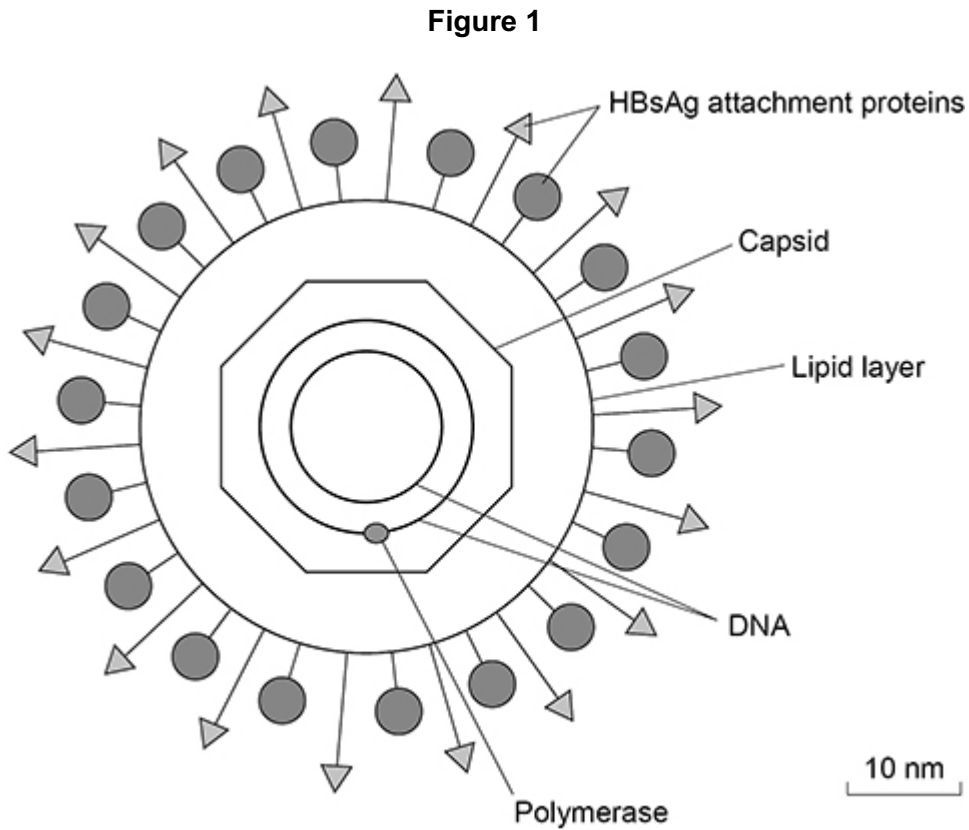


Q1.

Hepatitis B is a life-threatening liver infection caused by the hepatitis B virus (HBV).

Figure 1 shows the structure of HBV.



(a) HBV infects a liver cell. The liver cell is 25 μm in diameter.

Use **Figure 1** to calculate how many times larger in diameter this cell is than HBV. You should use the lipid layer to measure the diameter of HBV.

Answer _____ times larger

(2)

Scientists investigated the effectiveness of two types of RNA interference (RNAi) molecules on reducing HBV replication. These molecules were:

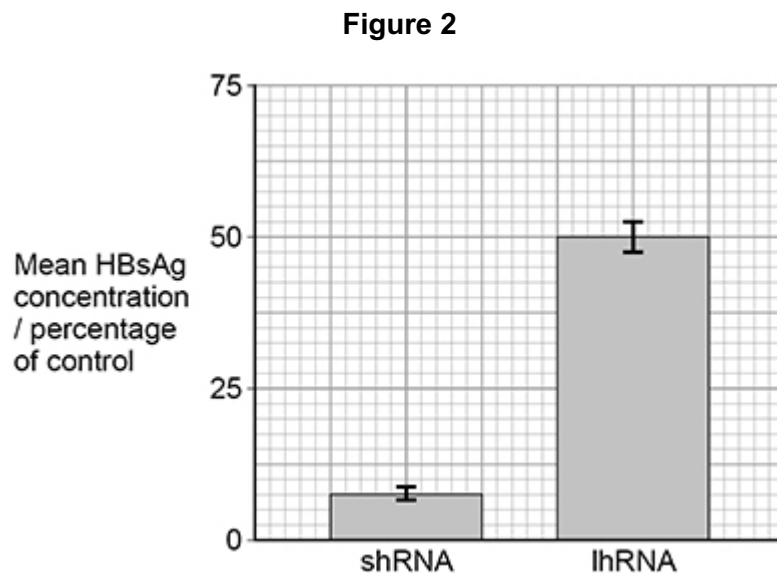
- short hairpin RNA (shRNA)
- long hairpin RNA (lhRNA).

The scientists infected mouse liver cells with HBV and transferred either shRNA or lhRNA into these cells. Then they determined the concentration of the attachment proteins, HBsAg, in these cells.

The concentration of HBsAg is a measure of HBV replication.

Figure 2 shows the scientists' results.

The error bars represent ± 2 standard deviations from the mean, which includes over 95% of the data.



- (b) One method of transferring RNAi molecules into cells involves combining these molecules with a lipid. Suggest why this increases uptake of RNAi molecules into cells.

(1)

- (c) Using all the information provided, evaluate the use of the two types of RNAi in treating hepatitis B in humans.

Do **not** refer in your answer to how RNAi reduces HBV replication.

(5)
(Total 8 marks)

Q2.

Testosterone is a steroid hormone that belongs to a group of male sex hormones called androgens.

- (a) Steroid hormones are hydrophobic.

Explain why steroid hormones can rapidly enter a cell by passing through its cell-surface membrane.

(2)

- (b) In the cytoplasm, testosterone binds to a specific androgen receptor (AR). An AR is a protein.

Suggest and explain why testosterone binds to a specific AR.

(2)

- (c) The binding of testosterone to an AR changes the shape of the AR. This AR molecule now enters the nucleus and stimulates gene expression.

Suggest how the AR could stimulate gene expression.

(2)

The gene that codes for the AR has a variable number of CAG repeats. Some studies have shown an association between the number of CAG repeats and the risk of developing prostate cancer.

The table below shows the results of a statistical test from one study.

Number of CAG repeats in the AR gene	Probability (P) value
≤ 16	0.02
≤ 17	0.30
≤ 18	0.07
≤ 19	0.09
≥ 20	0.06

- (d) What can you conclude from the data in the table above?

(3)

(Total 9 marks)

Q3.

Plants transport sucrose from leaves to other tissues for growth and storage. SUT1 is a sucrose co-transporter protein.

Scientists investigated whether the cells of tobacco plant leaves used SUT1 to transport sucrose to other tissues.

- (b) To study the role of SUT1 in tobacco plants, scientists reduced the expression of the *SUT1* gene.

When the *SUT1* gene is transcribed, the SUT1 mRNA produced is called 'sense' SUT1 mRNA. The scientists genetically modified plants by inserting an **extra** gene so that this **also** allowed the production of 'antisense' SUT1 mRNA.

The scientists had two types of tobacco plants:

- type **A** – plants that were genetically modified
- type **B** – plants that were **not** genetically modified.

Suggest how the production of 'antisense' SUT1 mRNA in type **A** plants would reduce the expression of the *SUT1* gene.

(4)

Q4.

Guillain–Barré syndrome is a rare disease in which the immune system damages the myelin sheath of neurones. Myelin sheath damage can cause a range of symptoms, for example numbness, muscular weakness and muscular paralysis. Sometimes, neurones of the autonomic nervous system are affected, causing heart rate irregularities.

5

Huntington’s disease is a disorder caused when a protein called huntingtin damages the brain. Huntingtin is produced because of a dominant, mutant allele.

The first successful drug trial to reduce concentrations of huntingtin in the human brain involved 46 patients. The patients received the drug for 4 months. The concentration of huntingtin was reduced in all the patients. The drug was injected at the base of the spine into the cerebrospinal fluid bathing the brain and spinal cord. The drug contains single-stranded DNA molecules. These single-stranded molecules inhibit the mRNA needed to produce huntingtin.

10

15

Symptoms of Huntington’s disease can start at any time, but usually develop between 30 and 50 years of age. The likelihood and age when symptoms start are linked to the number of CAG base sequence repeats in the gene for Huntington’s disease. However, recent studies have suggested that epigenetics may also affect the age when symptoms first start.

(c) The first successful drug trial to reduce concentrations of huntingtin in the brain used single-stranded DNA molecules (lines 13–14).

Suggest and explain how this drug could cause a reduction in the concentration of the protein huntingtin.

(3)

- (d) Scientists from the first successful drug trial to reduce concentrations of huntingtin (lines 9–11) reported that the drug is not a cure for Huntington’s disease.

Suggest **two** reasons why the drug should not be considered a cure. Do **not** include repeats of the drug trial in your answer.

1 _____

2 _____

(2)

- (e) Suggest **two** reasons why people had the drug injected into the cerebrospinal fluid (lines 12–13) rather than taking a pill containing the drug.

1 _____

2 _____

(2)

- (f) Suggest and explain **one** way epigenetics may affect the age when symptoms of Huntington’s disease start.

(2)

Q5.

Scientists investigated the role of a protein called CENP-W in mitosis. Their method involved cell fractionation and ultracentrifugation.

- (a) The scientists began by lysing (breaking open) cells and organelles using a detergent that dissolves lipids in water.

Suggest how the detergent releases CENP-W from cells.

(2)

- (b) Explain how ultracentrifugation separates CENP-W from other molecules.

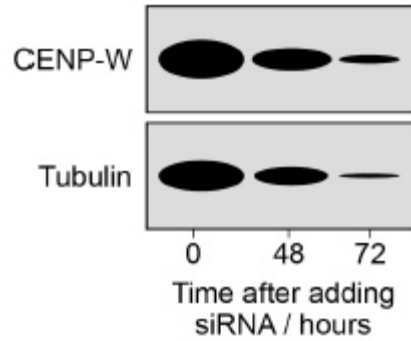
(2)

- (c) CENP-W is involved in the formation of spindle fibres in mitosis. Spindle fibres are made of molecules of a protein called tubulin.

The scientists treated cells in a culture with small interfering RNA (siRNA).

This siRNA causes RNA interference of expression of the *CENP-W* gene. The scientists took samples of cells at 0, 48 and 72 hours after adding the siRNA. They then used gel electrophoresis to separate CENP-W and tubulin from these samples.

The diagram shows the results of the electrophoresis. The size of each band is proportional to the amount of CENP-W or tubulin present.



Suggest how the siRNA produced these results.

(3)
(Total 7 marks)

Q6.

(a) Define what is meant by epigenetics.

(2)

(b) In eukaryotes, transcription of target genes can be stimulated or inhibited when specific transcriptional factors move from the cytoplasm into the nucleus.

Oestrogen, methyl groups and acetyl groups are control factors that can play a role in initiating transcription.

Complete the table to show features of these control factors.

Put a tick (✓) in the box if the control factor shows the feature.

Control factor	Feature	
	Binds with DNA	Binds with protein
Oestrogen		
Methyl groups		
Acetyl groups		

(2)

(c) Explain how increased methylation could lead to cancer.

(3)