Surname	Date	Tutor
First name(s)		

BioWelsh

GCE A LEVEL

BW-A2-4.5-W1

TOPIC WORKSHEET 1 – 4.5 APPLIED GENETICS

BIOLOGY – A2 unit 4

Variation, Inheritance and Options

Suggested time: 3 hours 25 minutes

For Tutor's use only

Question	Maximum Mark	Mark Awarded	Question	Maximum Mark	Mark Awarded
1.	11		9.	10	
2.	10		10.	10	
3.	12		11.	11	
4.	11		12.	10	
5.	9		13.	10	
6.	12		14.	10	
7.	10		15.	9	
8.	9		Total	154	

ADDITIONAL MATERIALS

In addition to this worksheet, you will require a calculator and a ruler.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen or correction fluid.

You may use a pencil for graphs and diagrams only.

Write your name and the date in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet. If you are working on screen, write your answers on paper and number each one clearly.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question. The worksheet is out of **154** marks.

The assessment of the quality of extended response (QER) will take place in question **15**.

The quality of written communication will affect the awarding of marks.

This worksheet is written by BioWelsh in the style of the WJEC A level Biology examination, following the WJEC specification (topic 4.5). It is not an official WJEC paper.

Tutor only

Answer **all** questions.

1. The Human Genome Project used Sanger sequencing. A short fragment of DNA is copied many times in the presence of chain terminator nucleotides, which stop copying when they are added. Four reactions are set up, each with a terminator for one base, and the fragments are separated by gel electrophoresis. **Image 1.1** shows the gel for one short fragment.

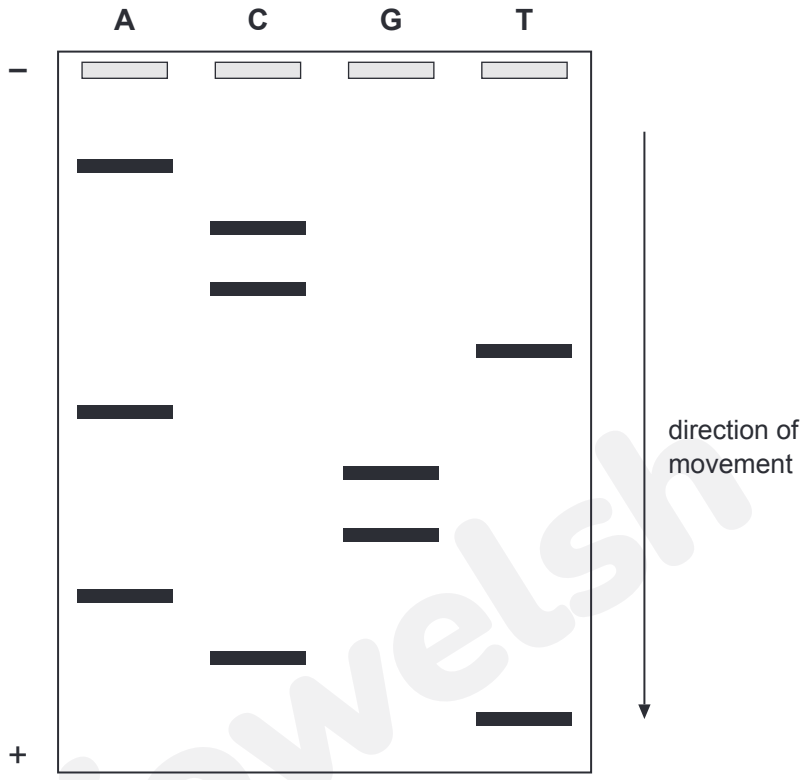


Image 1.1

(a) State **two** aims of the Human Genome Project. [2]

.....

.....

.....

.....

(b) Explain why the shortest fragments are found furthest from the wells. [2]

.....

.....

.....

Tutor only

(c) Use **Image 1.1** to write the base sequence of the new strand, starting from the shortest fragment. [2]

(d) Give the base sequence of the template strand that matches the first **five** bases you gave in part (c). [1]

(e) Next generation sequencing (NGS) replaced Sanger sequencing and can sequence a whole human genome in about a day. Suggest **two** reasons why NGS is so much faster. [2]

(f) The 100K Genome Project sequenced the genomes of NHS patients with rare diseases and linked each genome to the patient's medical records. Suggest how this could benefit a child with an undiagnosed rare disease. [2]

11

Turn over.

Tutor only

2. Cystic fibrosis is caused by a recessive allele, **f**, of the CFTR gene. A couple who are both carriers (**Ff**) have in vitro fertilisation (IVF). One cell is removed from each of eight embryos, the DNA is copied by PCR and the CFTR gene is tested. This is pre-implantation genetic diagnosis (PGD). **Table 2.1** shows the results.

Table 2.1

Embryo	1	2	3	4	5	6	7	8
Genotype	FF	Ff	ff	Ff	FF	Ff	ff	Ff

(a) State the probability that any one embryo from this couple has cystic fibrosis. [1]

.....

(b) Calculate the percentage of the embryos in **Table 2.1** that would have cystic fibrosis, and state whether this agrees with your answer to part (a). [2]

Percentage = ... %

(c) Identify the embryos that could be implanted so that the child would not have cystic fibrosis **and** would not be a carrier. [1]

.....

(d) Explain why PCR is needed before the CFTR gene of the embryo can be tested. [2]

.....

.....

.....

.....

(e) Huntington's disease is caused by a dominant allele and symptoms usually start in middle age. Some people whose parent has Huntington's disease decide not to be tested. Suggest **two** reasons for this decision. [2]

.....

.....

.....

.....

Tutor only

(f) Evaluate the use of PGD to screen embryos for genetic disorders. Give **one** argument for and **one** argument against. [2]

.....

.....

.....

.....

10

Tutor only

3. Malaria is caused by the protoctist *Plasmodium falciparum*, which is transmitted by female *Anopheles gambiae* mosquitoes. **Image 3.1** shows one of these mosquitoes.

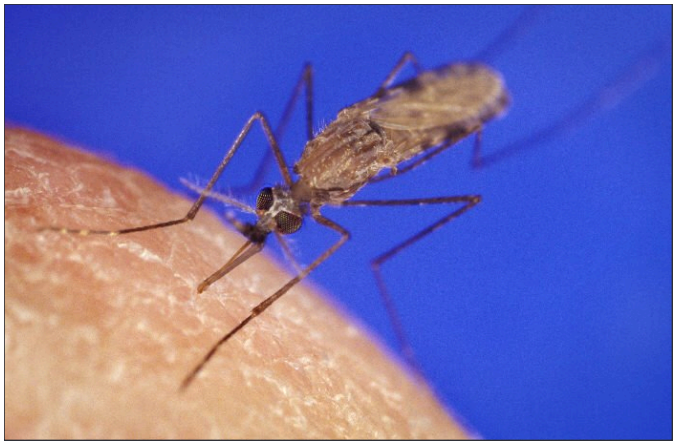


Image 3.1

(a) State the role of the organism in **Image 3.1** in the spread of malaria. [1]

.....

(b) The genomes of both *A. gambiae* and *P. falciparum* have been sequenced. State **two** pieces of information obtained from a genome project. [2]

.....

.....

.....

.....

For many years the drug chloroquine was used to treat malaria in one African country, until resistance became common. Resistance is caused by an allele of one *Plasmodium* gene. The drug was withdrawn from use in 1993. **Table 3.2** shows the percentage of *Plasmodium* samples from patients that carried the resistance allele.

Table 3.2

Year	1992	1996	1998	2000	2002
Samples with the resistance allele / %	86	49	27	13	4

(c) (i) Explain how the resistance allele became common while chloroquine was in use. [3]

.....

.....

.....

Tutor only

.....

.....

.....

(ii) Calculate the percentage decrease in samples with the resistance allele between 1992 and 2002. [2]

Percentage decrease = ... %

(iii) Suggest an explanation for the change shown in **Table 3.2** after 1993. [2]

.....

.....

.....

.....

(d) Suggest how the *P. falciparum* genome sequence could help to control malaria in future. [2]

.....

.....

.....

.....

12

Tutor only

4. Fish sold in restaurants is sometimes labelled as a more expensive species than it really is. To identify the species, DNA is extracted from a small sample of fish and a short section of one gene is copied by the polymerase chain reaction (PCR). The copied DNA is then sequenced. **Table 4.1** shows the temperatures used in each cycle of PCR.

Table 4.1

Stage	Temperature / °C	Time / s
1	95	30
2	55	30
3	72	45

(a) Describe what happens to the DNA at stage 1. [2]

.....

.....

.....

.....

(b) Describe the structure of a primer and explain its function in stage 2. [2]

.....

.....

.....

.....

(c) The DNA polymerase used comes from *Thermus aquaticus*, a bacterium that lives in hot springs. Explain why. [1]

.....

.....

(d) A sample contained 40 molecules of the DNA to be copied. Calculate the number of copies that would be present after 30 cycles, assuming every cycle doubles the DNA. **Give your answer in standard form.** [2]

Number of copies = ...

Tutor only

(e) The same equipment is used to test fish from many restaurants. Suggest **two** precautions that should be taken to make sure the results are valid. [2]

.....

.....

.....

.....

(f) Explain why a contaminated sample could give a misleading result. [2]

.....

.....

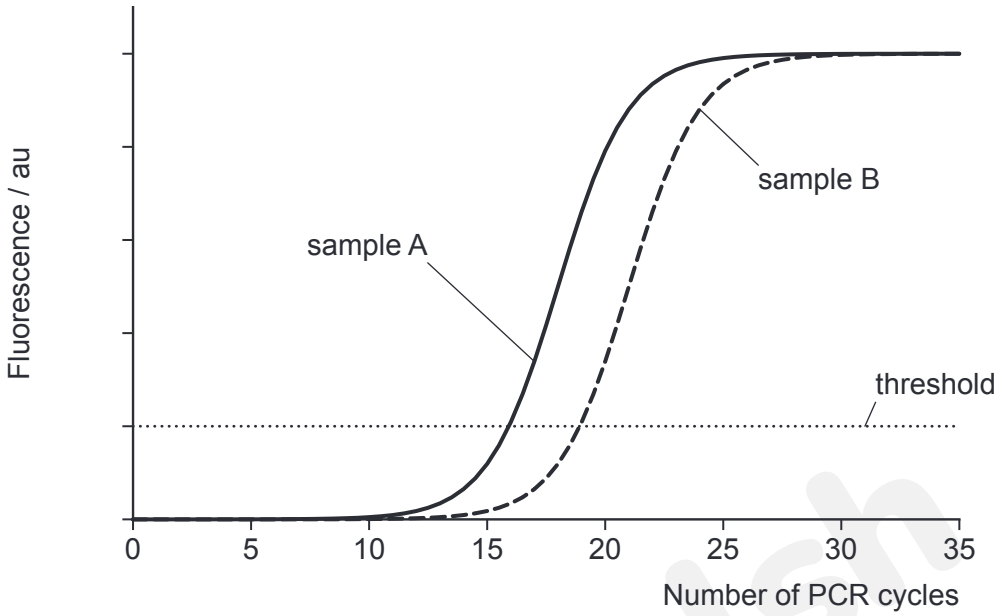
.....

.....

11

Tutor only

5. Mosquitoes caught in two villages were tested for *Plasmodium* DNA using real-time PCR. The primers were designed from the *Plasmodium* genome sequence. A fluorescent dye binds to double-stranded DNA, so fluorescence increases as copies are made. A sample is recorded as positive when it passes the threshold shown. **Graph 5.1** shows the results for a sample from each village.



Graph 5.1

(a) Explain why the primers had to be designed from the *Plasmodium* genome sequence. [2]

.....

.....

.....

.....

(b) Use **Graph 5.1** to state the number of cycles taken for each sample to reach the threshold. [2]

Sample A .....

Sample B .....

(c) Each cycle doubles the DNA. Use your answers to part (b) to calculate how many times more *Plasmodium* DNA there was at the start in sample A than in sample B. [2]

Number of times more = ...

Tutor only

(d) Explain why both curves level off after about 25 cycles. [2]

.....

.....

.....

.....

(e) Suggest **one** control that should be included when testing the mosquitoes. Give a reason for your answer. [1]

.....

.....

9

Tutor only

6. A student ran a DNA ladder, a mixture of DNA fragments of known length, on an agarose gel. The distance moved by each fragment from the well was measured. **Table 6.1** shows the results.

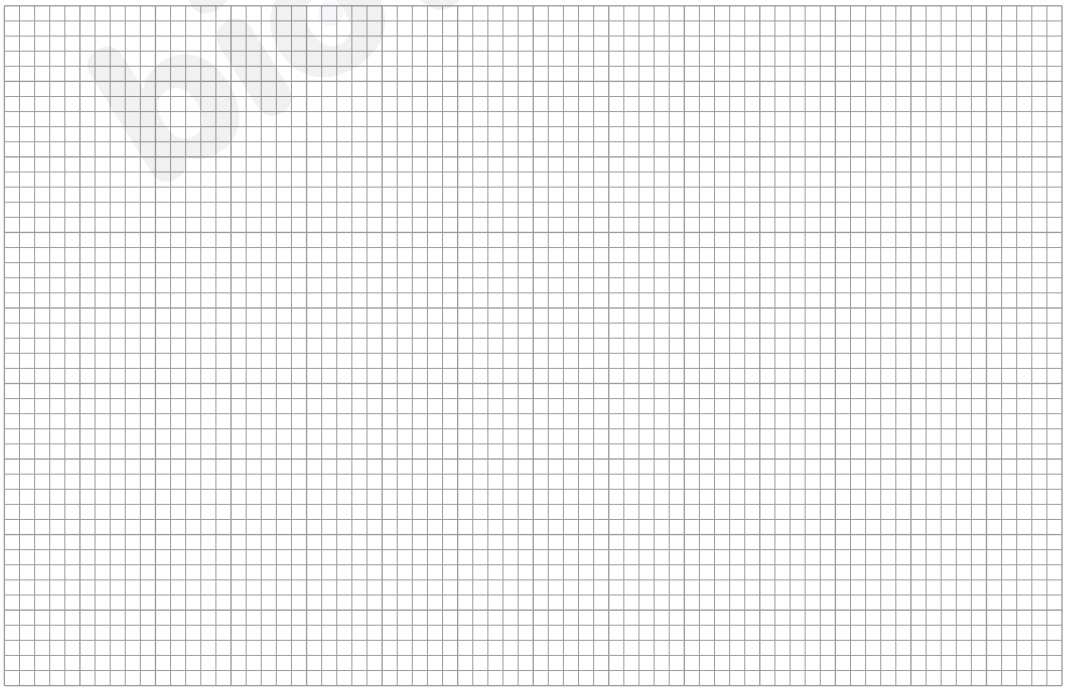
Table 6.1

Fragment length / bp	$\log_{10}$ (fragment length)	Distance moved / mm
5000	3.70	8.5
3000	3.48	18.6
2000	3.30	26.2
1500	3.18	32.1
1000	3.00	40.0
750	2.88	45.1
500	2.70	53.8
250	2.40	66.8

(a) State why DNA moves towards the positive electrode. [1]

.....

(b) Plot a graph of $\log_{10}$ (fragment length) against distance moved on the grid below. Draw a line of best fit. [4]



Tutor only

(c) A fragment from a sample run on the same gel moved 36.0 mm. Use your graph to estimate its length in base pairs. [2]

Length = ... bp

(d) Explain why the ladder must be run on the same gel and at the same time as the sample. [2]

.....

.....

.....

.....

(e) The student stained the gel with a dye that glows under ultraviolet light. State **one** hazard of this procedure and how the risk is reduced. [2]

.....

.....

.....

.....

(f) Explain why smaller fragments move further than larger fragments. [1]

.....

.....

12

Tutor only

7. Blood was found on a broken window after a burglary. DNA profiles were produced from the blood, from the victim and from three suspects, **P**, **Q** and **R**, using several short tandem repeats (STRs). **Image 7.1** shows the profiles.

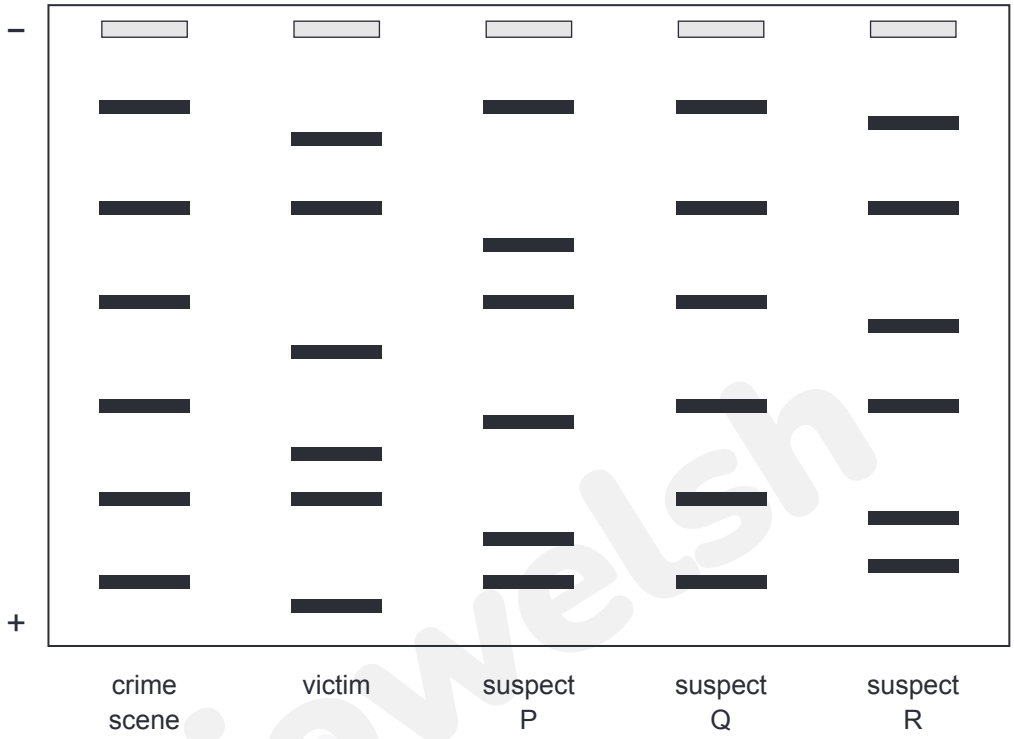


Image 7.1

(a) Explain what is meant by a short tandem repeat. [2]

.....

.....

.....

.....

(b) Identify which suspect the blood came from. Explain your answer. [2]

.....

.....

.....

.....

Tutor only

(c) The victim shares two bands with the crime scene sample. Explain why this does not suggest the blood came from the victim. [1]

.....

.....

(d) Explain why a person usually shows two bands for each STR. [2]

.....

.....

.....

.....

(e) Each STR pattern in the profile is shared by about 1 person in 10. Ten independent STRs are used. Calculate the probability that an unrelated person would have the same profile by chance. **Give your answer in standard form.** [2]

Probability = ...

(f) Suggest **one** reason why some people object to the police keeping DNA profiles on a national database. [1]

.....

.....

10

Tutor only

8. The kākāpō is a flightless parrot from New Zealand. There are fewer than 250 birds, and every one is monitored in a conservation programme. DNA profiles are used to find the father of each chick. **Image 8.1** shows the profiles of a chick, its mother and three males that were near the nest.

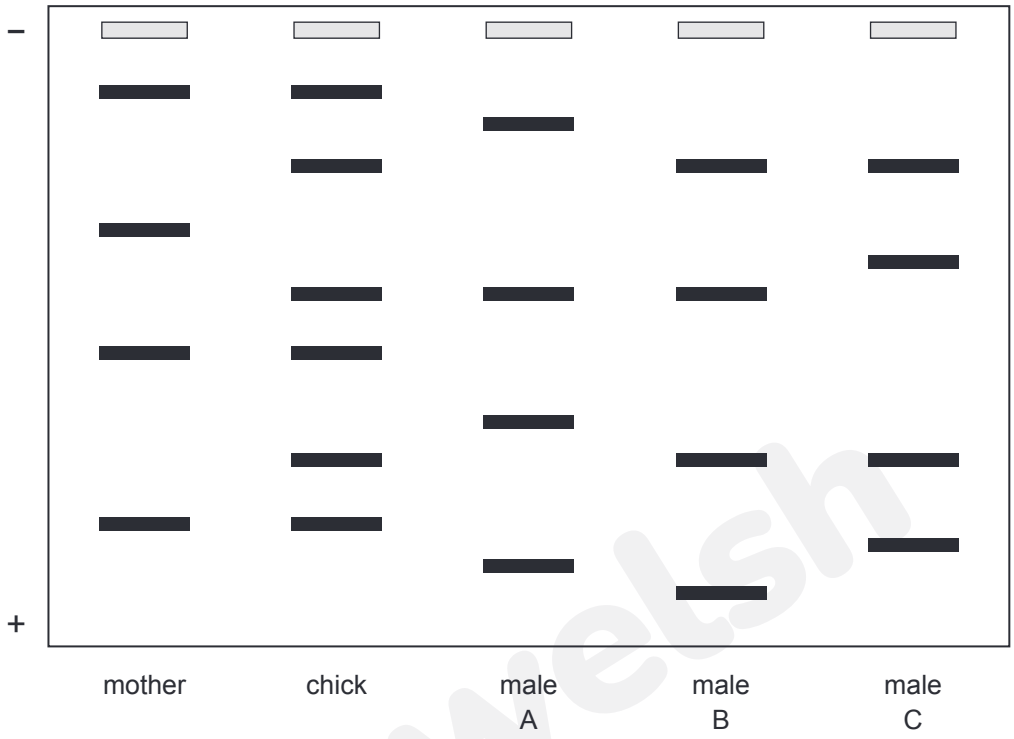


Image 8.1

(a) Identify the father of the chick. [1]

.....

(b) Explain how you used **Image 8.1** to reach your answer. [3]

.....

.....

.....

.....

.....

.....

(c) Suggest why the chick does not match either parent exactly. [2]

.....

Tutor only

.....

.....

.....

(d) The profile gives only a high probability that the male identified is the father, not certainty. Suggest why. [1]

.....

.....

(e) Suggest why it is important for the conservation programme to know which male fathered each chick. [2]

.....

.....

.....

.....

9

Tutor only

9. Human insulin for people with diabetes is made by genetically modified bacteria. **Image 9.1** shows how a recombinant plasmid containing the insulin gene is made.

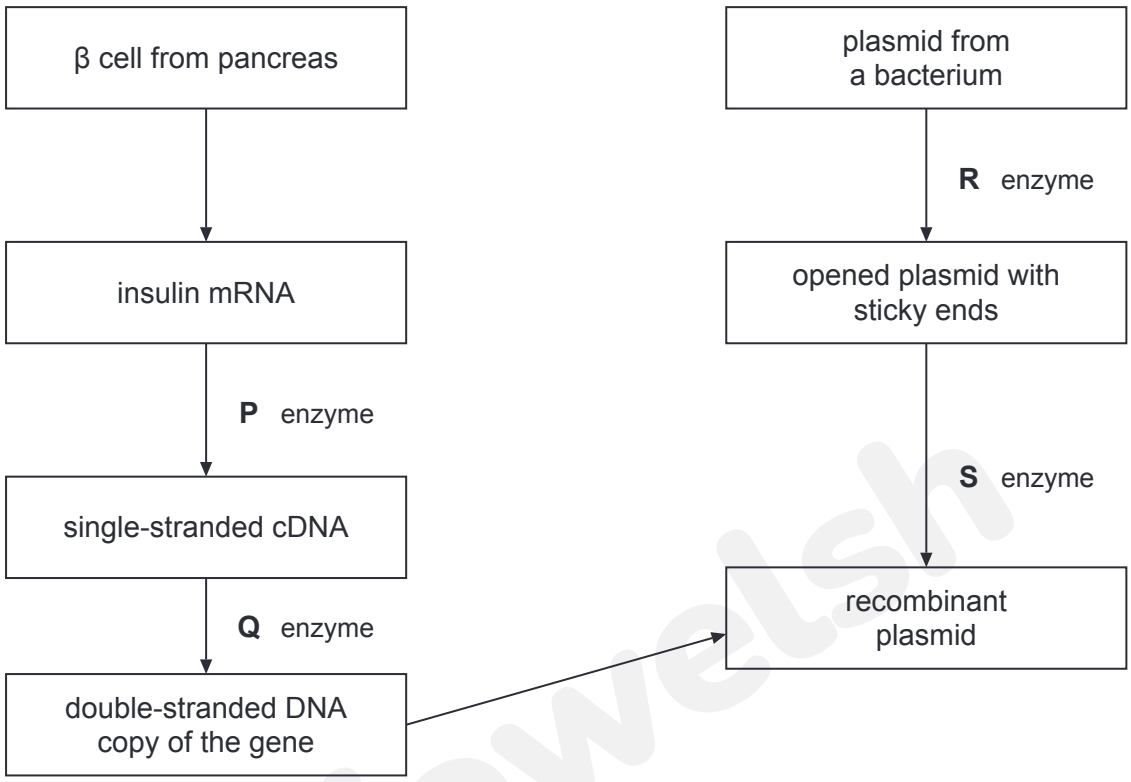


Image 9.1

(a) Name enzymes **P**, **Q**, **R** and **S**. [4]

P .....

Q .....

R .....

S .....

(b) Explain why mRNA is extracted from β cells of the pancreas, rather than from another type of body cell. [1]

.....

.....

(c) Explain why a copy of the gene made from mRNA can be expressed by bacteria, but the gene cut directly from human DNA would not produce working insulin. [2]

.....

.....

Tutor only

.....

.....

The restriction enzyme BamHI recognises the sequence:

5′ G G A T C C 3′

It cuts each strand between the two G nucleotides.

(d) (i) Give the sequence of the single-stranded sticky end left on the DNA to the right of the cut on this strand. [1]

.....

(ii) Explain why the gene and the plasmid must be cut with the same restriction enzyme. [2]

.....

.....

.....

.....

10

Tutor only

10. Bacteria are mixed with recombinant plasmids like the one in **Image 10.1**. The foreign gene is inserted into the restriction site in the *lacZ* gene. The *lacZ* gene codes for an enzyme that breaks down a colourless substance, X-gal, into a blue product.

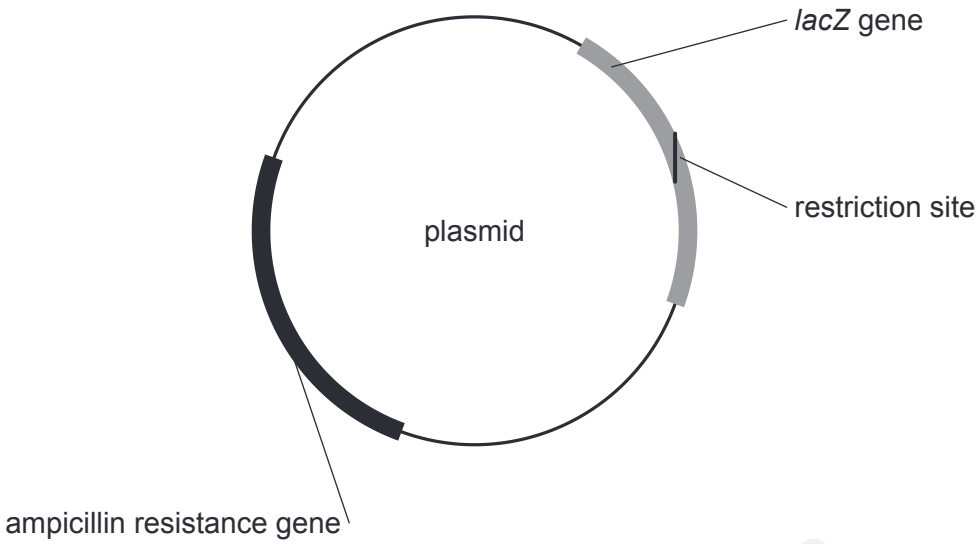


Image 10.1

(a) The bacteria are spread on agar containing ampicillin and X-gal. Explain why ampicillin is added. [2]

.....

.....

.....

.....

Tutor only

Image 10.2 shows the colonies that grew on the plate.

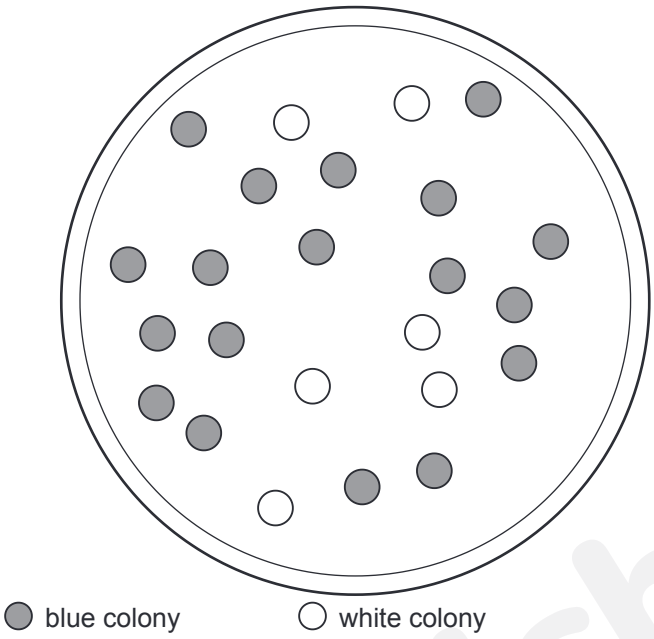


Image 10.2

(b) Explain why some colonies are white and others are blue. [3]

.....

.....

.....

.....

.....

.....

(c) On a larger plate there were 132 blue colonies and 48 white colonies. Calculate the percentage of colonies that contain the recombinant plasmid. Give your answer to **1 decimal place**. [2]

Percentage = ... %

(d) Suggest why a white colony may still fail to produce the human protein. [1]

.....

Tutor only

(e) Antibiotic resistance genes have also been used as markers when making genetically modified crops. Suggest why some people are concerned about this. [2]

10

Tutor only

11. Bt brinjal (aubergine) is a genetically modified crop grown in Bangladesh. It contains a gene from the soil bacterium *Bacillus thuringiensis* that codes for a protein toxic to the fruit and shoot borer, the caterpillar of a moth. **Table 11.1** shows results from a comparison of farms growing Bt and non-Bt brinjal.

Table 11.1

	Non-Bt brinjal	Bt brinjal
Insecticide sprays per season	48	9
Fruit damaged by borers / %	36	2
Yield / tonnes per hectare	15.2	19.8

(a) Describe how *Agrobacterium tumefaciens* could be used to insert the Bt gene into brinjal cells. [3]

.....

.....

.....

.....

.....

.....

(b) Calculate the percentage reduction in insecticide sprays per season when Bt brinjal is grown. [2]

Percentage reduction = ... %

(c) Use **Table 11.1** to suggest **two** benefits of growing Bt brinjal. [2]

.....

.....

.....

.....

Tutor only

(d) Explain how fruit and shoot borers could become resistant to the Bt protein if Bt brinjal is grown for many years. [3]

.....

.....

.....

.....

.....

.....

(e) Herbicide-tolerant soya contains a gene that allows it to survive spraying with the herbicide glyphosate. Suggest **one** environmental concern about growing this crop. [1]

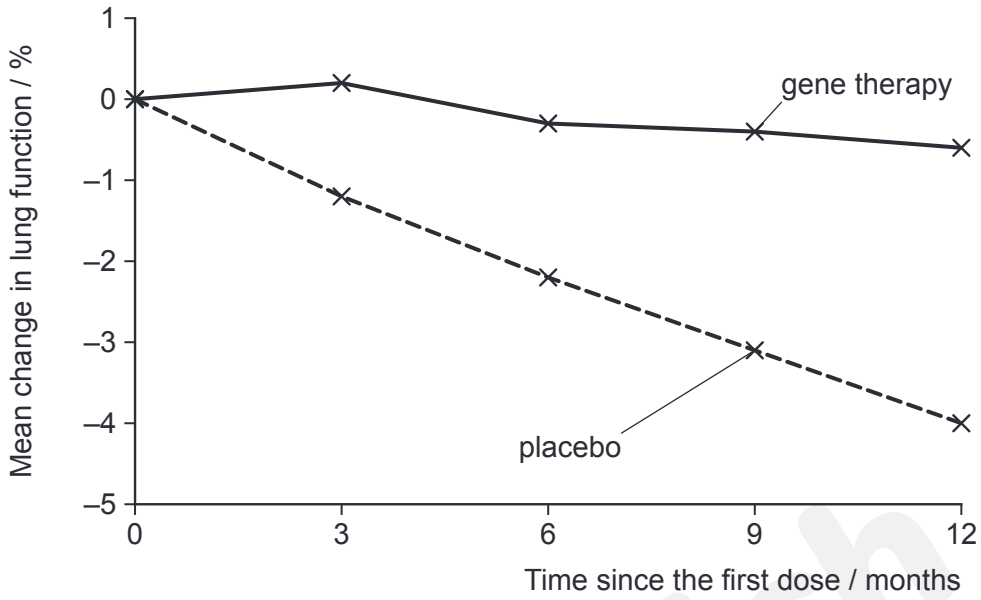
.....

.....

11

Tutor only

12. Cystic fibrosis is caused by a faulty CFTR protein, a chloride ion channel in the membranes of epithelial cells. In a trial of gene therapy, patients inhaled liposomes carrying the normal CFTR allele once a month for a year. Another group inhaled a placebo. **Graph 12.1** shows the mean change in lung function in the two groups.



Graph 12.1

(a) Explain why a faulty CFTR protein causes thick, sticky mucus in the airways. [2]

.....

.....

.....

.....

(b) Suggest **one** advantage of using liposomes rather than viruses to carry the allele into the cells. [1]

.....

.....

(c) Describe the results shown in **Graph 12.1**. [2]

.....

.....

.....

.....

Tutor only

(d) Explain why the gene therapy had to be given every month. [2]

.....

.....

.....

.....

(e) Explain why a placebo group was included and why neither the patients nor the doctors knew who received the gene therapy. [2]

.....

.....

.....

.....

(f) This treatment is somatic gene therapy. State why germ line gene therapy is not allowed in humans in the UK. [1]

.....

.....

10

Tutor only

13. Duchenne muscular dystrophy (DMD) is caused by mutations in the dystrophin gene. One boy has a deletion of exon 52. His doctors use exon skipping: an antisense oligonucleotide binds to exon 53 in the pre-mRNA, so exon 53 is also left out of the mature mRNA. **Table 13.1** shows the number of bases in these exons.

Table 13.1

Exon	Number of bases
52	118
53	212

(a) Use **Table 13.1** to explain why the deletion of exon 52 prevents functional dystrophin from being made, but also losing exon 53 allows a shorter dystrophin to be made. [4]

Part of the pre-mRNA of exon 53 has the sequence:

5′ C A G A U C U G G 3′

(b) Give the base sequence of the part of the antisense oligonucleotide that binds to it, using RNA bases. [1]

(c) Explain why the boy needs the treatment for the rest of his life. [2]

Tutor only

(d) Before choosing this drug, the boy's genome was sequenced. Suggest why this was necessary. [1]

.....

.....

(e) Researchers hope to edit the dystrophin gene in the boy's muscle stem cells instead. Suggest **one** advantage of changing the stem cells rather than the mRNA. [2]

.....

.....

.....

.....

10

Tutor only

14. Age-related macular degeneration causes loss of sight when the layer of pigmented cells at the back of the retina dies. In one trial, skin cells from a patient were reprogrammed into induced pluripotent stem (iPS) cells, grown into a sheet of retinal pigment cells, and transplanted into the patient's eye. **Image 14.1** shows stem cells growing in culture.

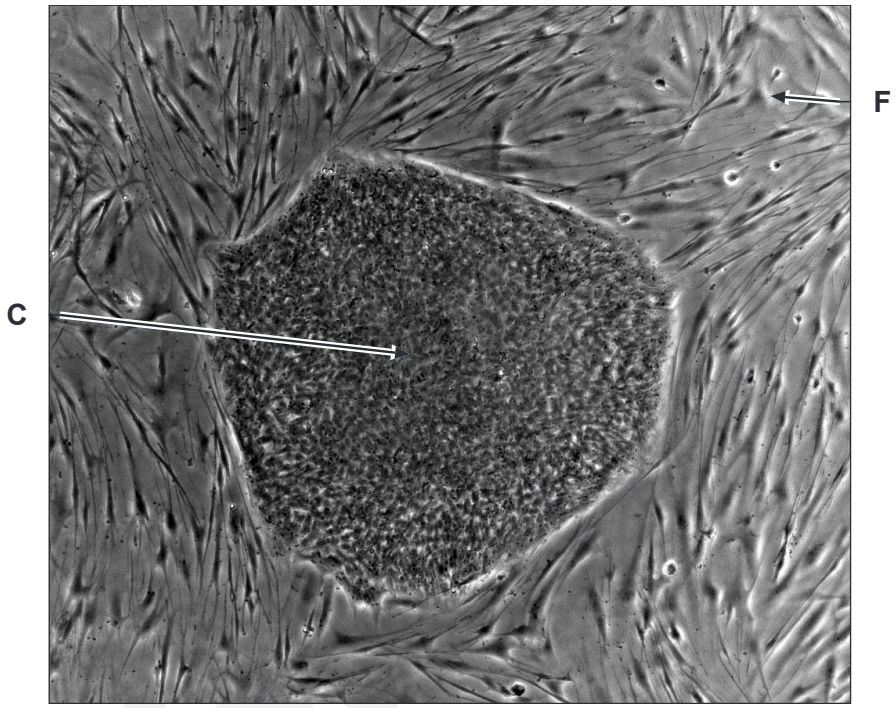


Image 14.1

(a) Define the term stem cell. [2]

.....

.....

.....

.....

(b) Structure **C** is a colony of embryonic stem cells growing on a layer of feeder cells, **F**. State the type of stem cell found in the inner cell mass of an embryo, and describe what this type can become. [2]

.....

.....

.....

.....

Tutor only

(c) Suggest **two** advantages of using the patient's own iPS cells rather than embryonic stem cells in this trial. [2]

.....

.....

.....

.....

(d) Before transplanting, the cells were grown on a thin, biodegradable scaffold. Explain the role of the scaffold. [2]

.....

.....

.....

.....

(e) Suggest **two** reasons why this treatment is not yet widely available. [2]

.....

.....

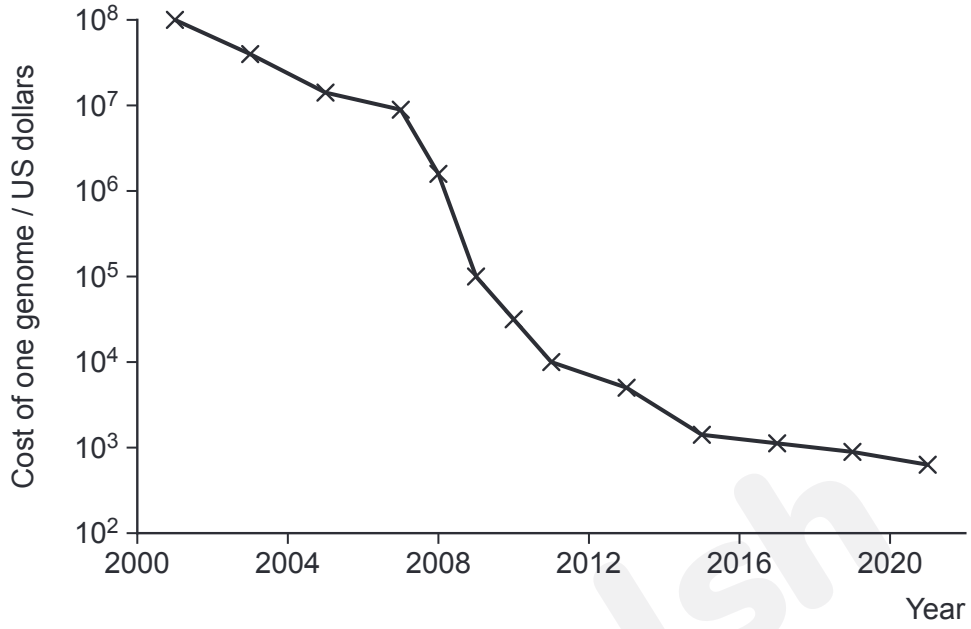
.....

.....

10

Tutor only

15. The cost of sequencing one human genome has fallen dramatically since the Human Genome Project was completed. **Graph 15.1** shows approximate costs between 2001 and 2021. The vertical axis is a logarithmic scale.



Graph 15.1

Use **Graph 15.1** to describe how the cost of sequencing a genome has changed, and explain how the methods used have made this possible. Describe how genomics could change healthcare for patients in the future. Discuss the ethical issues raised by sequencing and storing the genomes of large numbers of people. [9 QER]

Tutor only

END OF WORKSHEET

9

A Tutor Meets Tutee project

BioWelsh worksheets are written and checked by Tutor Meets Tutee tutors for WJEC A level Biology students.

Mark this worksheet with the BioWelsh mark scheme **BW-A2-4.5-W1** (MS).

Acknowledgements

Image 3.1: Photo: James Gathany, CDC, public domain (Wikimedia Commons, 'AnophelesGambiaemosquito.jpg'). Resized.

Image 14.1: Micrograph: Id711, public domain (Wikimedia Commons, 'Human embryonic stem cell colony phase.jpg'). Letters and label lines added.