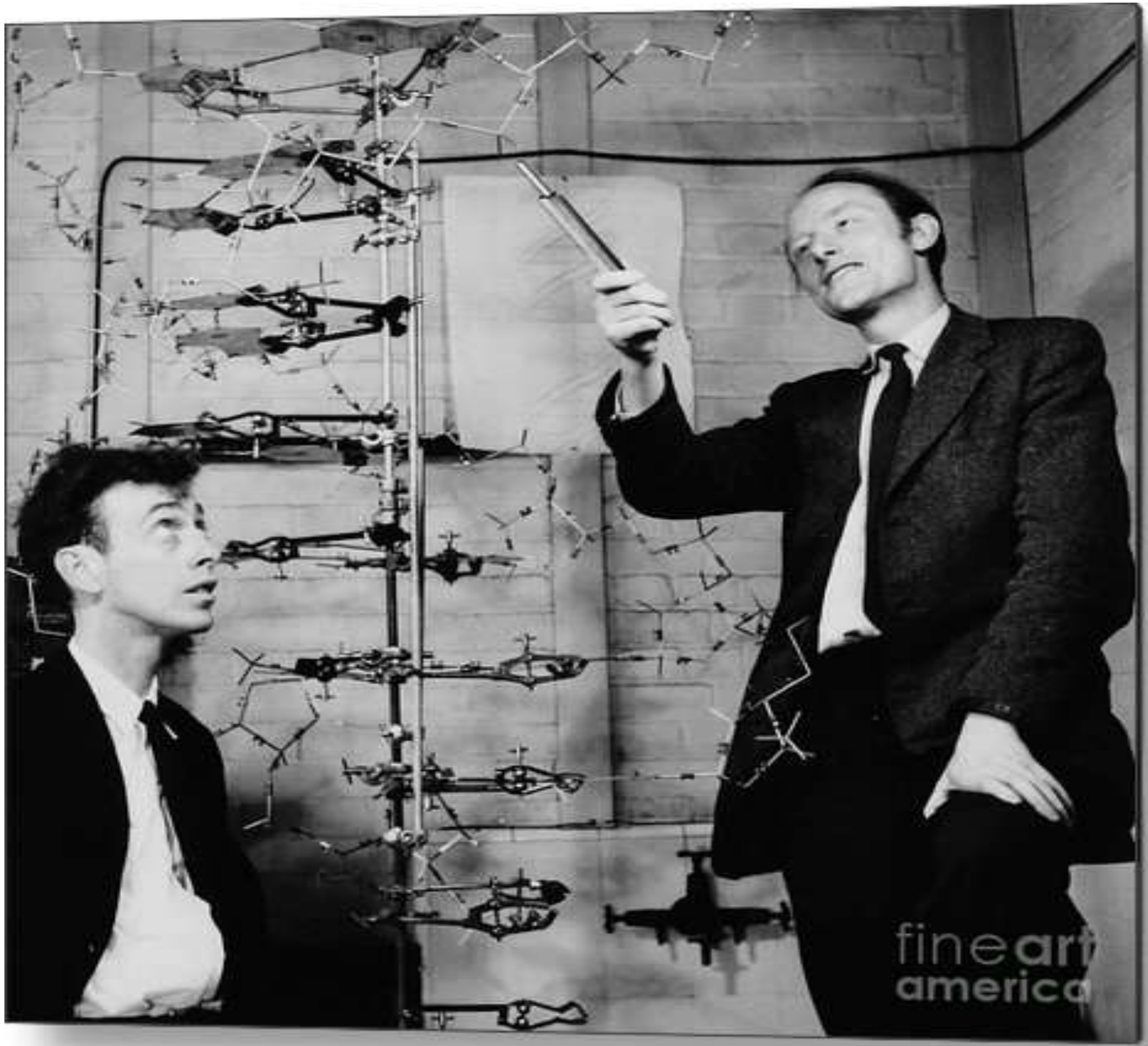
- By the early 1950s, considerable evidence had accumulated indicating that DNA was the genetic material of cells, and now the race was on to discover its three-dimensional structure.
- Around this time, Austrian biochemist Erwin Chargaff[1] (1905–2002) examined the content of DNA in different species and discovered that adenine, thymine, guanine, and cytosine were not found in equal quantities, and that it varied from species to species, but not between individuals of the same species.
- He found that the amount of adenine was very close to equaling the amount of thymine, and the amount of cytosine was very close to equaling the amount of guanine, or A = T and G = C. These relationships are also known as Chargaff's rules.

- In 1952, American scientist Linus Pauling (1901–1994), based upon X-ray diffraction images of DNA made in his laboratory, proposed a triple-stranded model of DNA.
- At the same time, British researchers Rosalind Franklin (1920–1958) and her graduate student R.G. Gosling were also using X-ray diffraction to understand the structure of DNA .
- It was Franklin's scientific expertise that resulted in the production of more well-defined X-ray diffraction images of DNA that would clearly show the overall double-helix structure of DNA.



James Watson

Francis Crick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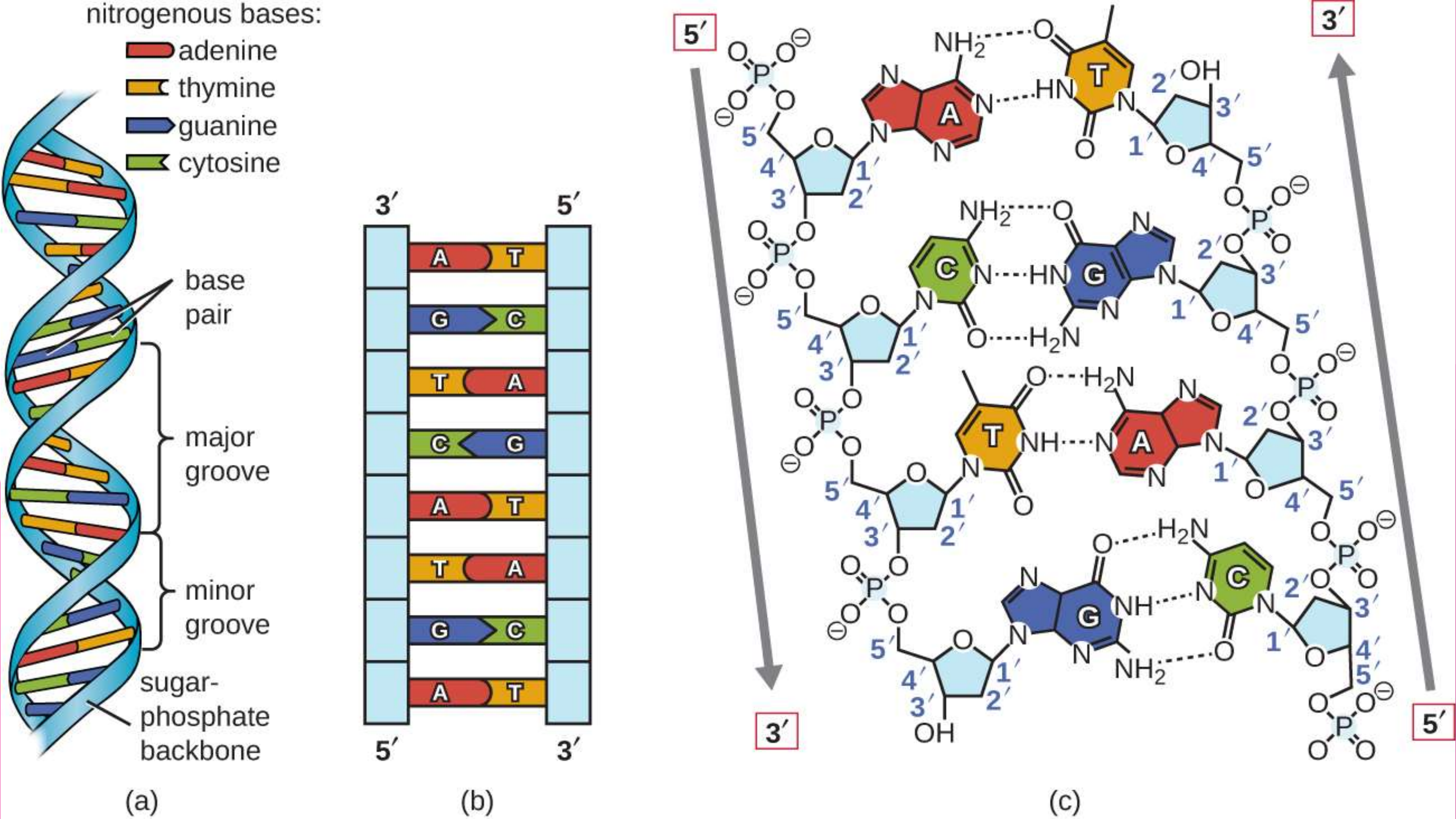
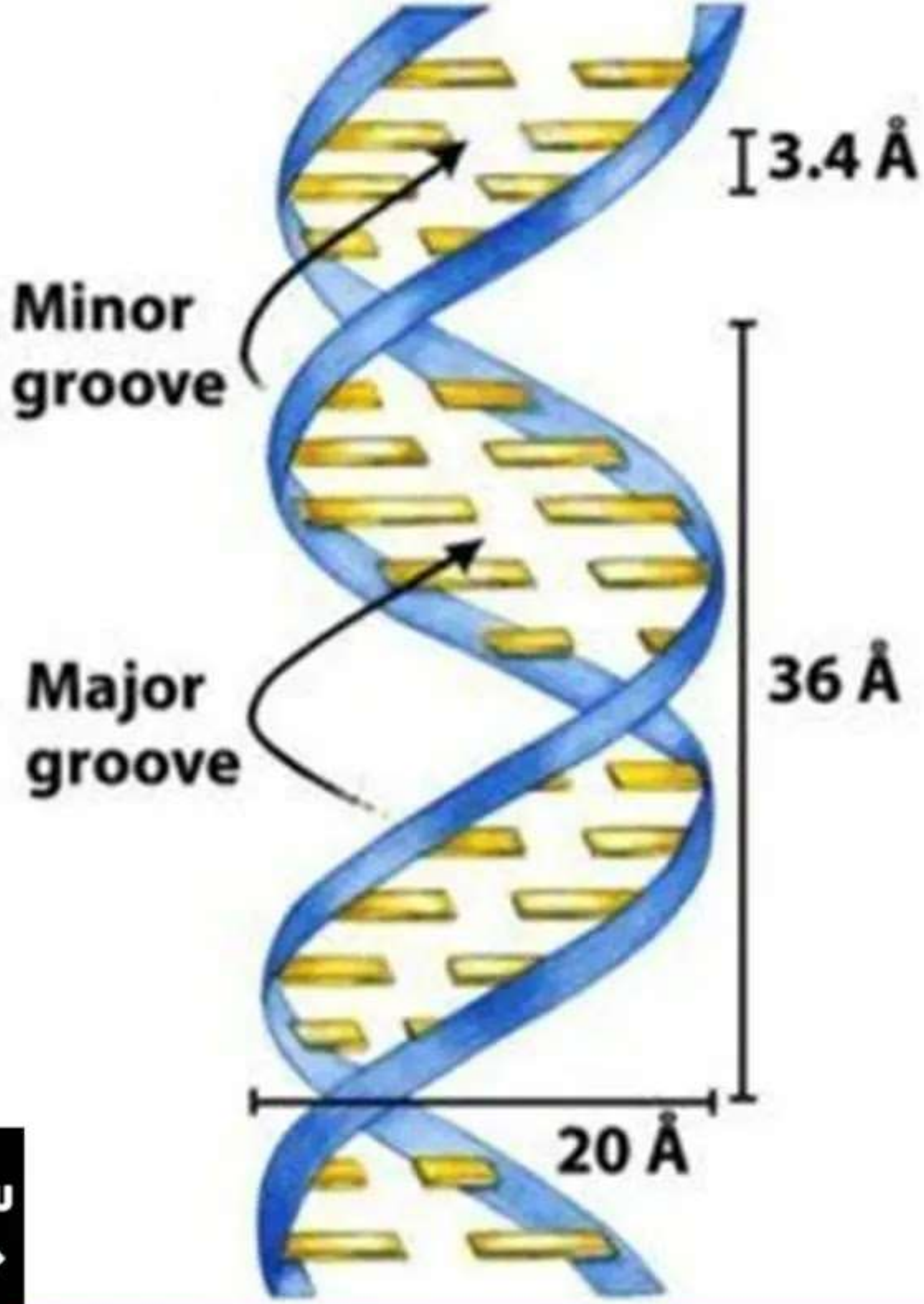
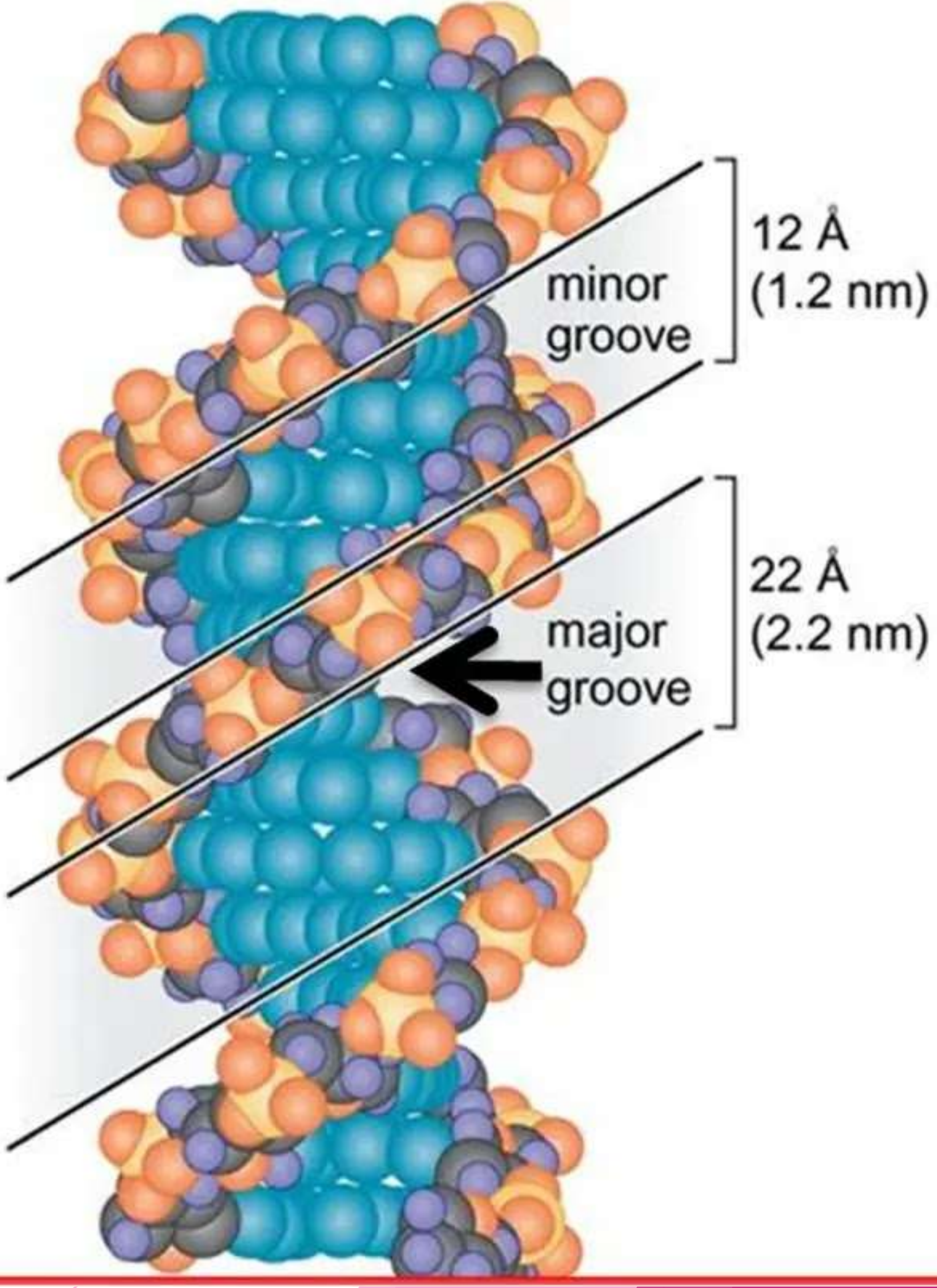
DNA Structure

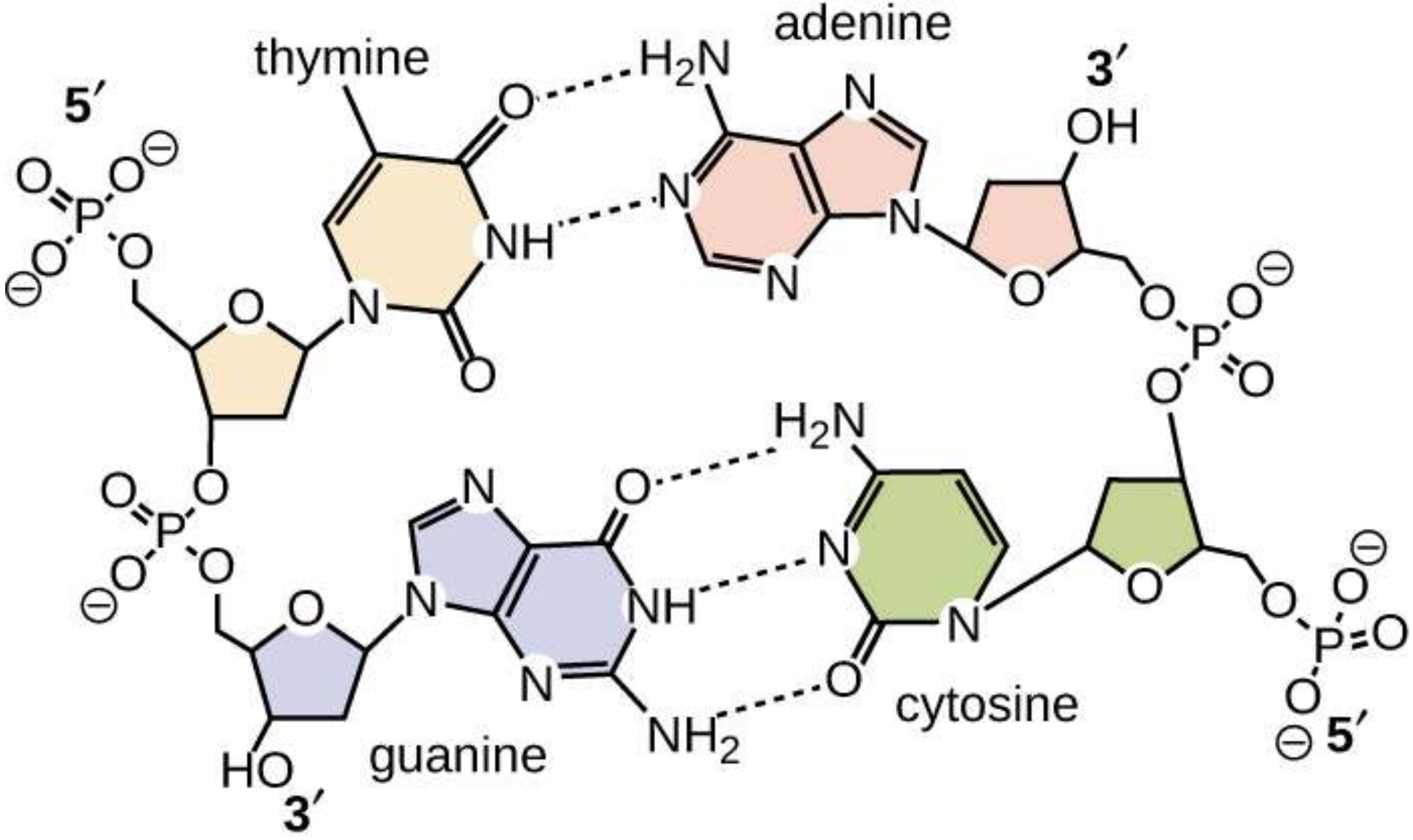
- Watson and Crick (1953) proposed that DNA is made up of two strands that are twisted around each other to form a right-handed helix.
- The two DNA strands are antiparallel, such that the 3' end of one strand faces the 5' end of the other.
- The 3' end of each strand has a free hydroxyl group, while the 5' end of each strand has a free phosphate group.
- The sugar and phosphate of the polymerized nucleotides form the backbone of the structure, whereas the nitrogenous bases are stacked inside.
- These nitrogenous bases on the interior of the molecule interact with each other, base pairing.

- Analysis of the diffraction patterns of DNA has determined that there are approximately 10 bases per turn in DNA.
- The asymmetrical spacing of the sugar-phosphate backbones generates major grooves (where the backbone is far apart) and minor grooves (where the backbone is close together).
- These grooves are locations where proteins can bind to DNA. The binding of these proteins can alter the structure of DNA, regulate replication, or regulate transcription of DNA into RNA.

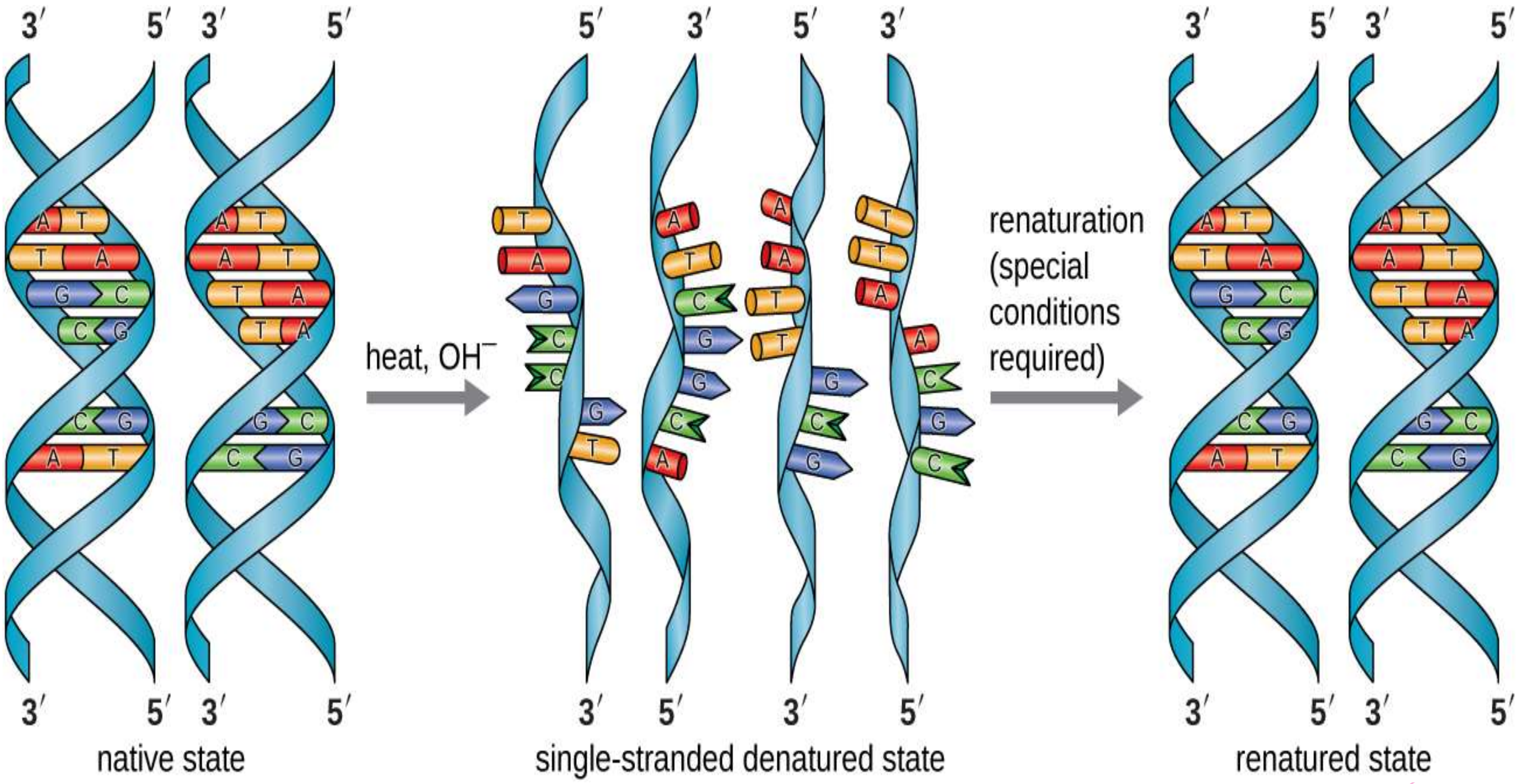

nitrogenous bases:
adenine
thymine
guanine
cytosine
base pair
major groove
minor groove
sugar-phosphate backbone
(a)
3′
5′
A T
G C
T A
C G
A T
T A
G C
A T
5′
3′
(b)
5′
3′
A
T
C
G
T
A
G
C
NH2
HN
N
O
OH
OH
P
1′
2′
3′
4′
5′
3′
5′
(c)


3.4 Å
Minor groove
Major groove
36 Å
20 Å


12 Å
(1.2 nm)
minor groove
22 Å
(2.2 nm)
major groove


thymine
adenine
guanine
cytosine
5′
3′
3′
5′
OH
HO
H_2N
H_2N
NH
NH
NH_2

Denaturation and Renaturation



DNA Function

- DNA stores the information needed to build and control the cell.
- The transmission of this information from mother to daughter cells is called vertical gene transfer and it occurs through the process of DNA replication.
- DNA is replicated when a cell makes a duplicate copy of its DNA, then the cell divides, resulting in the correct distribution of one DNA copy to each resulting cell.
- DNA can also be enzymatically degraded and used as a source of nucleosides and nucleotides for the cell.
- Unlike other macromolecules, DNA does not serve a structural role in cells.