Principles of Genetic Technology (19.1): Cambridge (CIE) A Level Biology 9700 Exam Questions by Topic

22 questions · 60 marks · about 72 minutes. Answer in the spaces, then check the mark schemes at the end.

Question 1 · Paper 4 · February/March 2020 (42) · Q5(a) · 1 mark

5 To identify the function of a gene, scientists can insert (add) a copy of the gene into a plasmid to create recombinant DNA. The plasmid is then transferred into a host bacterium to express the gene.

(a) Define recombinant DNA.

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Question 2 · Paper 4 · October/November 2022 (42) · Q4(a) · 4 marks

4 Haemophilia is a blood clotting disorder in humans caused by a mutant allele on the X chromosome.

Table 4.1 compares two forms of haemophilia: haemophilia A and haemophilia B.

Table 4.1

	haemophilia A	**haemophilia B**
gene	*F8*	*F9*
clotting factor protein	factor VIII	factor IX
proportion of males born with haemophilia	1 in 5000	1 in 30 000
length of functional gene (exons only) / kilobase pairs	7.0	1.6

(a) Genetic engineering is used to make recombinant human proteins to treat people with haemophilia A and haemophilia B.

Outline the principles of genetic engineering.

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Question 3 · information from earlier in the question

4 Genetic technology uses many different enzymes and techniques.

Question 3 · Paper 4 · May/June 2023 (42) · Q4(b) · 4 marks

(b) Originally, the method used to obtain a restriction endonuclease was to:

- grow large numbers of the specific prokaryotic cells that are the source of the enzyme
- break open the cells and extract and purify the restriction endonuclease.

This original method produced only a small quantity of restriction endonuclease and was **not** economical.

The newer method for large-scale production is to:

- obtain the gene coding for a specific restriction endonuclease
- introduce the gene into *Escherichia coli*, with a promoter that allows the gene to be expressed continuously.

The newer method increases the quantity of specific restriction endonuclease produced.

Suggest **and** explain the steps needed to carry out the newer method for large-scale production of a specific restriction endonuclease.

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Question 4 · information from earlier in the question

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

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

(b) The gene that codes for human factor VIII can be synthesised from messenger RNA purified from human liver cells.

(i) Name the enzyme that uses messenger RNA as a template to produce complementary DNA.

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Question 5 · Paper 4 · February/March 2022 (42) · Q5(b)(ii) · 2 marks

(ii) Outline **two** sources, other than messenger RNA, from which genes can be obtained for genetic engineering.

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Question 6 · Paper 4 · May/June 2024 (43) · Q4(a)(i) · 4 marks

4 Genetic engineering is a technique used to modify the genetic material of a specific organism to change a characteristic.

(a) (i) Genetic engineering uses specific enzymes and commonly involves the use of plasmids for the transfer of genes into an organism.

Four enzymes that are used in genetic engineering techniques involving plasmids are:

- restriction endonuclease
- DNA ligase
- DNA polymerase
- reverse transcriptase.

Outline the role of these enzymes in genetic engineering involving plasmids.

restriction endonuclease .....

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DNA ligase .....

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DNA polymerase .....

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reverse transcriptase .....

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[4]

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Question 7 · Paper 4 · October/November 2019 (42) · Q3(c)(i) · 2 marks

(c) Salmon calcitonin to treat osteoporosis is made by genetically engineered *Escherichia coli* bacteria. To produce these bacteria, a plasmid was cut and joined to the new gene to form a recombinant plasmid. The recombinant plasmid was then introduced into the bacterial cells.

(i) Name an enzyme that can:

- cut plasmid DNA

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- join the salmon calcitonin gene with plasmid DNA.

Question 8 · Paper 4 · October/November 2019 (42) · Q3(c)(ii) · 2 marks

(ii) Identify **and** explain two properties of plasmids that allow them to be used as vectors in gene cloning.

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Question 9 · Paper 4 · October/November 2019 (42) · Q3(d) · 2 marks

(d) The gene coding for salmon calcitonin is introduced into bacteria in a specially designed plasmid called an expression vector. An expression vector must contain a prokaryotic promoter, such as the *lac* promoter.

Explain why differences in the control of gene expression in prokaryotes and eukaryotes mean that expression vector plasmids must contain a prokaryotic promoter.

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Question 10 · 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 10 · Paper 4 · October/November 2022 (42) · Q4(b)(ii) · 2 marks

(ii) In gene therapy trials to treat haemophilia, the gene coding for the clotting factor needs to be introduced together with a promoter.

Explain why a promoter has to be introduced as well as the desired gene.

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Question 11 · Paper 4 · October/November 2023 (42) · Q4(a) · 4 marks

4 **(a)** A marker gene can be used when a gene of interest is introduced into a plant by genetic engineering.

Describe **and** explain how the use of a marker gene coding for a fluorescent product can show that the introduced gene of interest is being expressed in plants.

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Question 12 · Paper 4 · October/November 2022 (42) · Q4(c) · 2 marks

(c) Gene editing is a newer technique for modifying DNA. Some scientists are researching the use of gene editing, instead of introducing a functional gene, to treat haemophilia.

State **two** possible advantages of using gene editing as a method of treating haemophilia.

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Question 13 · Paper 4 · May/June 2022 (42) · Q4(a) · 5 marks

4 In 1973, a technique for genetic engineering was used for the first time. Recombinant DNA was made using a plasmid and this was successfully transferred into an organism.

In 2012, a new technique for genetic engineering, called gene editing, was developed.

(a) Table 4.1 lists some statements about the two genetic engineering techniques.

Complete Table 4.1 to compare the original genetic engineering technique using a plasmid vector with the newer technique of gene editing. For each row, place a tick (✓) in the correct column if the statement applies and leave a blank if the statement does not apply.

Table 4.1

statement	genetic engineering using a plasmid	gene editing
It may cause the organism to produce a different protein.		
It may cause a single base pair in a gene to be changed.		
The success of the technique can be evaluated using marker genes.		
It may use the CRISPR system.		
It uses DNA ligase.		

[5]

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Question 14 · Paper 4 · October/November 2022 (42) · Q5(a) · 3 marks

5 *Myosotis* is a genus of small flowering plants. Many different *Myosotis* species grow on the islands of New Zealand, which are an important site of *Myosotis* evolution. Lowland *Myosotis* species grow at low altitude while alpine *Myosotis* species grow at high altitude at the tops of mountains.

(a) Scientists wanted to obtain molecular data to determine the evolutionary relationships of New Zealand's *Myosotis* species. They extracted DNA from individuals of *Myosotis* species collected from three different islands in New Zealand.

To carry out a polymerase chain reaction before DNA sequencing, the DNA samples were mixed with primers, deoxynucleotides and *Taq* polymerase and put through 35 cycles of treatment. Each treatment cycle involved one minute at 95 °C, followed by one minute at 50 °C and then four minutes at 72 °C.

Describe what happened to the DNA at each temperature.

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Question 15 · information from earlier in the question

(b) Sickle cell anaemia is an autosomal recessive inherited disorder:

- allele Hb^A codes for the normal β-globin polypeptide
- allele Hb^S codes for the sickle-cell polypeptide.

People who are heterozygous (Hb^A Hb^S) have sickle cell trait (SCT). For a child to inherit sickle cell anaemia (Hb^S Hb^S), both parents must have SCT.

A genetic screening program is available for sickle cell anaemia and SCT:

- when a mother is screened and found to have SCT, the father is then screened
- if the mother becomes pregnant, the fetus is screened for both sickle cell anaemia and for SCT
- the test is done either by amniocentesis or by chorionic villus sampling, both of which carry a small risk of the pregnancy failing.

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Question 15 · Paper 4 · October/November 2020 (42) · Q4(b)(ii) · 3 marks

(ii) To test for the presence of Hb^S, DNA is extracted and the polymerase chain reaction (PCR) is carried out with two specific primers.

One mutation to produce Hb^S is a base substitution in the sixth codon of the β-globin gene. The normal codon GAG changes to GTG. The normal-specific primer detects GAG whereas the mutant-specific primer detects GTG.

Explain:

- why primers are used in PCR
- how the use of two specific primers allows the amplification of the normal, sickle cell anaemia and SCT genotypes.

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Question 16 · Paper 4 · February/March 2025 (42) · Q3(a)(i) · 4 marks

3 Gentamicin is an antibiotic used to treat severe bacterial infections in children.

(a) Some children have a genetic mutation in the gene *MT-RNR1*. If gentamicin is given to children with this genetic mutation, it can cause deafness.

Before gentamicin can be given to a child with a severe bacterial infection, PCR (polymerase chain reaction) and electrophoresis are used to test whether the child has this mutation. If the mutation is found, a different antibiotic must be given.

(i) Describe **and** explain the role of *Taq* polymerase in PCR.

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Question 17 · Paper 4 · February/March 2025 (42) · Q3(a)(ii) · 1 mark

(ii) PCR with primers specific to the *MT-RNR1* gene is used to amplify DNA from the child that is being tested.

The PCR primers are designed so that the amplified product of the normal allele of *MT-RNR1* is longer than the amplified product of the mutant allele.

Gel electrophoresis is used to separate the PCR products.

Fig. 3.1 shows the results of gel electrophoresis after using this method of PCR on DNA samples collected from three children.

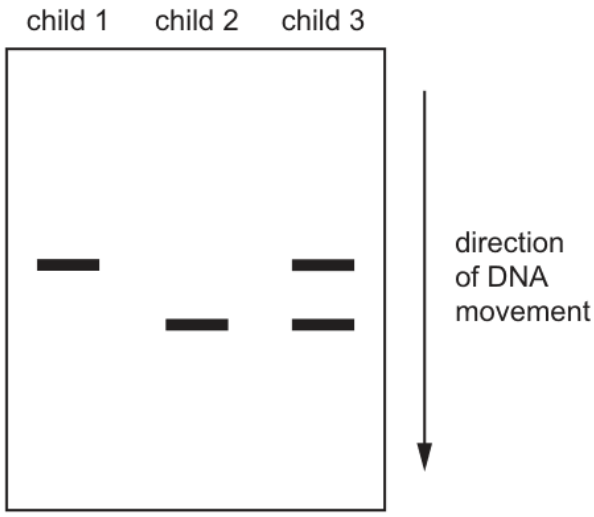


Fig. 3.1

State which of the children in Fig. 3.1 **cannot** receive the antibiotic gentamicin to treat a severe bacterial infection.

Question 18 · Paper 4 · February/March 2025 (42) · Q3(a)(iii) · 4 marks

(iii) Explain how gel electrophoresis produces the pattern of results shown in Fig. 3.1 from the PCR products of the *MT-RNR1* gene.

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Question 19 · Paper 4 · October/November 2023 (42) · Q4(c)(i) · 1 mark

(c) DNA microarray analysis is a technique used in genetic technology that involves fluorescence. A DNA microarray has single-stranded probes attached to its surface. These probes hybridise to the fluorescently tagged single-stranded DNA that is added.

(i) Explain why DNA hybridisation occurs between the probe DNA and the added DNA.

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Question 20 · Paper 4 · October/November 2023 (42) · Q4(c)(ii) · 3 marks

(ii) A DNA microarray analysis can be used to identify the level of expression of some genes.

Describe **and** explain how the level of expression of some genes can be identified using the DNA microarray analysis technique.

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Question 21 · Paper 4 · October/November 2021 (42) · Q4(a)(i) · 4 marks

4 **(a)** Genome-wide association studies find links between single nucleotide polymorphisms (SNPs) and phenotypic features such as human diseases. SNPs are points on the DNA that vary in the population because of DNA base substitutions.

A genome-wide association study investigates the effect of genetic variation on a disease. A large number of people with the disease and a large number of healthy control individuals provide DNA. Microarray chips are used to identify the genotype of each individual at many SNPs.

The Wellcome Trust Case Control Consortium (WTCCC) study was an important genome-wide association study.

- The study used a microarray chip that identified each person's genotype at 500 000 different SNPs.
- The study looked for links between SNPs and 7 different diseases.
- For each disease, 2000 people with the disease were tested.
- Their results were compared with the results of 3000 healthy control individuals.

(i) Outline how microarrays are used in the analysis of genomes.

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Question 22 · Paper 4 · October/November 2021 (42) · Q4(a)(ii) · 2 marks

(ii) Explain why bioinformatics was important to the WTCCC study.

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Mark schemes

Question 1 · Paper 4 · February/March 2020 (42) · Q5(a) · 1 mark

5(a)	DNA that contains genetic material from two different organisms / DNA from two different sources ;	1

Question 2 · Paper 4 · October/November 2022 (42) · Q4(a) · 4 marks

4(a)	*any **four** from:*	4
	1 manipulate DNA to modify organism's characteristics / AW ;	
	2 gene / allele / (section of) DNA, obtained using restriction, enzyme / endonuclease ;	
	3 use of reverse transcriptase to make, gene / allele / (section of) DNA, using mRNA ;	
	4 gene / allele / (section of) DNA, inserted into, vector / plasmid, using ligase ;	
	5 add / insert, (recombinant), vector / plasmid, into, (host) cell / bacterium ;	
	6 clone / multiply, cell / bacteria ; **A** put bacteria in a fermenter	
	7 gene is expressed and, protein / factor XIII / factor IX, is made ;	
	8 AVP ; e.g. artificial / chemical, synthesis of new gene	

Question 3 · Paper 4 · May/June 2023 (42) · Q4(b) · 4 marks

4(b)	*any **four** from:*	4
	1 obtain (specific restriction endonuclease) gene, qualified ; e.g. gene extracted from the, DNA / genome, of E. coli / bacteria gene synthesised from the mRNA of E. coli / bacteria gene synthesised from nucleotides	
	2 PCR to make more copies of, gene / DNA ;	
	3 cut a plasmid, with a restriction enzyme / to give sticky ends ;	
	4 combine / mix / join, gene with plasmid using ligase ;	
	5 add plasmid to, E. coli / bacteria ; **A** transformation of E. coli	
	6 use marker genes to, select / identify, bacteria / E. coli, with recombinant plasmids ;	
	7 *ref.* culture bacteria / use fermenter ;	
	8 *ref.* extraction / purification (of enzyme) ;	
	9 AVP ; e.g. heat shock / calcium ions / electroporation (detail mp5) complementary sticky ends anneal / make phosphodiester bonds (detail mp4)	

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

5(b)(i)	reverse transcriptase ;	1

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Question 5 · Paper 4 · February/March 2022 (42) · Q5(b)(ii) · 2 marks

5(b)(ii)	1 genes cut from (donor) DNA ; 2 genes synthesised (chemically) from nucleotides ;	2

Question 6 · Paper 4 · May/June 2024 (43) · Q4(a)(i) · 4 marks

4(a)(i)	*restriction endonuclease* 1 cuts, DNA / plasmid ; *DNA ligase* 2 joins DNA with the plasmid ; *DNA polymerase* 3 forms dsDNA **or** makes a complementary DNA strand ; r*everse transcriptase* 4 uses mRNA (as a template) to make, cDNA / complementary (ss)DNA ; **R** converts	4

Question 7 · Paper 4 · October/November 2019 (42) · Q3(c)(i) · 2 marks

3(c)(i)	restriction, enzyme / endonuclease ; (DNA) ligase ;	2

Question 8 · Paper 4 · October/November 2019 (42) · Q3(c)(ii) · 2 marks

3(c)(ii)	*any **two** from:* *one mark if only two features stated without explanation* 1 small **so** can be inserted (into cells) ; 2 replicate, independently / fast, **so**, high copy number / large number of plasmids **or** have origin of replication **so** high copy number / large number of plasmids ; 3 has restriction site(s) / can be cut by restriction enzymes, **so** (new) gene can be added ; 4 have, multiple cloning site / polylinker, **so** can be cut by different restriction enzymes ; 5 have marker genes **so**, recombinants / transformed bacteria , can be recognised / AW ; 6 circular **so** stable ;	2

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Question 9 · Paper 4 · October/November 2019 (42) · Q3(d) · 2 marks

3(d)	*any **two** from:* 1 eukaryote and prokaryote promoter sequences are different ; 2 eukaryote and prokaryote RNA polymerase enzymes are different ; 3 prokaryotic RNA polymerase does not, recognise / bind to, eukaryotic promoter **or** prokaryotic RNA polymerase only binds to prokaryotic promoter ; 4 so no, transcription / mRNA made / gene expression ; **ora** 5 eukaryotic promoter requires binding of (many) transcription factors that are not present in prokaryotic cell ;	**2**

Question 10 · Paper 4 · October/November 2022 (42) · Q4(b)(ii) · 2 marks

4(b)(ii)	*any **two** from:* 1 to allow binding of, RNA polymerase / transcription factors ; 2 to switch gene on / so gene is expressed / allow transcription (of gene) ; 3 at right time / all the time / in sufficient quantities ; 4 in correct tissue ;	**2**

Question 11 · Paper 4 · October/November 2023 (42) · Q4(a) · 4 marks

4(a)	*any **four** from:* 1 marker gene added with gene of interest (GOI) ; 2 use same promoter ; 3 (so) both genes, transcribed / expressed (together) ; 4 (so) both proteins are produced ; 5 use UV light (to detect fluorescence) ; 6 fluorescence shows, transcription / expression, of gene of interest (GOI) ; 7 AVP ; e.g. fluorescent proteins not harmful / have no effect on plant / do not affect quantity of desired protein produced	**4**

Question 12 · Paper 4 · October/November 2022 (42) · Q4(c) · 2 marks

4(c)	*any **two** from:* *list rule* 1 (gene editing) is, precise / exact / accurate ; 2 patient's own gene can be, edited / corrected **or** no introduction of, gene / allele ; 3 no need to introduce promoter ; 4 less / no, risk of cancer **or** less / no, immune response ;	**2**

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Question 13 · Paper 4 · May/June 2022 (42) · Q4(a) · 5 marks

4(a)

statement	genetic engineering using a plasmid	gene editing	
It may cause the organism to produce a different protein.	✓	✓	;
It may cause a single base pair in a gene to be changed.		✓	;
The success of the technique can be evaluated using marker genes.	✓		;
It may use the CRISPR system.		✓	;
It uses DNA ligase.	✓		;

5

Question 14 · Paper 4 · October/November 2022 (42) · Q5(a) · 3 marks

5(a)	1	at 95 °C, (DNA) denatures / (dsDNA) splits into single strands / H bonds break **;**	**3**
	2	at 50 °C, primers, anneal / bind, (to ssDNA) **;**	
	3	at 72 °C, complementary / second, (DNA) strand is made **; A** DNA replicated / (ssDNA) is made into dsDNA	

Question 15 · Paper 4 · October/November 2020 (42) · Q4(b)(ii) · 3 marks

4(b)(ii)

*any **three** from:* **3**

why

1 (primers) anneal / bind, to DNA **; A** hybridises

2 so that, DNA / *Taq*, polymerase, can bind to DNA
or
so that, DNA / *Taq*, polymerase, can replicate or amplify DNA **;**

how

3 (if) normal primers bind then, normal (genotype) / Hb^AHb^A **;**

4 (if) mutant primers bind then, sickle cell anaemia (genotype) / Hb^SHb^S **;**

5 (if) both primers bind then, SCT (genotype) / heterozygote / $Hb^A Hb^S$ **;**

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Question 16 · Paper 4 · February/March 2025 (42) · Q3(a)(i) · 4 marks

3(a)(i)	*any **four** from:* 1 DNA polymerase ; 2 synthesises, complementary / new, DNA strand ; 3 binds to primers on (target) DNA ; 4 adds (DNA) nucleotides to the end of primers **or** used in extension stage ; 5 (optimum) working temperature of 72 °C ; **A** 70–75 °C 6 thermostable / does not denature at 95 °C ; 7 (so) can be used for many PCR cycles / does not need replacing ; 8 AVP ; e.g. forming phosphodiester bonds (between adjacent nucleotides)	**4**

Question 17 · Paper 4 · February/March 2025 (42) · Q3(a)(ii) · 1 mark

3(a)(ii)	(child) 2 **and** (child) 3 ;	**1**

Question 18 · Paper 4 · February/March 2025 (42) · Q3(a)(iii) · 4 marks

3(a)(iii)	*any **three** from:* 1 separates DNA fragments of different, sizes / lengths / mass ; 2 DNA fragments are negatively charged ; 3 (so) DNA fragments move (from cathode) to anode ; 4 smaller DNA fragments migrate, faster / further ; **ora** 5 DNA fragments from, normal (*MT-RNR1*) gene travels shorter distance ; **ora**	**4**

Question 19 · Paper 4 · October/November 2023 (42) · Q4(c)(i) · 1 mark

4(c)(i)	complementary (base pairing between DNA strands) / described ;	**1**

Question 20 · Paper 4 · October/November 2023 (42) · Q4(c)(ii) · 3 marks

4(c)(ii)	*any **two** from:* 1 use mRNA to make (ss)cDNA ; 2 fluorescent, tag / dye / substance / label, attached to cDNA ; 3 hybridisation / binding, of cDNA to probe ; 4 use, lasers / UV light, to produce fluorescence ; *plus* 5 idea of intensity of, fluorescence / light, indicates level of (gene) expression ;	**3**

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Question 21 · Paper 4 · October/November 2021 (42) · Q4(a)(i) · 4 marks

4(a)(i)	*any **four** from:*	**4**
	1 obtain single-stranded DNA ;	
	2 label DNA with fluorescent, dye / tag / label ;	
	3 probes on, chip / microarray ;	
	4 each probe is unique to a particular, SNP / gene / allele ;	
	5 DNA (added), binds / hybridises, to probes ;	
	6 wash off excess DNA (after hybridisation) ;	
	7 (view under) UV light / laser scanner / high resolution digital camera ;	
	8 fluorescence indicates presence of, SNP / gene ; **R** gene expressed	

Question 22 · Paper 4 · October/November 2021 (42) · Q4(a)(ii) · 2 marks

4(a)(ii)	*any **two** from:*	**2**
	1 large database ;	
	2 use database to find, SNPs / probes ;	
	3 fast / accurate / efficient ;	
	4 *ref. to* (computer) software / algorithms ;	
	5 *ref. to* statistics / statistical analysis ;	
	6 *idea of*, $17\,000 \times 500\,000 / 8.5 \times 10^9$, data points ;	

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