The University of Burdwan
Three year UG course in Zoology under CBCS
Core T11 (Molecular Biology)

DNA

SALIENT FEATURES & WATSON-CRICK MODEL

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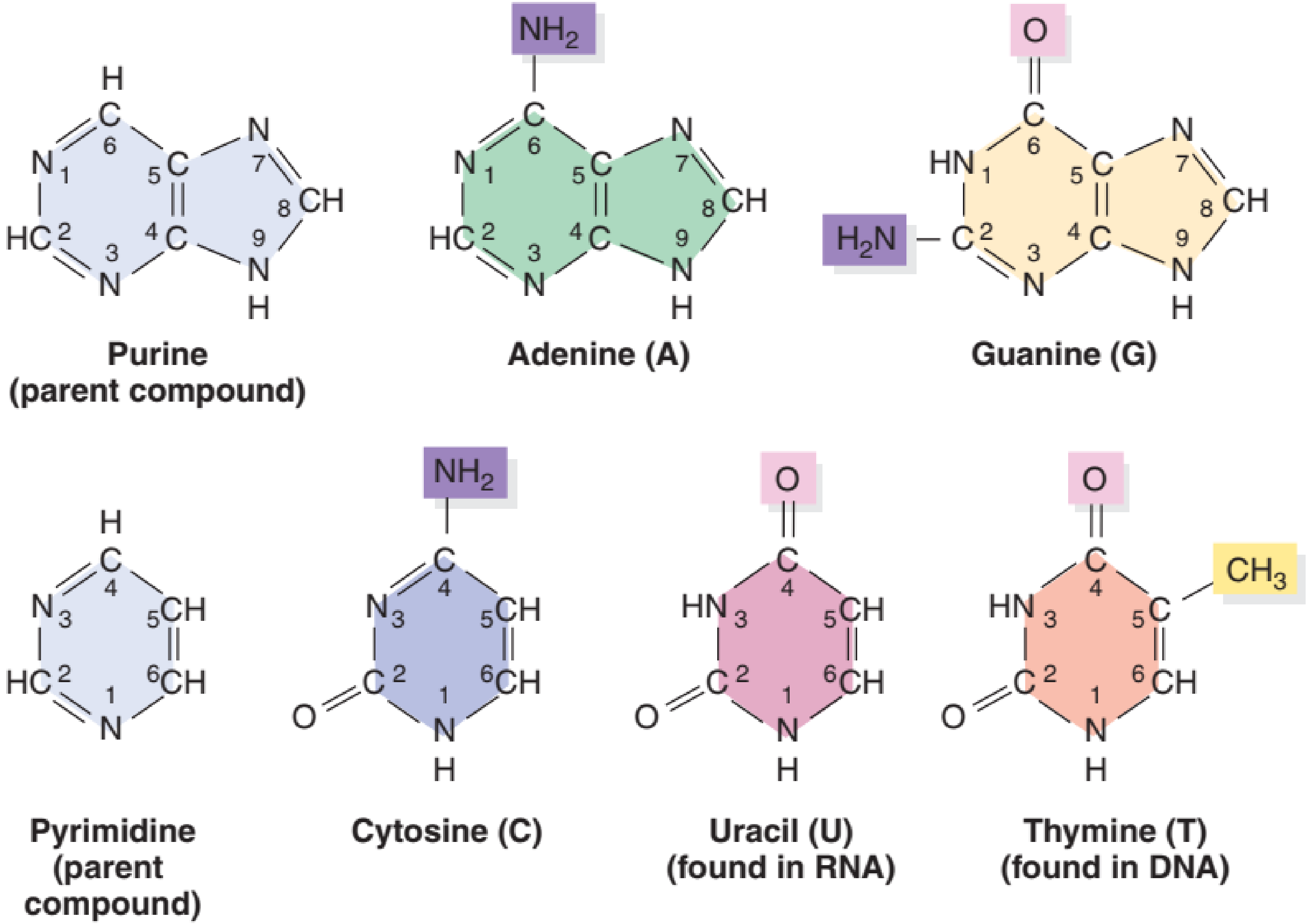
Nucleic Acids

- Nucleic acids are the basic building blocks of Deoxyribose Nucleic Acid (DNA) and Ribonucleic Acids (RNA).
- It was first discovered by Friedrich Miescher from the nuclei of pus cells (leukocytes) from the discarded surgical bandages and called *nuclein*.
- Monomeric units of nucleic acids called nucleotide, which is composed of:
  - A Nitrogenous base
  - A Pentose sugar
  - A phosphate group

Nitrogenous base



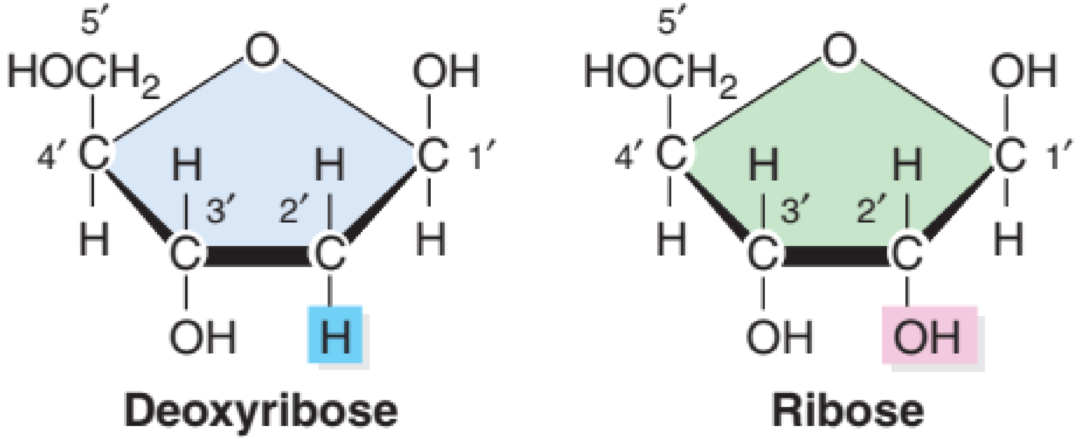
Purine

- **Adenine:** 6-aminopurine
- **Guanine:** 6-oxy-2-aminopurine

Pyrimidine

- **Cytosine:** 2-oxy-4-aminopyrimidine
- **Uracil:** 2,4-dioxypyrimidine
- **Thymine:** 5-methyl-2,4-dioxypyrimidine

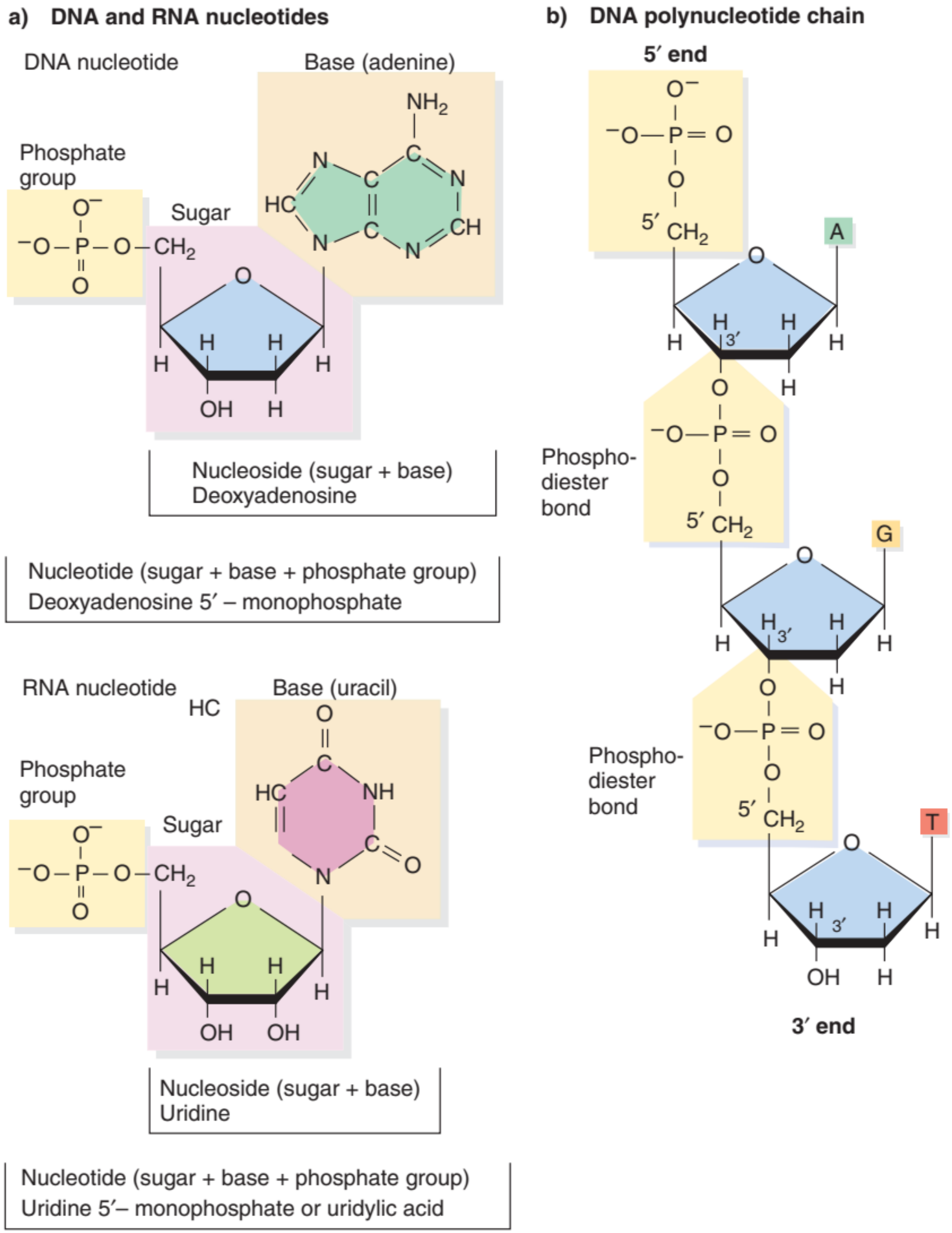
Pentose sugar



Nucleoside and Nucleotide

Table 2.1 Names of the Base, Nucleoside, and Nucleotide Components Found in DNA and RNA

		Base: Purines (Pu)		Base: Pyrimidines (Py)		
		Adenine (A)	**Guanine (G)**	**Cytosine (C)**	**Thymine (T) (deoxyribose only)**	**Uracil (U) (ribose only)**
DNA	Nucleoside: deoxyribose + base	Deoxyadenosine (dA)	Deoxyguanosine (dG)	Deoxycytidine (dC)	Deoxythymidine (dT)	
	Nucleotide: deoxyribose + base + phosphate group	Deoxyadenylic acid or deoxyadenosine monophosphate (dAMP)	Deoxyguanylic acid or deoxyguanosine monophosphate (dGMP)	Deoxycytidylic acid or deoxycytidine monophosphate (dCMP)	Deoxythymidylic acid or Deoxythymidine monophosphate (dTMP)	
RNA	Nucleoside: ribose + base	Adenosine (A)	Guanosine (G)	Cytidine (C)		Uridine (U)
	Nucleotide: ribose + base + phosphate group	Adenylic acid or adenosine monophosphate (AMP)	Guanylic acid or guanosine monophosphate (GMP)	Cytidylic acid or cytidine monophosphate (CMP)		Uridylic acid or uridine monophosphate (UMP)



Watson and Crick Model of DNA structure

Figure 2.10

James Watson (left) and Francis Crick (right) in 1953 with the model of DNA structure.

They devised the model based on data available from two sources:

1. Base composition study by Erwin Chargaff
2. X-ray diffraction studies conducted by Rosalind Franklin and Maurice H. F. Wilkins.

Chargaff’s rule

He hydrolysed the DNA of many organisms with chemical treatments and quantified the number of different N-bases.

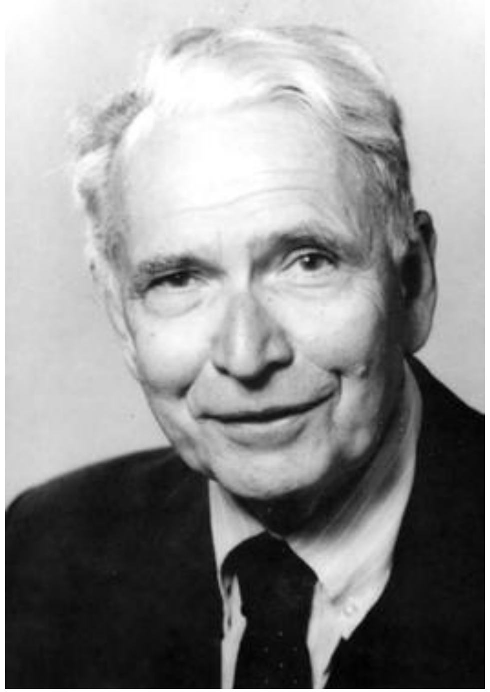


Table 2.2 Base Compositions of DNAs from Various Organisms

	Percentage of Base in DNA				Ratios		
DNA origin	A	T	G	C	A/T	G/C	(A + T)/(G + C)
Human (sperm)	31.0	31.5	19.1	18.4	0.98	1.03	1.67
Corn (*Zea mays*)	25.6	25.3	24.5	24.6	1.01	1.00	1.04
Drosophila	27.3	27.6	22.5	22.5	0.99	1.00	1.22
Euglena nucleus	22.6	24.4	27.7	25.8	0.93	1.07	0.88
Escherichia coli	26.1	23.9	24.9	25.1	1.09	0.99	1.00

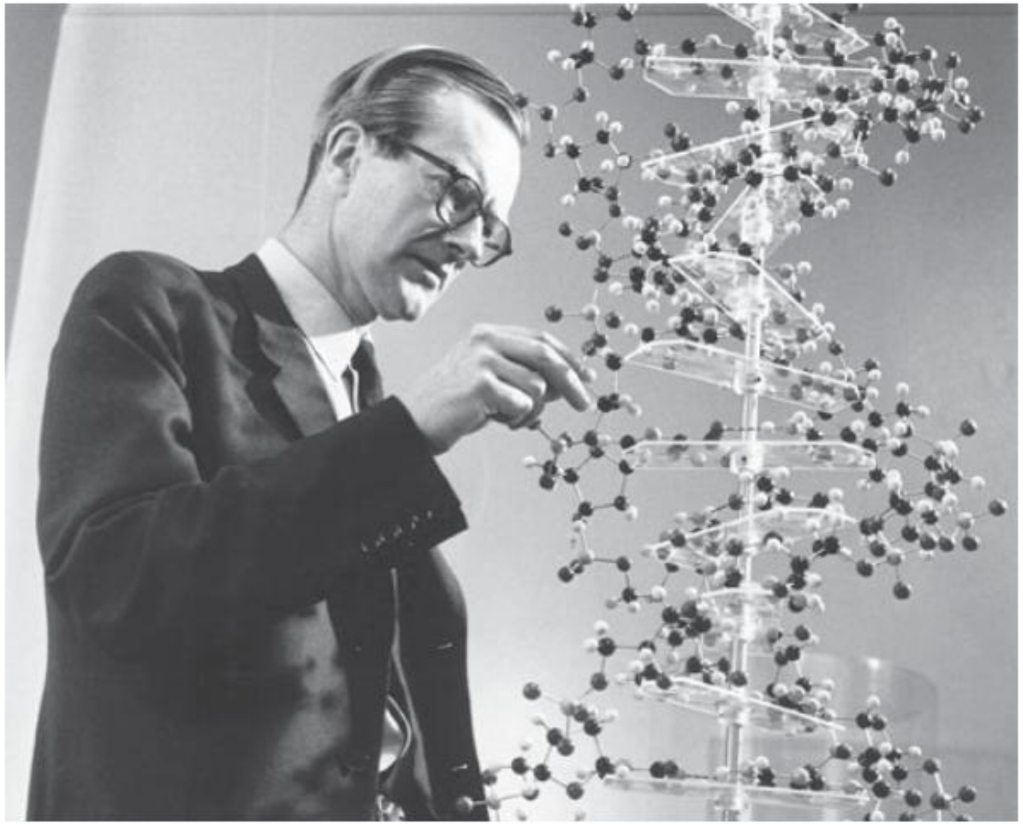
Chargaff’s rule

- The molar ratio of A to T equals 1. Similarly, the molar ratio of G to C equals 1.
- The sum of purines equals that of the pyrimidines.
- The percentage of A+T, does not necessarily equal the percentage of G+C.

X-Ray diffraction studies

a) Rosalind Franklin

Maurice H. F. Wilkins



X-Ray dif studies

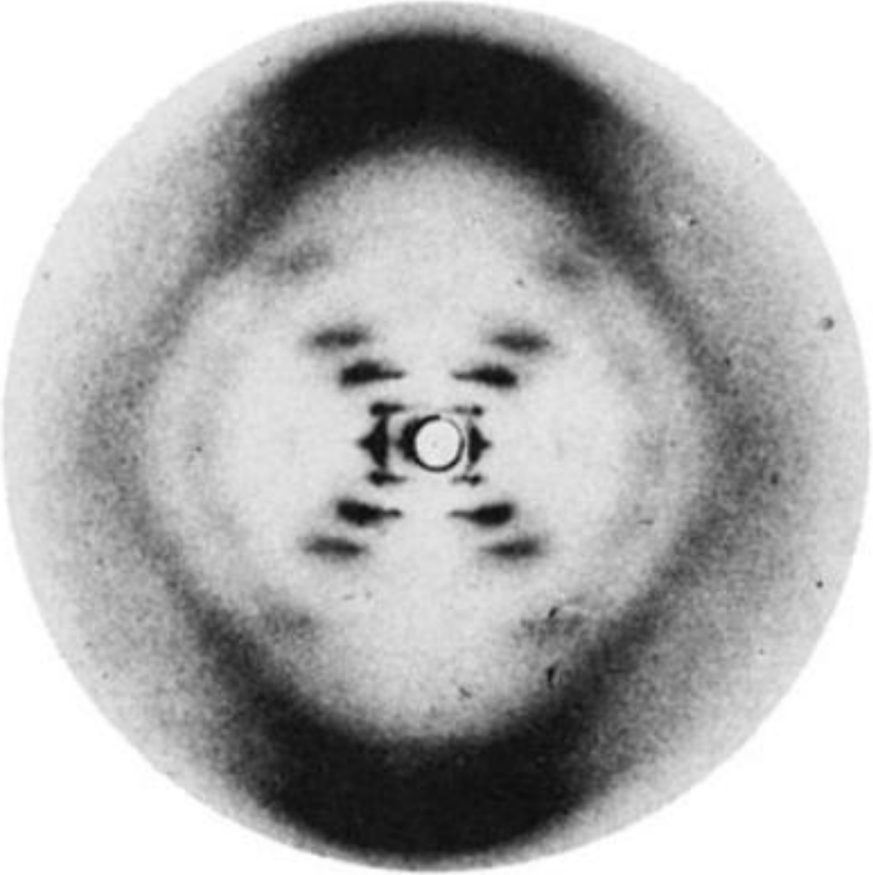
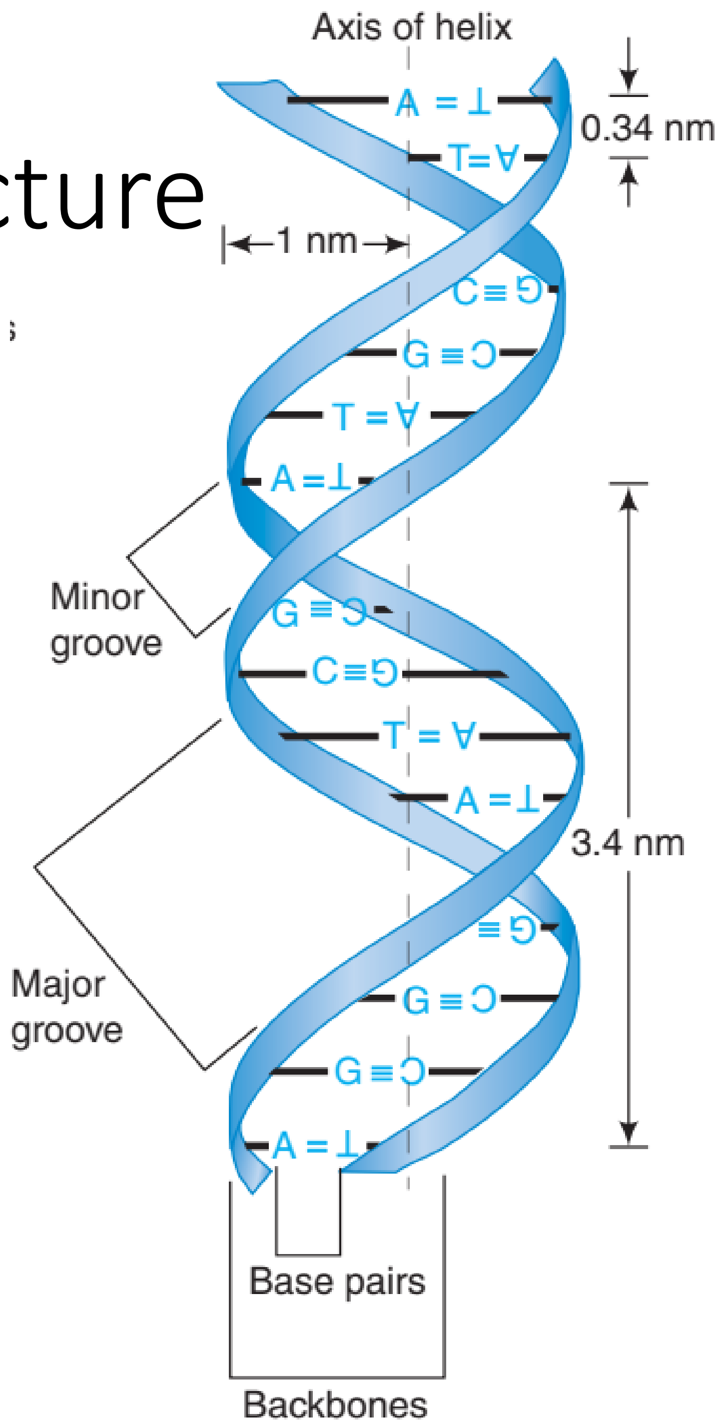
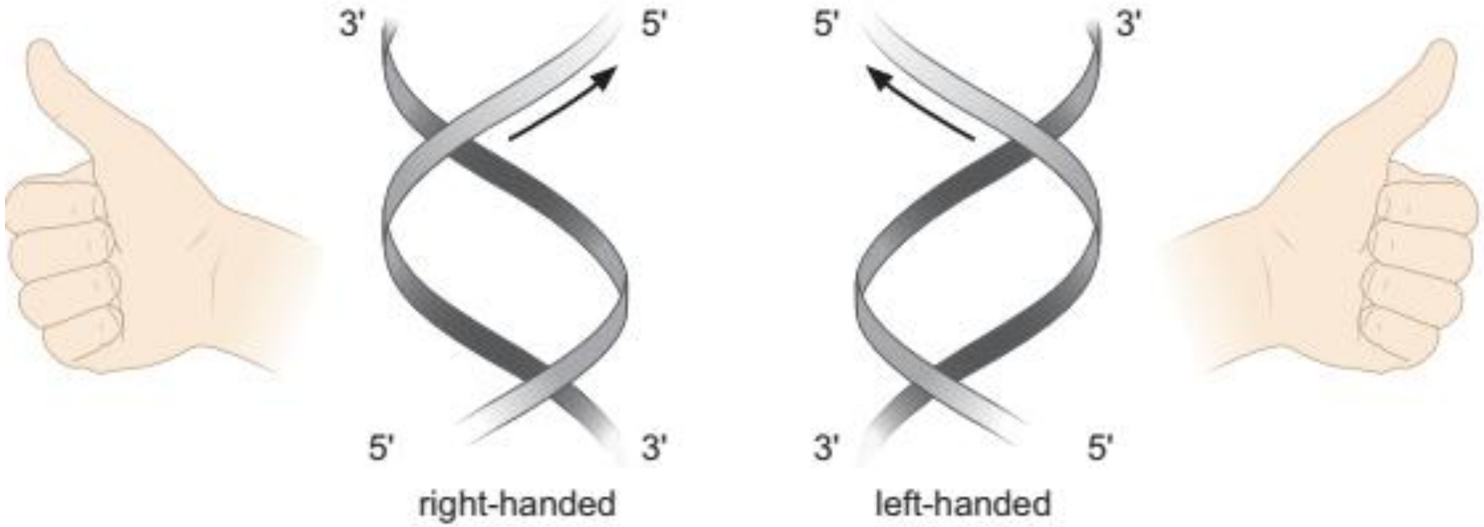


FIGURE 2-4 The key X-ray photograph involved in the elucidation of the DNA structure. This photograph, taken by Rosalind Franklin at King's College, London, in the winter of 1952–1953, confirmed the guess that DNA was helical. The helical form is indicated by the crossways pattern of X-ray reflections (photographically measured by darkening of the X-ray film) in the center of the photograph. The very heavy black regions at the top and bottom reveal that the 3.4-Å-thick purine and pyrimidine bases are regularly stacked next to each other, perpendicular to the helical axis. (Printed, with permission, from Franklin R.E. and Gosling R.G. 1953. *Nature* **171:** 740–741. © Macmillan.)

Watson & Crick’s Model of DNA structure

- The DNA molecule consists of two polynucleotide chains wound around each other in a right-handed double helix.
- The two chains are antiparallel (show opposite polarity).
- The sugar-phosphate backbones are on the outsides of the double helix, with the bases oriented toward the central axis. The bases of both chains are flat structures oriented perpendicularly to the long axis of the DNA so that they are stacked like pennies on top of one another, following the twist of the helix.





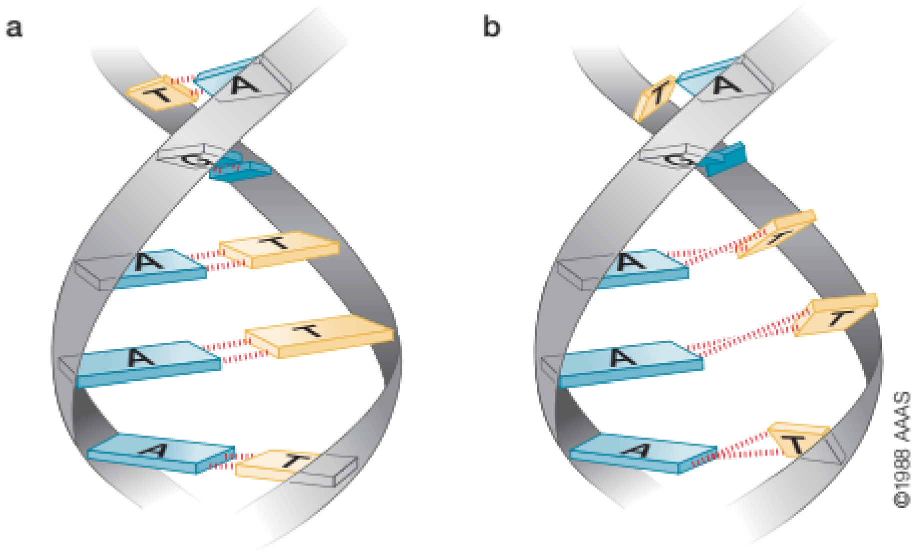
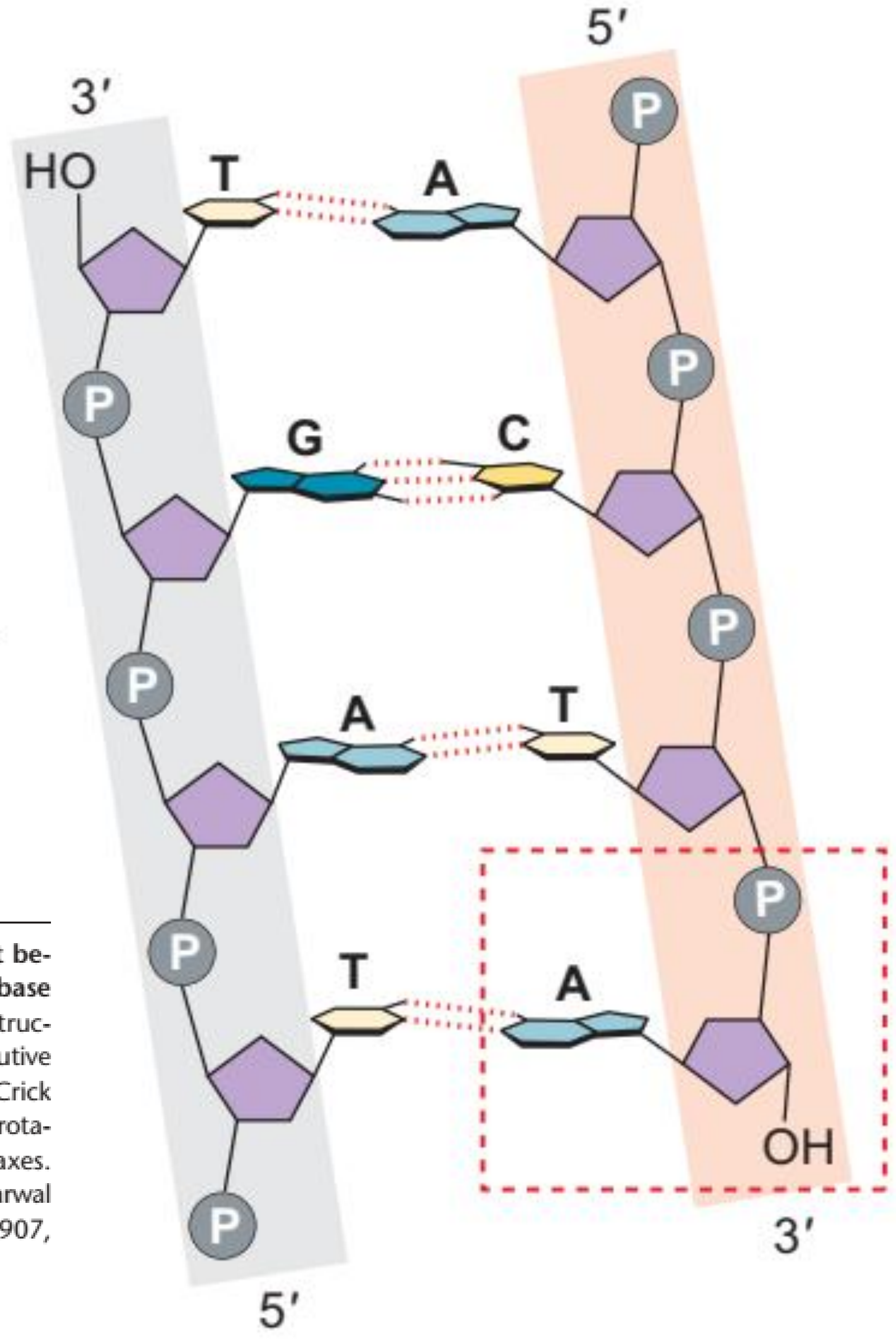
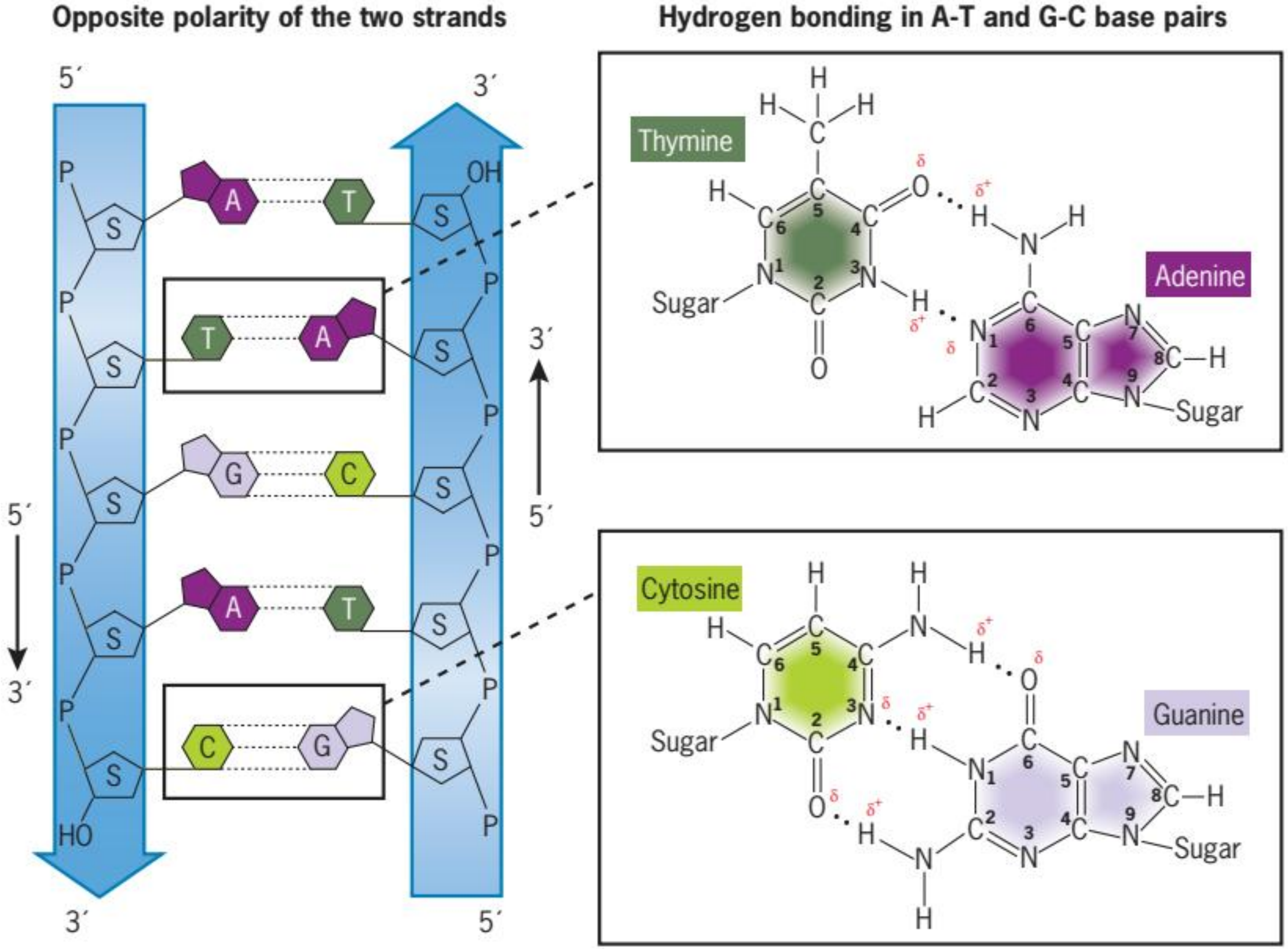


FIGURE 4-12 The propeller twist between the purine and pyrimidine base pairs of a right-handed helix. (a) The structure shows a sequence of three consecutive A:T base pairs with normal Watson–Crick bonding. (b) A propeller twist causes rotation of the bases about their long axes. (Adapted, with permission, from Aggarwal A.K. et al. 1988. *Science* **242:** 899–907, Fig. 5b. © AAAS.)



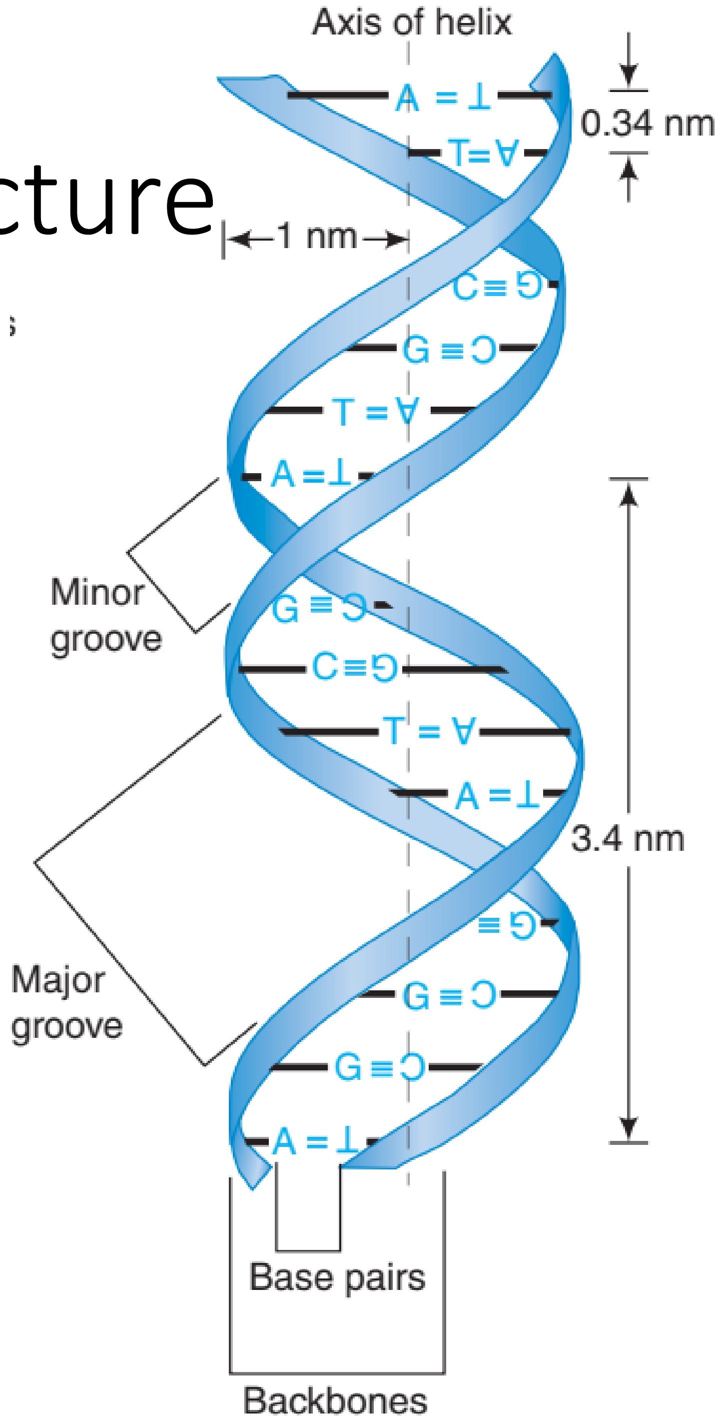
Watson & Crick's Model of DNA structure

- The bases in the two polynucleotide chains are bonded together by hydrogen bonds, which are relatively weak chemical bonds. The specific pairings observed are A bonded with T (two hydrogen bonds) and G bonded with C (three hydrogen bonds). The specific A–T and G–C pairs are called *complementary base pairs*.



Watson & Crick’s Model of DNA structure

- The base pairs are 0.34 nm (actually 0.332 nm) apart in the DNA helix. A complete (360°) turn of the helix takes 3.4 nm (actually 33.2 nm); therefore, there are 10 base pairs (bp) (actually 10.4 bp) per turn. The external diameter of the helix is 2 nm.
- Because of the way the bases bond with each other, the two sugar-phosphate backbones of the double helix are not equally spaced from one another along the helical axis. This unequal spacing results in grooves of unequal size between the backbones; one groove is called the major (wider) groove, and the other is the minor (narrower) groove.



Types of DNA

TABLE 4-2 A Comparison of the Structural Properties of A, B, and Z DNAs as Derived from Single-Crystal X-Ray Analysis

	Helix Type		
	A	**B**	**Z**
Overall proportions	Short and broad	Longer and thinner	Elongated and slim
Rise per base pair	2.3 Å	3.32 Å	3.8 Å
Helix-packing diameter	25.5 Å	23.7 Å	18.4 Å
Helix rotation sense	Right-handed	Right-handed	Left-handed
Base pairs per helix repeat	1	1	2
Base pairs per turn of helix	~11	~10	12
Rotation per base pair	33.6°	35.9°	−60° per 2 bp
Pitch per turn of helix	24.6 Å	33.2 Å	45.6 Å
Tilt of base normals to helix axis	+19°	−1.2°	−9°
Base-pair mean propeller twist	+18°	+16°	~0°
Helix axis location	Major groove	Through base pairs	Minor groove
Major-groove proportions	Extremely narrow but very deep	Wide and of intermediate depth	Flattened out on helix surface
Minor-groove proportions	Very broad but shallow	Narrow and of intermediate depth	Extremely narrow but very deep
Glycosyl-bond conformation	*anti*	*anti*	*anti* at C, *syn* at G

Adapted, with permission, from Dickerson R.E. et al. 1982. *Cold Spring Harbor Symp. Quant. Biol.* **47**: 14.

Properties of DNA

Absorbance

- N-bases of DNA absorb UV light strongly at wavelengths 254 to 260 nm.
- The increase in absorbance of DNA in the denatured state compared to the native double-stranded state is called **hyperchromatic shift.**
- If we plot the optical density of DNA as a function of temperature, we observe that the increase in absorption occurs abruptly over a relatively narrow temperature range. The midpoint of this transition is the melting point or T_m.

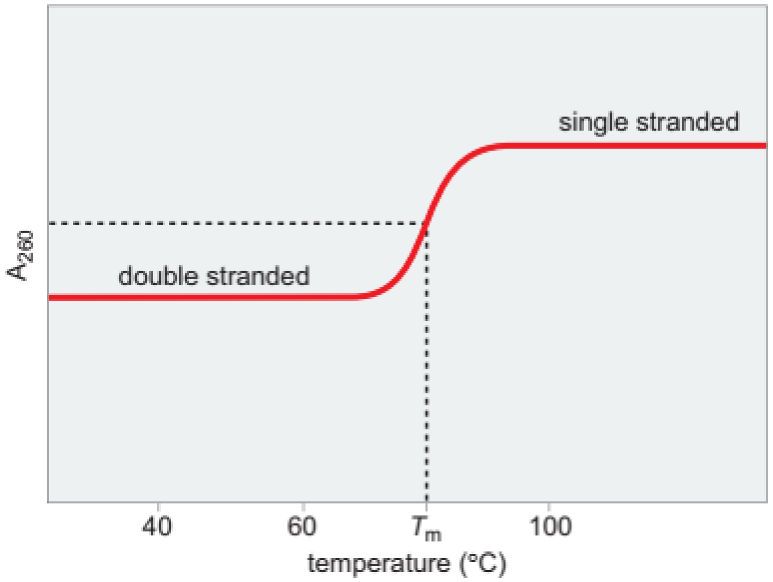


FIGURE 4-15 DNA denaturation curve.

Properties of DNA

Denaturation and renaturation

- When duplex DNA molecules are subjected to specific conditions of pH, temperature or ionic strengths that disrupt the hydrogen bonds and stacking interactions, the strands no longer hold together, resulting in **denaturation**.
- If the denatured DNA is cooled slowly, the complementary strands will base pair, and the native conformations will be restored, this process is called **renaturation** or **annealing**.

Properties of DNA

Solubility

- DNA is soluble in both water and alcohol.
- In chilled alcohol, it is insoluble and thus becomes visible.

Fuelgen reaction

- DNA if treated with warm acid (hydrolysis), a reddish-purple staining reaction would occur upon adding Schiff's reagent, called Fuelgen reaction after the name of its discoverer.
- This reaction is specific for DNA. Neither RNA nor any other cell substance give similar staining reaction.