

**Model Answers: Hard**

1a

(a) The difference between a structural and regulatory gene is as follows...

- A structural gene codes for a protein that functions within a cell; [1 mark]
- A regulatory gene codes for a protein that controls the expression of another gene; [1 mark]

**[Total: 2 marks]**

1b

(b) High tryptophan levels will have the following effect on the trp operon...

Any **four** of the following:

- Tryptophan/Trp binds to the trp repressor protein; [1 mark]
- This causes a change in the (trp repressor) protein shape/conformation **SO** allowing it to bind to the operator; [1 mark]
- RNA polymerase cannot bind to the operator/DNA (due to the presence of the repressor protein); [1 mark]
- This (binding) prevents the transcription of the structural genes **OR** the enzymes needed for the production of tryptophan cannot be synthesised; [1 mark]
- Tryptophan will not be produced (due to the absence of the enzymes needed for its synthesis); [1 mark]

**[Total: 4 marks]**

The trp operon functions in a similar way to the *lac* operon, except that in this case the presence of high levels of tryptophan will repress the expression of the structural genes in order to regulate the amount of tryptophan in the bacterial cell. It would be a waste of energy to synthesise tryptophan when levels are already high.

1c

(c) (i) The enzymes produced by the structural genes of the trp operon can be classified as:

- Repressible (enzymes); [1 mark]

(c) (ii) The reason for this is that...

- The binding of the trp repressor protein to the operator/O will prevent/repress the synthesis of the enzymes / prevent/repress the transcription of the genes coding for the enzymes; [1 mark]

**[Total: 2 marks]**

1d

(d) Attenuation would regulate the amount of tryptophan in the bacterial cells as follows...

Any **two** of the following:

- RNA polymerase detaches from the DNA before the end of the gene / stop codon; [1 mark]
- mRNA that forms would be incomplete / the mRNA strand would be shorter than usual; [1 mark]
- The tertiary/3D structure of the resulting proteins would be altered **OR** the shape of the enzyme active site would be altered / the active site would no longer be complementary to the substrate (and tryptophan would no longer be produced); [1 mark]

**[Total: 2 marks]**

This question requires you to apply knowledge of transcription and translation. If the structural genes are not fully transcribed then the enzymes necessary to produce tryptophan will not have the required structure and will therefore be non-functional. This would prevent an overproduction of tryptophan, which would be very wasteful.

2a

(a) Transcription means....

Any **two** of the following:

- The conversion of DNA into mRNA/messenger RNA / mRNA is produced from DNA; [1 mark]
- A complementary copy of the DNA template strand is produced **OR** one strand of the DNA molecule acts as a template; [1 mark]
- The mRNA/messenger RNA contains the information for the synthesis of a polypeptide/protein / can be translated into a polypeptide/protein; [1 mark]

**[Total: 2 marks]**

Make sure to brush up on your AS knowledge of transcription and translation for questions from this section.

2b

(b) Tamoxifen is an effective treatment for breast cancer because....

Any **three** of the following;

- It binds to oestrogen receptor/ER **OR** tamoxifen prevents oestrogen from binding to oestrogen receptor/ER; [1 mark]
- Tamoxifen is not complementary in shape to the cofactor (protein); [1 mark]
- (This) prevents oestrogen receptor/ER from binding to a cofactor (protein) **SO** it cannot bind to the promoter region (of a gene); [1 mark]
- No transcription (of the gene) can occur **SO** tumour formation is prevented / does not occur; [1 mark]

**[Total: 3 marks]**

You are not expected to know about tamoxifen, but you should be familiar with transcription factors and Fig. 1 provides you with all the additional information that you need to answer this question. Fig. 1 shows that tamoxifen binds to ER and that the slight difference in shape between tamoxifen and oestrogen prevents ER from binding to the cofactor. This will prevent the cofactor from binding to the promoter, RNA polymerase will not bind and the gene will not be transcribed. Given that the question tells you that oestrogen can induce tumours, preventing transcription in this way will logically prevent tumour formation.

2c

(c) Ways in which transcription factors might prevent transcription from occurring include...

Any **two** of the following:

- Prevent the breaking of hydrogen bonds between base pairs/bases/nucleotides; [1 mark]
- Prevent the attachment of RNA polymerase (to DNA); [1 mark]
- Prevent the movement/progress of RNA polymerase (along a gene); [1 mark]
- Prevent the (temporary) joining of RNA nucleotides to their complementary DNA bases / the formation of (temporary) hydrogen bonds between RNA and DNA bases; [1 mark]

- Prevent the joining of new nucleotides to each other / the joining of the sugars and phosphates of the new nucleotides / formation of phosphodiester bonds between nucleotides; [1 mark]

**[Total: 2 marks]**

This is another question that relies on knowledge of the process of transcription. Remember that in order for transcription to occur the hydrogen bonds between the nucleotides of the DNA strands must break and RNA polymerase must bind to DNA to construct an mRNA molecule. Anything that prevents this from happening will also prevent transcription.

2d

(d) The importance of gene transcription for an organism is...

- It ensures that genes are expressed in the correct cells / at the correct time / to the correct level **OR** it enables cells to specialise/differentiate; [1 mark]

**[Total: 1 mark]**

3a

(a) Transcription factors stimulate the expression of a gene in the following way...

- In the nucleus, transcription factors bind to a specific base sequence/promoter region on the DNA; [1 mark]
- This initiates transcription of the gene **OR** transcription can then begin **OR** mRNA can then join by complementary base pairing to the gene sequence; [1 mark]
- mRNA is then translated **OR** a polypeptide is formed using the mRNA (meaning the gene is expressed); [1 mark]

**[Total: 3 marks]**

Transcription factors are the necessary molecules to initiate transcription. They act as a starting point for mRNA to start forming using the template of the DNA to copy the gene sequence. Without a transcription factor, the gene is inactivated because the mRNA cannot form and copy the gene sequence.

3b

(b) We can compare the action of oestrogen and non-competitive inhibitors as follows...

- Oestrogen binds to a receptor on the transcription factor **in the same way as** a non-competitive inhibitor binds to an alternative/allosteric site on an enzyme; [1 mark]
- Binding to the receptor triggers a change to the shape of the transcription factor **in the same way as** binding to the alternative/allosteric site on an enzyme causes a change in the active site shape; [1 mark]
- (However), non-competitive inhibitor inhibits enzyme function, **whereas** oestrogen stimulates gene expression **OR** a non-competitive inhibitor prevents the enzyme from forming enzyme-substrate complexes, **whereas** oestrogen stimulates the attachment of the transcriptional factor to the DNA; [1 mark]

**[Total: 3 marks]**

Oestrogen can enter the cell cytoplasm across the phospholipid bilayer because it is lipid soluble. Once in the cytoplasm, it can bind to the transcription factor which allows the transcription factor to bind to a specific site on the DNA. This will initiate transcription. Linking this mechanism back to the topic of enzymes, non-competitive inhibitors work by binding to the enzyme to cause a change to the tertiary structure and therefore the shape of

the active site so that the enzyme can no longer form enzyme-substrate complexes.

Be sure to use comparative language in your answer so you show the examiner you understand the two processes being compared and contrasted.

3c

(c) Oestrogen is unable to bind to the progesterone receptor because...

- It is not complementary to the shape of the progesterone receptor / the molecules are not complementary in shape to each other; [1 mark]

**[Total: 1 mark]**

3d

(d) Differential gene expression forms an organism with specialised cells in the following way...

Any **four** of the following:

- Transcription factors are used to activate/switch on and deactivate/switch off genes (in different cell types); [1 mark]
- mRNA is transcribed from these active genes; [1 mark]
- This mRNA is translated to synthesise/make proteins (specific to that cell type); [1 mark]
- The proteins that are produced give the cell a specific function; [1 mark]
- mRNA is translated to synthesise/make proteins; [1 mark]

**[Total: 4 marks]**

Every cell in the human body contains a huge amount of DNA and lots of it is not being used as it is either non-coding DNA or genes which are switched off. Not every single gene is required to be expressed all in one go because the cells don't need to be able to do everything all at once. This question is asking you to acknowledge that genes can be switched on and switched off depending on what is required for the gene and that the genes which are active will give the cell a particular function by providing specific proteins to carry out certain jobs within the cell.