Model Answers: Medium

1a

a) i) Mutations occur in DNA when…

Any **one** of the following:

- Copying errors / mistakes occur during DNA/semi-conservative replication; [1 mark]
- A base / series of bases is deleted/inserted/substituted; [1 mark]

a) ii) Mutations in BRCA1 and BRCA2 genes could increase the likelihood of tumour development because…

Any **three** of the following:

- The sequence of amino acids /primary structure of the protein (that they code for) is altered; [1 mark]
- The 3D/tertiary structure of the protein is altered **SO** it becomes non-functional; [1 mark]
- DNA mutations/copying errors are not repaired; [1 mark]
- Mutations in the genes that control the cell cycle can lead to uncontrolled cell division (which leads to tumour development); [1 mark]

[Total: 4 marks]

You have been told in the question that BRCA1 and 2 code for proteins that are involved with the repair of DNA mutations; this, together with your knowledge of the effect of mutations on protein function and how tumours develop, should enable you to work out the answer. Non-functional proteins from the BRCA1 and 2 genes will prevent the repair of mutations; if this occurs in the genes that regulate the cell cycle then tumour development may result.

1b

b) Genetic screening can reduce the risk of breast cancer in high risk individuals by…

Any **two** of the following:

- A patient will be aware that they are at increased risk of breast cancer; [1 mark]
- A patient may decide to have a mastectomy / breast tissue removed; [1 mark]
- A patient may have more regular breast cancer checks/screening tests; [1 mark]
- A patient may take medication to lower their risk of cancer / may decide not to take medication that might increase their risk of cancer; [1 mark]

[Total: 2 marks]

1c

c) A DNA probe can be used to show the presence of a particular allele by…

Any **two** of the following:

- The probe is complementary / has bases that are complementary to the allele being screened for; [1 mark]
- The probe binds/hybridises / forms hydrogen bonds with the allele (in a patient DNA sample); [1 mark]
- If it is present the probe label shows up / fluoresces (under UV light); [1 mark]

[Total: 2 marks]

You are not expected to know how genetic screening works but your knowledge of DNA base pairing, together with Fig. 1, should help you to answer this question. You have been shown an image of a single-stranded DNA probe binding to a single strand of patient DNA;

in order for two single strands of DNA to bind together they must have complementary base sequences. The probe allows the allele to be seen at the end of the test if it is present in the sample as the label will fluoresce under UV light.

1d

d) Social and ethical issues around genetic screening are as follows...

Any **three** of the following:

- Preventative treatments / lifestyle advice can be offered to those at increased risk of disease; [1 mark]
- Health services can save money on treatments (if preventative measures are successful); [1 mark]
- People can make decisions on whether or not to have (natural) children based on their genetics **OR** people might decide to have IVF (along with PGD) to avoid passing a genetic disorder on to their children; [1 mark]
- Screening embryos raises the possibility of designer babies / parents being able to choose the features of their child; [1 mark]
- The technology around embryo screening is expensive and can only be afforded by wealthy sections of the population; [1 mark]
- A positive screening result during pregnancy means that people may consider terminating a pregnancy / having an abortion; [1 mark]

[Total: 3 marks]

2a

a) Symptoms of beta thalassemia could include...

Any **three** of the following:

- Breathlessness; [1 mark]
- Fatigue; [1 mark]
- Muscle weakness; [1 mark]
- Pale skin / red blood cells are pale in colour; [1 mark]
- Slow growth; [1 mark]
- Inability to digest food / absorb nutrients; [1 mark]
- Differently shaped / small red blood cells; [1 mark]
- Increased production of red blood cells; [1 mark]

[Total: 3 marks]

Your knowledge of the function of haemoglobin should allow you to come up with answers to this question. Haemoglobin's role is to transport oxygen around the body. This fuels aerobic respiration and allows the production of ATP. The absence of functioning haemoglobin will mean a lack of oxygen reaching the body cells, leading to feelings of breathlessness and a lack of ATP production. This will affect any processes that require ATP such as muscle contraction, digestion, absorption of nutrients, and growth, as well as general feelings of fatigue. Red blood cells will be smaller as their development is affected by the lack of beta haemoglobin, and the body will increase red blood cell production in an attempt to compensate for the lack of oxygen in the blood. Haemoglobin is a red pigment so a lack of this pigment will cause a pale appearance in the red blood cells and the skin.

2b

b) i) The stem cells found in bone marrow are...

Any **two** of the following:

- Multipotent / no longer toti/pluripotent; [1 mark]
- Able to differentiate into only a few different types of cell; [1 mark]
- Able to differentiate into types of blood cell / red and white blood cells; [1 mark]

b) ii) The process by which the stem cells can be altered involves...

Any **three** of the following:

- The desired allele is inserted into a virus vector; [1 mark]
- The (stem) cells are exposed to / mixed with the virus/vector; [1 mark]
- The virus/vector inserts the desired allele into the (DNA of the stem) cells; [1 mark]
- The altered/transgenic cells are grown/cultured in the lab (before being infused back into the patient); [1 mark]

Reject gene or DNA in the place of the allele.

[Total: 5 marks]

It is good to get into the habit of referring to the inserted gene as an **allele** as opposed to just a gene or some DNA. In this particular case, it means that the mark point requires you to provide more information that you are given in the question stem to part c) below, but in general, it is helpful to make it clear that the inserted genetic information is another version of an existing gene rather than a new gene altogether or just a piece of DNA.

2c

c) The insertion of DNA in the wrong location could be a problem because...

Any **two** of the following:

- (DNA) could be inserted in the middle of / within a gene / within a gene regulatory sequence; [1 mark]
- (This would lead to) altered / non functional / no proteins being produced/synthesised (from that gene)/ a gene being switched on/off; [1 mark]
- (This could lead to) harmful side effects / a different genetic disorder / tumour development / named example of a harmful side effect that results from a failure to produce a particular protein; [1 mark]

OR

Any **two** of the following:

- (DNA) could be inserted into a non-coding section of DNA / intron **OR** a section of DNA without a promoter; [1 mark]
- (This would mean that) the new/desired gene would not be expressed / protein would not be produced/synthesised from the new/desired gene; [1 mark]
- The gene therapy would be ineffective / have no effect / fail to cure/treat the genetic disorder; [1 mark]

[Total: 2 marks]

In any attempt at genetic engineering, it is essential that a new gene is inserted in such a way that it is able to function and does not negatively impact the individual in question. If a new gene is inserted into the middle of another important gene, this will negatively impact the expression of that gene and the effect of this on an individual could be harmful, e.g. the development of a tumour, or a failure to produce an important enzyme or hormone. Similarly, if the new gene is inserted into a section of DNA that is not expressed by a cell then the new gene itself will not be expressed and the therapy will fail.

2d

d) Other concerns related to gene therapy could be...

Any **three** of the following:

- It can be difficult to find a safe/effective vector / the immune system can attack/react to the vector; [1 mark]
- Gene therapies are often temporary / may not offer a permanent cure; [1 mark]
- Gene therapies can (currently) only treat recessive conditions; [1 mark]
- Concern around inserting new genes into germ/gamete/embryo cells; [1 mark]
- Concern around the ethics of removing (so-called) undesirable genes from the gene pool / attempting to 'improve' humanity / eugenics; [1 mark]
- Concern around the ethics of people choosing to alter non-medical / non-life-threatening characteristics / a named characteristic of this type (e.g. appearance, height, sporting ability); [1 mark]
- There is a lack of incentive for drug companies to develop treatments for rare diseases (meaning that those suffering from such diseases are treated unfairly); [1 mark]
- Gene therapy is expensive so it may not be affordable for everyone; [1 mark]

[Total: 3 marks]

Note here that the question requires difficulties that are not connected with causing harm to gene expression, so problems relating to side effects such as cancer will not be accepted.

3a

a) ADA deficiency can lead to severe combined immune deficiency (SCID) because...

Any **four** of the following:

- (Mature) B/T lymphocytes have specific receptors on their cell surface membranes which bind to antigens / allow clonal selection; [1 mark]

	Advantage	Disadvantage
ERT	Any **one** of the following: • Injection is a straightforward procedure; [1 mark] • Can take effect quickly; [1 mark] • Enzymes can be sourced/produced reliably (so there will not be any shortages); [1 mark] • No/less risk of infection with (recombinant	Any **one** of the following: • A short-term treatment / injections would need to be repeated; [1 mark] • Some might be concerned by the ethics of producing human proteins in animals / animal cells / cabbage looper moths; [1 mark] • Proteins may be processed / modified differently in animal cells **SO** there is a risk of immune response; [1 mark]

	proteins); [1 mark] • Can be used while waiting to receive another treatment; [1 mark]	
HSCT	Any **one** of the following: • A long-term treatment/cure; [1 mark] • Will enable the patient to produce healthy lymphocytes / white blood cells (produced by bone marrow stem cells); [1 mark]	Any **one** of the following: • Risk of immune rejection (if donor is not a good match); [1 mark] • May have to take drugs to suppress the risk of immune rejection; [1 mark] • Matching donor may not be available / may be a long waiting list; • Risk of infection during procedure; [1 mark] • May take time for the new cells to begin producing (mature) lymphocytes; [1 mark]

- (Activated) B/T lymphocytes divide by mitosis / carry out clonal expansion / differentiate into different cell types; [1 mark]
- Plasma cells produce antibodies to neutralise pathogens / prevent pathogens from infecting host cells / increase phagocytosis of pathogens / reduce the mobility of pathogens / cause lysis of pathogen cells; [1 mark]
- Helper T cells release chemicals/cytokines that activate B cells / increase phagocyte activity; [1 mark]
- Killer T cells secrete toxins that destroy pathogens; [1 mark]
- Memory B/T cells remain in the blood and provide immunity; [1 mark]

Accept antibodies instead of receptors in reference to B lymphocytes for mark point 1.

[Total: 4 marks]

The question tells you that ADA deficiency prevents the maturation of lymphocytes, so your answer needs to explain the role of mature lymphocytes. In the absence of this function, there would be greatly reduced immune activity.

3b

b) An advantage and a disadvantage of each of these treatment types could be...

[Total: 4 marks]

You should know about the advantages and disadvantages associated with recombinant proteins, so these can be applied to the use of recombinant enzymes here, along with other logical advantages such as simplicity of injections and the immediate action of enzymes injected into the blood.

You are not expected to know about stem cell transplants but your knowledge of stem cells, their role in the bone marrow, and the role of antigens in identifying foreign cells should allow you to answer this part of the question. Bone marrow stem cells are responsible for the production of new blood cells, so a donation of stem cells from a healthy donor should allow

a patient to produce their own healthy white blood cells. The risk with any donor tissue is that if the antigens are not a good match immune rejection may occur.

3c

c) The process of gene therapy for ADA SCID involves...

Any **three** of the following:

- Ex vivo gene therapy is carried out in adult/somatic cells/lymphocytes that have been taken out of the body; [1 mark]
- A normal allele for ADA is transferred into viral vectors; [1 mark]
- T-lymphocytes from the patients are combined/mixed with vectors / the vectors transfer the allele into patient T-lymphocytes; [1 mark]
- (Modified) T-lymphocytes/cells are transfused/inserted/replaced/ into the patient; [1 mark]
- The infusion process / treatment needs to be repeated regularly / every few months; [1 mark]

[Total: 3 marks]