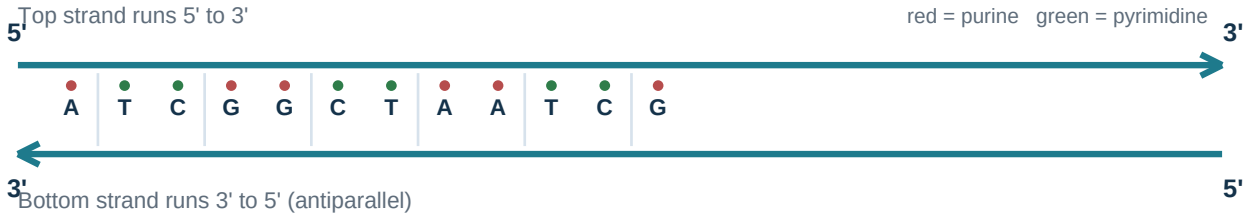
HL A1.2.11-A1.2.15
DNA / RNA Directionality, Base Pairing, Nucleosomes, Hershey-Chase and Chargaff

Exam-preparation notes focused on core definitions, significance, applications and common markscheme traps.

Core focus	What you must be able to explain
Directionality of nucleic acids	Why strands are described 5' and 3', why DNA is antiparallel, and why synthesis proceeds only 5' to 3'.
Purine-pyrimidine pairing	How A-T and C-G pairing keeps the helix width constant and increases stability.
Nucleosome structure	DNA wrapped around 8 histones with an additional histone on linker DNA for packaging.
Evidence for DNA	How the Hershey-Chase experiment used 32P and 35S to show DNA enters bacteria.
Chargaff's rule	Why A approximately equals T and G approximately equals C, and how this falsified the tetranucleotide idea.

1. A1.2.11 Directionality of DNA and RNA

Definition. The labels 5' and 3' refer to the fifth and third carbon atoms in the pentose sugar of each nucleotide. Adjacent nucleotides are joined by **5' to 3' phosphodiester linkages** in the sugar-phosphate backbone.



- **Each strand has its own 5' end and 3' end.** A double-stranded DNA molecule does not have just one overall 5' end and one overall 3' end.
- **DNA strands are antiparallel.** If one strand runs 5' to 3', the complementary strand runs 3' to 5'.
- **New nucleic acid strands always elongate 5' to 3'.** Polymerases add each incoming nucleotide to the free 3' OH group of the growing strand.
- **Replication:** each old DNA strand acts as a template, but the new complementary strand is still synthesized only in the 5' to 3' direction.
- **Transcription:** RNA polymerase synthesizes mRNA 5' to 3' while reading the DNA template strand in the opposite direction.
- **Translation:** the ribosome reads mRNA codons from the 5' end toward the 3' end, so directionality determines the amino-acid sequence produced.

Exam trap

Do not say one DNA molecule has only one 5' and one 3' end. Each strand has both ends, and the strands run antiparallel.

2. A1.2.12 Purine-to-pyrimidine bonding and helix stability

Purines (adenine and guanine) have a double-ring structure, whereas pyrimidines (thymine and cytosine) have a single-ring structure. In DNA, **a purine always pairs with a pyrimidine**.

Pair	Ring sizes	Why it matters
A-T	purine + pyrimidine	keeps the strands the correct distance apart; hydrogen-bond pattern fits
C-G	purine + pyrimidine	same overall width as A-T, so the helix diameter stays constant
A-C or G-T	purine + pyrimidine	wrong hydrogen-bond arrangement, so these are not normal complementary pairs

- **Equal width:** because every base pair contains one large base and one small base, the double helix keeps the same 3D shape along its length.
- **Stability:** the regular spacing of the two backbones supports the stable helical structure and helps accurate complementary pairing during replication.
- **Accuracy:** correct base-pairing rules reduce mismatches when new strands are made.

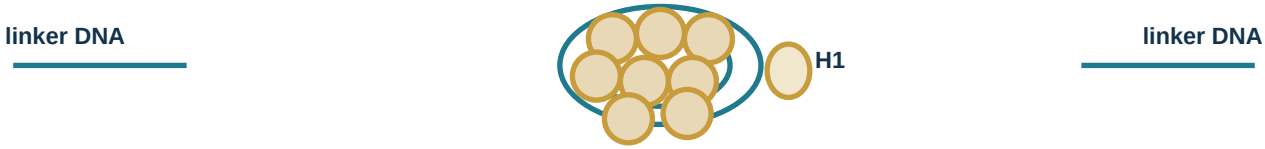
One-line summary

Purine + pyrimidine pairing gives DNA a uniform width and allows only the correct complementary pairs to stabilize the helix.

3. A1.2.13 Nucleosome structure and efficient DNA packaging

DNA molecules are extremely long, so they must be packaged efficiently to fit inside the nucleus. The basic packaging unit is the **nucleosome**.

DNA wrapped around an octamer of histones



One nucleosome = DNA wrapped around 8 histones, stabilized by an extra histone bound to linker DNA

Component	Description
Histone octamer	8 histone proteins forming the nucleosome core around which DNA wraps.
Wrapped DNA	DNA coils around the histone core, allowing a long molecule to be compacted.
Linker DNA	Short stretch of DNA connecting one nucleosome to the next.
Additional histone	Attached to linker DNA; helps maintain nucleosome structure and packing.

- **Beads on a string:** biologists often describe nucleosomes in this way because DNA passes from one wrapped unit to the next via linker DNA.
- **Why packaging matters:** compacting DNA protects it, organizes it, and allows chromosomes to fit inside the nucleus.
- **Skills link:** when using molecular visualization software, identify DNA wrapped around the histone core and locate linker DNA between adjacent nucleosomes.

4. A1.2.14 Hershey-Chase experiment: evidence that DNA is the genetic material

Before the 1950s, many scientists thought proteins were the genetic material because proteins seemed more chemically complex than DNA. Hershey and Chase tested this directly using bacteriophages that infect *E. coli*.

Label used	What became radioactive	What happened after infection	Conclusion
^{32}P	DNA (phosphate groups contain phosphorus)	Radioactivity detected **inside** bacteria	DNA entered the cell
^{35}S	Protein coat (some amino acids contain sulfur)	No radioactivity detected inside bacteria after blending	Protein coat stayed outside

- **Why phosphorus labels DNA:** nucleotides contain phosphate, but proteins do not normally contain phosphorus as a structural component.
- **Why sulfur labels protein:** DNA contains no sulfur, but proteins may contain sulfur in amino acids such as cysteine and methionine.
- **The blender step:** blending sheared off the viral protein coats from the bacterial cells, so scientists could see which label entered the cells.
- **Key conclusion:** the genetic material transferred from phage to bacterium was DNA, not protein.

Nature of science

The experiment was possible because radioisotopes had become available as research tools. New technology often opens up entirely new experiments.

5. A1.2.15 Chargaff's rule and falsification of the tetranucleotide hypothesis

Chargaff used chromatography-based methods to measure the proportions of the four bases in DNA from different organisms. His data showed two crucial patterns:

- **A approximately equals T** in double-stranded DNA.
- **G approximately equals C** in double-stranded DNA.
- **The total proportions of A, T, G and C are not all equal** and vary between species.

Source	A	T	G	C	Pattern
Calf thymus	1.7	1.6	1.2	1.0	A about T; G about C
Yeast	1.8	1.9	1.0	1.0	same paired pattern
Tubercle bacillus	1.1	1.0	2.6	2.4	base composition differs

- **Why this mattered:** if DNA were a simple repeating tetranucleotide, all four bases would have appeared in equal amounts. The data did *not* show that pattern.
- **Therefore the tetranucleotide hypothesis was falsified.** This opened the way for the idea that DNA sequence could carry genetic information.
- **Why ratios are not perfectly 1:1 in raw data:** experimental error and technique limits can create small deviations without changing the overall conclusion.

NOS link

Science often progresses by falsifying ideas rather than proving them with certainty. Chargaff's data ruled out one model and helped make better models possible.

6. Synoptic summary: what to remember for exams

Topic	Must-know sentence
Directionality	Strands are built by adding nucleotides to the 3' end, so synthesis always proceeds 5' to 3'.
Antiparallel DNA	The two DNA strands run in opposite directions, allowing complementary base pairing.
Purine + pyrimidine	A-T and C-G pairings keep the helix width constant and help stabilize DNA.
Nucleosome	DNA wraps around 8 histones, with an additional histone associated with linker DNA.
Hershey-Chase	32P-labelled DNA entered bacteria; 35S-labelled protein did not, so DNA is the genetic material.
Chargaff	A approximately equals T and G approximately equals C; unequal overall base composition falsified the tetranucleotide idea.

7. Quick-check questions

- 1. If one DNA strand is labelled 3' at the left-hand end, what must be at the right-hand end of that strand? What are the two ends of the complementary strand?
- 2. Explain why replication, transcription and translation all depend on nucleic-acid directionality.
- 3. Why does purine-to-pyrimidine pairing help DNA remain stable?
- 4. Outline the structure of a nucleosome in one or two sentences.
- 5. Why did 32P label DNA but 35S label protein in the Hershey-Chase experiment?
- 6. A DNA sample contains 22% cytosine. What percentages of guanine, adenine and thymine would you expect?

Fast answers

1. The right-hand end is 5'. The complementary strand runs antiparallel, so its left end is 5' and its right end is 3'.
2. Polymerases synthesize only 5' to 3', and ribosomes read mRNA from 5' toward 3'.
3. One purine plus one pyrimidine gives constant helix width and correct hydrogen-bonding patterns.
4. DNA wrapped around 8 histones; linker DNA connects nucleosomes; an extra histone helps maintain structure.
5. DNA contains phosphorus in phosphate groups, whereas sulfur is found in some amino acids in protein.
6. G = 22%, so A + T = 56%; therefore A = 28% and T = 28%.

Common mistakes

• Writing synthesis as 3' to 5' instead of 5' to 3'.
• Saying DNA has one overall 5' end and one overall 3' end.
• Confusing histones with nucleosomes.
• Forgetting that Chargaff's data varied between species.
• Saying sulfur was in DNA in Hershey-Chase.

Challenge-yourself answer

If the left end of one strand is 3', the other end of that strand must be 5'. Because the complementary strand is antiparallel, its left end is 5' and its right end is 3'.

Revision tip: in structured biology questions, use the precise vocabulary of the syllabus - antiparallel, phosphodiester linkage, complementary base pairing, histone, linker DNA, genetic material, and falsified hypothesis.