# 2018 Gene Expression, Organisation and Control STQ

**2018 / H2 / ACJC PRELIM / P2 Q3**

**1** tRNA molecules have an important role in gene expression. They can be found in the cytoplasm, mitochondria and chloroplasts of eukaryotic cells. Fig. 3.1 shows the structure of a tRNA molecule that is able to carry the amino acid threonine in the cytoplasm of a eukaryotic cell. It is 77 ribonucleotides long.

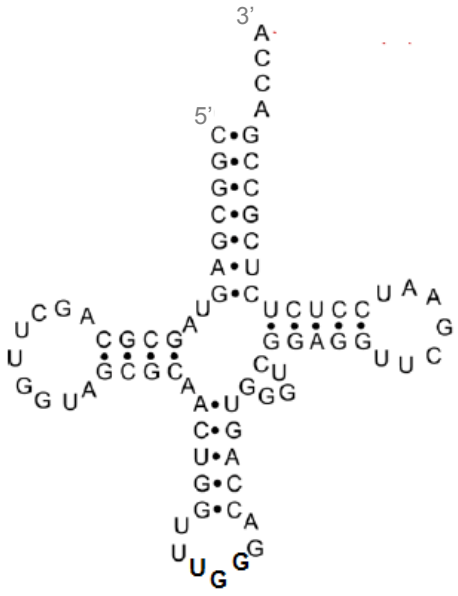


**Fig. 3.1**

**(a) (i)** With reference to Fig. 3.1, describe how the structure of a tRNA molecule differs from the structure of a mRNA molecule.

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..... [2]

**(ii)** Explain how these differences allow tRNA and mRNA molecules to perform their roles.

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..... [2]

Fig. 3.2 shows a tRNA molecule that is able to carry the amino acid threonine in mitochondria. It is 62 ribonucleotides long.

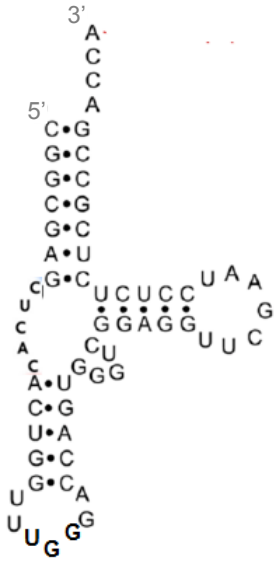


**Fig. 3.2**

**(b)** The structures of the tRNA molecules in the mitochondria and the cytoplasm of a eukaryotic cell are different although they are both able to carry the amino acid threonine. Suggest a reason for this difference.

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..... [2]

There are 61 unique tRNA molecules in the cytoplasm of a eukaryotic cell.

**(c) (i)** Explain why there are 61 unique tRNA molecules in the eukaryotic cell.

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..... [2]

**(ii)** Scientists found that there are more than 120 gene loci coding for tRNA molecules in the nuclear DNA, many of which are duplicate copies of the same tRNA gene.

Suggest an advantage of having more than 120 gene loci coding for the 61 tRNA molecules in the eukaryotic cell.

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..... [1]

**(d)** Explain how the structure of RNA polymerase allows for the synthesis of tRNA molecules.

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..... [3]

[Total: 12]

**2** RNA molecules play important roles within cells. One of the major types of RNA found in all cells is the ribosomal RNA (rRNA).

Fig. 2.1 shows rRNA molecules forming the large ribosomal subunit in eukaryotes.

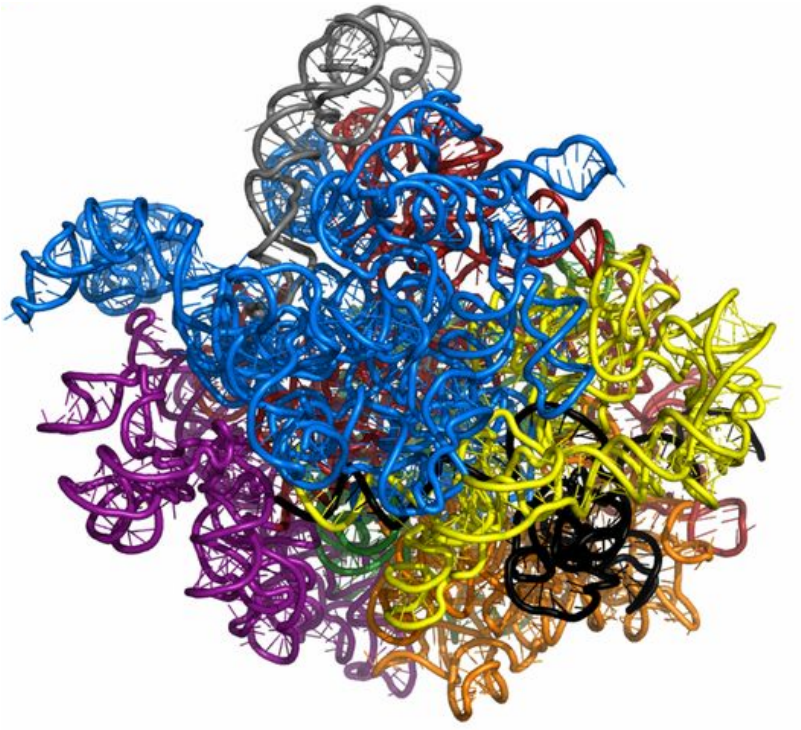

**Fig. 2.1**

**(a)** Explain why the rRNA molecules must adopt the shapes shown in Fig. 2.1.

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…… [3]

**(b)** Another important RNA molecule found in eukaryotic cells is the telomerase RNA.

Telomerase RNA is found within the telomerase enzyme, an enzyme essential for elongating telomeres.

**(i)** Outline how RNA molecules such as telomerase RNA and rRNA are synthesised.

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..... [3]

Fig. 2.2 shows the mode of action of telomerase.

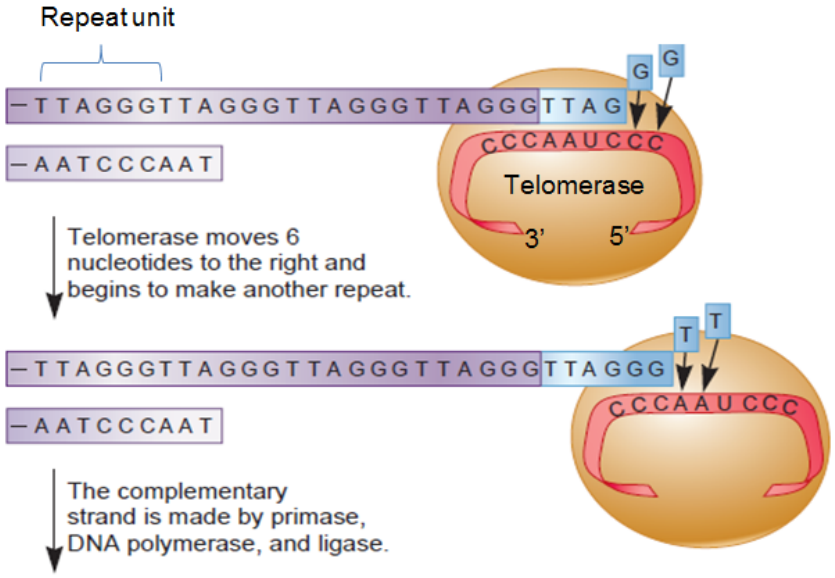


**Fig. 2.2**

**(ii)** Describe **three** visible differences between telomere elongation shown in Fig. 2.2 and translation.

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..... [3]

[Total:9]

**3** Eukaryotes regulate the expression of their genes at various levels of protein synthesis.

**(a)** Describe the effect of histone acetylation on gene expression.

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…… [3]

**(b)** Eukaryotic gene expression can also be regulated at translation initiation after the mRNA is synthesised.

Fig. 3.1 shows translation occurring on a eukaryotic mRNA.

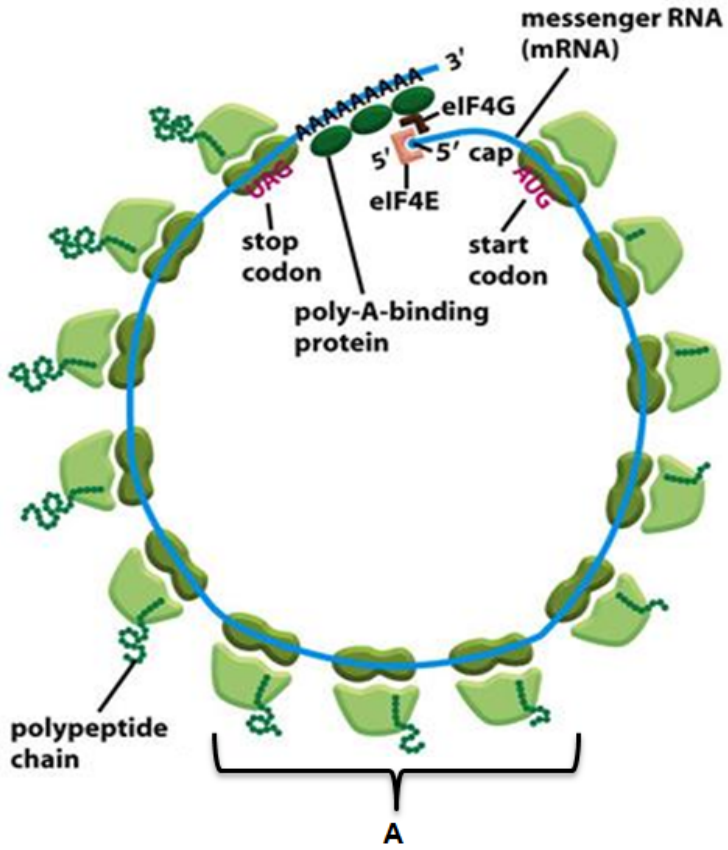


**Fig. 3.1**

**(i)** Explain the significance of the pattern of translation, labelled **A** in Fig. 3.1**.**

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…… [2]

**(ii)** During translation initiation, translation initiation factors like eIF4E and eIF4G form part

of a complex which aid in recruiting ribosomal subunits to mRNA.

With reference to Fig. 3.1, describe the role of the poly-A tail and 5' cap in the assembly of ribosomes.

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…… [2]

**(iii)** State **one** other function of the poly-A tail.

……

…… [1]

**(c)** In mammals, sex is determined by the X and Y chromosomes, females being XX and males XY. In females, the expression of all the genes on one of the two X chromosomes in each cell is inactivated throughout the life of the female. This ensures that the effective dosages of products of X-linked genes are equal in males and females since a double dose of X-linked genes may potentially be toxic.

Suggest if the inactivation of gene expression on the X chromosome occurs via chromatin modification or at translation initiation. Explain your answer.

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……. [3]

[Total: 11]

**2018 / H2 / DHS PRELIM / P2 Q4**

**Question 4**

*For Examiner's use*

The *APP* gene provides instructions for making a protein called amyloid precursor protein. This protein is found in many tissues and organs, including the brain and spinal cord. The most common mutation on the *APP* gene involves one codon being changed from GCC to GUC. Fig. 4.1 shows the genetic code.

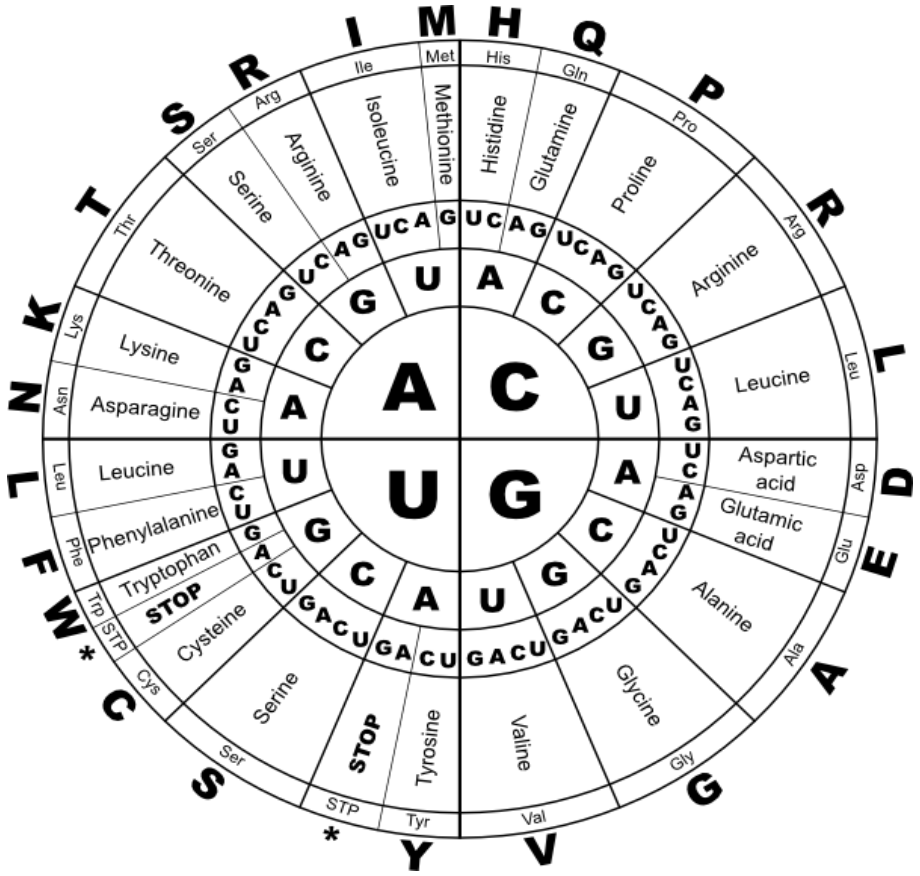


**Fig. 4.1**

**(a)** Explain the significance of codon in translation. [3]

**(b)** With reference to Fig. 4.1, describe the mutation that has occurred. [2]

*For Examiner's use*

**(c)** Amyloid precursor protein is cut by enzymes to create smaller fragments, some of which are released outside the cell. Two of these fragments are called soluble amyloid precursor protein (sAPP) and amyloid beta (β) peptide. This mutation in the *APP* gene can lead to the production of a "stickier" form of the β peptide. When these protein fragments are released from the cell, they can accumulate in the brain and form clumps called amyloid plaques. These plaques are characteristic of Alzheimer disease.

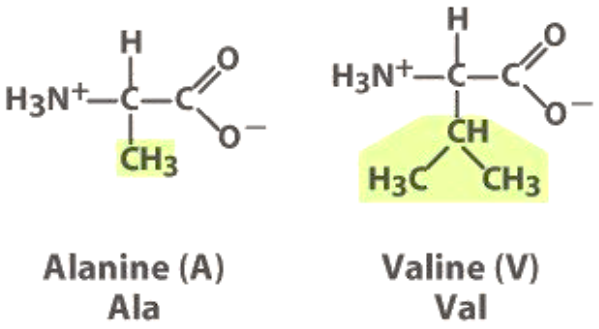


**Fig. 4.2**

Fig. 4.2 shows the structures of alanine and valine. Both amino acids contains non-polar R group. Suggest how a change from alanine to valine can result in a mutated amyloid precursor protein which then give rise to amyloid plaques. [2]

**Total:[7]**

**2018 / H2 / JJC PRELIM / P2 Q4**

**5** Fig. 4.1 shows the elongation phase of translation.

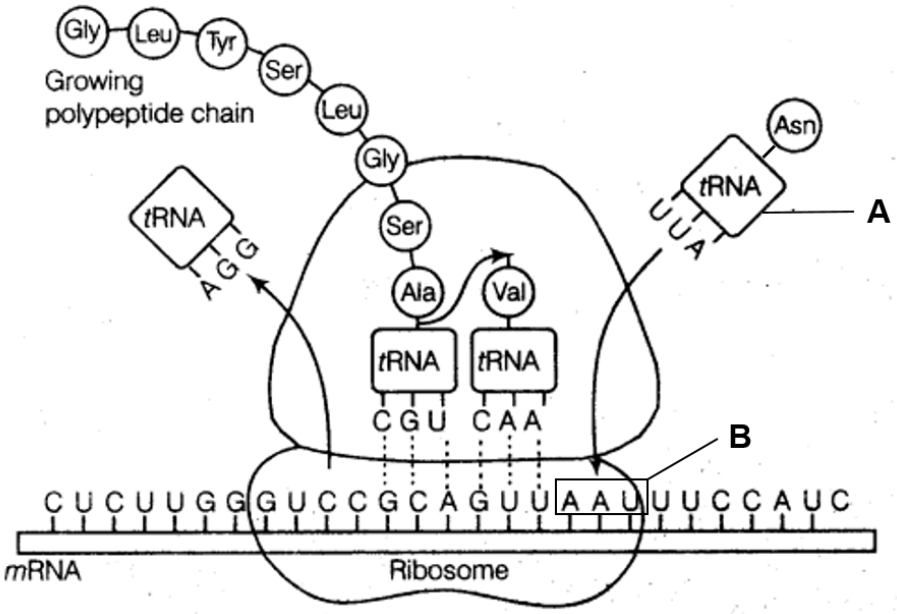


**Fig. 4.1**

**(a)** On Fig. 4.1, draw an arrow to show the direction of translocation of the ribosome. [1]

**(b)** Name the structures **A** and **B** in Fig. 4.1. [2]

**A** _____

**B** _____

**(c)** Explain how the molecular structure of **A** is related to its functions. [2]

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**(d)** Describe the phase of translation that occurs before elongation. [3]

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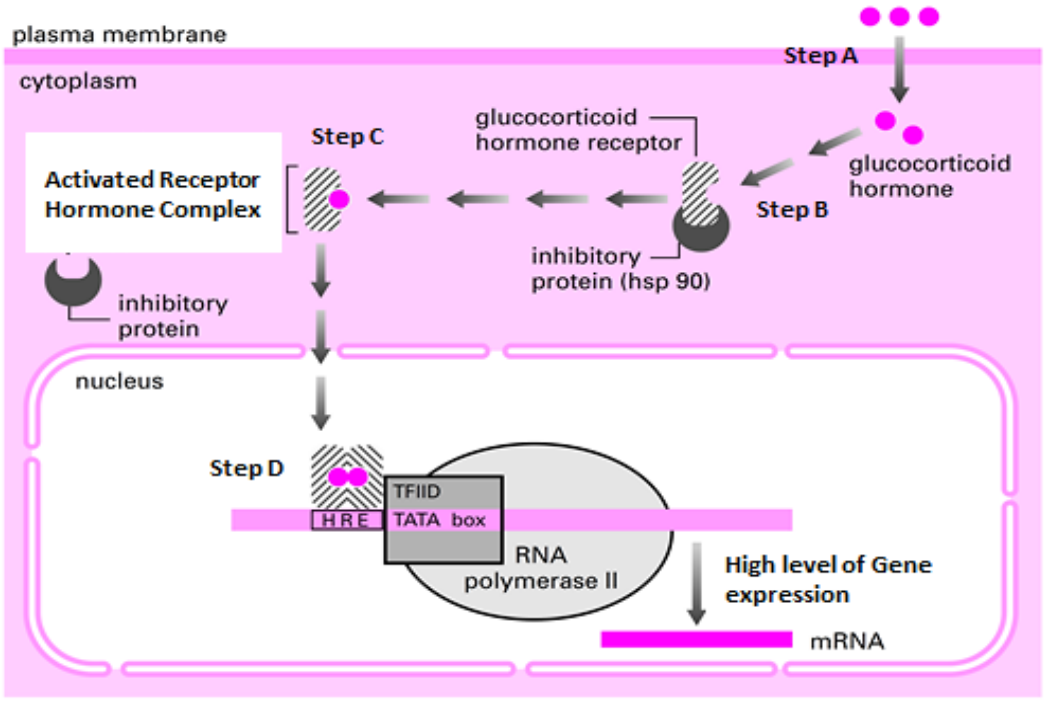
**(e)** State two differences between translation in prokaryotes and translation in eukaryotes. [2]

[Total: 10]

**2018 / H2 / NYJC PRELIM / P2 Q5**

**3**
**4**
**5**

**6** Glucocorticoids are steroid hormones produced by the adrenal cortex that increase the transcription of several genes important in carbohydrate and protein metabolism.
**Fig. 5.1** below shows how glucocorticoids can pass through the plasma membrane to enter the cytosol and bind to glucocorticoid hormone receptors. In the absence of glucocorticoid hormone, its receptor remains in the cytosol and is inactive.




*Hormone response element (HRE)*

**Fig. 5.1**

**(a) (i)** Glucocorticoid hormone receptor is a class of transcription factors. With reference to **Fig. 5.1**, explain how receptor hormone complex (Step C) can be activated.

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[2]

**(ii)** Suggest how glucocorticoid hormone receptor is able to bind to the specific region of the DNA known as HRE site shown in step D of **Fig. 5.1**.

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[2]

**(iii)** With reference to **Fig. 5.1**, explain how high level of gene expression may be regulated by activated receptor hormone complex within the nucleus.

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[3]

**Fig. 5.2** below shows the various steps involved in the processing of primary RNA transcript.

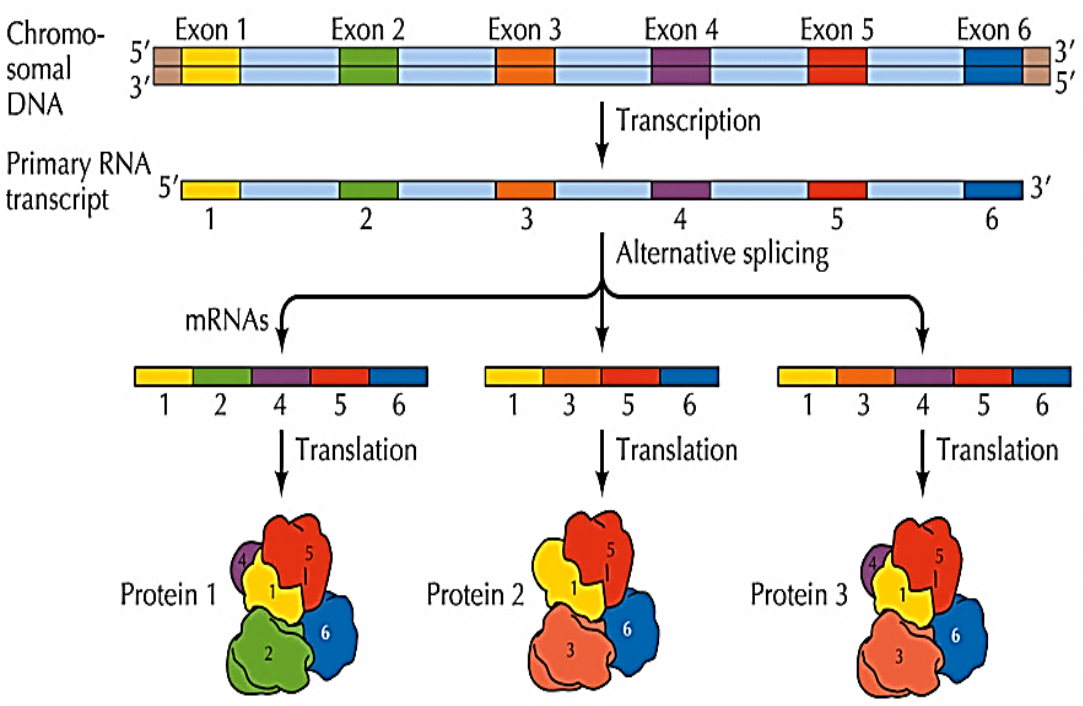


**Fig. 5.2**

**(b) (i)** Name process A and explain why it is essential in eukaryotic cells from an evolutionary view point.

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[3]

**(ii)** Prior to completion of step A, the primary RNA is modified in several important ways. Explain how **one** of these ways helps to regulate gene expression.

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[1]

**(iii)** With reference to **Fig. 5.3**, label the following region (label only once):

(i) 5' UTR

(ii) 3' UTR

(iii) coding sequence

(iv) promoter

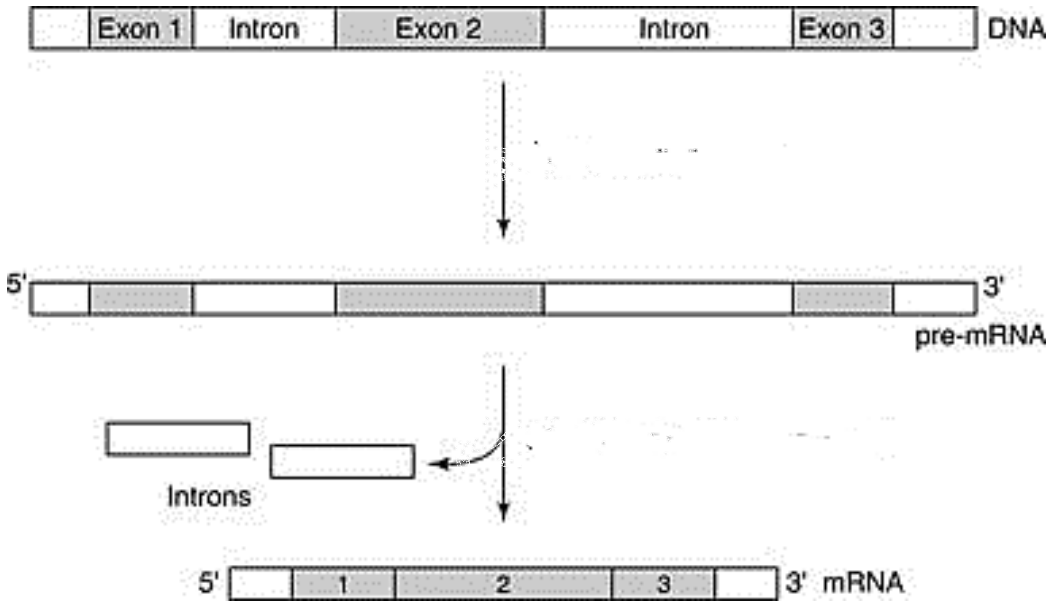


**Fig. 5.3**

[1]

**[Total: 12]**

**7** The central dogma of molecular biology describes the flow of genetic information from DNA to messenger RNA (mRNA) to protein.

**(a)** A molecule involved in the flow of genetic information from mRNA to protein is transfer RNA (tRNA). Outline the role of tRNA in the production of a polypeptide.

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…….. [2]

Each step in the flow of information from DNA to mRNA to protein provides the eukaryotic cell with a potential control point for regulating its functions by adjusting the amount and type of proteins synthesised.

Fig. 3.1 shows the regulation of gene expression of the albumin gene during transcription in eukaryotes. The albumin gene is associated with two control elements and a promoter.

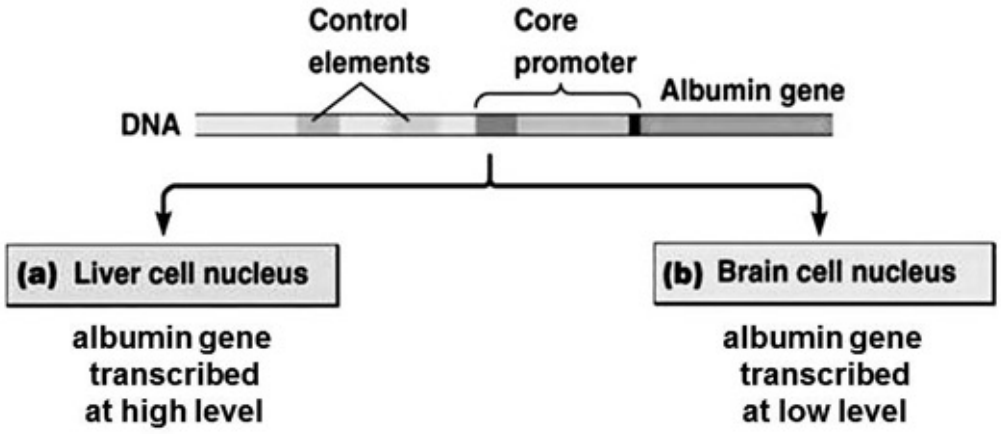


**Fig. 3.1**

**(b)** Explain how differential albumin gene expression in liver cells and brain cells is possible.

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…….. [3]

**[Turn Over**

In a normal person, the fragile X mental retardation protein (FMRP), regulates the synthesis of neuron proteins by stopping ribosomal translocation on target mRNAs. Fig. 3.2 shows how patients

with fragile X syndrome (FXS) have non-functional FMRP, resulting in accelerated synaptic protein synthesis that leads to abnormal synaptic function and intellectual disability.

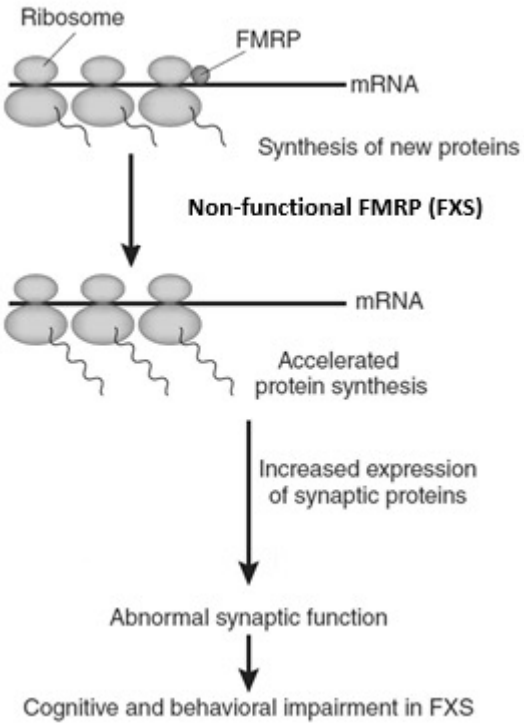


**Fig. 3.2**

**(c)** **(i)** State the level of control by FMRP on synaptic protein expression.

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…….. [1]

**(ii)** Describe one other control mechanism of a similar level as **(c)(i)**.

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…….. [2]

Research pertaining to gene regulation can contribute significantly to the treatment of genetic diseases. Spinal muscular atrophy (SMA) is a heritable motor neuron disease where patients have insufficient levels of functional survival motor neuron (SMN) protein in their motor neurons and muscle. Genetic studies have shown that all SMA patients have at least one copy of the functional SMN gene at another chromosomal locus (a result of chromosomal duplication), which is not expressed.

Scientists have shown in a study that trichostatin A (TSA), a histone deacetylase inhibitor, caused increased SMN protein levels, improved motor function and survival in mice.

Fig. 3.3 shows some results from the study. Different doses of TSA were injected in the mice and after two hours, muscle tissues were isolated. The levels of acetylated histone H3, histone H4 and SMN mRNA were measured.

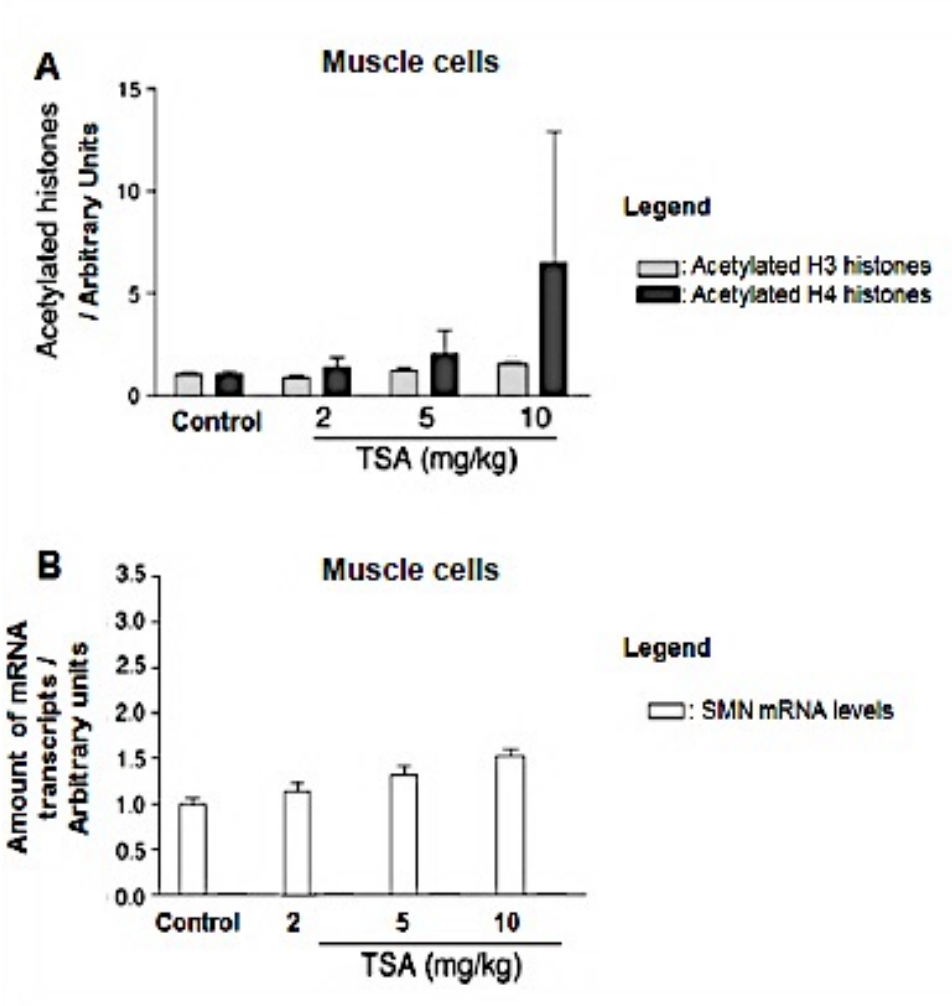


**Fig. 3.3**

**(d)** With reference to Fig. 3.3,

**(i)** describe the effect of TSA on the amount of SMN mRNA transcripts in muscle cells.

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…….. [1]

**[Turn Over**

**(ii)** explain the effect of an increase in H4 histone acetylation on the regulation of transcription of the SMN gene in muscle cells.

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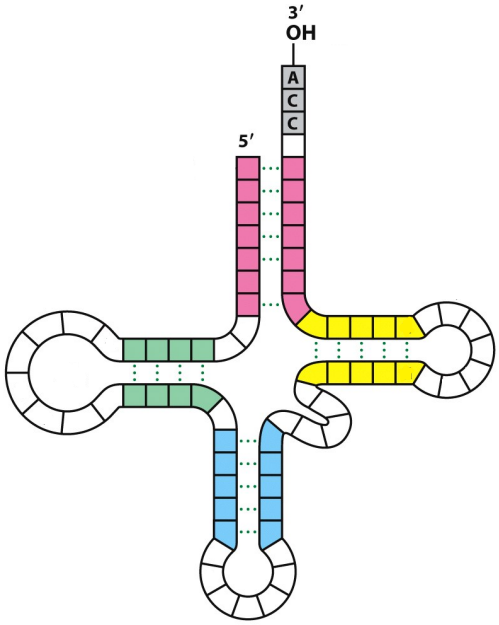
…… [3]

[Total: 12]

**2018 / H2 / RVHS PRELIM / P2 Q3**

**8** Fig. 3.1 shows the structure of a tRNA.




*Source: Biochem, Seventh edition, 2012*

**Fig. 3.1**

**(a)** Describe how the structure of tRNA allows for its role in translation. [4]

Synthetic RNA, which binds to bacterial mRNA, could interfere with translation. Fig. 3.2 shows the sequences of a bacterial mRNA and two different synthetic RNA.

Bacterial mRNA

| 5’- GUCAACCAUGCCAAUUAUCACGGACAUUCAUGGUAGGCCUUAGUAGACAACUG-3 |
|---|

Synthetic RNA 1 Synthetic RNA 2


**Fig. 3.2**

**(b)** With reference to Fig. 3.2, suggest how synthetic RNA binds to mRNA. [1]

The effectiveness of synthetic RNA 1 and 2 are investigated by introducing them to separate bacterial cultures and incubating for 24 hours. The results of the investigation is shown in Fig. 3.3.

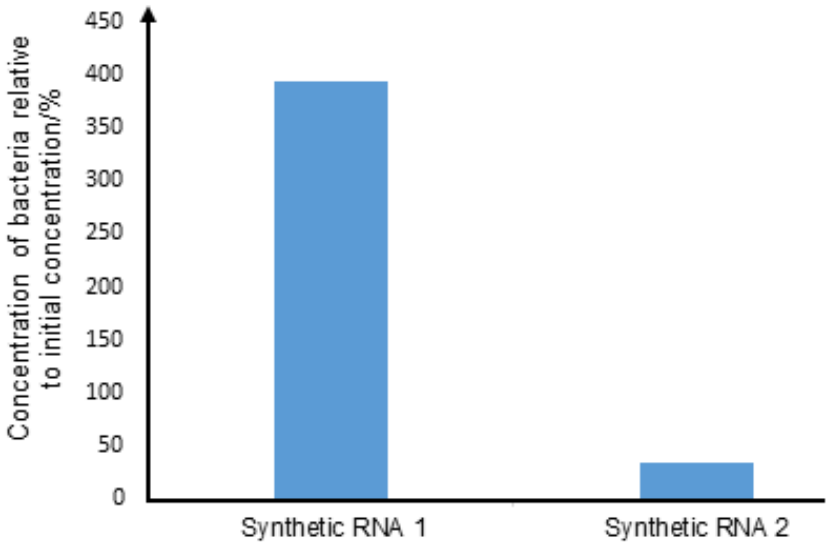



**Fig. 3.3**

**(c)** With reference to Fig. 3.2 and Fig. 3.3, explain the results of the investigation. [6]

**(d)** Suggest a limitation of using synthetic RNA as an oral antibiotic for bacterial infections in humans. [1]

[Total: 12]

**2018 / H2 / SAJC PRELIM / P2 Q2**

## QUESTION 8

**Fig. 2.1** shows Process X in an eukaryotic cell which produces ribosomal RNA (rRNA).

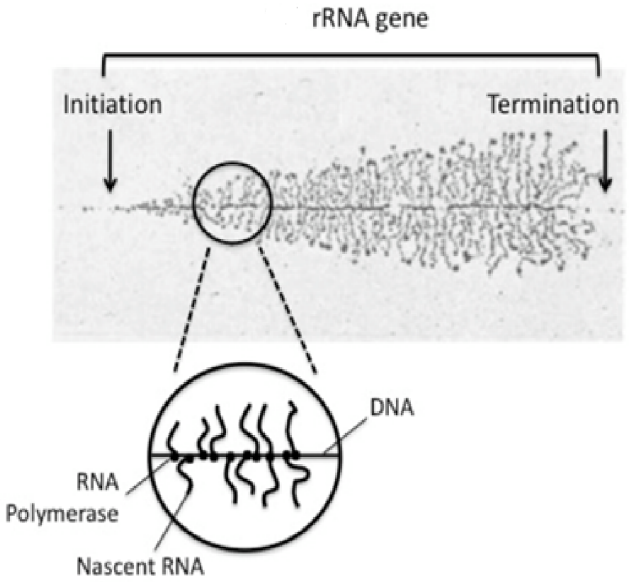



**Fig. 2.1**

**(a)(i)** Name the Process X occurring in **Fig. 2.1**.

…….[1]

**(ii)** List one molecule **not mentioned in Fig. 2.1** that is required for Process X.

…….[1]

**(iii)** Describe how RNA polymerase is able to recognise and bind to the promoter on DNA and not to other DNA regions.

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……..

…….. [2]

**(iv)** Explain for the observed pattern of Process X in **Fig. 2.1**.

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…..……..…….. [2]

**(v)** State the roles of rRNA in protein synthesis.

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…..……..…….. [2]

**(b)** During protein synthesis in cells of an embryo, all tRNA molecules with UAC anticodon sequence, are observed to be bound to arginine amino acid instead of methionine.

**(i)** Suggest how these tRNA molecules attached with the wrong amino acid might arise.

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…..…..…….. [2]

**(ii)** Suggest and explain the effect of this wrong pairing of amino acid to tRNA on the embryo.

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…..……..…….. [3]

**[Total: 13m]**

**2018 / H2 / TJC PRELIM / P2 Q9**

**9** Table 9.1 provides statements regarding the bonds found in four biological molecules.

**Table 9.1**

| statement | protein | DNA | messenger RNA | cellulose |
|---|---|---|---|---|
| hydrogen bonds stabilise the molecule | | | | |
| subunits are joined by peptide bonds | | | | |

**(a)** Complete Table 9.1 by indicating with a tick (✓) or a cross (×) whether the statements apply to proteins, DNA, messenger RNA and cellulose.

You should put a tick or a cross in each box of the table. [2]

**(b)** Telomeres are parts of chromosomes. Describe the function of telomeres.

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_____

_____ [4]

**(c)** A piece of mRNA is 660 nucleotides long but the DNA coding strand from which it was transcribed is 870 nucleotides long.

**(i)** Explain this difference in number of nucleotides.

_____

_____ [1]

**(ii)** What is the maximum number of amino acids in the protein translated from this piece of mRNA? Explain your answer.

Number of amino acids _____

Explanation

_____

_____

_____ [2]

**(d)** Identify **one** other process that leads to the formation of mature mRNA and state its function.

_____

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_____

_____ [2]

**(e)** Describe **one** difference between the structure of mRNA and tRNA.

_____

_____ [1]

[Total: 12]

**10** Telomeres have a nucleotide sequence that is repeated as many as 2000 times. This repetition is shown in Fig. 3.1. Attached to the DNA of the telomere are protein units.

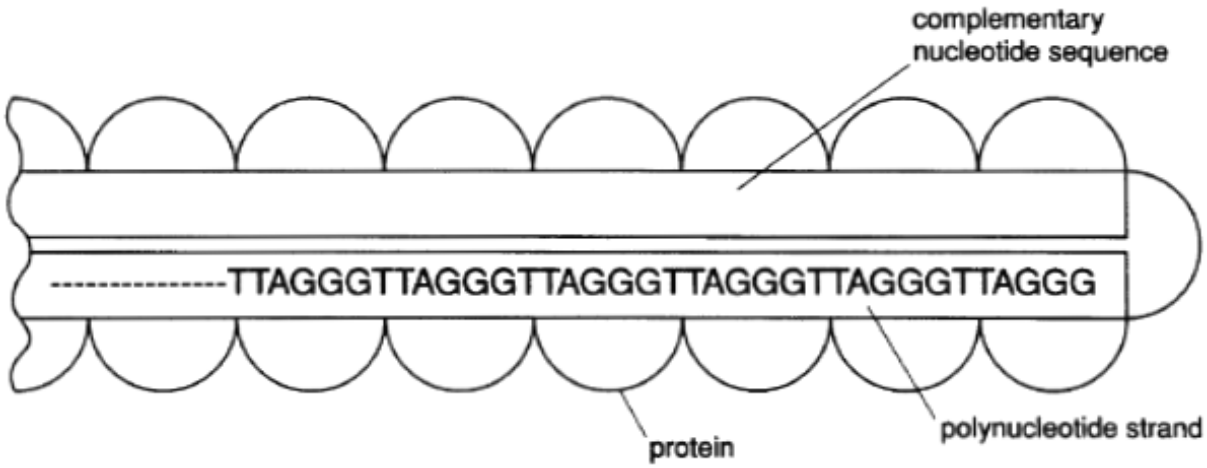


**Fig. 3.1**

**(a) (i)** What sequence of bases is repeated in the complementary polynucleotide shown in Fig. 3.1?

…… [1]

**(ii)** Suggest one reason for the presence of protein units in the telomere.

……..

…… [1]

**(b)** In the past, repeating sequences were referred to as “junk DNA”. Explain why the term “junk DNA” is misleading in the context of telomere.

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…… [2]

**(c)** The repetitive base sequence of telomere DNA is an example of a non-coding base sequence.

Explain what is meant by non-coding.

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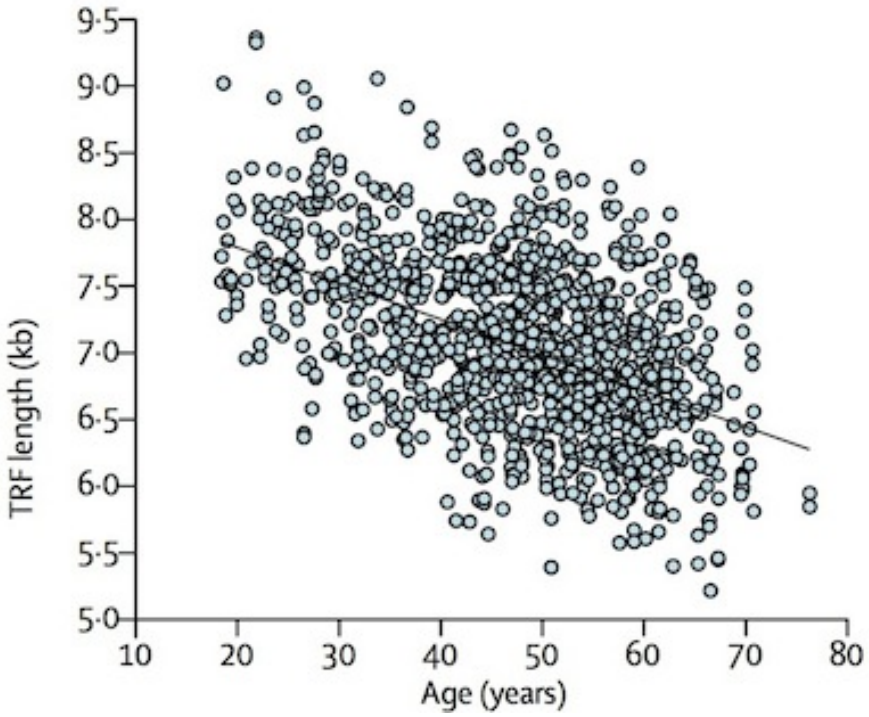
…… [1]

**(d)** A study of individual telomere lengths and its correlation with age is shown in Fig. 3.2.




(Taken from https://www.wired.com/images_blogs/wiredscience/2011/05/telomere_graph.jpg)

**Fig. 3.2**

Account for the trend line shown in Fig. 3.2.

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…… [4]

[Total: 9]