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VCE Biology ¾
Nucleic Acids & the Structure of Genes [1.2]
Workbook

Outline:

Study Design Key Knowledge:

Study Design: The relationship between Nucleic Acids and Proteins

Nucleic acids as information molecules that encode instructions for the synthesis of proteins: the structure of DNA, the three main forms of RNA (mRNA, rRNA and tRNA), and a comparison of their respective nucleotides.

The genetic code as a universal triplet code that is degenerate.

The structure of genes: exons, introns, and promoter and operator regions.

https://www.vcaa.vic.edu.au/Documents/vce/biology/2022BiologySD.docx

Section A: Nucleic Acids

Sub-Section: Nucleic Acids as Information Molecules

How do cells know what to do, and when to do it?

1.2 – 1.4

Discussion: The Purpose of Nucleic Acids

DNA → genetic instructions

↳ NUCLEUS – "brain"

THE CENTRAL DOGMA

DNA → Proteins

INSTRUCTIONS → FINAL PRODUCT

Nucleic Acids

- Function - genetic instructions (inherited) of the cell.
  - Large polymers are effectively packed with the nucleus to ensure large amounts of information are stored in an extremely compact manner.
  - They determine how a cell will develop as they encode for the production of proteins that are responsible for specific functions in a cell.
- What is a polymer?
  - ↳ large chain molecule made up of small repeating subunits called monomers
- Types of nucleic acids:
  - DNA - deoxyribonucleic acid
  - RNA - Ribonucleic Acid

Analogy: A Blueprint for the Cell

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Sub-Section: Nucleotides

What are the monomers that make up a molecule of nucleic acid?

Exploration: Nucleotides

- Nucleotides are the monomers that make up nucleic acids.

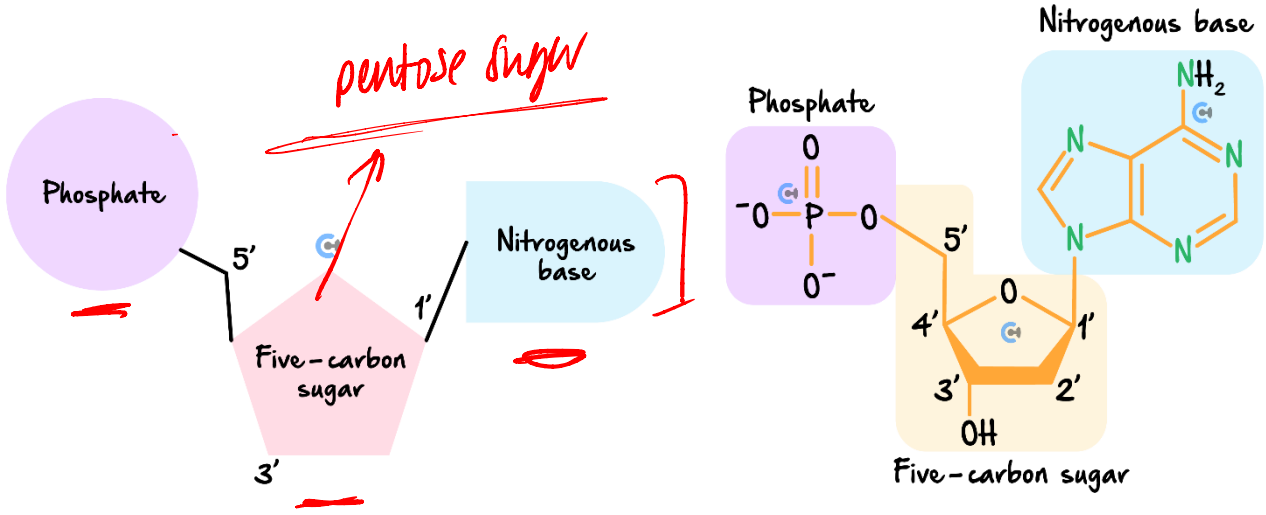
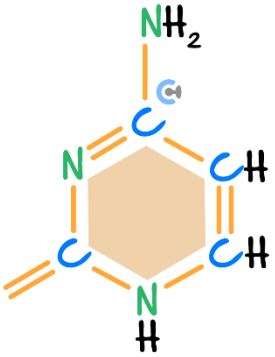


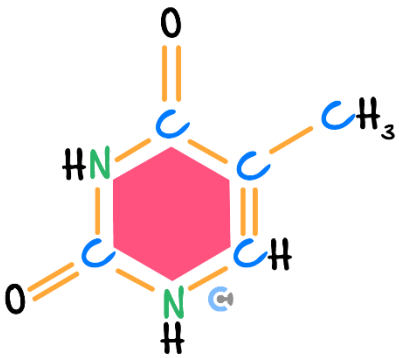
Figure 1 (a) The basic structure of a nucleotide and (b) the chemical structure of a DNA nucleotide.

- Phosphate group.
- 5 carbon sugar.
- Nitrogenous bases.
  - 5 types of nitrogenous bases - Adenine, Thymine, Cytosine, Guanine, or Uracil.
  - Purines = Adenine and Guanine.
  - Pyrimidines = Thymine, Uracil, and Cytosine.

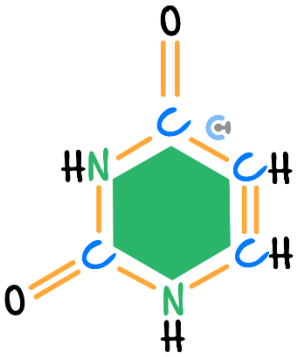
Pyrimidines



Cytosine (C)

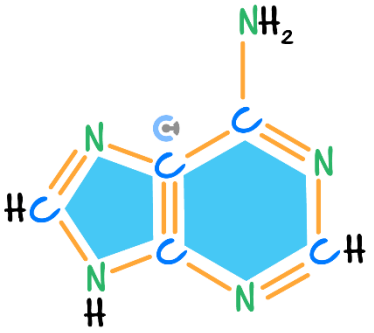


Thymine (T, in DNA)

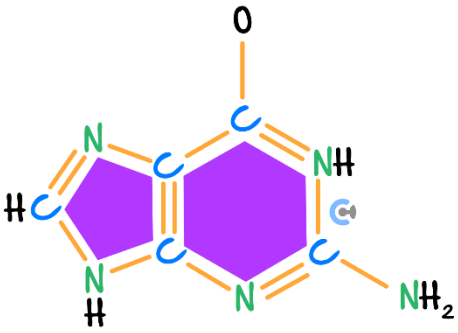


Uracil (U, in RNA)

Purines



Adenine (A)



Guanine (G)

Discussion: If DNA and RNA are both made up of nucleotides, why are they different?

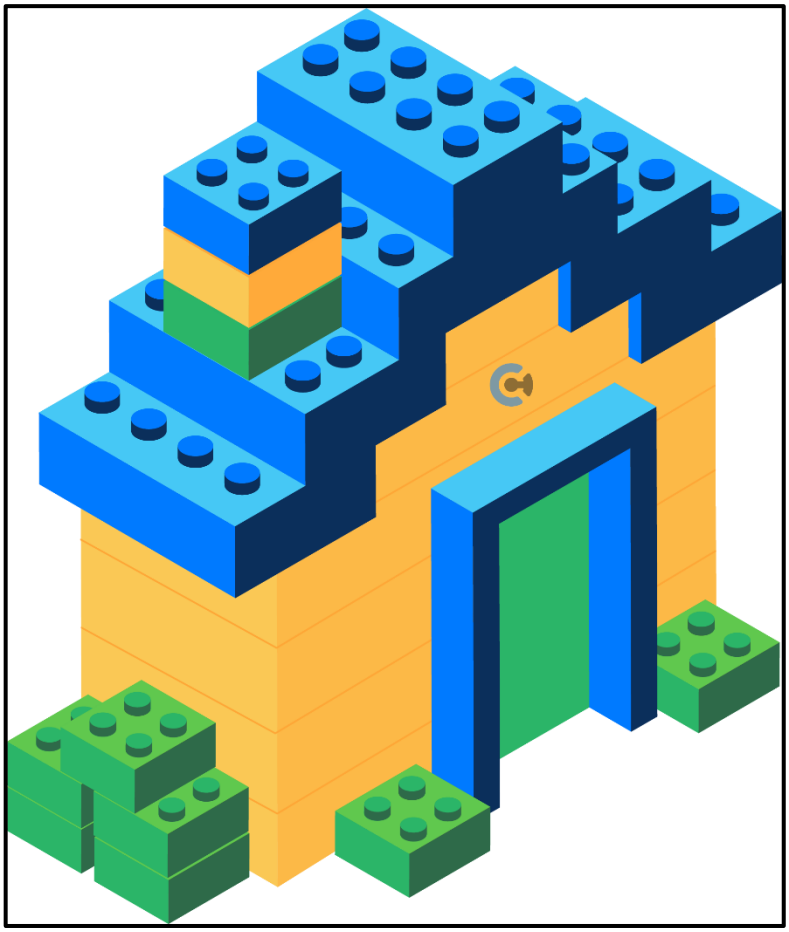
→ (1) Nucleotides Different]

(2) Arrangement is Different]

* try putting things in "categories" or make sure your memory is organised.

Analogy: Building Lego!

- The bricks will all be put together the same way, and will all have those little circles to help join them together.
- However, depending on slight differences in the bricks, and the WAY we arrange them, they will have different final outcomes!



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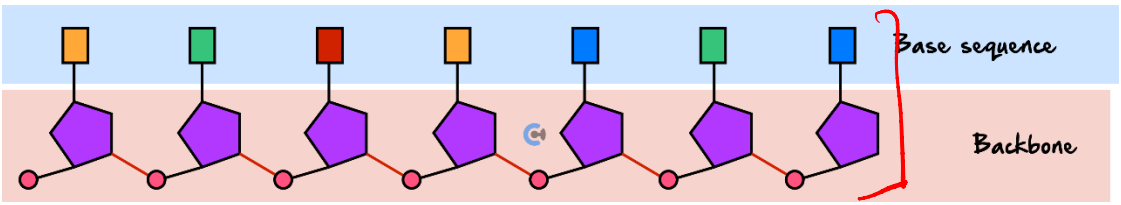
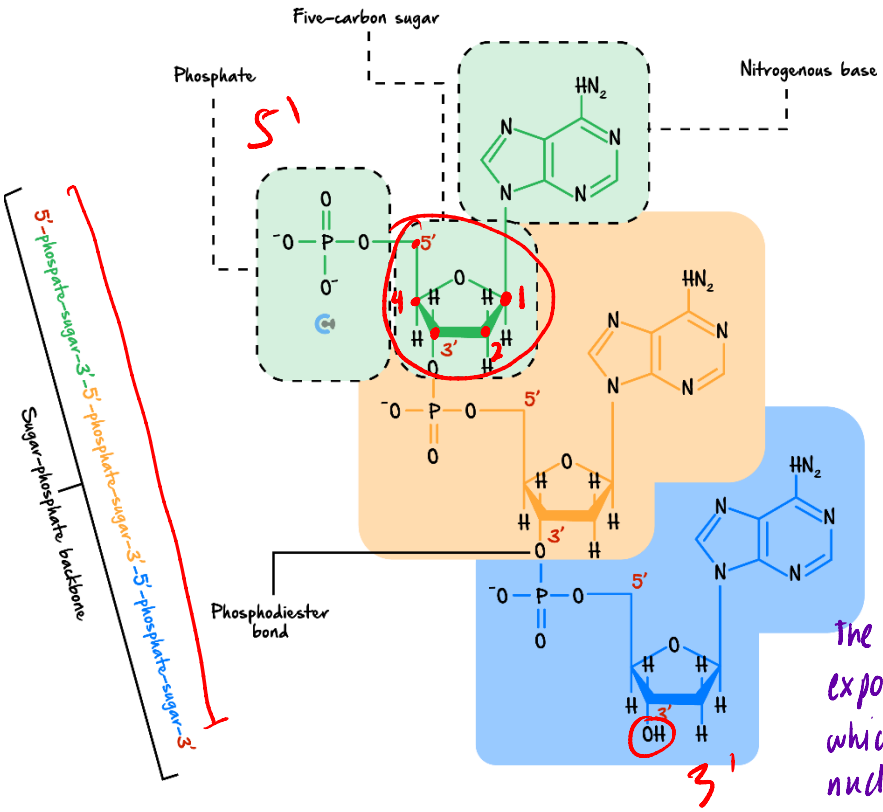
Sub-Section: Condensation Polymerisation

How can we put those bricks together?

Condensation Polymerisation

- Reaction between nucleotides that allows the nucleic acid chain to build up.
  - Condensation - producing H_2O as a byproduct.
  - Polymerisation - making a polymer (joining the monomers)
- The nucleotides are linked together by strong covalent bonds - specifically, these are known as phosphodiester.





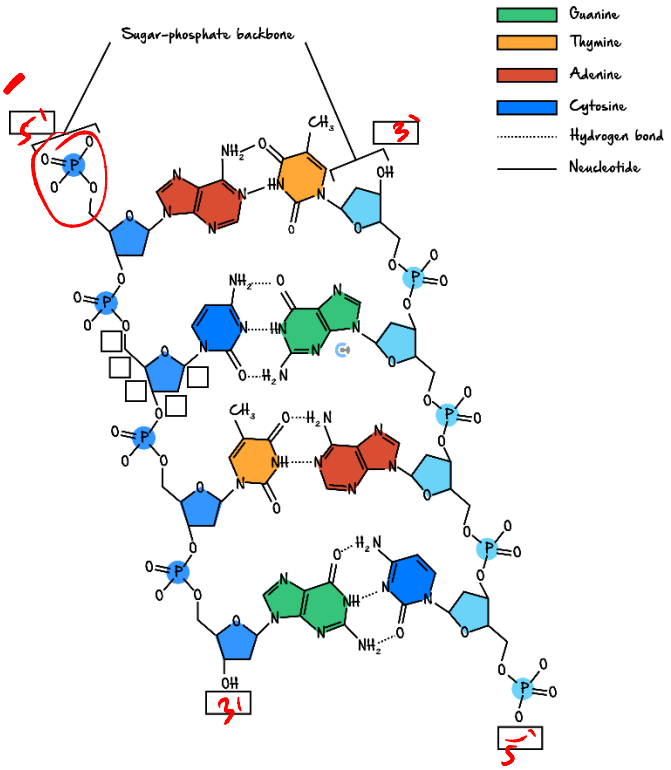
The 3' end has an exposed hydroxyl group which allows for more nucleotides to be added here

* new nucleotides only @ 3'

Discussion: What do you notice about the way the nucleotides are joined together?

- What forms the backbone of the DNA?
  - Sugar Phosphate backbone
- Numbering of the Carbons? Why is this important?
  - 1 - connects the sugar to nitrogenous base
  - 3 - connects the sugar to phosphate of ADJACENT nucleotide
  - 5 - connects the sugar to the phosphate WITHIN the same nucleotide!
  -

- Annotate this diagram of a DNA molecule!



TIP: Phosphate sounds like Phosphate; hence it is at the 5'!

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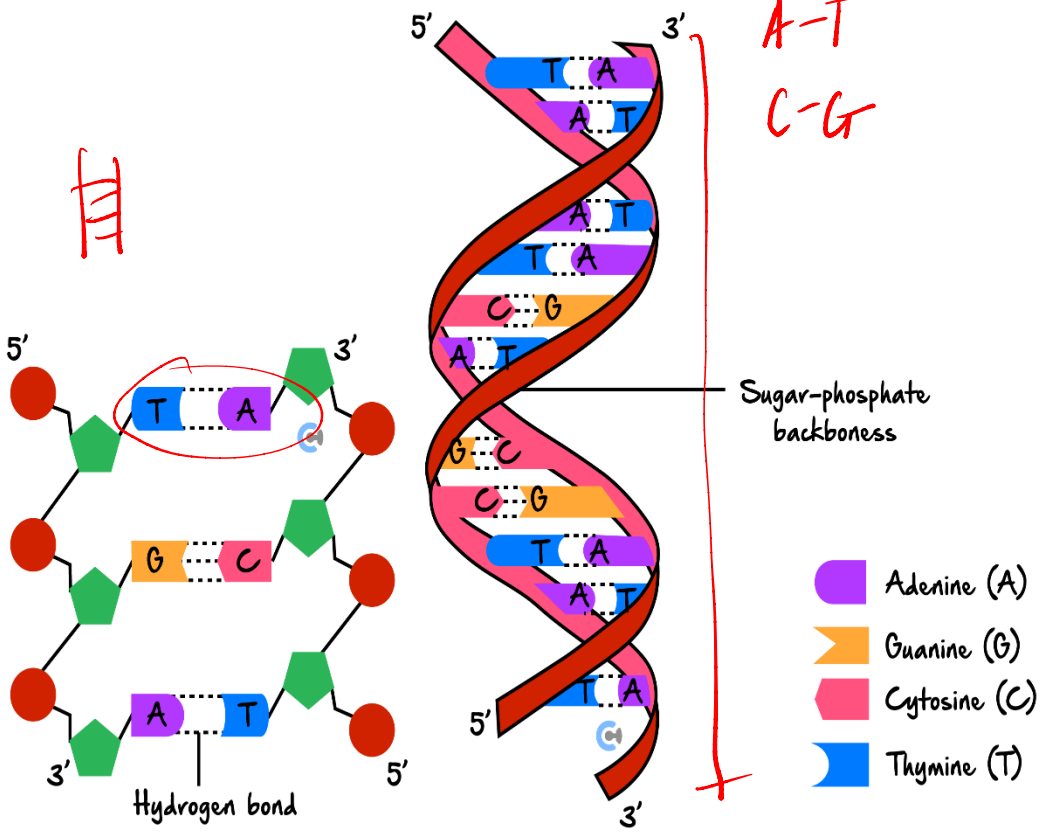
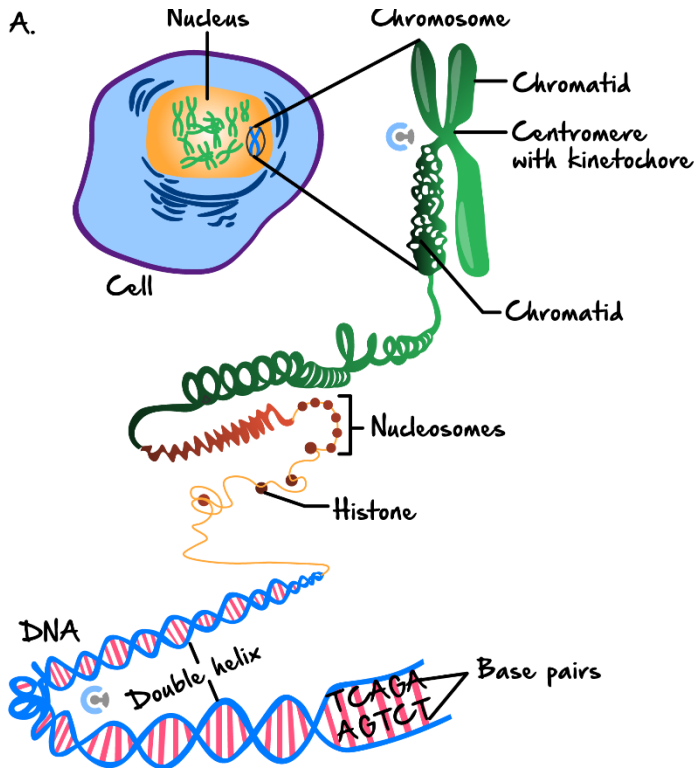
Sub-Section: DNA

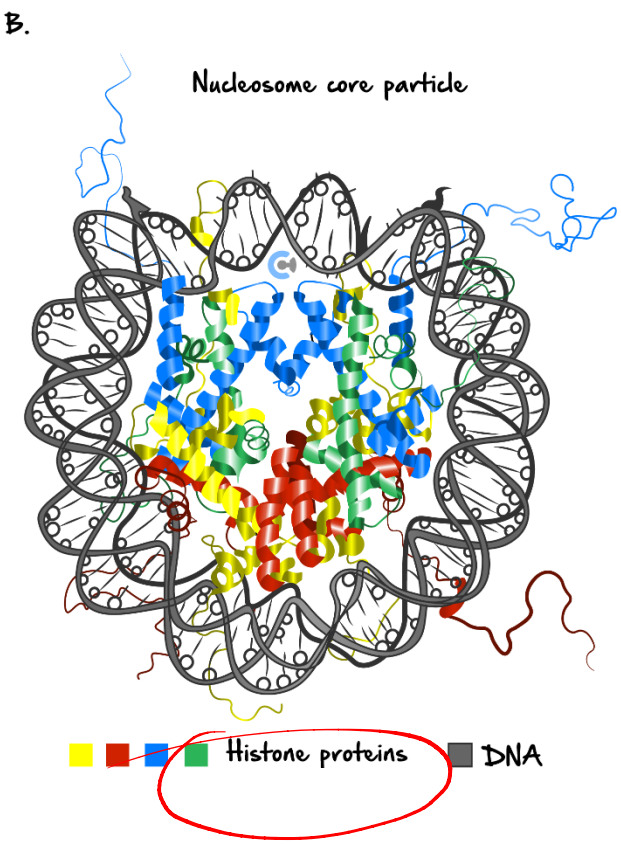
Exploration: DNA

- Found in the nucleus of cells - humans have DNA packaged as 46 chromosomes which contain **genes**.
- To be able to accommodate large amounts of DNA, these chromosomes are long DNA strands tightly coiled around "histone" proteins.
  - Deoxyribonucleic Acid
  - Deoxyribose Sugar
  - Nitrogenous Bases - Adenine Thymine Guanine Cytosine
- Double-stranded Double Helix Structure. → Arrangement
- Joined together by complementary base pairing - hydrogen bonding between complementary bases
  - antiparallel



Extension: How is DNA organised in a cell?





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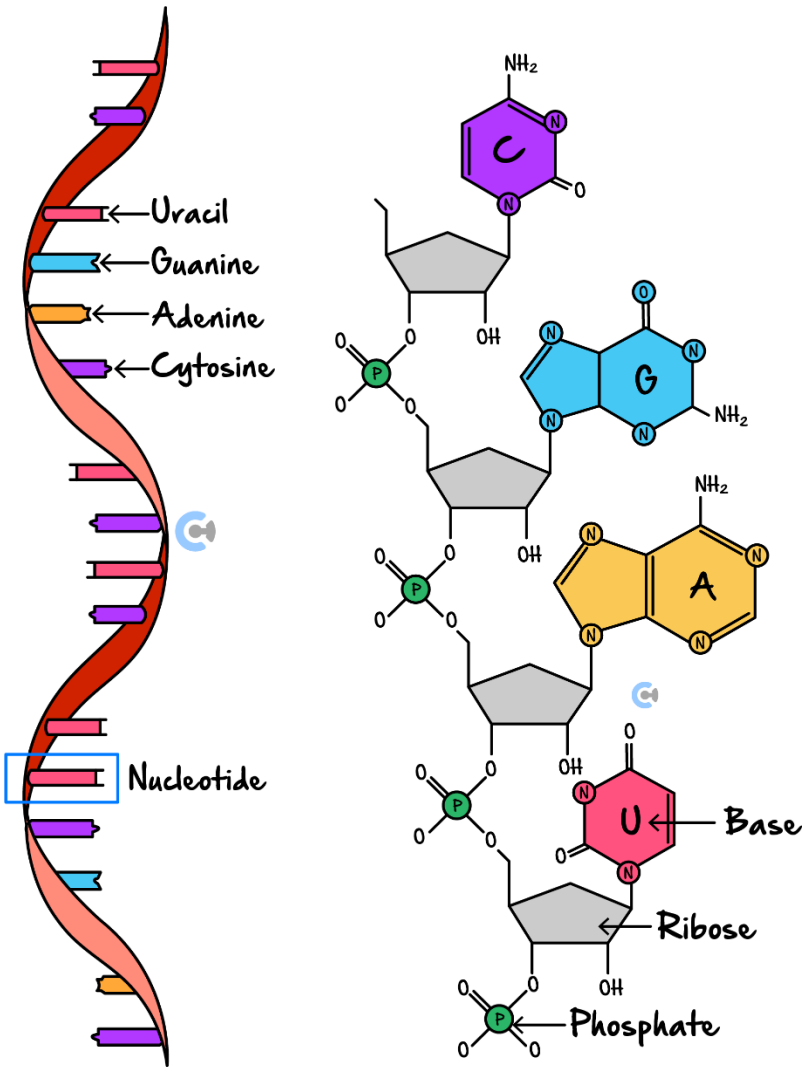
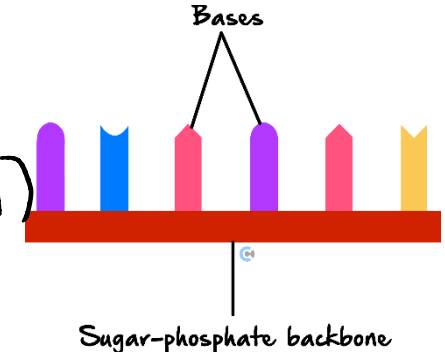
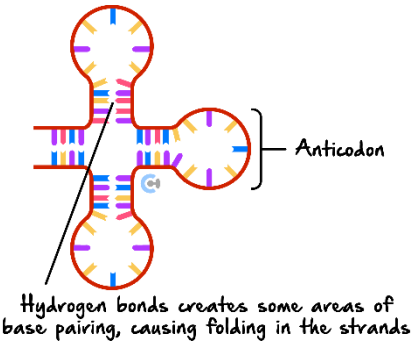
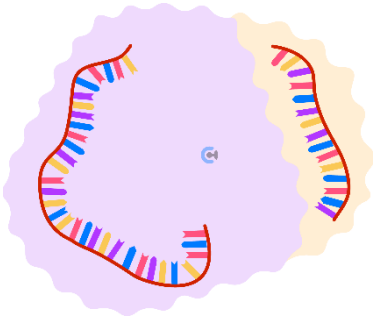
Sub-Section: RNA

RNA

- Ribonucleic acid has different forms including mRNA, tRNA, rRNA.
  - ribose Sugar
  - Phosphate Group
  - Nitrogenous Bases – Adenine, Uracil, Cytosine, Guanine
- Single-stranded
  - Multiple forms each with different functionalities.



RNA	Function	Representation
messenger RNA (mRNA)	carries a copy of genetic material from the nucleus (DNA) to the ribosome	
transfer RNA (tRNA)	carries specific amino acids in their correct order by matching with the mRNA, to the ribosome for protein synthesis	
ribosomal RNA (rRNA)	makes up the structure and function of the ribosome ↳ which makes protein	

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Discussion: What do you think is the purpose of mRNA?

☆ Conceptual

① Temporary + Expendable

② Smaller – only a gene NOT entire info

Discussion: What similarities and differences can you think of between DNA and RNA?

DNA	Similarities	RNA
Double Stranded Deoxyribose • Thymine Larger! Single more permanent Inherited nucleus	– both have information about protein – nucleotides • phosphate • ACG SP backbone – CP – phosphodiester bond	Single Stranded ribose • Uracil smaller multiple forms temporary made by you nucleus, cytosol

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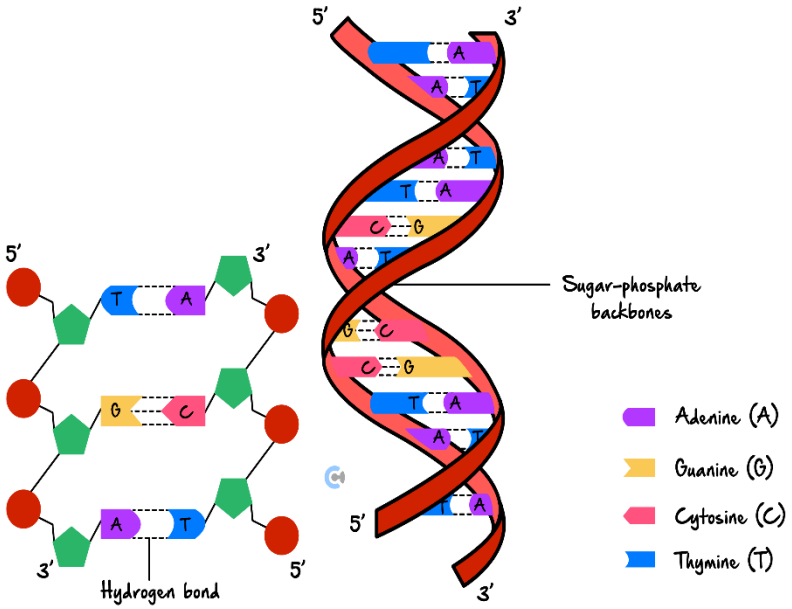
Key Takeaways

- Nucleic acids (DNA and RNA) encode instructions for protein synthesis.
- DNA is a double-stranded helix composed of nucleotides containing a deoxyribose sugar, phosphate group, and nitrogenous bases (adenine, thymine, cytosine, guanine).
- DNA strands are aligned anti-parallel.
- Complementary base pairing occurs in DNA with adenine pairing with thymine (A-T) and cytosine pairing with guanine (C-G).
- RNA exists in three main forms – mRNA (messenger RNA), rRNA (ribosomal RNA), and tRNA (transfer RNA) – each with distinct functions in protein synthesis.
- mRNA carries the genetic code transcribed from DNA to the ribosomes for translation.
- rRNA forms the structural and functional core of ribosomes, where proteins are synthesised.
- tRNA transports specific amino acids to the ribosome during protein synthesis, matching them to the mRNA codons via its anticodon.
- RNA is single-stranded, contains the sugar ribose, and uses uracil (U) instead of thymine (T).
- A nucleotide contains a phosphate group, a 5 carbon sugar, and a nitrogenous base
- DNA nucleotides include deoxyribose, whereas RNA nucleotides include ribose; both share phosphate groups but differ in one nitrogenous base (U in RNA, T in DNA).

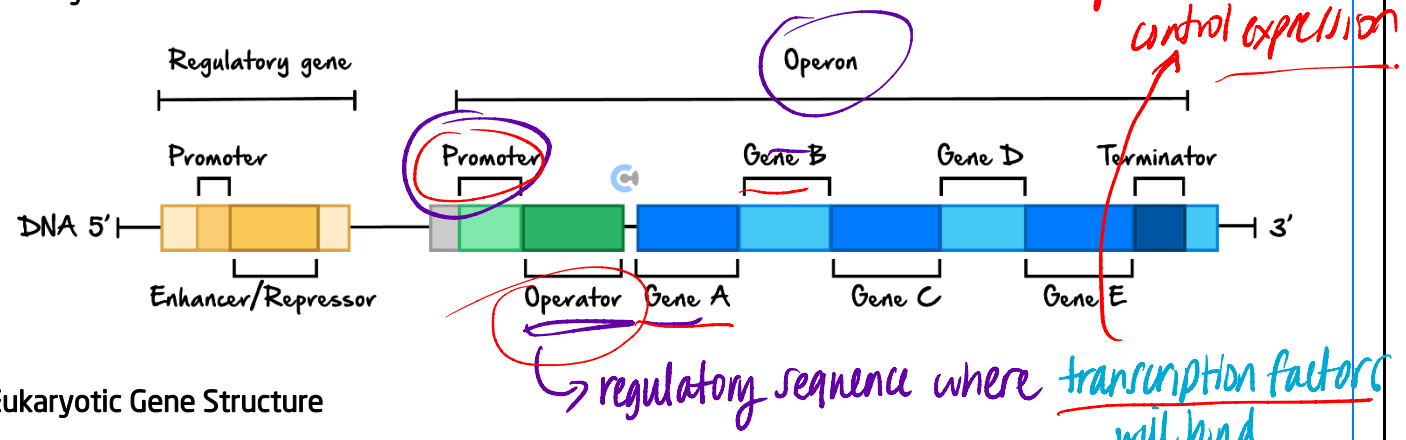


Section B: Genes and the Genetic Code

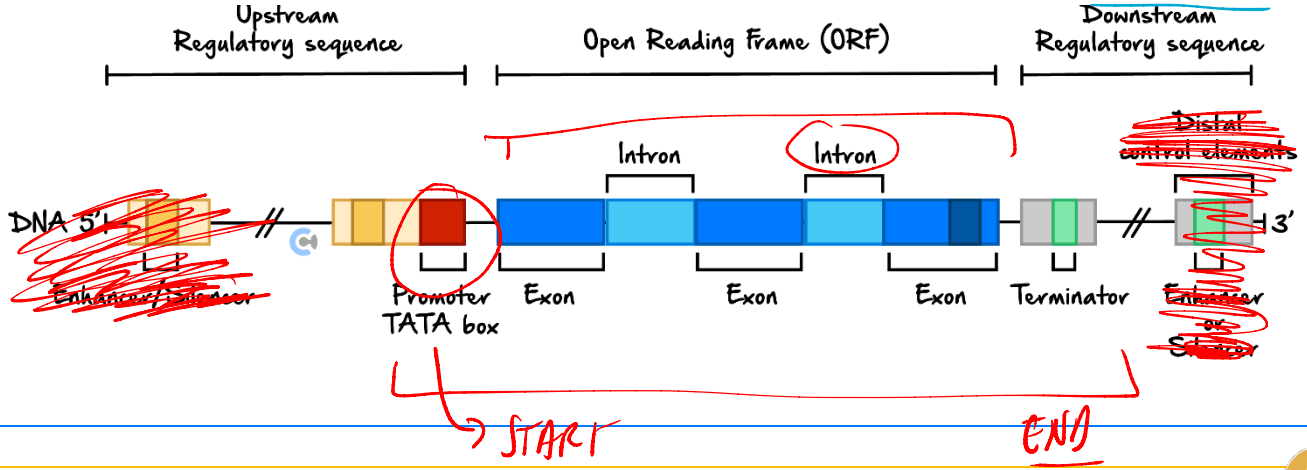
Genes

- We know that information in the cell is encoded in DNA, and this DNA is wrapped around proteins to make chromosomes.
  - In each chromosome, we can break them down to "genes" - a section of DNA that codes for a protein.
  - We have thousands of genes that correspond to our thousands of proteins.
  - The process by which a protein is made from a gene is known as "gene expression" and will be covered next lesson.

Prokaryotic Gene Structure



Eukaryotic Gene Structure



REMINDER: Genes are the instructions, and proteins are the final product! Compare it to the blueprint (DNA) and the building produced (protein).

NOTE: I am describing these as "components" but please be aware that this is still just a strand of DNA!

Characteristics of the Genetic Code

triplet – DNA
codon – mRNA anticodon – tRNA

Universal	ALL LIVING ORGANISMS HAVE DNA
Triplet	AGA — $4 \times 4 \times 4$ $4^3 = 64$ 3 nucleotides/bases code for 1 amino acid 64 combination → 20 amino acid
Degenerate ↳ redundancy	multiple codons code for the same amino acid

First Letter \ Second Letter	U	C	A	G	Third Letter
U	Phe {UUU, UUC} Leu {UUA, UUG}	Ser {UCU, UCC, UCA, UCG}	Tyr {UAU, UAC} **UAA Stop** **UAG Stop**	Cys {UGU, UGC} **UGA Stop** UGG Trp	U C A G
C	Leu {CUU, CUC, CUA, CUG}	Pro {CCU, CCC, CCA, CCG}	His {CAU, CAC} Gln {CAA, CAG}	Arg {CGU, CGC, CGA, CGG}	U C A G
A	Ile {AUU, AUC, AUA} ~~Met AUG~~	Thr {ACU, ACC, ACA, ACG}	Asn {AAU, AAC} Lys {AAA, AAG}	Ser {AGU, AGC} Arg {AGA, AGG}	U C A G
G	Val {GUU, GUC, GUA, GUG}	Ala {GCU, GCC, GCA, GCG}	Asp {GAU, GAC} Glu {GAA, GAG}	Gly {GGU, GGC, GGA, GGG}	U C A G

TIP: In the exam, these features will almost certainly be tested, so make sure to memorise their definitions.

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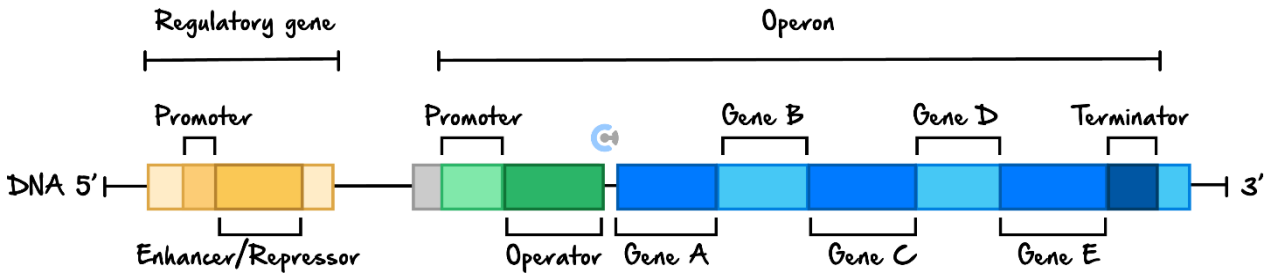
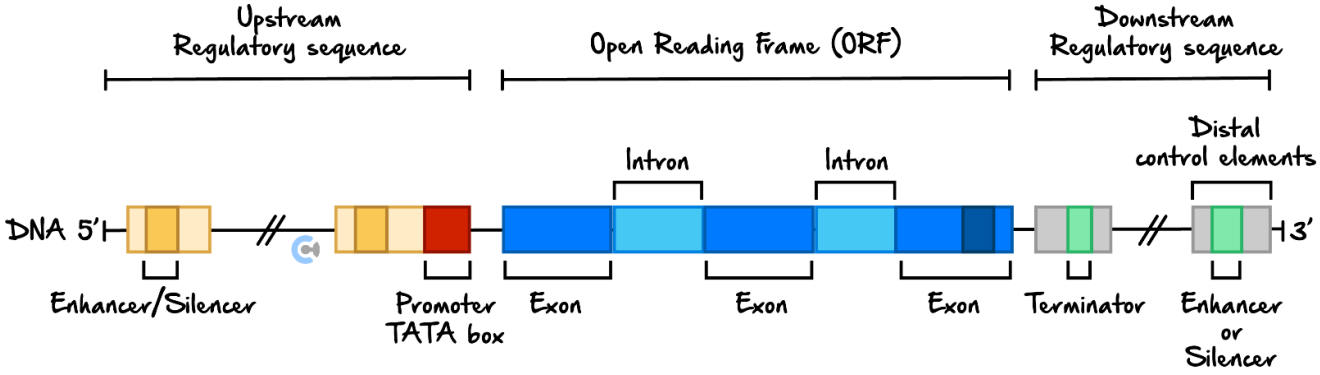
Key Takeaways

Prokaryotic Gene Structure



Eukaryotic Gene Structure



Component	Definition
Exons	Regions of DNA that are expressed as a protein.
Introns	Regions of DNA that aren't expressed in the final protein.
Promoter	A sequence of DNA that is responsible for initiating gene expression.
Operator	Binding site for a transcription factor (protein that regulates gene expression).
Terminator	Where transcription of the gene ends.

Contour Check

Learning Objective: [1.2.1] – Identify and compare the characteristic features of the structures of nucleic acids and their monomers, including DNA, mRNA, tRNA and rRNA, including base pairing

Study Design

Nucleic acids as information molecules that encode instructions for the synthesis of proteins: the structure of DNA, the three main forms of RNA (mRNA, rRNA and tRNA) and a comparison of their respective nucleotides.

Key Takeaways

- ☐ Nucleic acids (DNA and RNA) encode instructions for _____.
- ☐ DNA is a _____ helix composed of nucleotides containing a deoxyribose sugar, phosphate group, and nitrogenous bases (_____).
- ☐ Complementary base pairing occurs in DNA with adenine pairing with _____ and cytosine pairing with _____.
- ☐ RNA exists in three main forms–mRNA (_____ RNA), rRNA (_____ RNA), and tRNA (_____ RNA) – each with distinct functions in protein synthesis.
- ☐ mRNA _____ transcribed from DNA to the ribosomes for translation.
- ☐ rRNA forms the _____, where proteins are synthesised.
- ☐ tRNA transports _____, matching them to the mRNA codons via its _____.
- ☐ Unlike DNA, RNA is _____, contains the sugar _____, and uses uracil (U) instead of thymine (T).

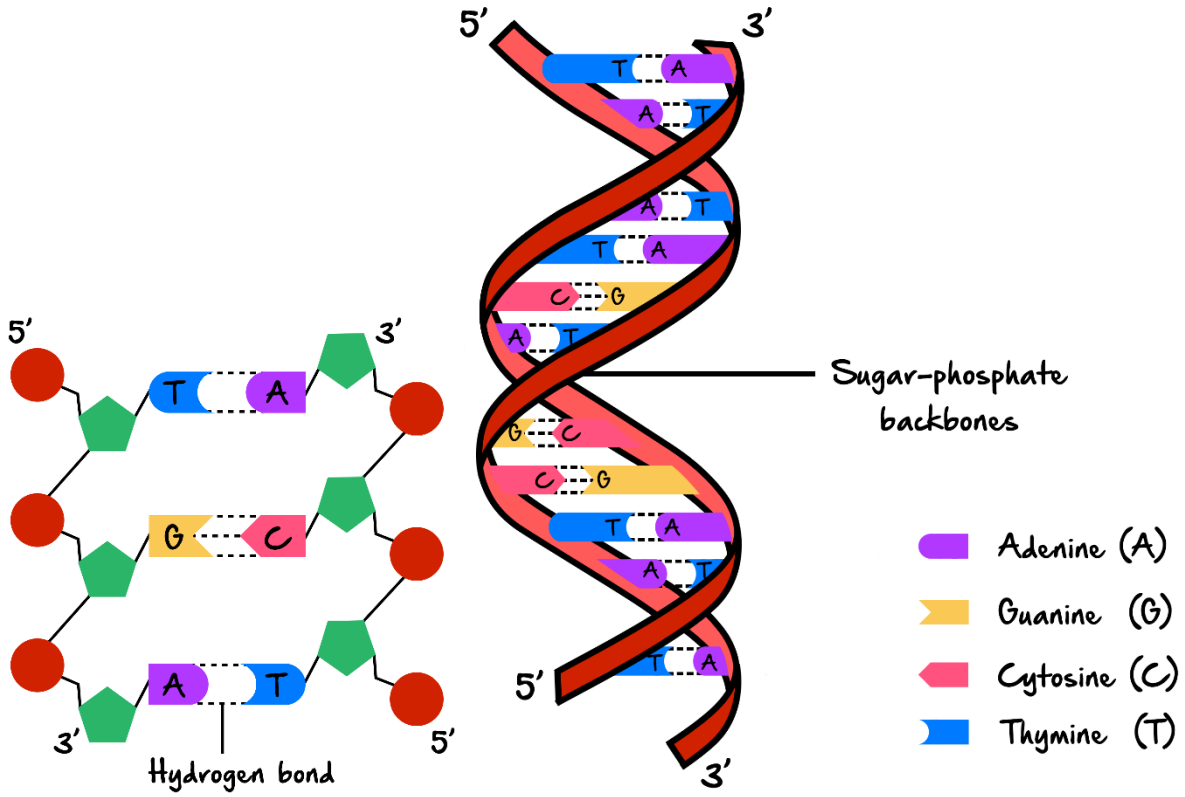
Learning Objective: [1.1.2] – Identify and describe the structure of a nucleotide in DNA and RNA

Study Design

Nucleic acids as information molecules that encode instructions for the synthesis of proteins: the structure of DNA, the three main forms of RNA (mRNA, rRNA, and tRNA), and a comparison of their respective nucleotides.

Key Takeaways

- A nucleotide contains a _____, _____, and _____ – label these on the diagram below!
- DNA nucleotides include _____, whereas RNA nucleotides include _____; both share phosphate groups but differ in one nitrogenous base (_____ in RNA, _____ in DNA).



Learning Objective: [1.2.3] – Define the key components of a gene, including a comparison between the structure of genes in eukaryotes and prokaryotes

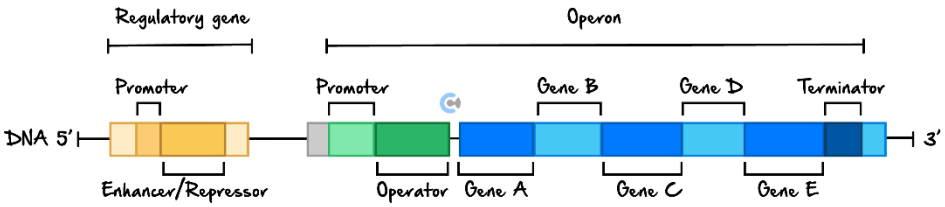
Study Design

The structure of genes: exons, introns and promoter and operator regions.

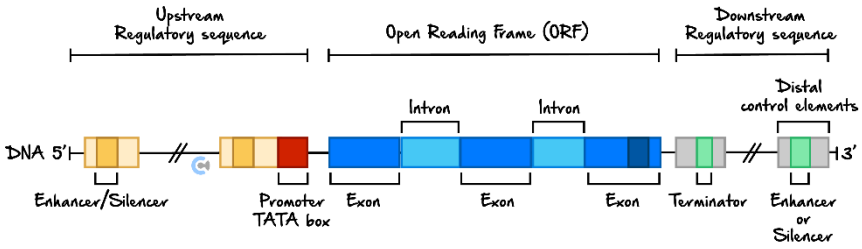
Key Takeaways

Component	Definition
Exons	CODING REGIONS sequence of DNA that WILL be expressed in final protein
Introns	NON CODING REGION sequence of DNA that WON'T be exp. in final protein
Promoter	START/STOP sequence ON/OFF SWITCH sequence of DNA where transcription of a gene begins
Operator	
Terminator	STOP sequence of DNA where transcription STOPS

Prokaryotic Gene Structure



Eukaryotic Gene Structure



Learning Objective: [1.2.4] – Identify and practically apply the characteristics of the genetic code - universal, unambiguous, degenerate, triplet – to real-life examples

Study Design

The genetic code as a universal triplet code that is degenerate.

Key Takeaways

Component	Definition
Exons	
Introns	
Promoter	
Operator	
Terminator	

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