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

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?

Discussion: The Purpose of Nucleic Acids

Head Tutor's Comment:

- Start off by getting students to think about this concept – usually, no one has ever put any thought into thinking about how this stuff actually works – will help in making sure everyone is at a "blank slate" in order to then go about teaching the process of how the instructions – DNA – are actually followed in order to achieve a function.
- Get students to think about the pathways of information becoming the functional components of the cell.

Nucleic Acids

- **Function -** __ genetic instructions __ 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?

  They are composed of small repeating subunits called nucleotides.
- 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.

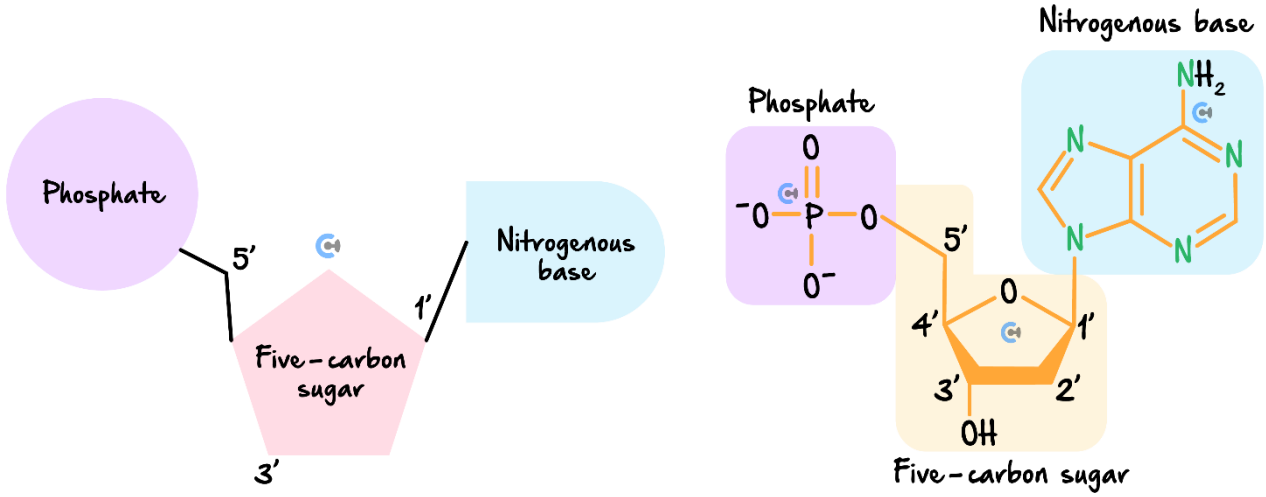
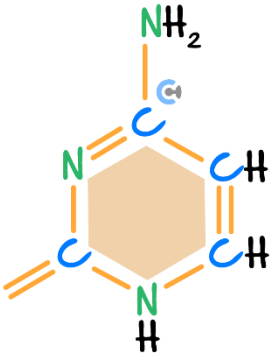


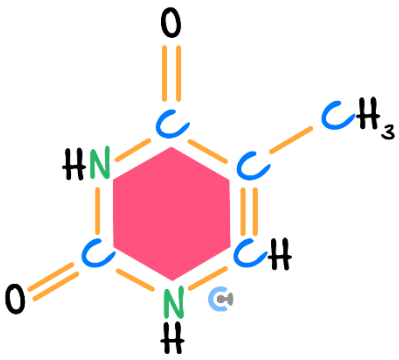
Figure 1 (a) The basic structure of a nucleotide and (b) the chemical structure of a DNA nucleotide.

- 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.

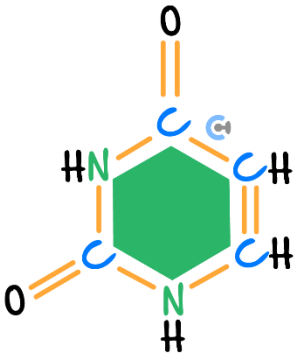
Pyrimidines



Cytosine (C)

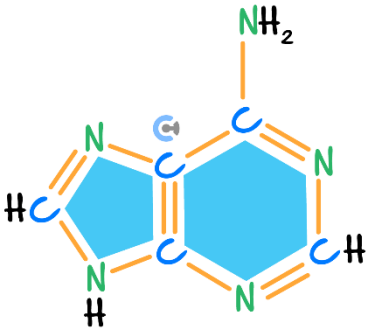


Thymine (T, in DNA)

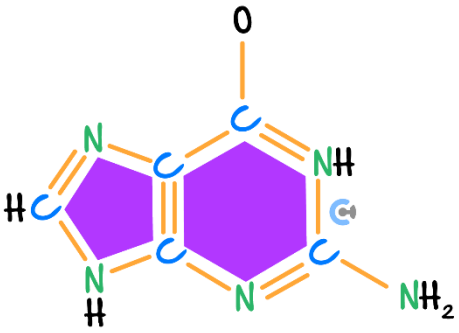


Uracil (U, in RNA)

Purines



Adenine (A)



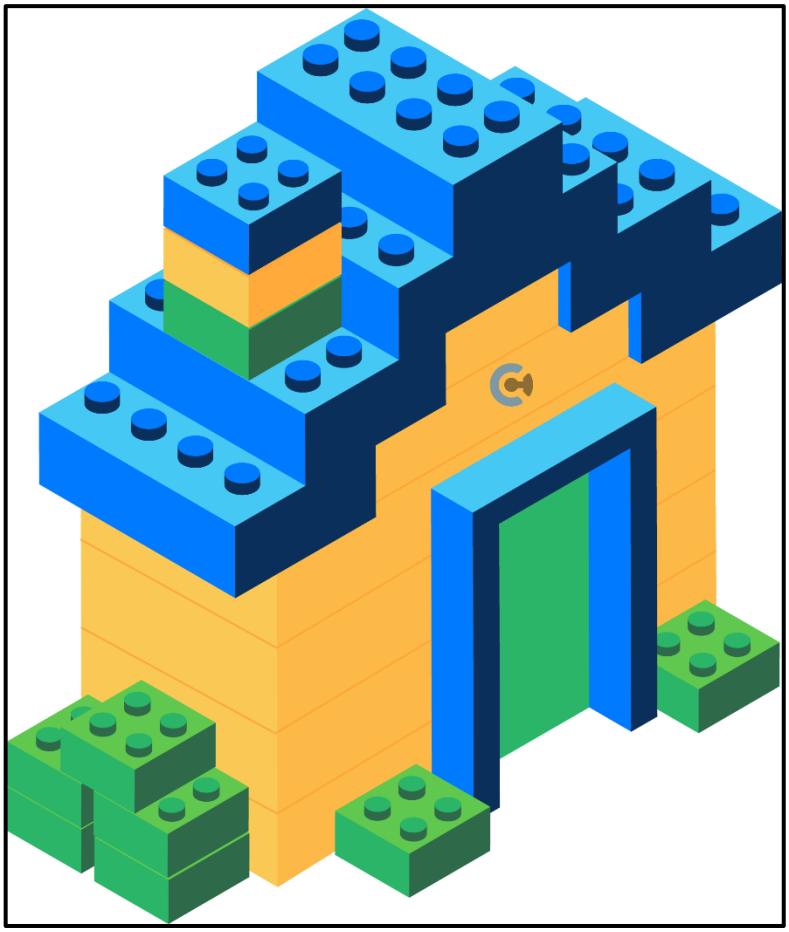
Guanine (G)

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

They must have different nucleotides that make them up!

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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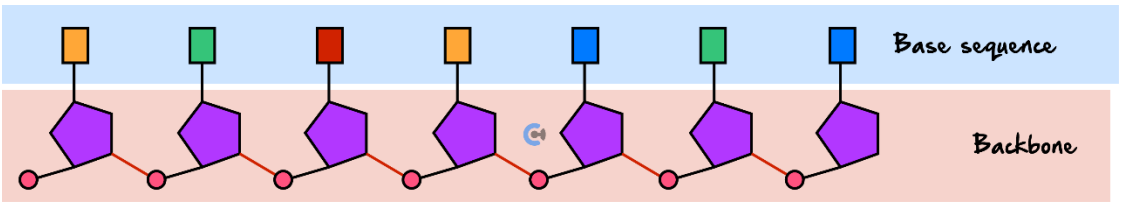
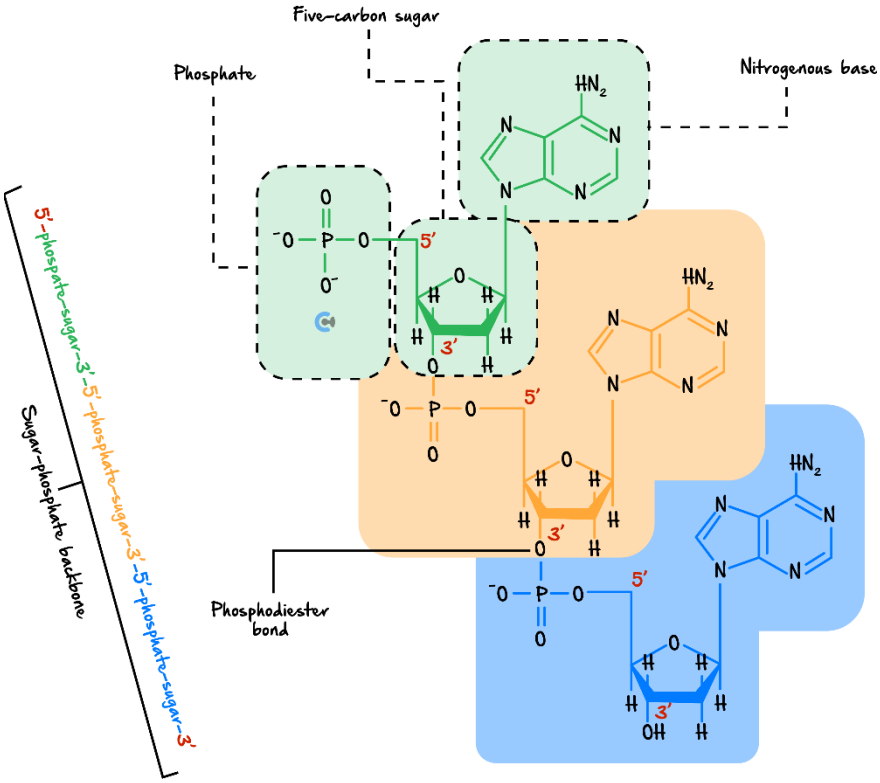
Sub-Section: Condensation Polymerisation

How can we put those bricks together?

Condensation Polymerisation

- Reaction between nucleotides that allows the nucleic acid chain to build up.
  - Condensation – Reaction produces water.
  - Polymerisation – Reaction results in the formation of a polymer.
- The nucleotides are linked together by strong covalent bonds - specifically, these are known as phosphodiester bonds.





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

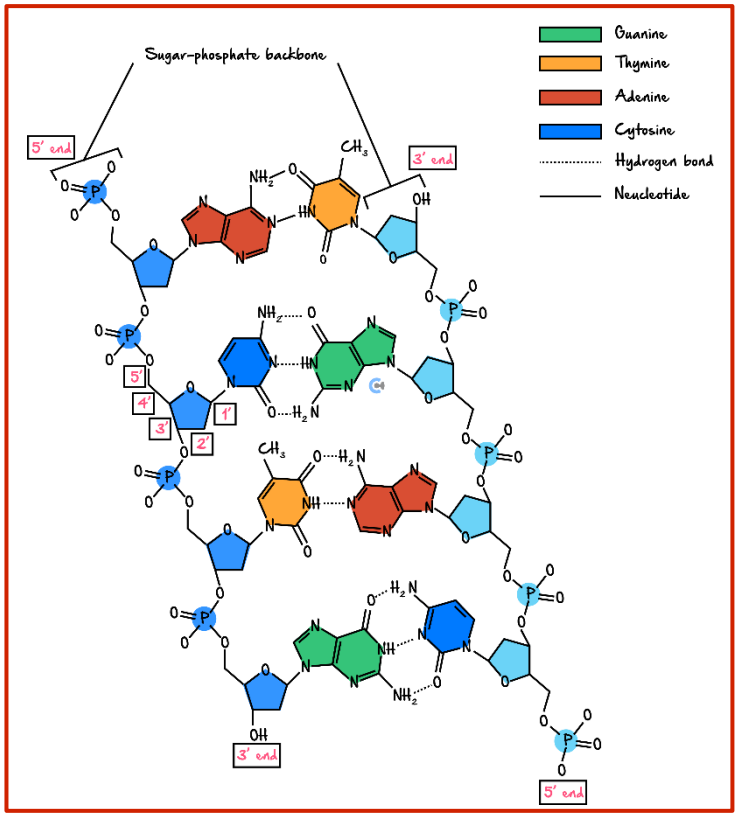
- What forms the backbone of the DNA?
  - Sugar Phosphate Backbone
- Numbering of the Carbons? Why is this important?
  - The carbons which are important in attachment.
  - 1 - nitrogenous base
  - 3 – phosphate group of the other nucleotide connects to the sugar group.
  - 5 - the phosphate group of the nucleotide itself attached to the sugar.

Looking at this diagram – it is clear that the numbering is very important as it determines the orientation of the molecule.

5' end is the one with the phosphate.
3' end is the one with the sugar.

DNA is synthesised by adding nucleotides to the 3' end.

- Annotate this diagram of a DNA molecule!



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

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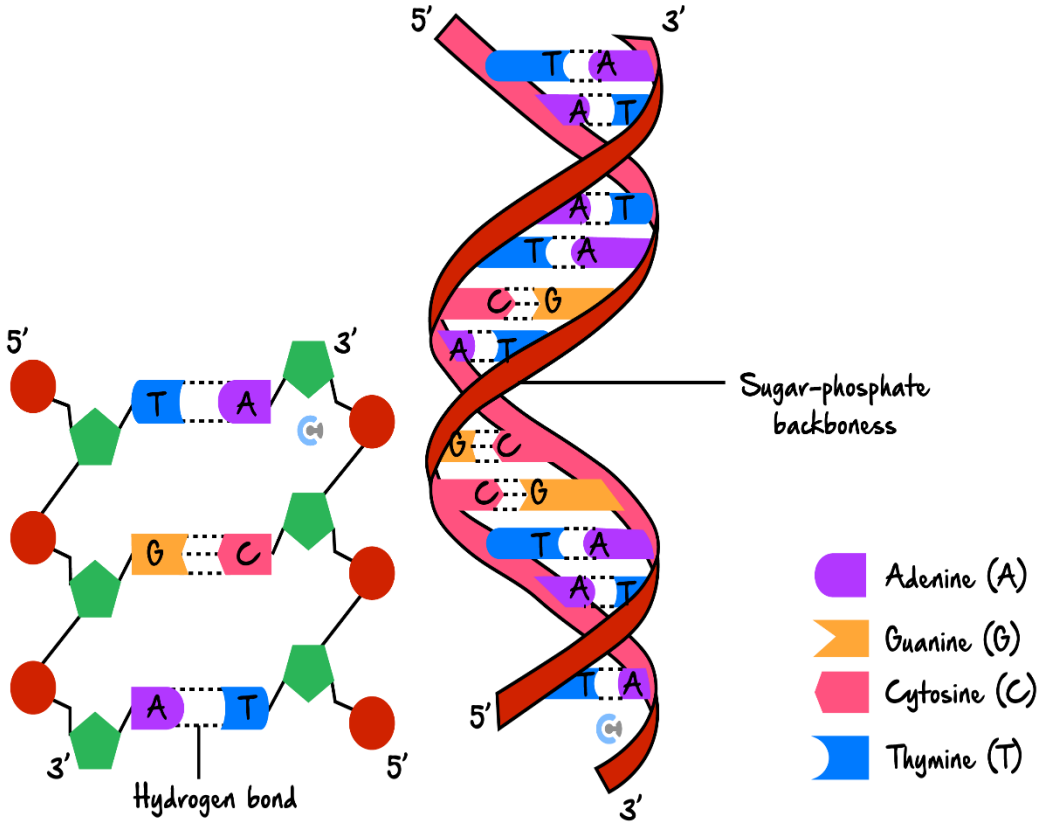
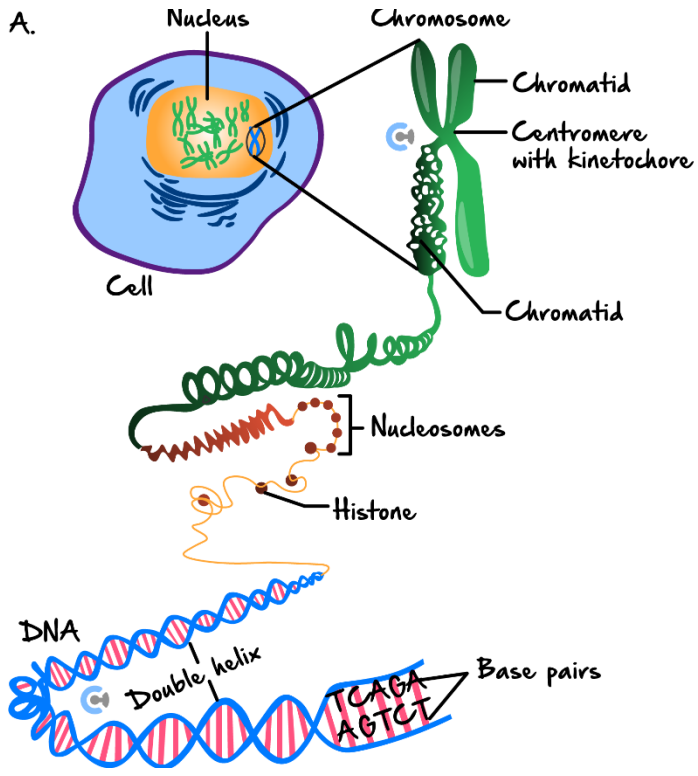
Sub-Section: DNA

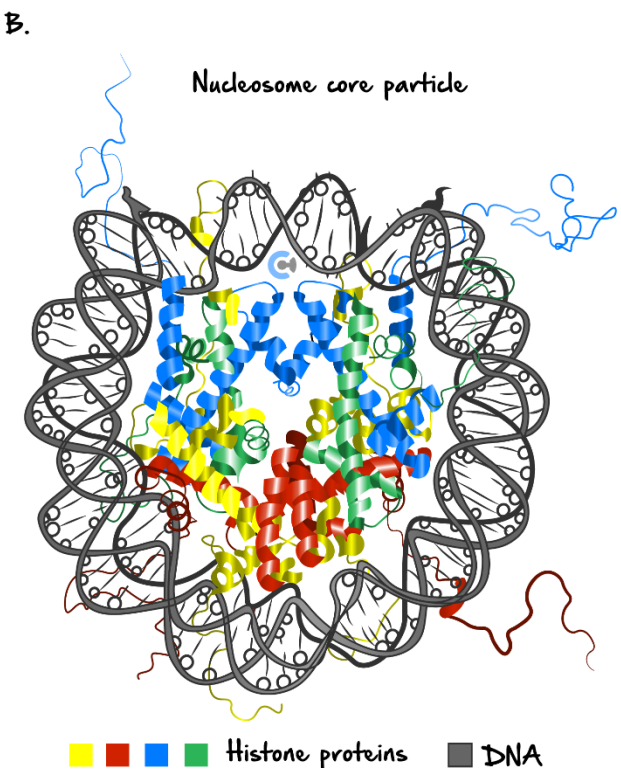
Exploration: DNA

- 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, Cytosine, Guanine ___
- Double-stranded Double Helix Structure.
- Joined together by complementary base pairing - hydrogen bonding between nitrogenous bases.
  - ___ Anti-parallel arrangement ___



Extension: How is DNA organised in a cell?





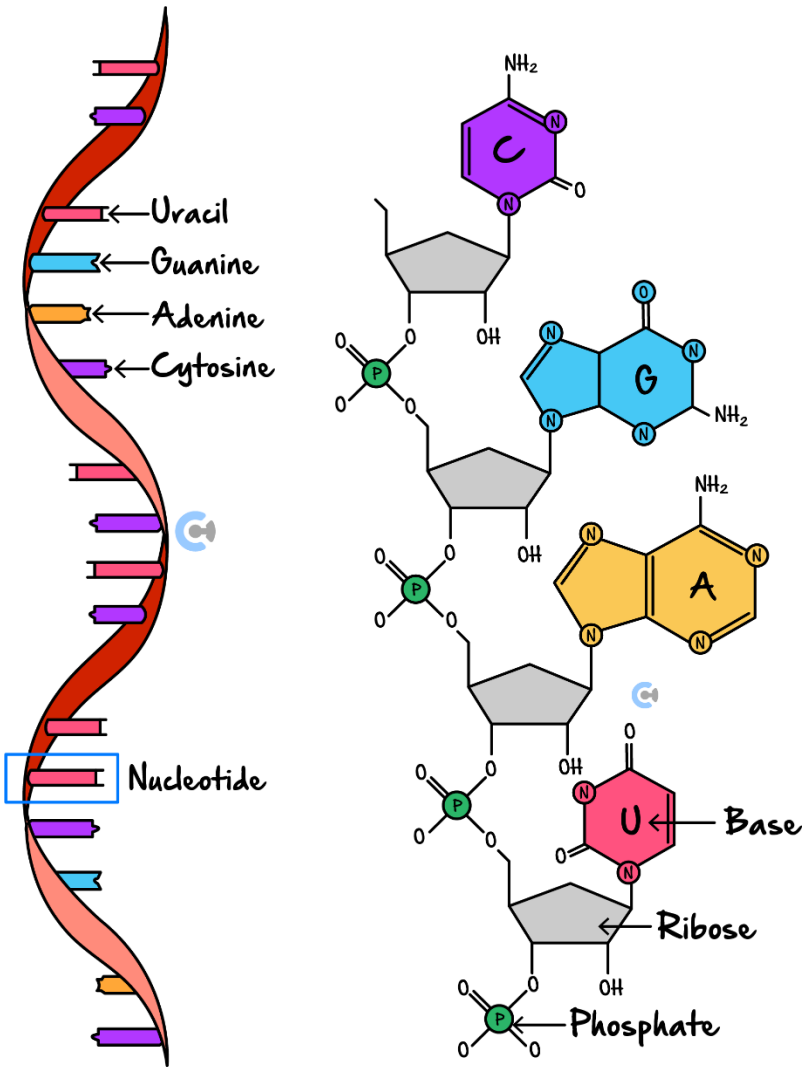
Head Tutor's Comment: Relate this to gene expression (methylation and acetylation).

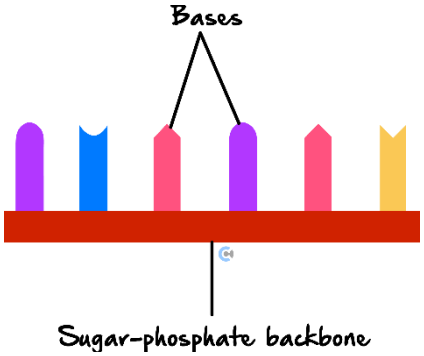
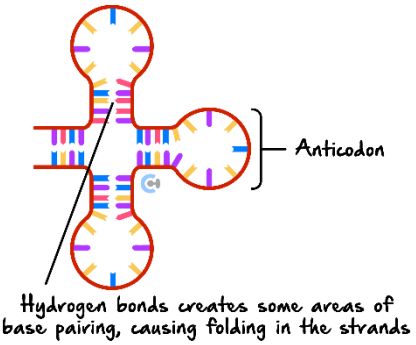
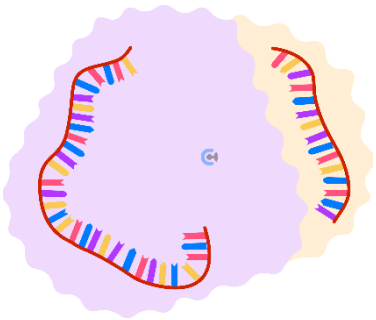
Space for Personal Notes

Sub-Section: RNA

RNA

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



RNA	Function	Representation
messenger RNA (mRNA)	Carrying a copy of the genetic instructions (DNA) from the nucleus to the ribosome in order to make a protein.	
transfer RNA (tRNA)	Carries specific amino acids to the ribosome after "matching" with specific nucleotide sequences in mRNA.	
Ribosomal RNA (rRNA)	Forms the structure of the ribosome.	

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

The purpose of mRNA is to carry the genetic code from DNA in the nucleus to ribosomes in the cytoplasm, where it directs the synthesis of specific proteins.

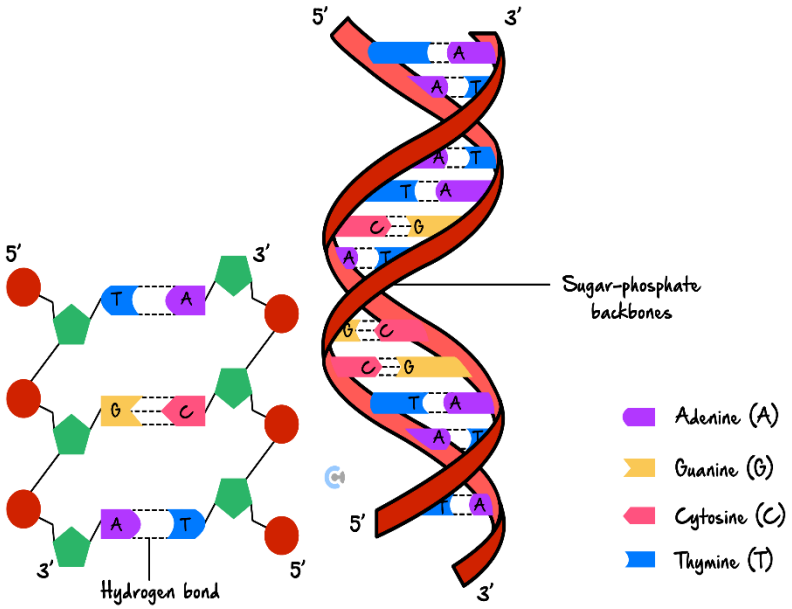
Discussion: What similarities and differences can you think of between DNA and RNA?

DNA	Similarities	RNA
➢ Nucleotides contain a deoxyribose sugar. ➢ Contains the base thymine(T). ➢ Double stranded. ➢ Inherited/long-term storage.	➢ Nucleotides follow the same basic structure (phosphate group, five-carbon sugar, nitrogen bases). ➢ Contain the nucleotides adenine, guanine, and cytosine. ➢ Contain a sugar phosphate backbone. ➢ Follow the complementary base pairing rule: C pairs with G, A pairs with T (or U).	➢ Nucleotides contain a ribose sugar. ➢ Contains the base uracil(U). ➢ Single stranded. ➢ Temporary molecules.

Space for Personal Notes

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).

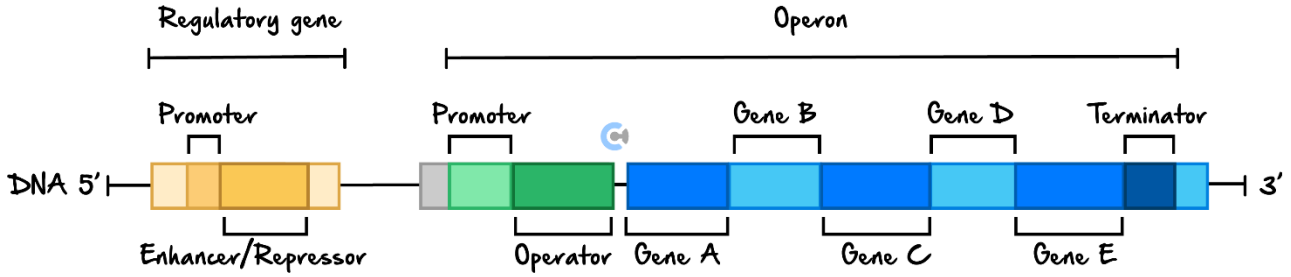


Section B: Genes and the Genetic Code

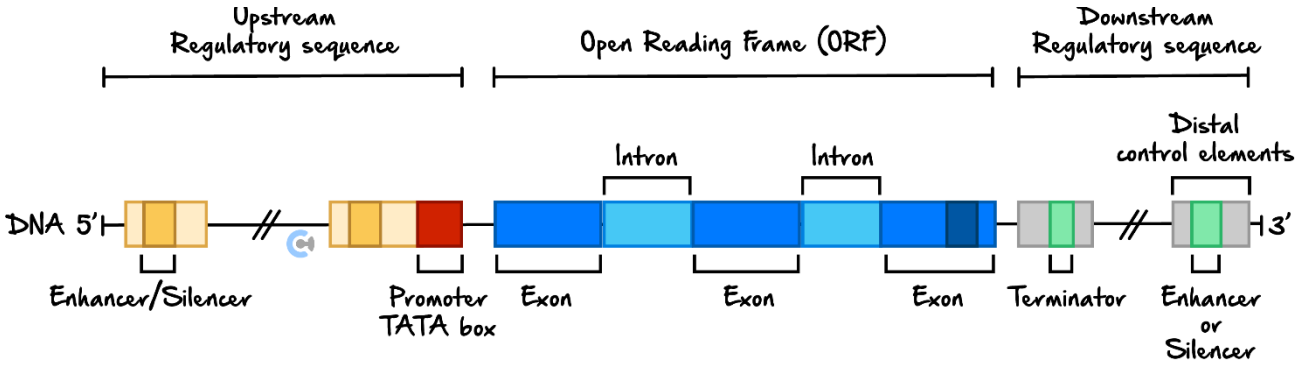
Genes

- 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" - ___segments of DNA that code to make a specific 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



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

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!

Space for Personal Notes

Characteristics of the Genetic Code

Universal	All living organisms use DNA or the language of DNA as the fundamental basis for all their operations.
Triplet	3 bases of DNA (or nucleotides) code for a single amino acid in a protein.
Degenerate	More than 1 triplet/codon codes for a single amino acid.

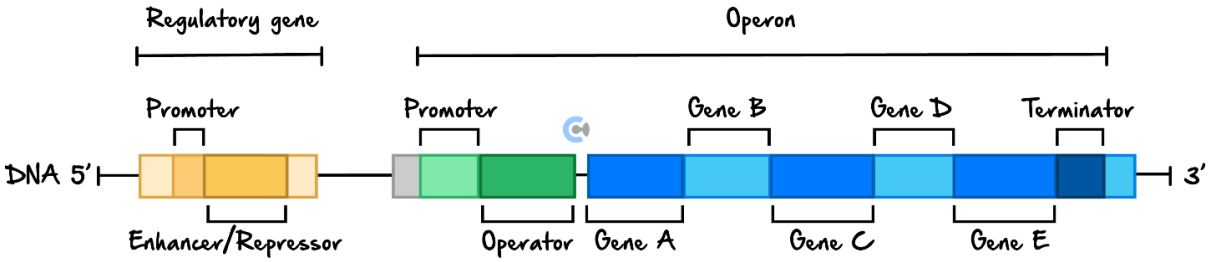
Second Letter

First 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

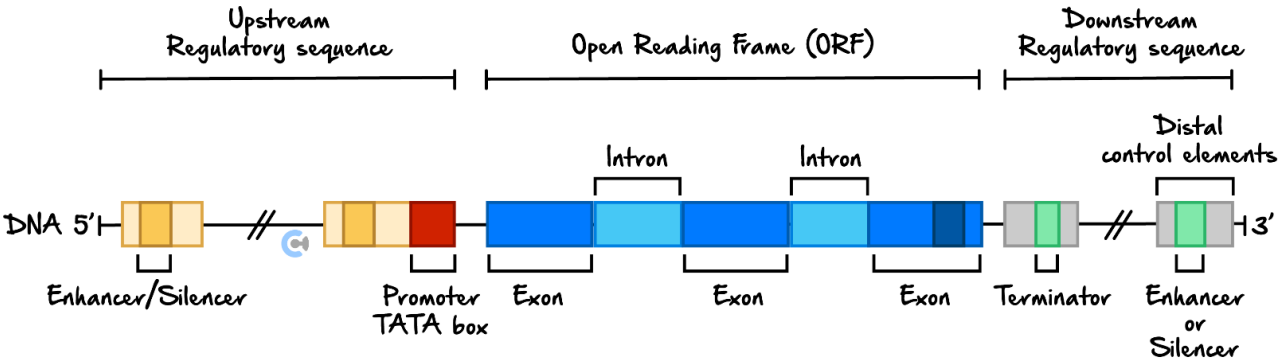
TIP: In the exam, these features will almost certainly be tested, so make sure to memorise their definitions.

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 ___protein synthesis___.
- DNA is a __double-stranded__ helix composed of nucleotides containing a deoxyribose sugar, phosphate group, and nitrogenous bases (_____adenine, thymine, cytosine, guanine_____).
- 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_.
- Unlike DNA, RNA is _single-stranded_, contains the sugar __ribose__, and uses uracil (U) instead of thymine (T).

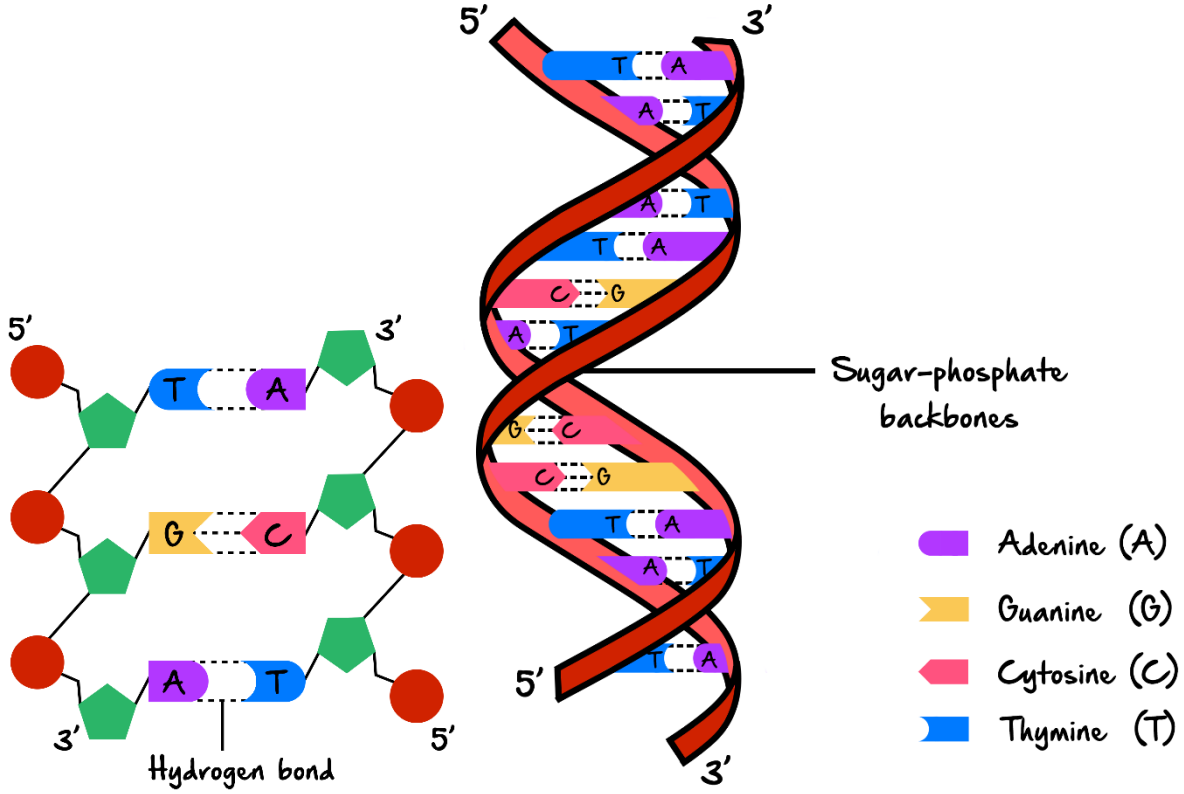
Learning Objective: [1.1.2] – Identify and describe the structure of a nucleotide in DNA and RNA

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 phosphate group, a 5 carbon sugar, and a nitrogenous base – label these on the diagram below!
- 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).



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

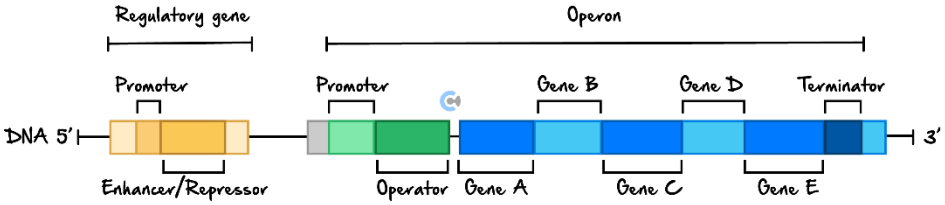
Study Design

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

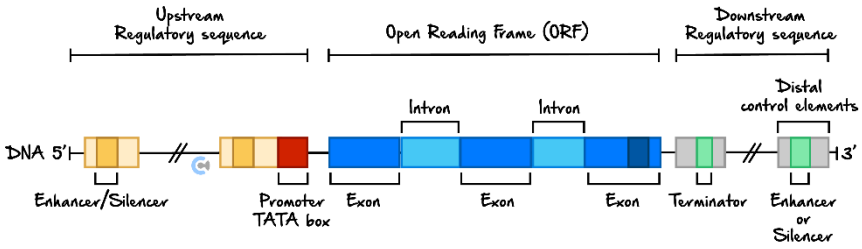
Key Takeaways

Component	Definition
Exons	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

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

Characteristics of the Genetic Code

Universal	All living organisms use DNA or the language of DNA as the fundamental basis for all their operations.
Triplet	3 bases of DNA (or nucleotides) code for a single amino acid in a protein.
Degenerate	More than 1 triplet/codon codes for a single amino acid.

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