Year 12 HL

IB BIOLOGY

2.7 DNA Replication, Transcription and Translation

7.1 DNA Structure and Replication

7.2 Transcription and Gene Expression

7.3 Translation

Name:

Teacher:

2.7 DNA Replication, Transcription and Translation

Understandings

- The replication of DNA is semi-conservative and depends on complementary base pairing.
- Helicase unwinds the double helix and separates the two strands by breaking hydrogen bonds.
- DNA polymerase links nucleotides together to form a new strand, using the pre-existing strand as a template.
- Transcription is the synthesis of mRNA copied from the DNA base sequences by RNA polymerase.
- Translation is the synthesis of polypeptides on ribosomes.
- The amino acid sequence of polypeptides is determined by mRNA according to the genetic code.
- Codons of three bases on mRNA correspond to one amino acid in a polypeptide.
- Translation depends on complementary base pairing between codons on mRNA and anticodons on tRNA.

Applications and Skills

- Application: Use of Taq DNA polymerase to produce multiple copies of DNA rapidly by the polymerase chain reaction (PCR).
- Application: Production of human insulin in bacteria as an example of the universality of the genetic code allowing gene transfer between species.
- Skill: Use a table of the genetic code to deduce which codon(s) corresponds to which amino acid.
- Skill: Analysis of Meselson and Stahl's results to obtain support for the theory of semi-conservative replication of DNA.
- Skill: Use a table of mRNA codons and their corresponding amino acids to deduce the sequence of amino acids coded by a short mRNA strand of known base sequence.
- Skill: Deducing the DNA base sequence for the mRNA strand.

7.1 DNA Structure and Replication (HL)

Essential idea: *The structure of DNA is ideally suited to its function.*

Understandings:

- Nucleosomes help to supercoil the DNA.
- DNA structure suggested a mechanism for DNA replication.
- DNA polymerases can only add nucleotides to the 3' end of a primer.
- DNA replication is continuous on the leading strand and discontinuous on the lagging strand.
- DNA replication is carried out by a complex system of enzymes.
- Some regions of DNA do not code for proteins but have other important functions.

Applications and skills:

- Application: Rosalind Franklin's and Maurice Wilkins' investigation of DNA structure by X-ray diffraction.
- Application: Use of nucleotides containing dideoxyribonucleic acid to stop DNA replication in preparation of samples for base sequencing.
- Application: Tandem repeats are used in DNA profiling.
- Skill: Analysis of results of the Hershey and Chase experiment providing evidence that DNA is the genetic material.
- Skill: Utilization of molecular visualization software to analyse the association between protein and DNA within a nucleosome.

Guidance:

- Details of DNA replication differ between prokaryotes and eukaryotes. Only the prokaryotic system is expected.
- The proteins and enzymes involved in DNA replication should include helicase, DNA gyrase, single strand binding proteins, DNA primase and DNA polymerases I and III.
- The regions of DNA that do not code for proteins should be limited to regulators of gene expression, introns, telomeres and genes for tRNAs.

7.2 Transcription & Gene Expression (HL)

Essential idea: *Information stored as a code in DNA is copied onto mRNA.*

Understandings:

- Transcription occurs in a 5’ to 3’ direction (RNA polymerase adds the 5’ end of the free RNA nucleotide to the 3’ end of the growing mRNA molecule).
- Nucleosomes help to regulate transcription in eukaryotes.
- Eukaryotic cells modify mRNA after transcription.
- Splicing of mRNA increases the number of different proteins an organism can produce.
- Gene expression is regulated by proteins that bind to specific base sequences in DNA.
- The environment of a cell and of an organism has an impact on gene expression.

Application and skills:

- Application: The promoter as an example of non-coding DNA with a function.
- Skill: Analysis of changes in the DNA methylation patterns.

7.3 Translation (HL)

Essential idea: *Information transferred from DNA to mRNA is translated into an amino acid sequence.*

Understandings:

- Initiation of translation involves assembly of the components that carry out the process.
- Synthesis of the polypeptide involves a repeated cycle of events.
- Disassembly of the components follows termination of translation (examples of start and stop codons are not required).
- Free ribosomes synthesize proteins for use primarily within the cell.
- Bound ribosomes synthesize proteins primarily for secretion or for use in lysosomes.
- Translation can occur immediately after transcription in prokaryotes due to the absence of a nuclear membrane.
- The sequence and number of amino acids in the polypeptide is the primary structure.
- The secondary structure is the formation of alpha helices and beta pleated sheets stabilized by hydrogen bonding.
- The tertiary structure is the further folding of the polypeptide stabilized by interactions between R groups (polar and non-polar amino acids are relevant to the bonds formed between R groups.)
- The quaternary structure exists in proteins with more than one polypeptide chain. (Quaternary structure may involve the binding of a prosthetic group to form a conjugated protein).

Guidance:

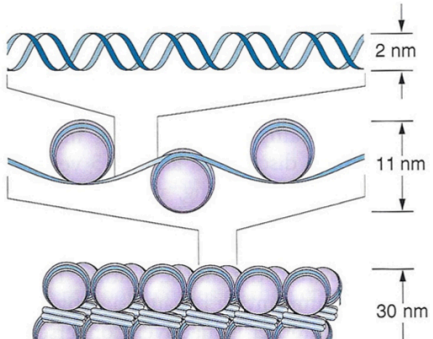
- Names of the tRNA binding sites are expected as well as their roles.

Application and skills:

- Application: tRNA-activating enzymes illustrate enzyme–substrate specificity and the role of phosphorylation.
- Skill: Identification of polysomes in electron micrographs of prokaryotes and eukaryotes.
- Skill: The use of molecular visualization software to analyse the structure of eukaryotic ribosomes and a tRNA molecule.

DNA Supercoiling

Define **supercoiling:**



List some reasons why supercoiling needs to occur:

Watch the video here:
https://www.dnalc.org/resources/3d/08-how-dna-is-packaged-advanced.html

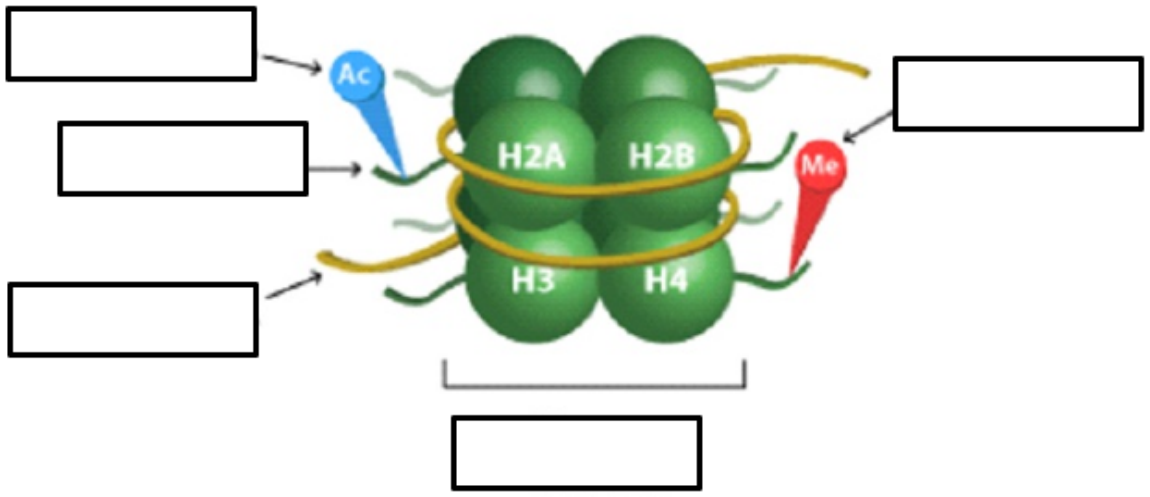
Answer these questions:

How many histone proteins make up the core of the nucleosome?

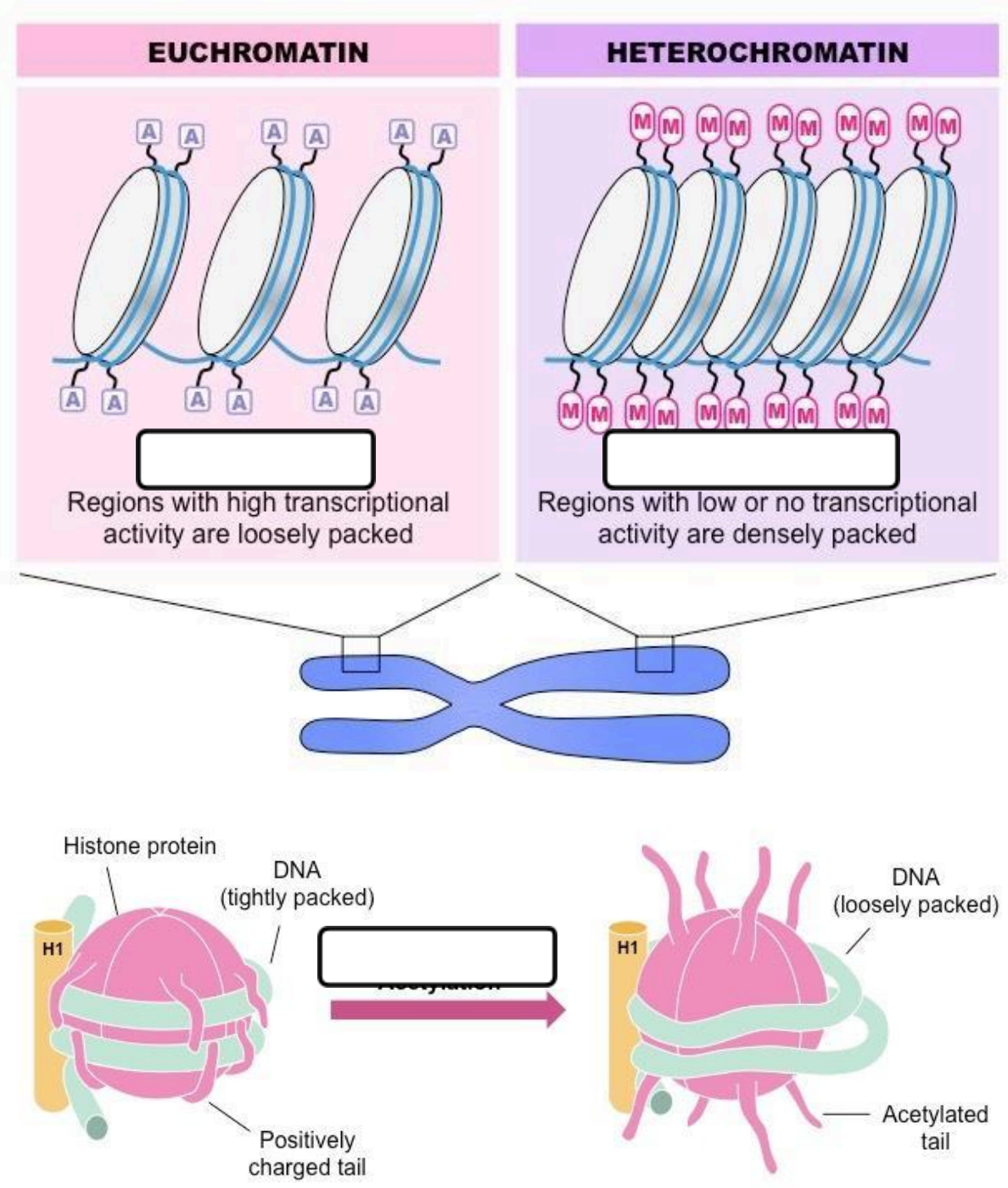
How many different types of histone proteins make up the core?

How many nucleotide bases are found in the DNA which wraps around the histone protein core?

What is the role of the ninth histone protein?



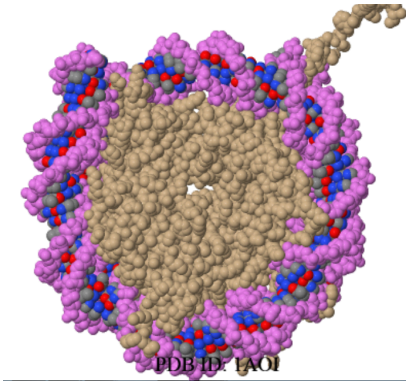
In the space below, draw and label a nucleosome:


EUCHROMATIN
HETEROCHROMATIN
A
M
Regions with high transcriptional activity are loosely packed
Regions with low or no transcriptional activity are densely packed
Histone protein
DNA (tightly packed)
H1
Positively charged tail
DNA (loosely packed)
Acetylated tail

Skill: Utilization of molecular visualization software to analyse the association between protein and DNA within a nucleosome.

Go to:
http://earth.callutheran.edu/Academic_Programs/Departments/BioDev/omm/jsmol/nucleosome/nucleosome.html

Use the animation to look at the nucleosome structure and make your own notes.



DNA Replication

DNA replication is a way of copying one DNA strand to make two new molecules with the same base sequence. We refer to DNA replication as being **semi-conservative** as each new molecule consists of one new strand and one old strand that is *conserved* from the original parent DNA molecule.

Alfred _____ and **Martha** _____ wanted to solve this problem by finding out if protein or DNA was the genetic material of viruses.
Hershey and Chase chose to study the _____, which infects the ***E. Coli*** bacterium (image of both above), because of its very simple structure consisting of just:

- _____ (capsid)
- _____ inside the coat

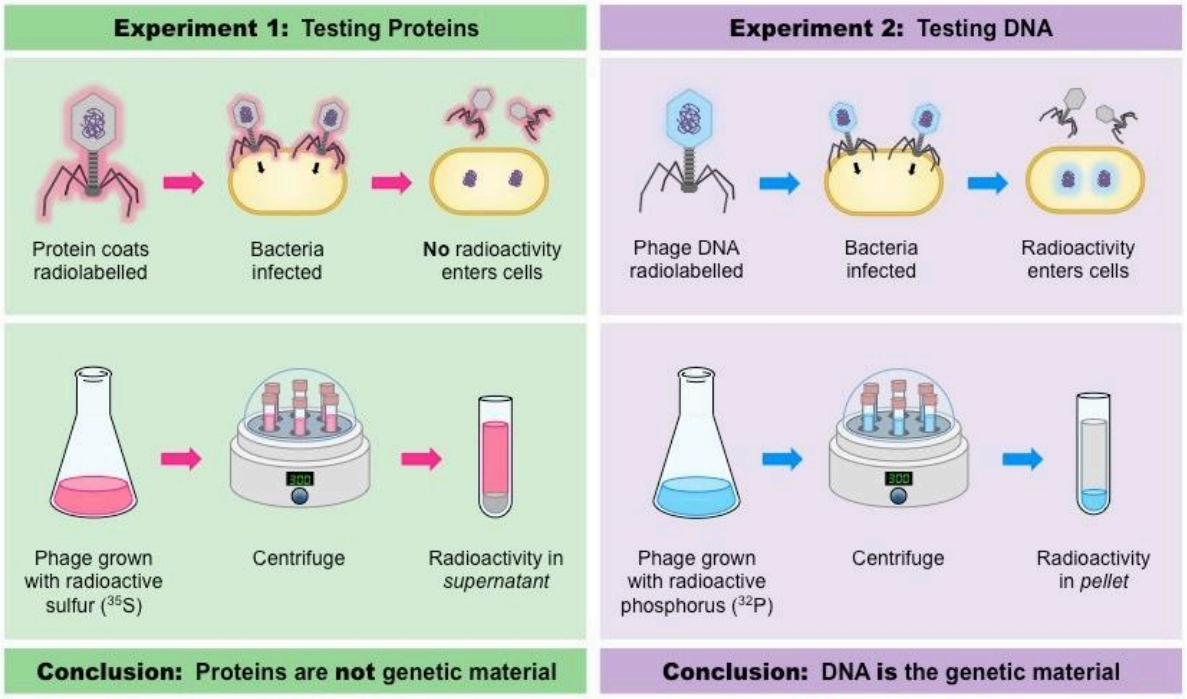
- Viruses **inject** their _____ into cells.
- The non-genetic part of the virus remains_____ the cell.

Amino acids containing _____ **isotopes** were used to **label** the virus:

- S_____ **(^{35}S)** for the **Protein** coat (capsid) Disulphide bridges
- P_____**(^{32}P)** for the **DNA** Phosphate group

- At the end of the experiment a **centrifuge** was used to separate them:
- the smaller **virus** remained in the **supernatant** (liquid)
- the _____ formed a **pellet**

- **Sulfur (^{35}S)**_____ remained in **supernatant**
- **Phosphorus (^{32}P)**_____ was found in the **pellet**
- Hershey and Chase **deduced** that **DNA** therefore was the _____ used by viruses because **DNA** (labelled by ^{32}P) was being _____ into the **bacteria**.

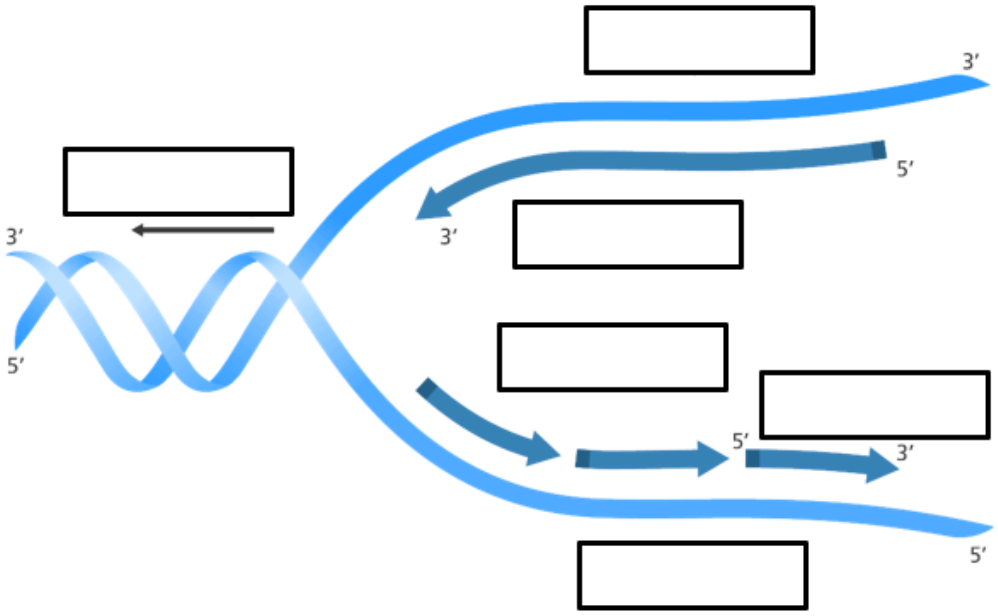


Outline the stages in DNA Replication

- DNA gyrase reduces the _____ strain created by the _____of DNA by helicase. It does this by relaxing positive supercoils (via negative supercoiling) that would otherwise form during the unwinding of DNA

- DNA _____ unwinds and unzips DNA by breaking the _____ bonds between _____ base pairs. The _____ separated strands become parent/_____strands for the replication process

- Label the DNA replication fork below



DNA Primase

- DNA _____ generates a **short** _____ (~10–15 nucleotides) on each of the template strands. The RNA primer provides an _____ for DNA polymerase III, which can extend a nucleotide chain but not start one

DNA Polymerase III

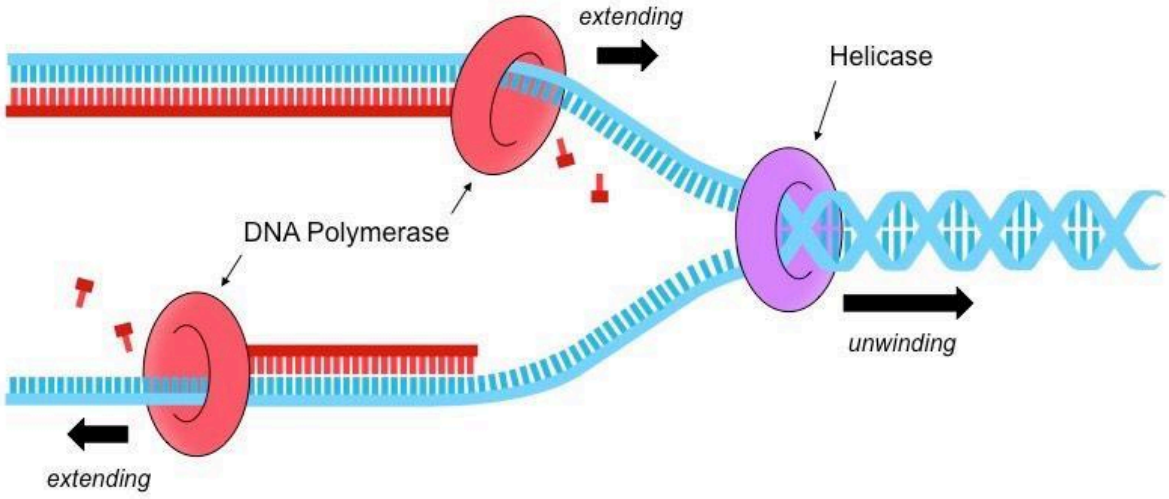
- DNA Polymerase III attaches to the _____ prime end of the _____
- DNA polymerase always moves in a _____ direction
- DNA polymerase catalyses the _____ bonds between _____ and _____ groups
- DNA Polymerase _____ the complementary base pairing. Consequently, mistakes are very infrequent occurring approx. once in every billion bases pairs.
- On the _____, DNA pol III is moving towards the replication fork and can synthesise continuously
- On the _____ *strand*, DNA pol III is moving away from the replication fork and synthesises in pieces (Okazaki fragments)

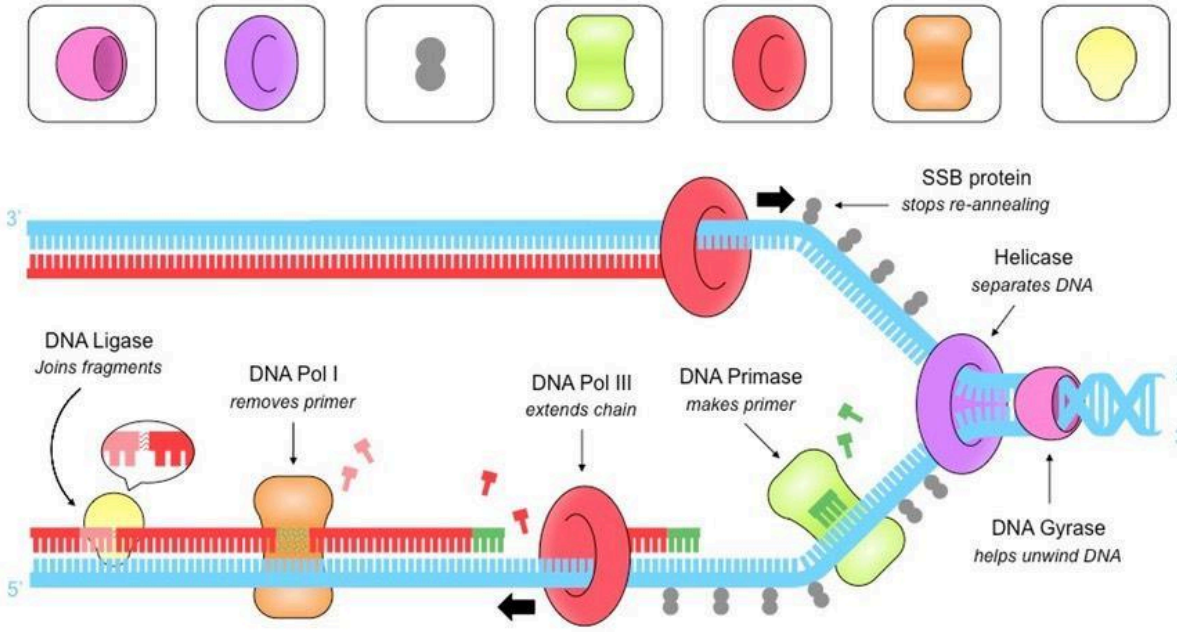
DNA Polymerase I

- As the _____strand is synthesised in a series of short fragments, it has multiple _____ along its length
- DNA pol I _____ from the lagging strand and replaces them with _____
- DNA Polymerase adds _____ which are complementary to the _____strand creating a _____strand

DNA Ligase

- DNA ligase joins the _____ together to form a continuous strand.
- It does this by covalently joining the _____together with a phosphodiester bond.


extending
Helicase
DNA Polymerase
unwinding
extending


SSB protein
stops re-annealing
Helicase
separates DNA
DNA Ligase
Joins fragments
DNA Pol I
removes primer
DNA Pol III
extends chain
DNA Primase
makes primer
DNA Gyrase
helps unwind DNA
3'
5'
5'
3'

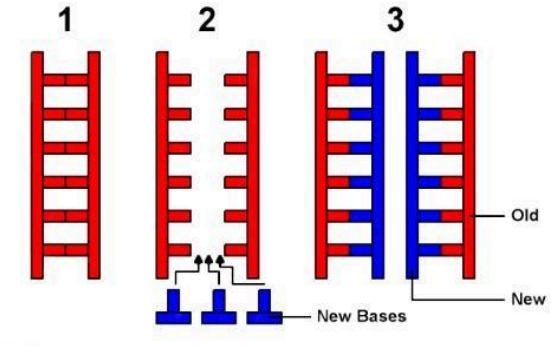
DNA Replication Drawing

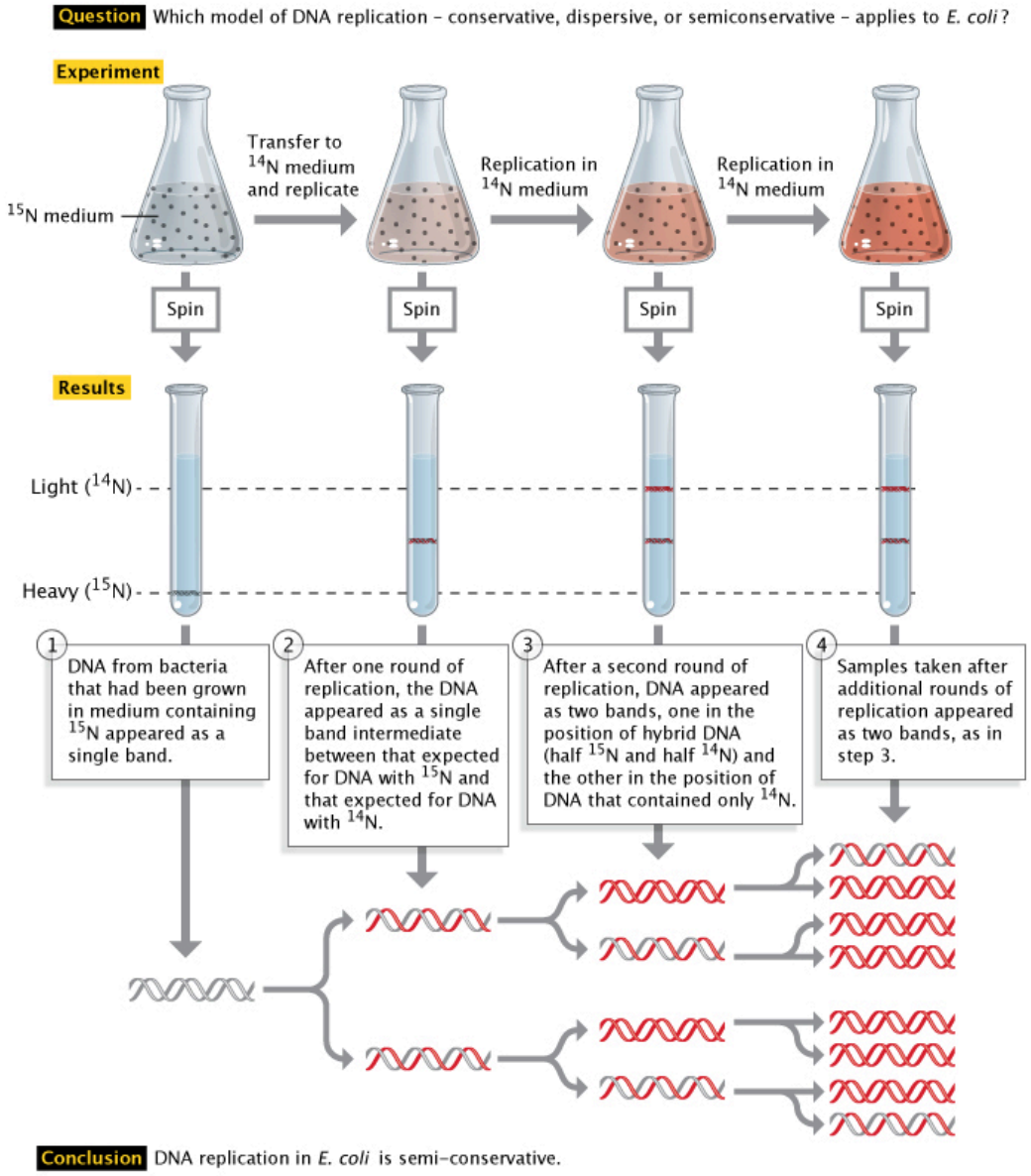
Using pencil, you will draw a representation of DNA replication along the leading and lagging strands. Follow the directions below, drawing each element in its proper location along the replicating DNA strand. Once you are sure everything is in the correct place, complete your drawing by adding color to distinguish objects as separate.

1. On the diagram below, label the 5' and 3' ends of both parental DNA strands (you can make up which is which)
2. Label the replication fork
3. Draw and label helicase
4. Label the overall direction of DNA replication
5. Draw and label the leading strand
6. Draw and label a single DNA polymerase on the leading strand
7. Draw and label an RNA primer on the leading strand
8. On the lagging strand, draw and label at least three Okazaki fragments
9. On the lagging strand, draw and label at least two DNA polymerase enzymes
10. On the lagging strand, draw and label at least two RNA primers

The two new strands formed will be _____to the original strand.

The new replicated DNA contains ___ strand of old and ____ strand of new DNA in each copy. This is called _____ _____ DNA replication.





What did Meselson and Stahl's results provide evidence for?

Replication in summary

1 *helicase* unwinds & unzips DNA

2 single strand binding proteins keep the two strands of DNA separate

3 *RNA primase* synthesizes a short RNA sequence known as an *RNA primer*

4 *DNA pol III* then binds to the 3' end of the RNA primer & makes a sequence of DNA

5 *DNA pol I* replaces the RNA of the RNA primer with DNA

6 *DNA ligase glues the* Okazaki fragments together

Checkpoint Quiz

1. What is the role of the Helicase?

2. What is the role of the RNA Primase?

3. Why is primase necessary?

4. What is the role of the DNA Polymerase III?

5. What two limitations does DNA polymerase III have?

6. What is the role of the DNA Polymerase I?

7. What is the role of the Ligase?

8. Is the leading strand being built toward or away from the replication fork?

9. Is the lagging strand being built toward or away from the replication fork?

Watch these animations:
http://highered.mcgraw-hill.com/sites/0072943696/student_view0/chapter3/animation__dna_repli

cation__quiz_1_.html
http://www.johnkyrk.com/DNAreplication.html

Replication Fork
http://highered.mcgraw-hill.com/olcweb/cgi/pluginpop.cgi?it=swf::535::535::/sites/dl/free/0072437316/120076/micro04.swf::DNA%20Replication%20Fork

Quiz
http://highered.mcgraw-hill.com/sites/0072556781/student_view0/chapter11/animation_quiz_2.html

More complicated animation talking about Okazaki fragments
http://highered.mcgraw-hill.com/sites/9834092339/student_view0/chapter14/dna_replication.html

… nucleotides in a 5’ → 3’ direction (in the ….
… is needed for building up a complementary strand for this template.

To this primer, DNA polymerase III adds nucleotides in a 5’ ® 3’ direction, moving…
… sealed up by DNA ligase which makes a sugar-phosphate bond between adjacent DNA fragments.
The DNA double helix is uncoiled and the two strands are…
… DNA polymerase III can follow along behind it, adding nucleotides in one continuous strand., however…
… a short length of RNA to the template strand of DNA, which acts as a primer.
… away from the replication fork as it does so. In this way…
… replication fork will be opening up in the opposite direction: another method, therefore,…
… short lengths of DNA – called *Okazaki fragments* - are formed between RNA primers.
… separated by the enzyme *Helicase*, producing a *replication fork*.
… reproduce or ‘replicate’ a double helix with anti-parallel strands.)
… the RNA primer and replaces it with DNA. A gap is left where…
…because the template strands are anti-parallel, for the other template strand, the…
At regular intervals along the lagging strand, RNA primase adds …
Behind the replication fork, the enzyme DNA polymerase III adds…
Next, DNA polymerase I removes…
… two nucleotides are still left unconnected – this gap is…
… opposite direction to the direction of the bases in the template strand, so as to…
As DNA helicase moves along *one* of the anti-parallel template strands …

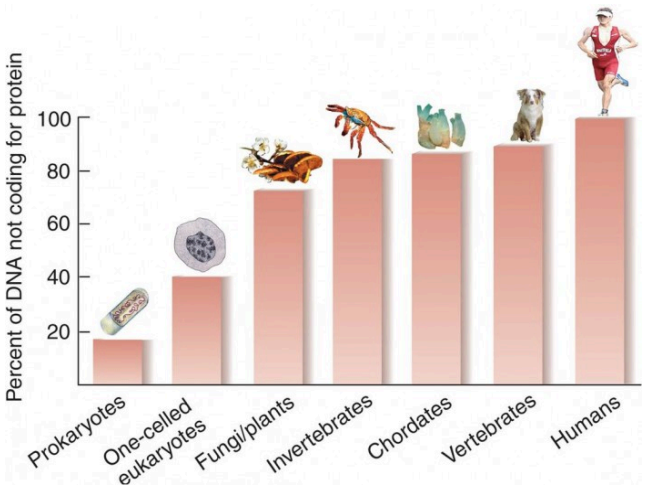
Does all DNA Code for Proteins?

Define **gene**

List some roles of non-coding regions on the DNA:

Satellite Genes	
Telomeres	
Introns	
Non-coding RNA Genes	
Gene Expression	

What does the graph tell us about the relationship between how complex an organism is and the amount of non-coding DNA?



Can you give an explanation for this trend?

Homework: Application: Tandem repeats are used in DNA profiling.

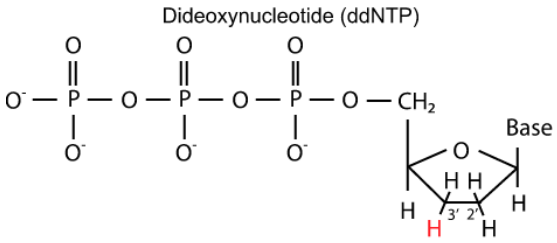
Define **short tandem repeats (STRs)**

Use the video here to make your own notes: https://www.youtube.com/watch?v=5S_GBfxvymI
on DNA profiling

Homework Application: Use of nucleotides containing dideoxyribonucleic acid to stop DNA replication in preparation of samples for base sequencing.

Go to: https://www.dnalc.org/resources/animations/cycseq.html

What are dideoxyribonucleic acids (ddNTP) and how do they differ from regular nucleotides?



What is Sanger sequencing?

Describe the role of ddNTP in this process:

Homework: PCR

Watch the animation here: http://learn.genetics.utah.edu/content/labs/pcr/

What does PCR stand for?

Name some uses of PCR:

What is the role of each of the following in PCR:

Primers

DNA polymerase

Nucleotides

The DNA polymerase used in the PCR process comes from a strain of bacteria called ***Thermus aquaticus*** that live in the hot springs of Yellowstone National Park.
What is special about it and why is it used?

Briefly describe the steps in the process of PCR using a diagram below:

Transcription

http://highered.mheducation.com/sites/9834092339/student_view0/chapter15/stages_of_transcription.html
http://highered.mheducation.com/sites/9834092339/student_view0/chapter15/transcription_comp

lex_and_enhancers.html

1. What two roles does the enzyme RNA polymerase perform during transcription?

2. Why does transcription occur in at 5’ □ 3’ direction?

3. What is a promoter?

4. What are transcription factors and in what type of organism are they found?

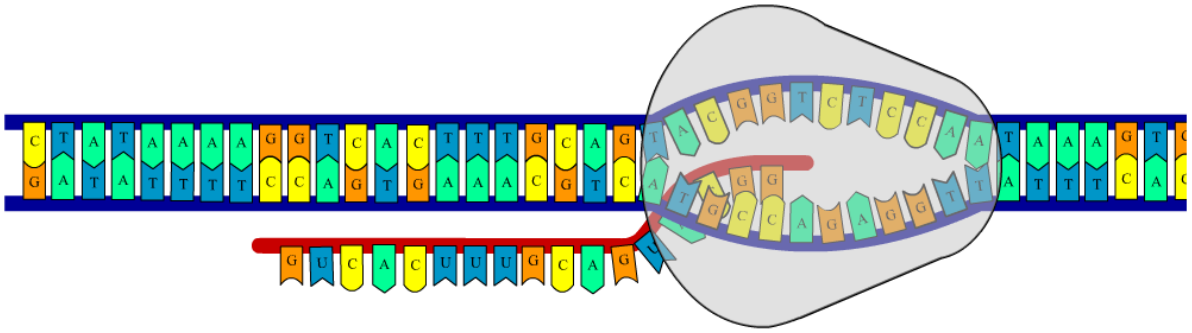
5. What happens during the “elongation” phase of transcription?

6. What happens during the “termination” phase of transcription?

Define
Transcription

RNA polymerase

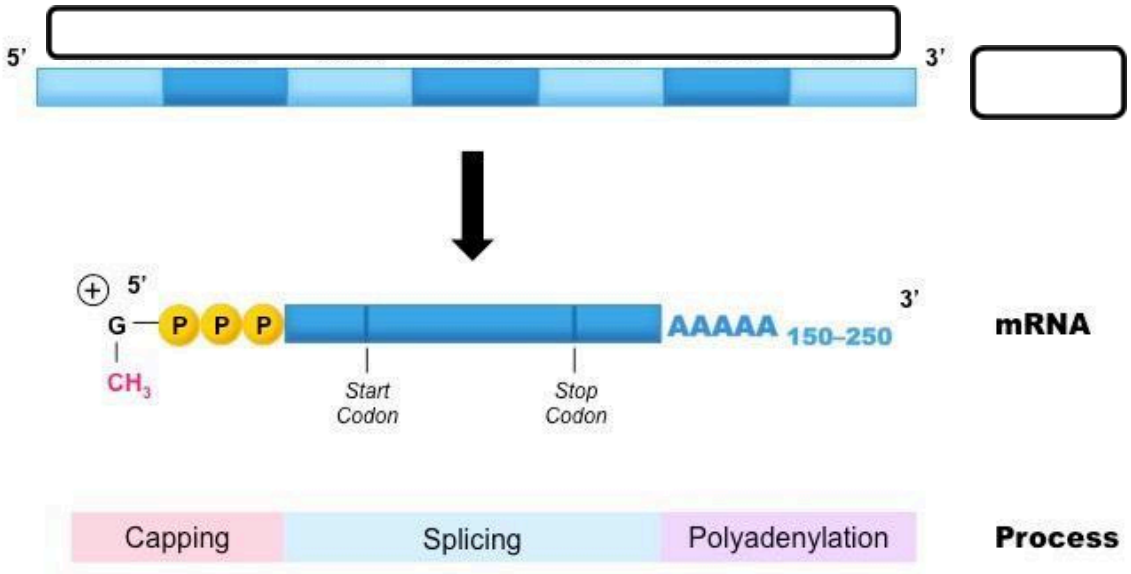
Go to: http://www.stolaf.edu/people/giannini/flashanimat/molgenetics/transcription.swf
Add the following labels to the diagram: RNA polymerase, DNA, mRNA, template strand, arrow showing the direction of transcription



Put the sentences in order to describe what happens during the process of transcription:

The DNA double helix unzips
The two DNA strands join together by complementary base pairing
RNA polymerase forms sugar-phosphate bonds between nucleotides.
as hydrogen bonds between complementary bases break
The DNA molecules winds back up into a helix
One strand called the sense strand acts as a template
and passes through the nuclear membrane into the cytoplasm.
to the exposed bases on this strand by forming hydrogen bonds.
and the two polynucleotide strands separate.
Once complete, the mRNA detaches from the sense strand
and free RNA nucleotides complementary base pair

Use the diagram below to explain the relationship between genes, introns and exons:



Capping:

Splicing:

Polyadenylation:

Spliceosome:

1. What are two functions of the 5' cap on mRNA?

2. What are three functions of the poly (A) tail on mRNA?

3. Define RNA splicing.

4. Describe the structure and function of the spliceosome.

5. What are ribozymes (snRNPs)? What functions do they have in the modification of mRNA?

6. Define alternative RNA splicing.

7. Give an example of how alternative RNA splicing can alter the phenotype of an organism.

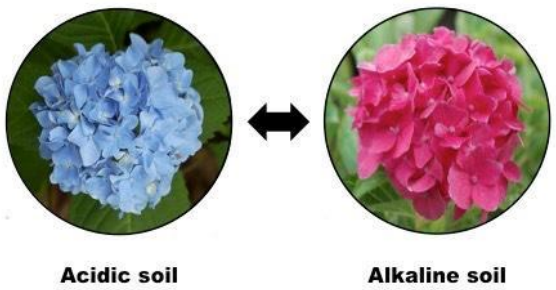
• Splicing of mRNA increases the number of different proteins an organism can produce.
http://highered.mheducation.com/sites/9834092339/student_view0/chapter15/animation_-_exon_shuffling.html

Regulation of gene expression

Watch Mr Andersen's 10m video: https://www.youtube.com/watch?v=3S3ZOmleAj0

Explain and give examples of how the environment of a cell and of an organism has an impact on gene expression

Explain what happened below:



Genetic code

https://studyrocket.co.uk/revision/a-level-biology-aqa/genetic-information-variation/dna-the-genetic-code#:~:text=The%20genetic%20code%20has%20three,%2C%20universal%20and%20non%2Doverl

apping.&text=At%20the%20end%20of%20every,stop%20translation%20from%20occurring%20further.

Define these terms

Gene

Genetic code

Codon

The genetic code is said to be universal, degenerate and non-overlapping. With the aid of diagrams explain the meaning and significance of each of these terms.

Universal

Degenerate

Non-overlapping

Are there exceptions to any of these rules?

Universal Genetic Code Chart

Messenger RNA Codons and Amino Acids for Which They Code

First base	Second base: U	Second base: C	Second base: A	Second base: G	Third base
U	UUU, UUC: PHE	UCU, UCC, UCA, UCG: SER	UAU, UAC: TYR	UGU, UGC: CYS	U C A G
	UUA, UUG: LEU		UAA, UAG: STOP	UGA: STOP; UGG: TRP	
C	CUU, CUC, CUA, CUG: LEU	CCU, CCC, CCA, CCG: PRO	CAU, CAC: HIS	CGU, CGC, CGA, CGG: ARG	U C A G
			CAA, CAG: GLN		
A	AUU, AUC, AUA: ILE	ACU, ACC, ACA, ACG: THR	AAU, AAC: ASN	AGU, AGC: SER	U C A G
	AUG: MET or START		AAA, AAG: LYS	AGA, AGG: ARG	
G	GUU, GUC, GUA, GUG: VAL	GCU, GCC, GCA, GCG: ALA	GAU, GAC: ASP	GGU, GGC, GGA, GGG: GLY	U C A G
			GAA, GAG: GLU		

Application: Production of human insulin in bacteria as an example of the universality of the genetic code allowing gene transfer between species.

Translation

Define:

Start Codon

Stop Codons

Translation

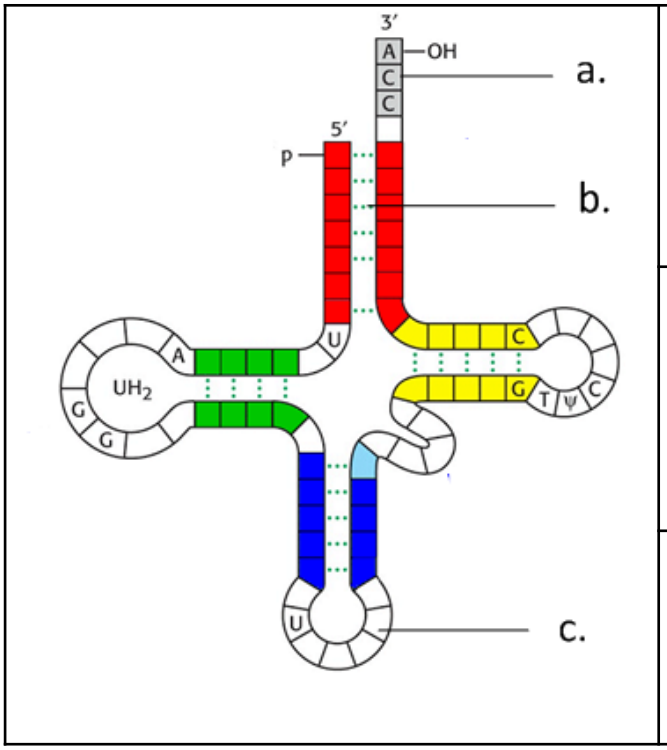
Explain the roles of the following in translation:

Ribosome

Draw a diagram to outline the structure of a ribosome. Label the following:

a. large subunit
b. small subunit
c. three tRNA binding sites (located on the large subunit)
d. mRNA and the mRNA binding site (located on the small subunit)
e. A growing polypeptide chain

Label the following regions on this generalised tRNA molecule, outlining the function of each.



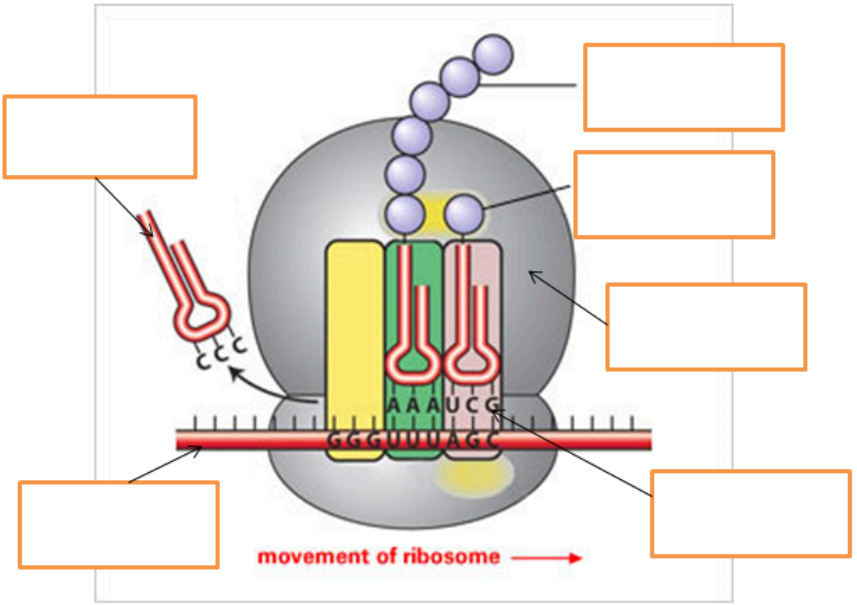
a.	
	function:
b.	hydrogen bonds
	function:
c.	
	function:

tRNA

Anticodon

Draw and label a diagram of a tRNA molecule and label the anticodon and site of attachment of the amino acid:

Add labels to the diagram:



See https://www.youtube.com/watch?v=kmrUzDYAmEI

These understandings require a more detailed summary of 2.7.U8. It is recommended, for clarity, that effective diagrams are used to make the steps as clear as possible. More than one diagram maybe used per step if required.

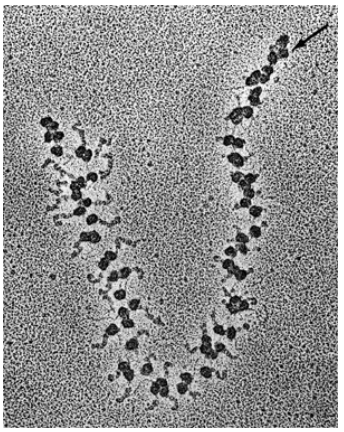
Complete the table to summarise the process of translation.

Stage	Key steps	Diagrams and Notes
Initiation	1. mRNA binds to the small subunit of the ribosome. 2. 3. 4. The large subunit of the ribosome binds to the tRNA and small subunit	● The mRNA contains a series of codons (3 bases) each of which codes for an amino acid.
Elongation	5. A second tRNA (with amino acid attached) complementary to the second codon on the mRNA then binds to the A site of the ribosome 6. 7. 8. Another tRNA binds, complementary to the next codon on the mRNA, binds to the A site. 9. Steps 6, 7, and 8 are repeated until a stop codon is reached.	● charged tRNA contains energy in the bond with the amino acid attached which will be used to form the peptide bond. ● There are three binding sites on the large subunit of the ribosome, but only two can contain tRNA molecules at a time.
Termination	10. When a stop codon is reached translation is stopped: ● ● ●	

State two reasons why translation can occur immediately after transcription in prokaryotes

A polysome is a structure that consists of multiple ribosomes attached to a single mRNA translating it simultaneously to quickly create many copies of the required polypeptide.

f. Label the eukaryote polysome to right to indicate:
   - mRNA
   - Ribosomes
   - Polypeptide chains



g. Describe how polysomes in prokaryotes may differ in structure from polysomes in eukaryotes.

Once translated the polypeptide will naturally fold into a structure. The structure is the result of the polar nature of water in the cytoplasm, hydrogen bonds and interactions between the R-groups. The R-groups of an amino acid are classified as having one of a number of different properties. List the properties can they possess.

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Complete the table to outline the four different levels of protein structure.

	Notes	**Fibrous or Globular**
Primary (polypeptide)	• *The order / sequence of the amino acids of which the protein is composed* • *Formed by covalent peptide bonds between adjacent amino acids*	*Neither (– will fold to become one of the subsequent levels of structure)*

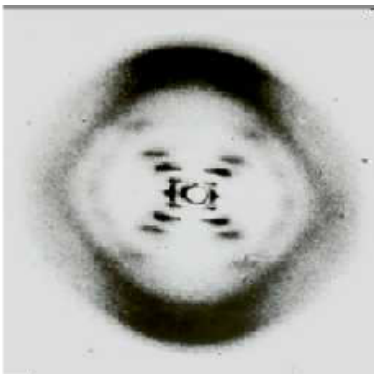
	• *Controls all subsequent levels of structure*	
Secondary	• • •	
Tertiary	• • •	
Quaternary	• •	

One gene one protein *What is the "central dogma" of molecular biology?* *Explain the one gene one peptide theory.* *Describe some exceptions to this theory.*	

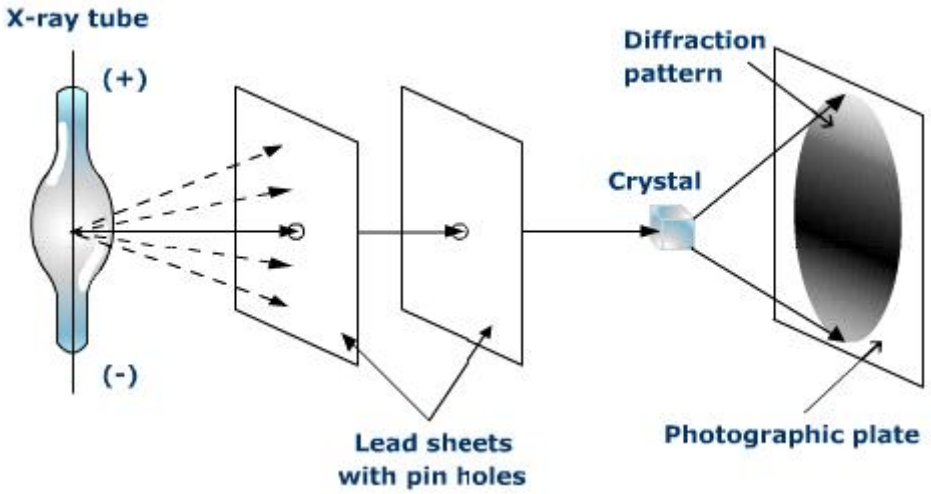
Application: Rosalind Franklin and Maurice Wilkins' investigation of DNA structure by X-ray

diffraction.

Go to: https://www.dnalc.org/view/15874-Franklin-s-X-ray.html



Indicate on the diagram the main piece of evidence for the structure of DNA being a helix.
What other critical piece of evidence does the image tell us?
Describe the process of X-ray diffraction using the diagram below:



1. What principle is necessary to preserve the sequence of DNA during replication?

A. Base pairing is complementary.

B. One gene codes for one polypeptide.

C. Substrates are specific to enzymes.

D. The genetic code is universal.

(Total 1 mark)

2. Which process is used in polymerase chain reaction (PCR)?

A. Transcription

B. Translation

C. Replication

D. Mutation

(Total 1 mark)

3. What is a codon?

A. A sequence of nucleotides on rRNA that corresponds to an amino acid

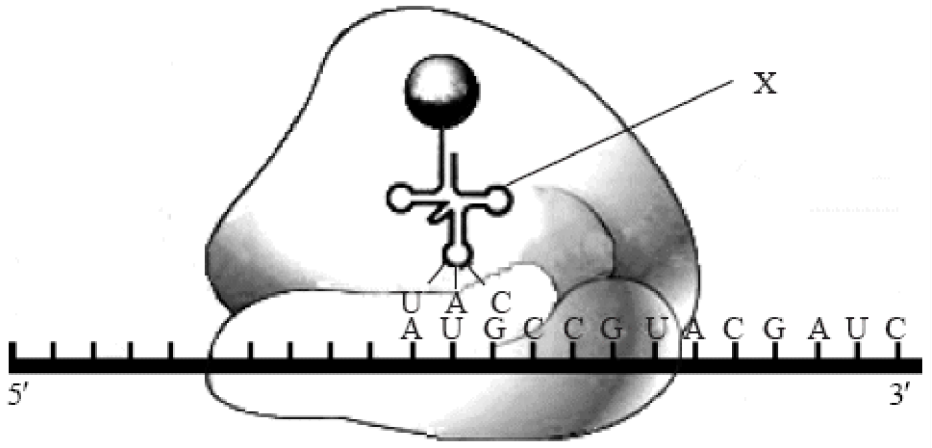
B. A sequence of nucleotides on mRNA that corresponds to an amino acid

C. A sequence of nucleotides on tRNA that corresponds to an amino acid

D. A sequence of nucleotides on DNA that corresponds to an amino acid

(Total 1 mark)

4. What sequence of processes is carried out by the structure labelled X during translation?



A. Combining with an amino acid and then binding to an anticodon

B. Binding to an anticodon and then combining with an amino acid

C. Binding to a codon and then combining with an amino acid

D. Combining with an amino acid and then binding to a codon

(Total 1 mark)

5. What is a polysome?

A. A ribosome that is synthesizing proteins from several mRNA molecules at the same time

B. A ribosome that is synthesizing different proteins for secretion

C. Several ribosomes using a mRNA molecule to synthesize protein at the same time

D. Several ribosomes that are synthesizing different proteins for use in the cytoplasm

(Total 1 mark)

6. What enzyme is used in transcription but **not** in translation?

A. DNA polymerase

B. Helicase

C. Protease

D. RNA polymerase

(Total 1 mark)

7. A certain gene in a bacterium codes for a polypeptide that is 120 amino acids long. How many nucleotides are needed in the mRNA to code for this polypeptide?

A. 30

B. 40

C. 360

D. 480

(Total 1 mark)

8. The table below shows the codons that determine different amino acids in protein translation.

First base in codon	Second base in codon				Third base in codon
	U	C	A	G	
U	Phe	Ser	Tyr	Cys	U
	Phe	Ser	Tyr	Cys	C
	Leu	Ser	—	—	A
	Leu	Ser	—	Trp	G
C	Leu	Pro	His	Arg	U
	Leu	Pro	His	Arg	C
	Leu	Pro	Gln	Arg	A
	Leu	Pro	Gln	Arg	G
A	Ile	Thr	Asn	Ser	U
	Ile	Thr	Asn	Ser	C
	Ile	Thr	Lys	Arg	A
	Met	Thr	Lys	Arg	G
G	Val	Ala	Asp	Gly	U
	Val	Ala	Asp	Gly	C
	Val	Ala	Glu	Gly	A
	Val	Ala	Glu	Gly	G

What is the sequence of the amino acids that is being translated from the following mRNA sequence?

5´ AUGGGUGCUUAUUGGUAA 3´

A. Met-Pro-Arg-Ile-Thr

B. Met-Cys-Ser-Tyr-Trp

C. Met-Gly-Ala-Tyr-Trp

D. Met-Gly-Tyr-Ala-Thr

(Total 1 mark)

9. What does the universal nature of the genetic code allow?

A. Change of genetic code in the same species

B. Transfer of genes between species

C. Formation of clones

D. Infection by bacteria

(Total 1 mark)

10. Which enzymes are needed to produce recombinant plasmids to be used in gene transfer?

A. DNA polymerase and DNA ligase

B. DNA polymerase and restriction enzyme (endonuclease)

C. Transcriptase and RNA polymerase

D. Restriction enzyme (endonuclease) and DNA ligase

(Total 1 mark)

11. Translation occurs in living cells. Explain how translation is carried out, from the initiation stage onwards.

(9)

12. DNA Replication is key to the process of mitosis.

(a) Explain why DNA must be replicated before mitosis and the role of helicase in DNA replication.

(4)

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(b) Explain how the base sequence of DNA is conserved during replication.

(5)

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1. A

[1]

2. C

[1]

3. B

[1]

4. D

[1]

5. C

[1]

6. D

[1]

7. C

[1]

8. C

[1]

9. B

[1]

10. D

[1]

11. translation involves initiation, elongation and termination;
mRNA binds to the small sub-unit of the ribosome;
ribosome slides along mRNA to the start codon;
anticodon of tRNA pairs with codon on mRNA:
complementary base pairing (between codon and anticodon);
(anticodon of) tRNA with methionine pairs with start codon / AUG is the start codon;
second tRNA pairs with next codon;
peptide bond forms between amino acids;
ribosome moves along the mRNA by one codon;
movement in 5′ to 3′ direction;
tRNA that has lost its amino acid detaches;
another tRNA pairs with the next codon/moves into A site;
tRNA activating enzymes;
link amino acids to specific tRNA;
stop codon (eventually) reached; 9 max

12. (a) two genetically identical nuclei/daughter cells formed during mitosis
(so hereditary information in DNA can be passed on);
two copies of each chromosome/DNA molecule/chromatid needed;
helicase unwinds the DNA/double helix;
to allow the strands to be separated;
helicase separates the two (complementary) strands of DNA;
by breaking hydrogen bonds between bases; 4 max

(b) DNA replication is semi-conservative;
DNA is split into two single/template strands;
nucleotides are assembled on/attached to each single/template strand;
by complementary base pairing;
adenine with thymine and cytosine with guanine / A with T and C with G;
strand newly formed on each template strand is identical to other template strand;
DNA polymerase used;
Marks may be awarded for any of the above points if clearly presented in a well-annotated diagram. 5 max

1. What does a nucleosome consist of?

A. DNA and histones

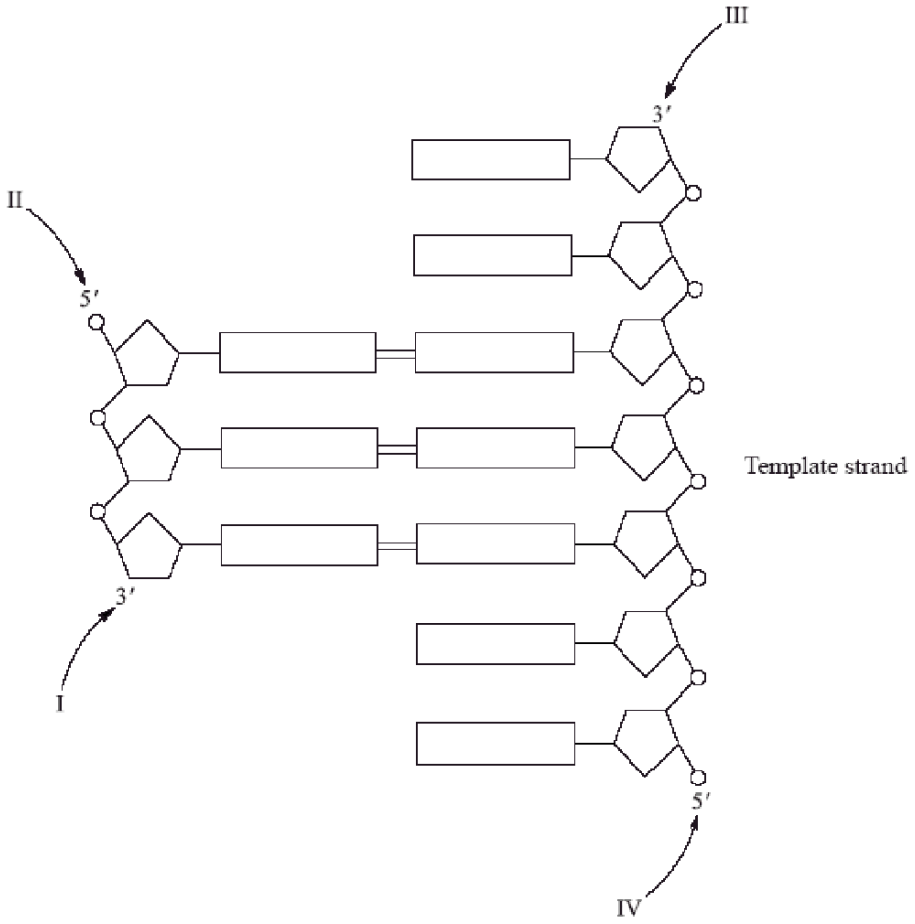
B. DNA and chromatin

C. Chromatin and nucleotides

D. Mature RNA and histones

(Total 1 mark)

2. The diagram below shows part of a DNA molecule that is being replicated.



Where would DNA polymerase link the next nucleotide during replication?

A. I

B. II

C. III

D. IV

(Total 1 mark)

3. What is the reason for Okazaki fragments being formed during DNA replication?

A. To enable replication of the 3′ → 5′ (lagging) strand

B. To form the template for the RNA primers

C. To initiate replication on the 5′ → 3′ (leading) strand

D. To help the DNA helicase unwinding the DNA helix

(Total 1 mark)

4. List three functions of the regions of DNA that do not code for proteins.

(3)

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5. Tandem repeats useful in DNA profiling.

(a) Describe what is meant by the term tandem repeat sequence.

(2)

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(b) Describe why tandem repeats are useful in DNA profiling.

(2)

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6. Explain the process of DNA replication.

(8)

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1. A

[1]

2. A

[1]

3. A

[1]

4. promoters (attachment points for RNA polymerase);
enhancers (increase the rate of transcription);
silencers (inhibit transcription);
telomeres (protect DNA molecule from degradation during replication);
synthesis of tRNA; *3 max*

5. Tandem repeats useful in DNA profiling.

(a) short sequences of (non-coding) DNA, normally of length 2-5 base pairs;
that are repeated numerous times (in a head-tail manner);

(b) TRs vary greatly between individuals in terms of the different number of copies of the repeat element;
An individual has two copies of each allele and the tandem repeat on each allele may vary;

Because of the great variation in TRs it can therefore be used to easily to distinguish between individuals (in DNA profiling);

6. occurs during (S phase of) interphase/in preparation for mitosis/ cell division;
DNA replication is semi-conservative;
unwinding of double helix by DNA gyrase;
separation of strands by helicase (at replication origin);
hydrogen bonds between two strands are broken;
each strand of parent DNA used as template for synthesis;
synthesis continuous on leading strand but not continuous on lagging strand;
leading to formation of Okazaki fragments (on lagging strand);
synthesis occurs in 5′ → 3′ direction;
RNA primer synthesized on parent DNA using RNA primase;
DNA polymerase III adds the nucleotides (to the 3′ end) added according to complementary base pairing;
adenine pairs with thymine and cytosine pairs with guanine; *(Both pairings required. Do not accept letters alone.)*
DNA polymerase I removes the RNA primers and replaces them with DNA;
DNA ligase joins Okazaki fragments;
as deoxynucleoside triphosphate joins with growing DNA chain, two phosphates broken off releasing energy to form bond;
Accept any of the points above shown on an annotated diagram. *8 max*

1. The sequence of nucleotides in a section of RNA is:

GCCAUACGAUCG

What is the base sequence of the DNA sense strand?

A. CGGUAUGCUAGC

B. GCCATACGATCG

C. CGGTATGCTAGC

D. GCCAUACGAUCG

(1)

2. What is removed during the formation of mature RNA in eukaryotes?

A. Exons

B. Introns

C. Codons

D. Nucleosomes

(1)

3. Where does the RNA polymerase bind during the process of transcription?

A. The polysome

B. The operator

C. The promoter

D. The initiator

(1)

4. Outline how the environment of a cell can impact gene expression and hence embryonic development

(4)

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5. Explain the process of transcription leading to the formation of mRNA.

(8)

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1. The antisense strand on the DNA molecule coding for three codons of a gene is

TATCGCACG

What are the anticodons of the three tRNA molecules that correspond to this sequence?

A. UAU, CGC and ACG

B. ATA, GCG and TGC

C. AUA, GCG and UGC

D. TAT, CGC and ACG

(1)

2. Explain how tRNA-activating enzymes illustrate enzyme–substrate specificity.

(3)

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3. During translation the ribosome moves across the mRNA until it encounters the stop codon. Outline the events that follow.

(3)

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4. The complex structure of proteins can be explained in terms of four levels of structure, primary, secondary, tertiary and quaternary.

(a) Primary structure involves the sequence of amino acids that are bonded together to form a polypeptide. State the name of the linkage that bonds the amino acids together.

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(1)

(b) Beta pleated sheets are an example of secondary structure. State **one** other example.

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(1)

(c) Tertiary structure in globular proteins involves the folding of polypeptides. State **one** type of bond that stabilizes the tertiary structure.

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(1)

(d) Outline the quaternary structure of proteins.

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(2)

1. A

[1]

2. there are (20) specific tRNA-activating enzymes one for each amino acid;
the tRNA-activating enzyme accepts both an amino acid and a tRNA into it's active site;
tRNA molecules are shaped differently, each tRNA-activating enzyme will only accept one or a few similarly shaped tRNA molecules;
Accepted tRNA molecules have very similar codons, this supported the induced fit model;
The amino acid is then bonded to the 3'-end of the appropriate tRNA;

3 max

3. release factor attaches to the A site;
Polypeptide is released;
tRNA and mRNA detach;
The ribosome splits into (large and small) subunits;

4. (a) peptide bonds / peptidic bonds;

1

(b) alpha-helix / alpha helices;

1

(c) ionic / polar / hydrogen / hydrophobic / van der Waals' / disulfide; (*not covalent*)

1

(d) linking together of polypeptides to form a single protein;
using the same bonding as for tertiary structure;
linking of a non-polypeptide structure / prosthetic group;
named example of quaternary structure
eg hemoglobin (has four polypeptides);

2 max