1(a). In 1991 a type of genetically modified tomato was being developed.

This tomato contained a gene from a fish called an arctic flounder.

Arctic flounder fish live in very cold conditions.

How would the tomato with the arctic flounder gene be useful to modern agriculture?

[1]

(b). Genetic modification has many wider applications.

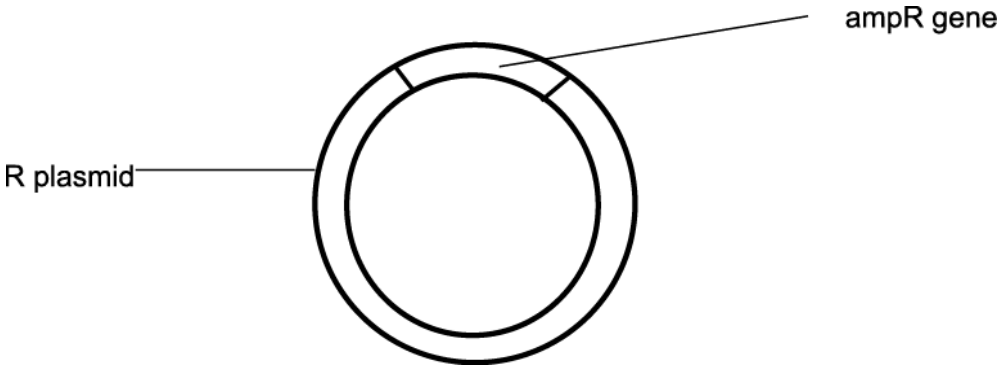
Children who lack human growth hormone can be injected with a genetically engineered version so they grow as normally as possible.

The bacterium *Escherichia coli* is used as part of the genetic engineering process.

Use this information to describe how human growth hormone is made.

[3]

2. Plasmids, such as the R plasmid shown below, may be found in bacteria.



What features of the R plasmid make it suitable as a **vector** in genetic engineering?

Use information in the diagram to help in your answer.

---

[2]

3(a). Scientists can genetically modify bacteria to make human insulin.

Describe procedures that scientists could use to genetically modify bacteria to make insulin and to identify the bacteria that have been successfully modified.

The quality of written communication will be assessed in your answer.

[6]

(b). There are lots of reasons that make bacteria ideal organisms for genetic modification.
One of the statements below is **not** a good reason.

Put a ring around the statement that is **not** a good reason.

rapid reproduction

presence of plasmids

may cause disease

ability to make complex molecules

simple biochemistry

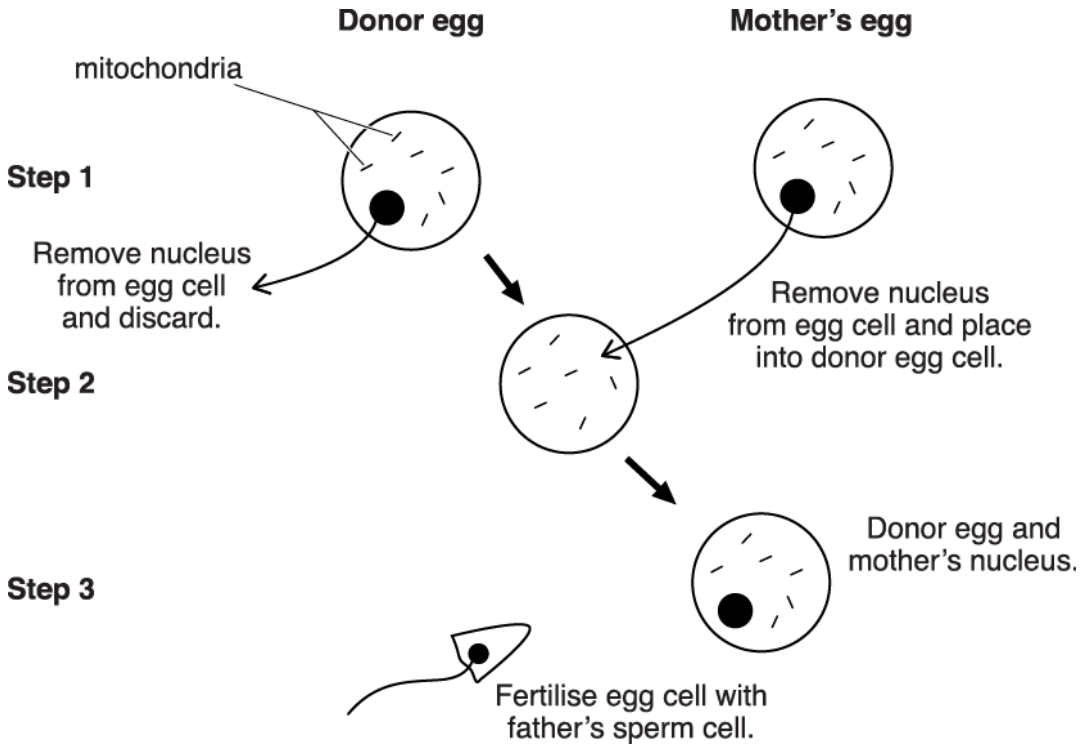
[1]

4(a). Scientists use cell structures from three people to make a baby:

- the nucleus from a mother's egg cell
- the nucleus from a father's sperm cell
- the mitochondria from a donor's egg cell.

This technique will help prevent some genetic diseases caused by faulty mitochondria.

The diagram below shows how the process will be done.



Step 4 Fertilised egg cell is then placed in the mother's uterus.

Mitochondria contain 37 genes.

The nucleus of a fertilised egg cell contains 40 000 genes.

What percentage of its genes does the fertilised egg cell receive from the donor?

Give your answer to 2 decimal places.

Show your working.

_____ % [2]

(b). Most of the baby's physical characteristics will be inherited from its father and mother.

Suggest why.

_____

_____

_____ [1]

(c). Genes code for proteins.

What type of protein could the genes in the mitochondria code for?

_____ [1]

(d). Babies created by this new technique will contain the DNA from 3 different individuals.

Some people do not agree with the use of this new technique.

Suggest and explain why.

_____

_____

_____

_____

_____ [3]

(e). Approximately 1 in 200 children have faulty mitochondria.

1 in 6500 children will have serious diseases as a result.

Do you think this justifies the development of this new technique?

Explain your answer.

[2]

(f). The DNA in the mitochondria of people affected by mitochondrial disease contains mutations.

A mutation is a change in the base sequence of the DNA.

Explain how these mutations can cause problems.

[2]

5.

(i) A doctor can prescribe drugs to treat heart disease.

It is now possible to genetically test people before prescribing drugs.

What are the benefits of this type of genetic testing?

Put ticks (✓) in the boxes next to the **three** correct answers.

Each drug works in the same way in every person. ☐

Less money is wasted prescribing drugs that don't work. ☐

Doctors don't have to learn about so many drugs. ☐

People won't have to visit the doctor any more. ☐

The drugs will always cure the patient from the disease. ☐

It may reduce the number of people who suffer dangerous side effects. ☐

The doctor can adjust the dose of the drug to suit the patient. ☐

[3]

(ii) Some people believe that this type of genetic testing should be compulsory for everyone.

Which of the following are **ethical** reasons why people might object to compulsory testing?

Put ticks (✓) in the boxes next to the **two** best **ethical** reasons.

Some people might be discriminated against when the test result is known. ☐

Some people might find the test painful. ☐

It will cost too much money to test everyone. ☐

The results of the test might be inaccurate. ☐

Everyone should have the right to choose whether they are tested or not. ☐

[2]

6. Harold has cystic fibrosis.

Hilda is a carrier for the disease.

Harold and Hilda are offered the chance to have a genetic test on their fetus before it is born.

Many people have concerns about the genetic testing of fetuses.

Describe **three** of these concerns.

1

2

3

---

[3]

7(a). Tim's father and grandfather both died from heart disease when they were 54 years old.

Tim is 35 years old.

His doctor tells him about a genetic test.

The test can predict how likely it is that he will develop heart disease.

Tim wants the test to tell him for certain whether or not he will develop heart disease.

Which of the statements are reasons why the test cannot do this?

Put ticks (✓) in the boxes next to the **three** best reasons.

A large number of people die from heart disease each year.	☐
Having a particular gene does not guarantee that you will develop heart disease.	☐
Tim's mother does not have heart disease.	☐
Tim's father and grandfather died from heart disease.	☐
The results of the test can sometimes be incorrect.	☐
There are lots of factors that can contribute to heart disease.	☐

[2]

(b). Suggest what implications the results of the test might have when Tim applies for life insurance.

---

[2]

8(a). Cystic fibrosis is an inherited disorder.

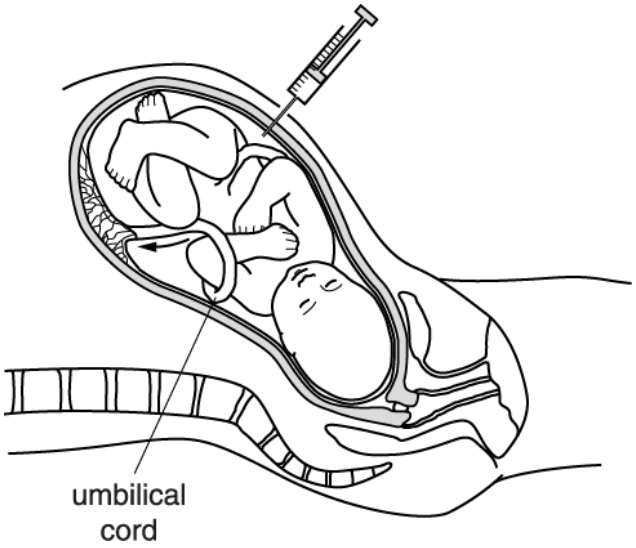
Sharon and Eric are both carriers for cystic fibrosis.

Sharon is pregnant. Eric is the father.

There is a chance that the fetus will have cystic fibrosis.

The fetus can be tested for cystic fibrosis.

This test usually involves pushing a long needle into the mother's uterus.



Cells from the fetus can then be removed and tested.

Scientists are developing a new method of collecting fetal cells.

They plan to remove a sample of the mother's blood from her arm.

This contains a very small number of fetal cells.

(i) Suggest **one** advantage of the current method that extracts fetal cells directly from the uterus.

---

[1]

(ii) Suggest **one** advantage of the new method that extracts fetal cells from a sample of the mother's blood.

---

[1]

(b). Sharon and Eric decide that they will have their fetus tested for cystic fibrosis.

Another couple, who are also both carriers for cystic fibrosis, decide not to have their fetus tested.

Discuss reasons why these two couples make a different decision about having their fetus tested.

The quality of written communication will be assessed in your answer.

[6]

9(a). This question is about genetic modification.

There are many examples of genetic modification.
Which of the following can be achieved by genetic modification?
Put ticks (?) in the boxes next to the **two** correct answers.

sexual reproduction in plants	☐
bacterial synthesis of medicines	☐
testing for genetic disorders	☐
selective breeding	☐
asexual reproduction in animals	☐
herbicide resistance in crop plants	☐

[2]

(b). One example of genetic modification is the production of golden rice.
Golden rice has a gene inserted that produces vitamin A.
White rice does not contain vitamin A.
Countries with people who eat mainly white rice have high levels of blindness due to a lack of vitamin A.

Suggest why people in these countries may be more in favour of the genetic modification of organisms than people who live in the United Kingdom.

---

[2]

(c). People with haemophilia lack the gene to make the protein Factor 8 (Factor VIII).
As a result their blood cannot clot if they cut themselves.

Suggest how the process of genetic modification could be carried out to treat people with haemophilia.

The quality of written communication will be assessed in your answer.

---

[6]

END OF QUESTION PAPER

Question			Answer/Indicative content	Marks	Guidance
1	a		Able to grow in colder conditions / less likely to be damaged by cold conditions ✓	1	DO NOT ALLOW reference to freezing tomatoes
	b		Any three from: Isolate the gene for human growth hormone ✓ Put the gene into a vector / plasmid ✓ Use the vector to put the (human growth hormone) gene into *E.coli* bacteria ✓ Grow bacteria / separate the hormone ✓	3	
			Total	4	
2			Any two from Separate circular DNA to main loop of DNA ✓ Naturally pass from one bacterial cell to another ✓ Can carry required genes (for resistance) into bacteria ✓	2	
			Total	2	
3	a		[Level 3] Some details from three areas. Quality of written communication does not impede communication of the science at this level. (5 – 6 marks) [Level 2] Some details from two areas. Quality of written communication partly impedes communication of the science at this level. (3 – 4 marks) [Level 1] Some details from one area. Quality of written communication impedes communication of the science at this level. (1 – 2 marks)	6	This question is targeted at grades up to A* Indicative scientific points regarding PROCESS of obtaining the gene: • Idea of gene from a human • Isolate / remove / cut out gene • Use of enzymes • Replicate gene • (Put gene into) vector / virus / plasmid Indicative scientific points regarding INSERTION into bacteria may include: • (DNA) incorporated into bacteria • Replication of bacteria • (Bacteria start) producing insulin Indicative scientific points regarding SELECTING bacteria include: Either with fluorescent marker • Production of gene probe • Addition of probe to DNA • Probe attaches to correct gene • Probe fluoresces under UV

<table>
<tr><th colspan="3">Question</th><th>Answer/Indicative content</th><th>Marks</th><th>Guidance</th></tr>
<tr><td></td><td></td><td></td><td>[Level 0]
Insufficient or irrelevant science. Answer not worthy of credit.

(0 marks)

Use the L1, L2, L3 annotations in RM Assessor; do not use ticks.</td><td></td><td>Or with antibiotic resistant gene

• Antibiotic resistant gene attached to insulin
• Both genes taken up by bacteria
• Bacteria treated with antibiotic
• Bacteria with resistant gene and insulin gene survive / others do not

Examiner's Comments

This question targeted A* candidates. Most candidates scored four of the six marks for correctly referring to how the gene is obtained and how it is inserted into the bacterium. Good answers referred to the gene being from a human, cutting the gene out with enzymes and using a vector for insertion into a bacterium. Many went on to write about replication of the bacteria to produce insulin. Only the most able candidates went on to score six marks by referring to the use of a gene probe to identify which bacteria had been modified.</td></tr>
<tr><td></td><td>b</td><td></td><td><table><tr><td>rapid reproduction</td><td></td></tr><tr><td>presence of plasmids</td><td></td></tr><tr><td>may cause disease</td><td>?</td></tr><tr><td>ability to make complex molecules</td><td></td></tr><tr><td>simple biochemistry</td><td></td></tr><tr><td>lack of ethical concerns in their production</td><td></td></tr></table></td><td>1</td><td>Examiner's Comments

This was an easy end to the paper with almost all candidates identifying “may cause disease” as the correct answer.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>7</td><td></td></tr>
</table>

Question			Answer/Indicative content	Marks	Guidance
4	a		40,037 / 40,000 + 37; 0.09;	2	 0.09 **must** be expressed to two decimal places. **Examiner's Comments** Given it was a calculation, this was answered relatively poorly with the majority of candidates gaining no marks. Of those who scored, many gave 0.09 as the answer, but with no working or the incorrect working. Many candidates got the answer 0.09 but often by carrying out the calculation (37/40000) × 100, which limited them to one mark. It is important to note that showing working here was essential to gain the second mark, and candidates should always be encouraged to show their working. Some candidates gave the answer to more than two decimal places, or to two significant figures. Many candidates calculated 40000/37.
	b		*any one from:* **majority of / most of / 99.91%** of their genes/chromosomes/genetic information/DNA from the mother and father/parents/sperm and egg/fertilised egg (not the donor); only small percentage of their genes/chromosomes/genetic information/DNA inherited from the donor; idea that most characteristics are coded for by DNA/genes/chromosomes/genetic material **found in the nucleus**;	1	 **ignore** reference to 50% from mother / 50% from father **Examiner's Comments** This question was answered poorly, with candidates not taking time to understand what was being asked. Many candidates focused on half of genes/23 chromosomes originating from each parent, without credit. Although some candidates had the correct idea that most genes come from the mother and father, they frequently forgot to say 'most', failing to understand what the question was actually asking. Some did say that characteristics are coded for by genes found in the nucleus. Very few made explicit the idea that few genes originated from the donor.

Question			Answer/Indicative content	Marks	Guidance
	c		enzymes	1	ignore named proteins / enzymes accept structural/structure / functional/function (proteins) Examiner's Comments Most candidates did not score on this question, with a surprising number of no response answers. Of those who did score, enzymes was frequently given, with some candidates giving functional as a response and very rarely structural. Some did name specific enzymes or proteins, such as e.g. amylase/keratin and some candidates wrote 'hair', but these were not worthy of credit. Many also wrote 'amino acids', but again this was not worthy of credit. Given enzymes are a type of protein, the proportion of wrong answers was surprising.

Question			Answer/Indicative content	Marks	Guidance
	d		*any three from any category:* *Consideration of consequences. Examples include:* not enough known (about the impact); DNA in the mitochondria may affect the characteristics of the child / cause complications; may be unsafe / harmful / risky; may cause disability; idea of concerns about where it could lead; likely to be costly / could the money be put to better use; problems caused by having three parents; causes problems for DNA testing; psychological problems; consideration of other consequences; *Consideration of ethics. Examples include:* unethical/morally wrong; is it right to select based on disease/to get rid of genetic disease; child unable to give consent/decide; uncertainty over legal parents/ donor may wish to parent the child / donor is not fully the parent of the children; should only have two parents / people may believe that a child should not have three parents; destruction of an egg cell / nucleus / genetic information / DNA which could have created life; other ethical consideration; *Religious argument. Examples include:* religious reasons / against God's will; other religious argument;	3	**accept** alternative ideas to those on left **ignore** mutations **ignore** 'unnatural' **ignore** reference to embryos **ignore** 'playing God' **Examiner's Comments** Most marks were awarded for simple statements of ethical or religious reasons or problems associated with having three parents. Some candidates talked about the nucleus which could become a life being discarded, although some gave this in the context of an embryo, which gained no credit. 'Playing God' and unnatural were very frequent responses which gained no credit. Centres are advised that these responses do not gain credit, and candidates should be advised against them. Only a small number candidates considered costs, or considered consequences. The candidates that did identify consequences tended to be around the ideas of where it may lead. Very few considered the impact on the child themselves.

Question			Answer/Indicative content	Marks	Guidance
	e		**any two from** (1 in 200 is a) **high** number of children affected; (so) less money will be spent treating children with diseases; (so) prevents faulty mitochondria being passed on to offspring/children; (but) **low number** (seriously) affected / **only** 1 in 6,500 / small chance of being (seriously) affected (so it may be) cheaper to treat those affected (than to develop the new technique); (however) idea that money used for the treatment only benefits few people / one disease / could benefit more patients/other diseases; it is worth it even to save one life / improve the quality of life / health;	2	**ignore** reference to religious and ethical arguments **accept** alternative idea that this is a high number in a whole population **Examiner's Comments** This question frequently scored 1 out of the 2 marks, with a significant number of candidates failing to use the information provided in the question. Many candidates gained credit for stating that the technique would improve quality of life, or save lives. Many candidates identified 1 in 6500 being a low number. Very few candidates discussed the idea of preventing faulty mitochondria being passed on. Some candidates did use both the 1 in 200 and the 1 in 6,500 figures thoughtfully in their answers to score 2 marks. Few candidates referred to it being cheaper to treat those affected than to develop the new technique.

Question			Answer/Indicative content	Marks	Guidance
	f		**any two from** amino acid **sequence** will be different/ the amino acids coded for will be different; no/different/incorrect protein/enzyme produced; protein/enzyme may not function;	2	**ignore** changes to the production/formation of amino acids **Examiner's Comments** Generally the idea that a different or wrong protein would be produced was scored by many candidates. The concept of amino acid sequence being changed seemed not to be so well understood, and rarely scored. There were quite a few references to amino acid *production*, which on its own did not gain credit. Quite a lot of candidates seized on the mutation idea and described how a mutation could affect an individual ranging from various disabilities to cancer, occasionally also talking about incorrect base pairing. The link between a protein being different and a protein not functioning was not often seen, so relatively few candidates scored the final marking point.
			Total	11	

<table>
<tr><th colspan="3">Question</th><th>Answer/Indicative content</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>5</td><td></td><td>i</td><td>
<table>
<tr><td>Each drug works in the same way in every person.</td><td></td></tr>
<tr><td>Less money is wasted prescribing drugs that don’t work.</td><td>✓</td></tr>
<tr><td>Doctors don’t have to learn about as many drugs.</td><td></td></tr>
<tr><td>People won’t have to visit the doctor anymore.</td><td></td></tr>
<tr><td>The drugs will always cure the patient from the disease.</td><td></td></tr>
<tr><td>It may reduce the number of people who suffer from dangerous side effects.</td><td>✓</td></tr>
<tr><td>The doctor can adjust the dose of the drug to suit the patient.</td><td>✓</td></tr>
</table>
</td><td>3</td><td>All three correct for three marks
Two correct for two marks
One correct for one mark

More than 3 boxes ticked, negate 1 mark for each additional tick.

<u>Examiner's Comments</u>

The majority of candidates were able to identify the three correct responses in relation to the benefits of genetic testing.</td></tr>
<tr><td></td><td></td><td>ii</td><td>
<table>
<tr><td>Some people might be discriminated against when the test result is known.</td><td>✓</td></tr>
<tr><td>Some people might find the test painful.</td><td></td></tr>
<tr><td>It will cost too much money to test everyone.</td><td></td></tr>
<tr><td>The results of the test might be inaccurate.</td><td></td></tr>
<tr><td>Everyone should have the right to choose whether they are tested or not</td><td>✓</td></tr>
</table>
</td><td>2</td><td>More than 2 boxes ticked, negate 1 mark for each additional tick.

<u>Examiner's Comments</u>

Most candidates could identify the two best ethical reasons against genetic testing.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>5</td><td></td></tr>
<tr><td>6</td><td></td><td></td><td>Any three from
risk of miscarriage / harm (the foetus / mother) / risk of infection (1)
termination / abortion (1)
false positive / negatives / not accurate / reliable (1)
who should be told (1)
religious / ethical concerns (1)
insurance / job implications (1)</td><td>3</td><td>Ignore damage unless qualified
ignore reference to safety
ignore ‘don't want to know’

<u>Examiner's Comments</u>

Candidates demonstrated secure knowledge in relation to concerns about genetic testing.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>3</td><td></td></tr>
</table>

<table>
<tr><th colspan="3">Question</th><th>Answer/Indicative content</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>7</td><td>a</td><td></td><td>
<table>
<tr><td>a large number of people die from heart disease each year</td><td></td></tr>
<tr><td>having a particular gene does not guarantee that you will develop heart disease</td><td>✓</td></tr>
<tr><td>Tim's mother does not have heart disease</td><td></td></tr>
<tr><td>Tim's father and grandfather died from heart disease</td><td></td></tr>
<tr><td>the results of the test can sometimes be incorrect</td><td>✓</td></tr>
<tr><td>there are lots of factors that can contribute to heart disease</td><td>✓</td></tr>
</table>
</td><td>2</td><td>3 correct = 2 marks
2 correct = 1 mark
1 correct = 0

<u>Examiner's Comments</u>

Most candidates were able to give all 3 correct responses to this question.</td></tr>
<tr><td></td><td>b</td><td></td><td>if test is positive:
may not get life insurance(1)
may be more expensive (1)</td><td>2</td><td>ora

<u>Examiner's Comments</u>

Many candidates knew the implications of a genetic test in relation to insurance companies and so scored at least 1 mark.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>4</td><td></td></tr>
</table>

Question			Answer/Indicative content	Marks	Guidance
8	a	i	idea of lots of (fetal) cells / don't need to separate mother's cells from fetal cells	1	ignore more accurate / reliable Examiner's Comments To get the mark for this question, candidates needed to identify either 'more fetal cells' or 'no need to separate maternal from etal cells'. Answers linked to accuracy/reliability did not get the mark.
		ii	less painful / invasive / less risk of miscarriage / less equipment needed	1	accept idea it is safer / easier accept idea that it can be done earlier in the pregnancy Examiner's Comments Many candidates were able to compare the methods given and give an advantage for the new one.
	b		[Level 3] Answer gives reasons from more than two areas why a couple may or may not choose to have the test done. Quality of written communication does not impede communication of the science at this level. (5 – 6 marks) [Level 2] Answer gives reasons from more than one area why a couple may or may not choose to have the test done. Quality of written communication partly impedes communication of the science at this level. (3 – 4 marks) [Level 1] Answer states a reason why a couple may or may not choose to have the test done. Quality of written communication impedes communication of the science at this level. (1 – 2 marks)	6	This question is targeted at grades up to A* Indicative scientific points may include: Ethical / moral / religious: may or may not believe in testing may or may not believe in terminations may or may not be worried about discrimination against a disabled child may or may not believe there should be any interference in nature (idea of playing God) economic: may or may not be able to afford care for child / treatment / counselling (since medical services cost in some countries) medical: increased risk of miscarriage risk to health of mother as a result of termination risk to health of mother / fetus as a result of testing false negative / positive test. Accuracy of the test plan for future medical treatment circumstances: may or may not have other healthy children

Question			Answer/Indicative content	Marks	Guidance
			[Level 0] Insufficient or irrelevant science. Answer not worthy of credit. (0 marks)		to consider may or may not have been trying for a baby for a long time may or may not have had many miscarriages prior to this baby may or may not plan for the future general: can make decisions regarding termination may, or may not, want to know whether the child has the disease couples will make different judgements about risks and benefits of the test idea that perception of risk is different to actual risk the quality of life the child / parents will have Examiner's Comments Candidates demonstrated secure knowledge in relation to genetic testing. Good responses were able to discuss in detail a variety of relevant factors.
			Total	8	

Question			Answer/Indicative content	Marks	Guidance
9	a		sexual reproduction in plants ☐ bacterial synthesis of medicines ✓ testing for genetic disorders ☐ selective breeding ☐ asexual reproduction in animals ☐ herbicide resistance in crop plants ✓	2	3 ticks = 1 mark max. 4 or more ticks = 0 marks **Examiner's Comments** Most candidates scored at least one of the two marks available for this question. Incorrect answers were randomly distributed across the remaining distractors. Candidates who gave an additional incorrect response were restricted to one mark.
	b		idea of need or benefit (1) relevant comparison to UK (1)	2	**Examiner's Comments** Candidates needed to give both points of view to gain the two marks for this question. Good answers referred to countries with high levels of blindness being more inclined to accept the genetically engineered rice, whereas, in the UK we had alternative sources of vitamin A and would be more likely to be concerned with the ethics and dangers of genetically modified food.
	c		**Level 3 (5–6 marks)** Includes reference to **getting** the gene AND **transferring** the gene AND **expressing** the gene. Quality of written communication does not impede communication of science at this level. **Level 2 (3–4 marks)** Includes reference to **getting** the gene AND **transferring** the gene OR **getting** the gene AND **expressing** the gene. OR **transferring** the gene **AND expressing** the gene. Quality of written communication partly impedes the communication of science at this level. **Level 1 (1–2 marks)** Includes reference to **getting** the gene OR **transferring** the gene OR **expressing** the	6	**This question is targeted at grades D to C** **Relevant points include:** **Getting the gene** • identify gene • isolate gene • replicate gene **Transferring the gene** • put gene into vector • example of vector eg virus, aerosol / plasmid / phage • explanation of how insertion occurs **Expressing the gene** • idea that DNA is common in all organisms *in humans*

Question			Answer/Indicative content	Marks	Guidance
			gene. Quality of written communication impedes the communication of science at this level. Level 0 Insufficient or irrelevant science. Answer not worthy of credit.		• transferred gene makes Factor 8 *in bacteria* • transferred gene makes Factor 8 • bacteria reproduce • isolate / purify F8 / give people F8 • If they inject bacteria into human, then max L2 Use the L1, L2, L3 annotations in Scoris; do not use ticks. Examiner's Comments This six-mark extended-writing question was common with the Foundation Tier.. Examiners were looking for how the gene was obtained, how the gene was transferred and how the gene was expressed. Some candidates went down the route of transferring the gene to a viral vector that could administer the gene to a human being, others went down the route of transferring the gene to a bacterium that could copy and express the gene such that factor 8 could be isolated and injected into a human being. Both types of answers were credit worthy. However those candidates that confused and mixed up both routes were restricted to Level 2 marks by the Examiners.
			Total	10	