Genetic Technology Applied to Medicine (19.2): Cambridge (CIE) A Level Biology 9700 Exam Questions by Topic

22 questions · 63 marks · about 76 minutes. Answer in the spaces, then check the mark schemes at the end.

Question 1 · Paper 4 · October/November 2019 (42) · Q3(a) · 4 marks

3 Therapeutic proteins are used to treat disease. The first purified therapeutic protein used was insulin, in 1922. The insulin was extracted from animal pancreases. Since 1982 most insulin has been made by recombinant DNA technology.

(a) Explain the advantages of producing human therapeutic proteins, such as insulin, by recombinant DNA technology.

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Question 2 · Paper 4 · February/March 2022 (42) · Q5(a)(i) · 1 mark

5 Factor VIII can be made as a recombinant human protein.

(a) (i) Name the disease that is treated using recombinant human factor VIII.

Question 3 · Paper 4 · February/March 2022 (42) · Q5(a)(ii) · 2 marks

(ii) Before recombinant human factor VIII was available, this disease was treated with factor VIII from donated blood.

Give **two** advantages of using recombinant human factor VIII, instead of factor VIII from donated blood, to treat this disease.

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Question 4 · Paper 4 · May/June 2023 (43) · Q4(a) · 3 marks

4 One cause of the genetic disease severe combined immunodeficiency (SCID) is a mutation in the *ADA* gene. This mutation results in a deficiency of the enzyme adenosine deaminase (ADA).

Although ADA is found throughout the body, it is especially active in lymphocytes. The absence of functional ADA causes the build-up of toxic metabolites that kill lymphocytes and damage organs.

Babies are often diagnosed with SCID by six months old. Treatment can greatly improve the life expectancy of children with SCID.

Some treatment options are available.

- Enzyme replacement therapy with recombinant human ADA made by genetically modified (GM) *Escherichia coli*. Weekly intra-muscular injections are given.
- Bone marrow transplant if a well-matched donor, such as a close relative, can be found.
- Gene therapy.

(a) Suggest **and** explain why it may be more appropriate to use enzyme replacement therapy to treat SCID instead of a bone marrow transplant.

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Question 5 · Paper 4 · May/June 2021 (42) · Q4(a) · 2 marks

4 **(a)** Genetic technology involving the creation of recombinant DNA can be used to treat different human diseases. These include diseases such as diabetes that may have multiple causes and inherited disorders that are caused by a single gene.

Outline **two different** ways of using recombinant DNA technology to treat these diseases.

diabetes .....

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single gene disorder .....

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[2]

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Question 6 · Paper 4 · October/November 2023 (41) · Q10 · 7 marks

10 Medicine is defined as the diagnosis, treatment and prevention of disease.

Outline the different ways in which genetic technology can be applied to medicine, with reference to named diseases.

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Question 7 · Paper 4 · May/June 2024 (42) · Q5(a) · 4 marks

5 The gene *BRCA1* is expressed in breast tissue and in several other tissues of the body. *BRCA1* codes for a tumour suppressor protein. This protein is involved in either repairing damaged DNA, or in triggering the death of a cell if DNA cannot be repaired.

Some mutations in *BRCA1* are associated with an increased risk of developing breast cancer.

(a) State **one** reason why a doctor would recommend that a person has genetic testing for a mutation in the gene *BRCA1* **and** explain why this mutation would put the person at a greater risk of breast cancer.

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Question 8 · information from earlier in the question

5 *BRCA2* is a tumour-suppressor gene. Its gene product, BRCA2, is involved in DNA repair. If the DNA cannot be repaired, BRCA2 has a role in causing the cell to die. BRCA2 is found in cells of breast tissue.

When a mutation occurs in *BRCA2*, damaged DNA may not be repaired and this increases the risk of breast cancer.

When a double-stranded piece of DNA breaks, BRCA2 binds to the damaged DNA directly and interacts with the enzyme RAD51 to repair the damage.

Repairing DNA prevents other mutations and gene rearrangements from occurring which could otherwise lead to breast cancer.

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(b) Scientists have identified hundreds of mutations in *BRCA2*, but not all of these mutations will increase the risk of cancer. One specific mutation in *BRCA2*, known as 999del5, is found in 0.6% of the general global population.

Iceland is an island country in the North Atlantic Ocean. The ancestors of most of the current population are people who arrived to settle in Iceland in AD 874.

In the Icelandic population, mutation 999del5 is the cause of 7–8% of breast cancer cases in women and 40% of breast cancer cases in men. This is much higher than the percentage of breast cancer cases in the general global population.

Question 8 · Paper 4 · May/June 2024 (43) · Q5(b)(ii) · 3 marks

(ii) One of the largest global genetic screening programmes for breast cancer involves identifying people with mutations in *BRCA2*.

Outline the advantages of genetic screening for mutations in *BRCA2*.

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Question 9 · Paper 4 · May/June 2024 (43) · Q5(b)(iii) · 1 mark

(iii) Suggest **one** advantage to a country of a genetic screening programme for breast cancer that screens for specific mutations in *BRCA2* in the population.

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Question 10 · information from earlier in the question

3 Cystic fibrosis is an autosomal recessive genetic disease. People with cystic fibrosis have a homozygous recessive genotype.

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(c) A screening programme for cystic fibrosis was introduced in 2007 for all children born in the UK. Children are tested within seven days of their birth. Children identified from the screening programme as being at high risk of having cystic fibrosis can have a genetic test to confirm whether they have the disease.

(i) Table 3.1 shows the median predicted life expectancy for people born in the UK who have cystic fibrosis. Predictions are shown for people born in 2008, 2012, 2016 and 2020.

Table 3.1

year of birth	median predicted life expectancy /years
2008	38.8
2012	43.5
2016	47.0
2020	50.6

Describe the trend shown in Table 3.1 **and** outline how early screening for cystic fibrosis may have contributed to this trend.

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Question 11 · information from earlier in the question

5 Huntington's disease is caused by a dominant allele of the gene that codes for the production of the huntingtin protein. This protein affects the development of many different tissues, including brain tissue.

- The Huntington allele contains several repeats of the base sequence CAG, which codes for glutamine.
- This results in a polyglutamine section in the synthesised protein.
- A gene with more than 39 CAG repeats produces a protein that does not fold properly and does not function.

- Symptoms of Huntington's disease usually first appear between the ages of 30 and 45 years.
- There is no treatment for the disease, which is progressive and always fatal.
- Some people with between 27 and 35 CAG repeats do not develop the disease, but may still pass on the Huntington allele to their children, who may develop the disease as the number of repeats tends to increase when gametes are produced.

(b) Young people who have a parent with Huntington's disease can choose to be screened for the presence of the Huntington allele.

Question 11 · Paper 4 · October/November 2017 (42) · Q5(b)(ii) · 2 marks

(ii) Suggest **one** advantage and **one** disadvantage of screening for Huntington's disease before any symptoms occur.

advantage .....

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disadvantage .....

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Question 12 · information from earlier in the question

4 One cause of the genetic disease severe combined immunodeficiency (SCID) is a mutation in the *ADA* gene. This mutation results in a deficiency of the enzyme adenosine deaminase (ADA).

Although ADA is found throughout the body, it is especially active in lymphocytes. The absence of functional ADA causes the build-up of toxic metabolites that kill lymphocytes and damage organs.

Babies are often diagnosed with SCID by six months old. Treatment can greatly improve the life expectancy of children with SCID.

Some treatment options are available.

- Enzyme replacement therapy with recombinant human ADA made by genetically modified (GM) *Escherichia coli*. Weekly intra-muscular injections are given.
- Bone marrow transplant if a well-matched donor, such as a close relative, can be found.
- Gene therapy.

Question 12 · Paper 4 · May/June 2023 (43) · Q4(b) · 4 marks

(b) Outline the procedure used for gene therapy treatment of a person with SCID.

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Question 13 · Paper 4 · February/March 2020 (42) · Q2(c) · 3 marks

(c) One form of SCID is caused by a mutation that results in a deficiency of the enzyme adenosine deaminase (ADA).

Children with ADA-deficient SCID can be treated with gene therapy using a virus. After successful gene therapy, the children are able to produce ADA for themselves.

Suggest how children with ADA-deficient SCID can be treated with gene therapy using a virus.

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Question 14 · Paper 4 · February/March 2020 (42) · Q2(d) · 3 marks

(d) Outline the challenges of using a virus for gene therapy.

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Question 15 · information from earlier in the question

4 Adenosine deaminase (ADA) deficiency is an immune system disorder caused by a recessive autosomal mutation.

Severe combined immunodeficiency caused by a lack of ADA is called ADA-SCID.

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Question 15 · Paper 4 · October/November 2022 (41) · Q4(b)(i) · 2 marks

(b) In 2016 gene therapy to cure ADA-SCID was approved in Europe. The gene therapy involves three main steps.

- Blood (haematopoietic) stem cells are taken from the bone marrow of the person with ADA-SCID.
- The functional gene and its promoter are inserted into the blood stem cells.
- A single infusion (injection) of the gene-corrected cells is given to the patient.

(i) Explain why a single infusion of gene-corrected stem cells is enough to cure the disease.

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Question 16 · Paper 4 · October/November 2024 (42) · Q3(b)(i) · 3 marks

(b) (i) Leber Congenital Amaurosis (LCA) is an inherited eye disease. In LCA, the photoreceptor cells in the retina die at an early age. This causes impaired vision (reduced eyesight) in children, which can progress to blindness.

Mutations in different genes cause different forms of LCA. One form of this disease, LCA2, is caused by a mutation in the *RPE65* gene. Gene therapy has been used to treat LCA2.

Outline how an inherited eye disease, such as LCA2, is treated with gene therapy.

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Question 17 · Paper 4 · October/November 2024 (42) · Q3(b)(ii) · 1 mark

(ii) Suggest why the eye is a suitable organ for gene therapy.

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Question 18 · information from earlier in the question

(b) Scientists are working towards a goal of treating haemophilia by gene therapy. They plan to use a common, harmless virus to introduce the functional gene. The virus has a genome that is 4.7 kilobase pairs long.

Question 18 · Paper 4 · October/November 2022 (42) · Q4(b)(iii) · 2 marks

(iii) Some individuals taking part in gene therapy trials have been naturally exposed to the virus carrying the functional gene, so that their blood already contains antibodies to the virus.

Predict how this will affect the success of the gene therapy treatment.

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Question 19 · information from earlier in the question

3 Cystic fibrosis is an autosomal recessive genetic disease. People with cystic fibrosis have a homozygous recessive genotype.

(c) A screening programme for cystic fibrosis was introduced in 2007 for all children born in the UK. Children are tested within seven days of their birth. Children identified from the screening programme as being at high risk of having cystic fibrosis can have a genetic test to confirm whether they have the disease.

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Question 19 · Paper 4 · February/March 2024 (42) · Q3(c)(ii) · 3 marks

(ii) In many countries, a genetic test for cystic fibrosis is available to **adults** who do **not** have cystic fibrosis but have a family member who either has cystic fibrosis or is heterozygous for the gene that causes cystic fibrosis.

These adults include partners, parents, offspring, brothers and sisters of the family member. The aim is to find out if any of **these adults** are heterozygous for the gene that causes cystic fibrosis.

Discuss the ethical and social considerations of making a genetic test for cystic fibrosis available to these adults.

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(d) MLD is a rare autosomal recessive disease. It is estimated that there is one case of MLD in every 40 000 births worldwide. Children with MLD have a reduced life expectancy.

- MLD is a degenerative disease that causes severe disability.
- Before 2022, there was no known cure for MLD and the only treatment for symptoms was to provide pain relief.

A new gene therapy treatment known as Libmeldy® became available in a number of countries in 2022. The treatment must start before symptoms are present. Although the treatment may provide a cure for MLD, a single dose is extremely expensive.

Blood samples from newborn babies are screened for a number of rare genetic diseases (neonatal screening) in most countries of the world, but none include screening for MLD.

Discuss the social and ethical considerations of including screening for MLD when carrying out neonatal screening in a country where gene therapy for MLD is available.

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Question 21 · Paper 4 · October/November 2021 (42) · Q4(c) · 3 marks

(c) Individuals can choose to have their DNA analysed on a microarray chip to predict their risk of developing different diseases.

Outline the social **and** ethical considerations of this type of DNA analysis.

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Question 22 · information from earlier in the question

4 One cause of the genetic disease severe combined immunodeficiency (SCID) is a mutation in the *ADA* gene. This mutation results in a deficiency of the enzyme adenosine deaminase (ADA).

Although ADA is found throughout the body, it is especially active in lymphocytes. The absence of functional ADA causes the build-up of toxic metabolites that kill lymphocytes and damage organs.

Babies are often diagnosed with SCID by six months old. Treatment can greatly improve the life expectancy of children with SCID.

Some treatment options are available.

- Enzyme replacement therapy with recombinant human ADA made by genetically modified (GM) *Escherichia coli*. Weekly intra-muscular injections are given.
- Bone marrow transplant if a well-matched donor, such as a close relative, can be found.
- Gene therapy.

Question 22 · Paper 4 · May/June 2023 (43) · Q4(c) · 3 marks

(c) Suggest the social and ethical implications of gene therapy for SCID that need to be considered before treatment is carried out.

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Mark schemes

Question 1 · Paper 4 · October/November 2019 (42) · Q3(a) · 4 marks

3(a)	*any **four** from:*	**4**
	1 identical to human, insulin / protein ; **R** similar	
	2 no, allergic reaction / immune response / side effects ;	
	3 human protein may, have high(er) activity / work better / (more) rapid response ;	
	4 no chance of developing tolerance (to animal insulin) ;	
	5 no risk of transmitting diseases ;	
	6 supply unlimited / large-scale production ; **ora** not enough animal pancreases to meet demand	
	7 cost (of production) low(er) ;	
	8 no ethical objections / no religious objections ; **ora**	

Question 2 · Paper 4 · February/March 2022 (42) · Q5(a)(i) · 1 mark

5(a)(i)	haemophilia (A) ;	**1**

Question 3 · Paper 4 · February/March 2022 (42) · Q5(a)(ii) · 2 marks

5(a)(ii)	*any **two** from:*	**2**
	accept ora throughout	
	1 large / unlimited, supply ;	
	2 no risk of infection ;	
	3 no / fewer, ethical issues ;	
	4 less chance of, rejection / immune response / allergic response / side effects ;	
	5 cheap / quick, to produce ;	
	6 no need to wait for donor ;	

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Question 4 · Paper 4 · May/June 2023 (43) · Q4(a) · 3 marks

4(a)	*any **three** from:* 1 donor not needed ; 2 immediate effect ; 3 *idea that* easy to administer treatment ; 4 no immune response / no rejection ; 5 less invasive ; 6 AVP ; e.g. lower risk to health / cheaper / quicker	**3**

Question 5 · Paper 4 · May/June 2021 (42) · Q4(a) · 2 marks

4(a)	*diabetes:* insulin from (GM) bacteria ; **A** ref to, yeast / animal cells *single gene disorder:* gene therapy **or** insert, functional / normal / dominant, allele into, target / somatic / stem, cells **or** genome ; **A** gene **R** *replacing one allele with another*	**2**

Question 6 · Paper 4 · October/November 2023 (41) · Q10 · 7 marks

10	*any **seven** from:* 1 genetic engineering / recombinant (DNA technology) ; 2 (named) drug / treatment / protein, from, (GM) bacteria / (GM) yeast / (named) (GM)O ; 3 make insulin (drug for diabetes) ; 4 make factor VIII (drug for haemophilia) ; 5 make adenosine deaminase (drug for SCID) ; 6 genetic, screening / diagnosis / testing ; 7 (detect) BRCA1 / BRCA2 ; 8 (detect number of repeats / allele for) Huntington's ; 9 (detect allele for) cystic fibrosis / CFTR ; 10 example of action if diagnosis positive ; 11 gene therapy ; 12 insert / add, normal allele into (named), cells / tissue (of person) ; 13 to treat, eye disease(s) / LCA / Leber's congenital amaurosis ; 14 to treat SCID ; 15/16 AVP ; ; e.g. *ref. to* help / develop, xenotransplantation GM / antigen-free, pigs / animals, to source, tissues / organs, for transplants GM plants to make vaccines GM / recombinant / DNA / mRNA, vaccines recombinant antibody technology other / different, recombinant therapeutic protein / genetic screening / gene therapy, example	**7**

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Question 7 · Paper 4 · May/June 2024 (42) · Q5(a) · 4 marks

5(a)	1 family history of, breast / ovarian, cancer ; *plus any **three** from:* 2 (mutation causes) change of primary structure (of tumour suppressor protein) ; 3 changes, folding / bonding / 3D shape / tertiary structure (of tumour suppressor protein) ; 4 non-functional (tumour suppressor) protein formed ; 5 DNA is not repaired / cells with damaged DNA do not die ; 6 (so) increases number of mutations / mutations accumulate ; 7 (some mutations) cause uncontrollable, cell division / mitosis (of breast cells) ;	**4**

Question 8 · Paper 4 · May/June 2024 (43) · Q5(b)(ii) · 3 marks

5(b)(ii)	*any **three** from:* 1 reduce worry if negative ; *(if positive)* 2 lifestyle changes / described ; 3 early treatment / breast removal / can have frequent checks ; 4 informed decision about having children ; 5 *ref. to* counselling ; 6 could lead to lower death rates from breast cancer ;	**3**

Question 9 · Paper 4 · May/June 2024 (43) · Q5(b)(iii) · 1 mark

5(b)(iii)	*any **one** from:* 1 only screen for mutations that occur with high frequency in a population (as opposed to hundreds of mutations) ; 2 cost effective ; 3 early diagnosis / early treatment / targeted treatment ; 4 identifies mutation known to increase the risk of developing breast cancer (as opposed to a neutral mutation) ; 5 could lead to lower death rates from breast cancer ;	**1**

Question 10 · Paper 4 · February/March 2024 (42) · Q3(c)(i) · 3 marks

3(c)(i)	*any **three** from*: 1 (median) predicted life expectancy increased (over time) ; 2 data quote ; e.g. from 2008 to 2020 increase from 38.8 to 50.6 years increase of 11.8 % increase of 30.4 3 treatment can be started **early** ; 4 better treatment / improved care (between 2008 and 2020) ;	**3**

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Question 11 · Paper 4 · October/November 2017 (42) · Q5(b)(ii) · 2 marks

5(b)(ii)	*two from:* *advantage (max 1)* 1 can choose whether to have children ; 2 can prepare for the future ; 3 (if negative) removes anxiety / AW ; *not awarded with mp5* *disadvantage (max 1)* 4 (if positive) no treatment possible ; 5 (if positive) may lead to anxiety / AW ; *not awarded with mp3* 6 (if positive) social / financial, discrimination ; e.g. life insurance refusal 7 (if positive) may still not develop disease (*ref. to* below 39 repeats) ;	**2**

Question 12 · Paper 4 · May/June 2023 (43) · Q4(b) · 4 marks

4(b)	*any **four** from:* 1 given a drug to increase number of stem cells (in bone marrow) ; 2 *ref. to* virus / vector, containing, normal / healthy, allele ; 3 remove, bone marrow / stem cells ; 4 mix stem cells with, viral / vector (to allow transfer of normal allele) ; 5 radiotherapy / drug, to make space in bone marrow / to kill stem cells (in bone marrow) ; 6 (transduced stem) cells, infused / injected, into blood ; 7 (lymphocytes) produce functioning ADA ; 8 AVP ; e.g. (gamma) retrovirus / adeno-associated virus e.g. tissue from bone marrow, purified / sorted, to obtain stem cells e.g. cells are grown in culture to check the ADA gene is active	**4**

Question 13 · Paper 4 · February/March 2020 (42) · Q2(c) · 3 marks

2(c)	*any **three** from:* 1 isolate / obtain, functional / normal, ADA allele ; **A** gene throughout 2 insert allele into virus (vector) ; I ref. to plasmid 3 remove, stem cells / T-lymphocytes / target cells ; 4 insert, allele / gene / virus, into, stem cells / T-lymphocytes / target cells ; 5 return, stem cells / T-lymphocytes / target cells, to body ; 6 AVP ; e.g. ref. to retrovirus / lentivirus ref. to difficulty in finding suitable donor for bone marrow transplant	**3**

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Question 14 · Paper 4 · February/March 2020 (42) · Q2(d) · 3 marks

2(d)	*any **three** from:*	**3**
	1 (retrovirus / lentivirus) can insert, viral DNA / healthy allele, randomly into (host) DNA ;	
	2 may cause, cancer / side effects / allergic response ;	
	3 inserted, allele / DNA, may be inactivated **or** inserted, allele / DNA, may inactivate another (host) gene ;	
	4 virus may not enter, target cells / T-lymphocytes **or** virus may enter non-target cells ;	
	5 AVP ; e.g. ref. to safe / clean, conditions required to produce virus ineffective immune response against virus	

Question 15 · Paper 4 · October/November 2022 (41) · Q4(b)(i) · 2 marks

4(b)(i)	1 stem cells, proliferate / divide / multiply / make new cells ;	**2**
	2 (correct) gene is, inherited by / passed on to / present in, new cells ;	

Question 16 · Paper 4 · October/November 2024 (42) · Q3(b)(i) · 3 marks

3(b)(i)	*any **three** from:*	**3**
	1 **add**, healthy / normal / correct / functional, gene / allele, to virus ;	
	2 inject virus into eye ;	
	3 gene integrated into (eye cell) genome / DNA ;	
	4 gene / allele, expressed to produce functioning, protein / enzyme ;	
	5 AVP ; e.g. adeno-associated virus / AAV voretigene neparvovec (drug)	

Question 17 · Paper 4 · October/November 2024 (42) · Q3(b)(ii) · 1 mark

3(b)(ii)	*any **one** from:*	**1**
	1 easily accessible / easy to inject ;	
	2 low risk of immune response ;	
	3 (eye small in size so) small amount of gene therapy treatment needed / AW ;	

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Question 18 · Paper 4 · October/November 2022 (42) · Q4(b)(iii) · 2 marks

4(b)(iii)	*any **two** from:* *decrease success because:* 1 antibodies / immune response, may, destroy / attack / AW, virus / vector ; 2 (so) limiting / stopping, delivery of, gene / allele / DNA, to cells ; 3 destroys GM cells **or** destroys cells that have successfully taken up the, virus / gene / allele / DNA ;	**2**

Question 19 · Paper 4 · February/March 2024 (42) · Q3(c)(ii) · 3 marks

3(c)(ii)	*any **three** from*: 1 reduces worry / AW, if result is negative ; **ora** 2 can make informed reproductive decisions / AW ; 3 cost / availability, of test ; 4 plan for care of child with CF ; 5 *idea of* further genetic testing ; e.g. counselling / testing of embryo / testing of partners 6 *idea that* test is not 100% accurate ; 7 problems related to, stigma / discrimination / insurance / confidentiality ;	**3**

Question 20 · Paper 4 · October/November 2025 (42) · Q5(d) · 4 marks

5(d)	*any **four** from:* 1 child may have disease when, neither parent has the disease / no family history ; 2 early, detection / treatment (for gene therapy to work) ; 3 improve, quality of life / life expectancy ; 4 *ref. to* informs family planning (for future pregnancies) ; 5 *idea that* it does not involve additional sampling ; 6 (screening is) expensive ; 7 treatment / gene therapy, expensive ; 8 test may not always be accurate ; 9 long-term effect of treatment, unknown / negative ;	**4**

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Question 21 · Paper 4 · October/November 2021 (42) · Q4(c) · 3 marks

4(c)	*any **three** from:*	**3**
	1 DNA analysis not available for everyone ;	
	2 lifestyle change ; **A** e.g. lose weight / stop smoking / take exercise	
	3 early treatment ;	
	4 allows people to plan ; e.g. organise care / appoint power of attorney / take out medical insurance / make will / gift property to children / retire early	
	5 decide whether to have children / ref. (therapeutic) termination ;	
	6 results may cause, anxiety / stress / panic / depression (if positive) **or** reduce worry (if negative) ;	
	7 results may affect ability to get, insurance / credit / jobs ;	
	8 *idea of* predictions may not be accurate ;	

Question 22 · Paper 4 · May/June 2023 (43) · Q4(c) · 3 marks

4(c)	*any **three** from:*	**3**
	1 expensive ;	
	2 cure / long term treatment / no longer chronically ill / better quality of life ;	
	3 no need for regular, injections / treatments **or** only a single treatment ;	
	4 cultural / religious, objections ;	
	5 no donor needed ;	
	6 *ref.* more money available to health system in the long term ;	
	7 may cause cancer ;	
	8 stressful ;	

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