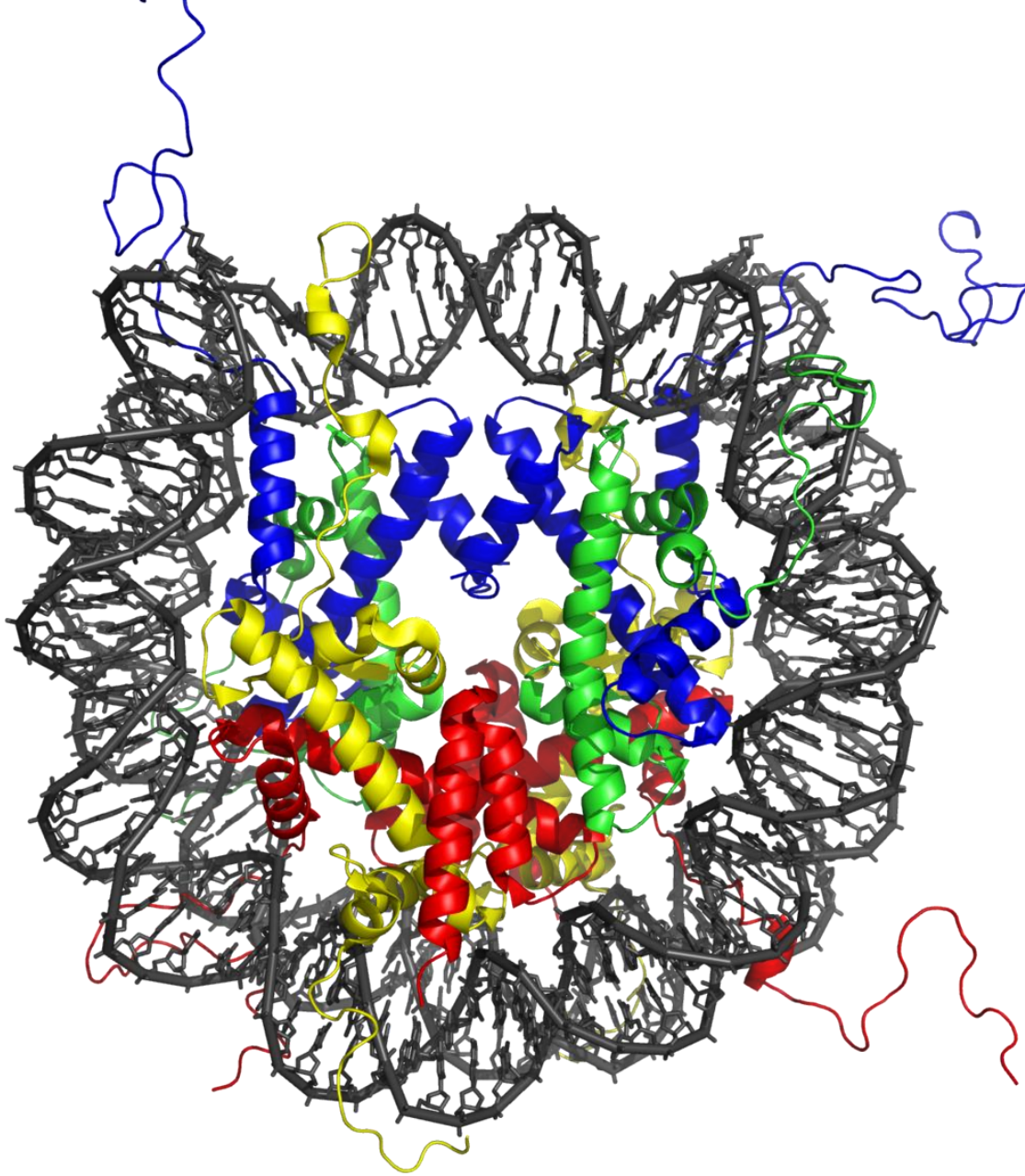
DP Biology – A1.2 (HL extension)

DNA: direction, pairing and packing

- How do nucleic acids store information that can be inherited?
- Which features of DNA allow it to be copied accurately?



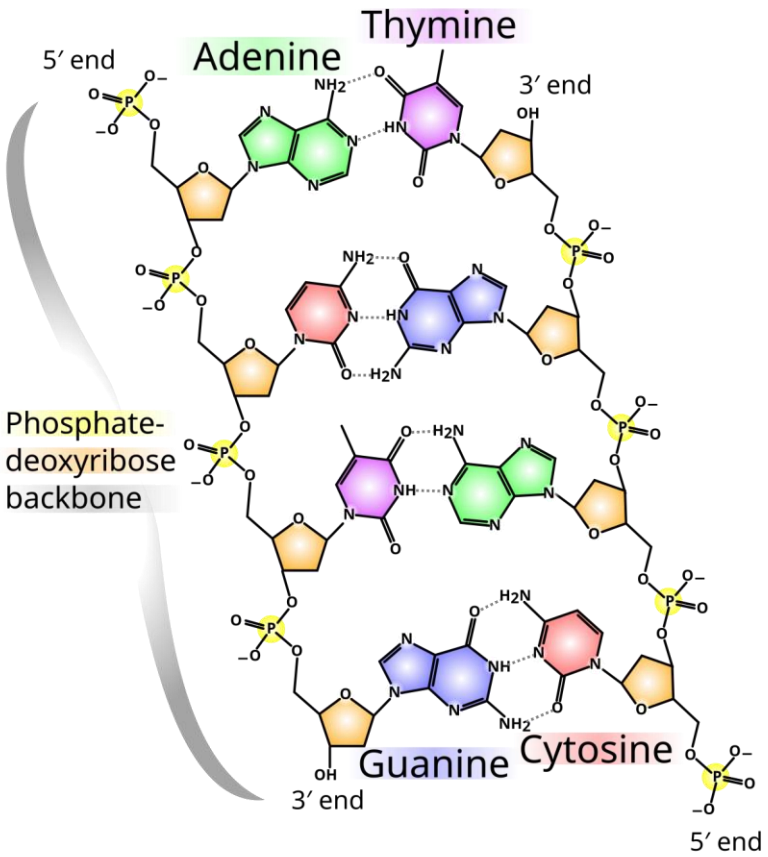
HL statements A1.2.11–15. Textbook pp. 25–33.
Image: a nucleosome, DNA wrapped around eight histones. Zephyris, CC BY-SA 3.0.

Objectives for each class

Class	Statements	By the end of the class, you can...
1	A1.2.11–12	Explain the 5′ to 3′ direction of nucleic acid strands and why purine-pyrimidine pairing keeps the helix regular
2	A1.2.13	Describe the structure of a nucleosome and explain why DNA is packed this way
3	A1.2.14–15	Evaluate the evidence from Hershey and Chase, and from Chargaff, about the genetic material

Strands have a direction

A1.2.11



DNA chemical structure. Wikimedia Commons, CC BY-SA 3.0.

- Carbons in deoxyribose are numbered 1′ to 5′
- A phosphate links carbon 3′ of one sugar to carbon 5′ of the next
- So each strand has a **5′ end** (free phosphate) and a **3′ end** (free -OH)
- The two strands of DNA run in opposite directions: **antiparallel**
- RNA strands have the same 5′ to 3′ direction

Key idea

New nucleotides can only be joined to the free 3′ -OH of a growing strand, so nucleic acids are always built in the 5′ to 3′ direction.

Why direction matters

A1.2.11

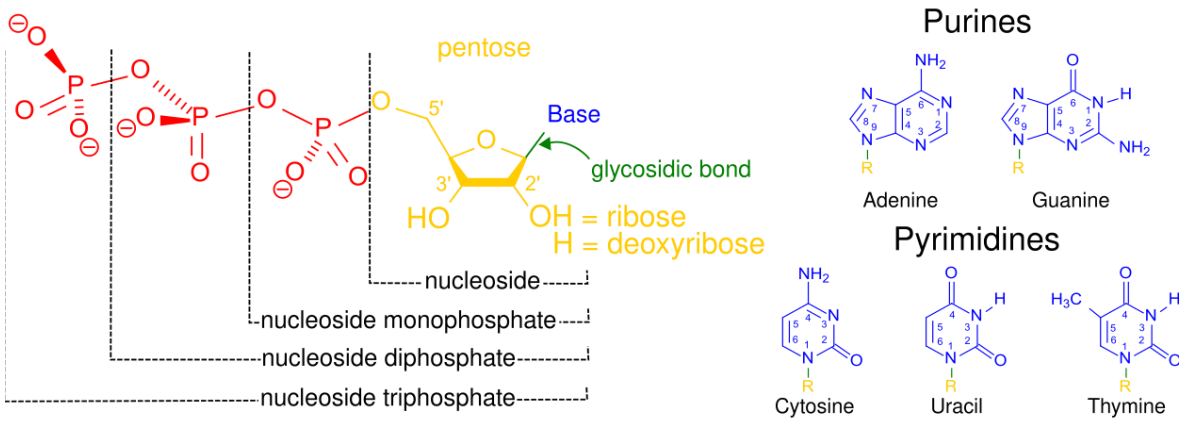
Process	Role of directionality
Replication	DNA polymerase adds nucleotides only to the 3′ end, so new strands grow 5′ to 3′. The two antiparallel strands are copied in opposite directions
Transcription	RNA polymerase reads the template strand 3′ to 5′ and builds mRNA 5′ to 3′
Translation	Ribosomes read mRNA from the 5′ end towards the 3′ end, so codons are read in a fixed order

Common mistake

The template strand for transcription is the non-coding strand. The coding strand has the same sequence as the mRNA (with T in place of U).

Purines pair with pyrimidines

A1.2.12



Nucleotide parts, purines and pyrimidines. Public domain.

	Purines	Pyrimidines
Rings	Two	One
Bases	Adenine, guanine	Cytosine, thymine (uracil in RNA)

- A-T and C-G pairs are each one purine plus one pyrimidine
- Both pairs are the **same width**, so the helix has the same diameter whatever the sequence
- A-T has 2 hydrogen bonds; C-G has 3
- Two purines would bulge; two pyrimidines would leave a gap

So

Any sequence can be stored without changing the shape of the molecule, and enzymes can work on all of it.

Build and check

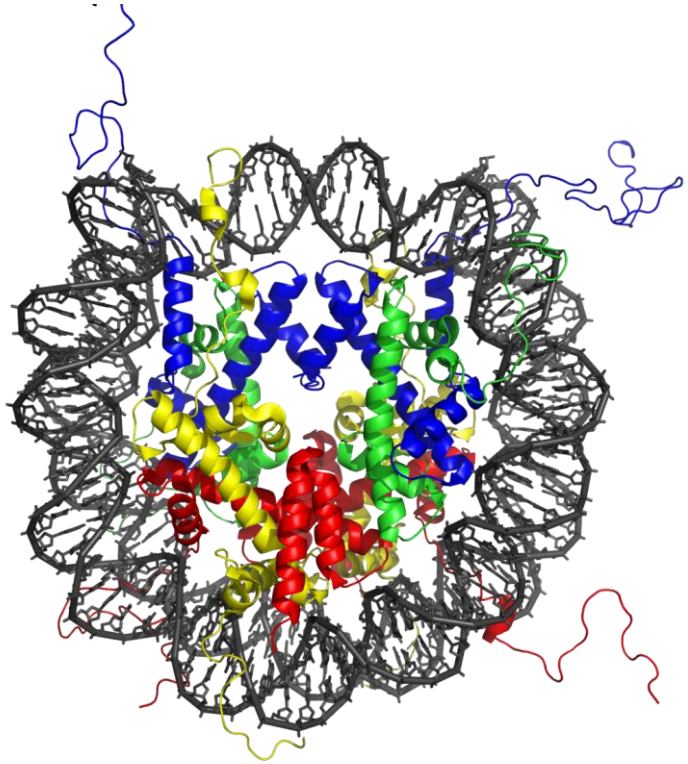
A1.2.11–12

1. Draw four nucleotide pairs of a DNA molecule. Label the 5′ and 3′ ends of each strand, and the hydrogen bonds.
2. **Predict** which of two 20-base-pair molecules is harder to separate: one with 14 C-G pairs or one with 6 C-G pairs. Explain.
3. **Explain** why a molecule with A paired with G could not fit in a regular helix.

Hint

Use the number of hydrogen bonds for the second question, and the number of rings for the third.

The nucleosome



- **Core**: eight histone proteins (two each of four types), an octamer
- DNA is wound about twice around each core
- **Linker DNA** joins one nucleosome to the next
- A further histone (**H1**) binds where the DNA enters and leaves, holding it in place
- Histones are rich in positively charged lysine and arginine, which attract negatively charged phosphate groups

Nucleosome (1KX5): DNA in grey around histones. Zephyris, CC BY-SA 3.0.

Eukaryotic DNA looks like beads on a string. Prokaryotic DNA has no histones: it is "naked".

Why package DNA?

A1.2.13

Fact	Size
DNA in one human nucleus	About 2 m
Nucleus diameter	About 5 to 10 μm
Typical chromosome at metaphase	About 5 μm long, holding about 5 cm of DNA

- Fits DNA into the nucleus
- Condensed chromosomes can be moved in division without tangling
- Unwinding particular regions lets genes be transcribed, so packing helps control gene expression

Molecular visualization

Open a nucleosome structure (for example PDB 1KX5) in a 3D viewer. Find the two copies of each histone and colour the positive amino acids. Where are they, compared with the DNA?

Hershey and Chase, 1952

A1.2.14



Martha Chase and Alfred Hershey. CC BY-SA 4.0.

Phages with 35S (protein labelled)

Phages with 32P (DNA labelled)

Phages infect E. coli

Blender shakes off phage coats

Centrifuge: cells form a pellet; coats stay in the liquid

Result	35S batch	32P batch
Radioactivity in pellet (cells)	Very little	Most
Radioactivity in liquid (coats)	Most	Little
Label in new phages	None	Some

What the experiment shows

A1.2.14

- Only phage DNA entered the bacteria; the protein coats stayed outside
- The DNA alone was enough to make new phages, coats and all
- So DNA, not protein, carries the genetic information
- The experiment needed radioactive isotopes, available after the Second World War

Evaluate

Some 35S did end up in the pellet, and some 32P stayed outside. Suggest why the results were not 100% clean, and why the conclusion was still accepted.

Why protein was expected

Proteins are built from 20 amino acids, so they seemed to offer more variety than DNA with only four bases.

Chargaff's data

Source of DNA	A %	G %	C %	T %
Human	30.9	19.9	19.8	29.4
Wheat	27.3	22.7	22.8	27.1
E. coli	24.7	26.0	25.7	23.6
Yeast	31.3	18.7	17.1	32.9

- A = T and G = C in every species
- So purines = pyrimidines
- But the proportion of A+T varies between species
- Data from Chargaff and colleagues, about 1950

Falsification

The tetranucleotide hypothesis said DNA was a simple repeat of the four bases in equal amounts, so it could not hold information. Chargaff's data showed the amounts differ between species, falsifying it. Equal A and T, G and C, later fitted Watson and Crick's base pairing.

Check that you can explain

1. What the 5′ and 3′ ends of a strand are, and why strands are antiparallel
2. How directionality affects replication, transcription and translation
3. Why purine-pyrimidine pairing gives a regular helix
4. The structure of a nucleosome, and why DNA is packaged
5. How Hershey and Chase showed DNA is the genetic material
6. What Chargaff's data showed, and which hypothesis it falsified

Exit activity: 5 minutes

On your own and without notes. Hand this in as you leave.

1. State which end of a DNA strand new nucleotides are added to.
2. Describe the structure of a nucleosome.
3. Explain why the 32P label ended up inside the bacteria in the Hershey-Chase experiment.

Image credits

Nucleosome 1KX5 colour coded.png – Zephyris at English Wikipedia – CC BY-SA 3.0

DNA chemical structure.svg – Madprime – CC BY-SA 3.0

Nucleotides 1.svg – Boris (PNG), SVG by Sjef – Public domain

Scientist Alfred Hershey and Martha Chase.jpg – Rohit Kumar Sengupta – CC BY-SA 4.0

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