

## 8: Molecular biology and gene technology – Topic questions

The questions in this document have been compiled from past papers, as indicated in the table below.

Use these questions to formatively assess your learners' understanding of this topic.

Question	Year	Series	Paper number
3	2017	May/June	41
4	2017	May/June	42
5	2017	May/June	42

The mark scheme for each question is provided at the end of the document.

- 3** Oil seed rape (canola), *Brassica napus*, has been genetically modified to be resistant to herbicides containing glufosinate ammonium. The genetically modified (GM) oil seed rape contains the *bar* gene, obtained from a soil bacterium. This gene codes for an enzyme that converts glufosinate ammonium into a non-toxic compound.

**(a)** Outline the advantages to farmers of growing glufosinate-resistant oil seed rape.

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**(b)** The *bar* gene was introduced into the oil seed rape using plasmids. The plasmids also contained a promoter taken from thale cress, *Arabidopsis thaliana*.

**(i)** Outline the structure of a plasmid.

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**(ii)** Explain how the properties of plasmids make them suitable for use during genetic modification programmes.

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(iii) Describe the role of a promoter in gene expression.

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- (c) The pollen of oil seed rape is transferred from one flower to another by insects. After pollination, fertilisation and seed formation can occur. One of the potential problems of growing glufosinate-resistant oil seed rape is that pollen from these plants could be transferred to the flowers of wild relatives, such as wild radish, *Raphanus raphanistrum*. This could result in genetic changes in these wild species.

An experiment was carried out to investigate whether glufosinate-resistant hybrids between GM oil seed rape and wild radish plants are likely to compete successfully with non-hybrid or non-resistant plants in the natural environment.

- Type 1 hybrids were produced by transferring pollen from wild radish (diploid number 18) to glufosinate-resistant oil seed rape (diploid number 38).
- Type 2 hybrids were produced by transferring pollen from glufosinate-resistant oil seed rape to wild radish.
- Each hybrid was then crossed with wild radish over several generations.
- The resulting offspring were then grown in field trials, together with normal wild radish.
- The height of the plants and number of seeds each produced were measured. Then the plants were tested for the *bar* gene.

Table 3.1 shows the results.

**Table 3.1**

type of plant	number of seeds per plant	mean height /cm	presence of <i>bar</i> gene
offspring from type 1 hybrid and wild radish	265	22.3	absent
	99	28.3	present
offspring from type 2 hybrid and wild radish	3958	88.7	absent
	2047	95.0	present
wild radishes	3515	76.5	absent

- (i) Predict the diploid number of chromosomes in a hybrid between oil seed rape and wild radish.

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- (ii) Suggest how the researchers could have determined whether or not the *bar* gene was present in the plants.

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 ..... [1]

- (iii) Many varieties of GM oil seed rape are male sterile, meaning that they do not produce pollen.

With reference to Table 3.1, suggest the advantages to the environment of growing male sterile varieties of GM oil seed rape, rather than GM varieties that produce pollen.

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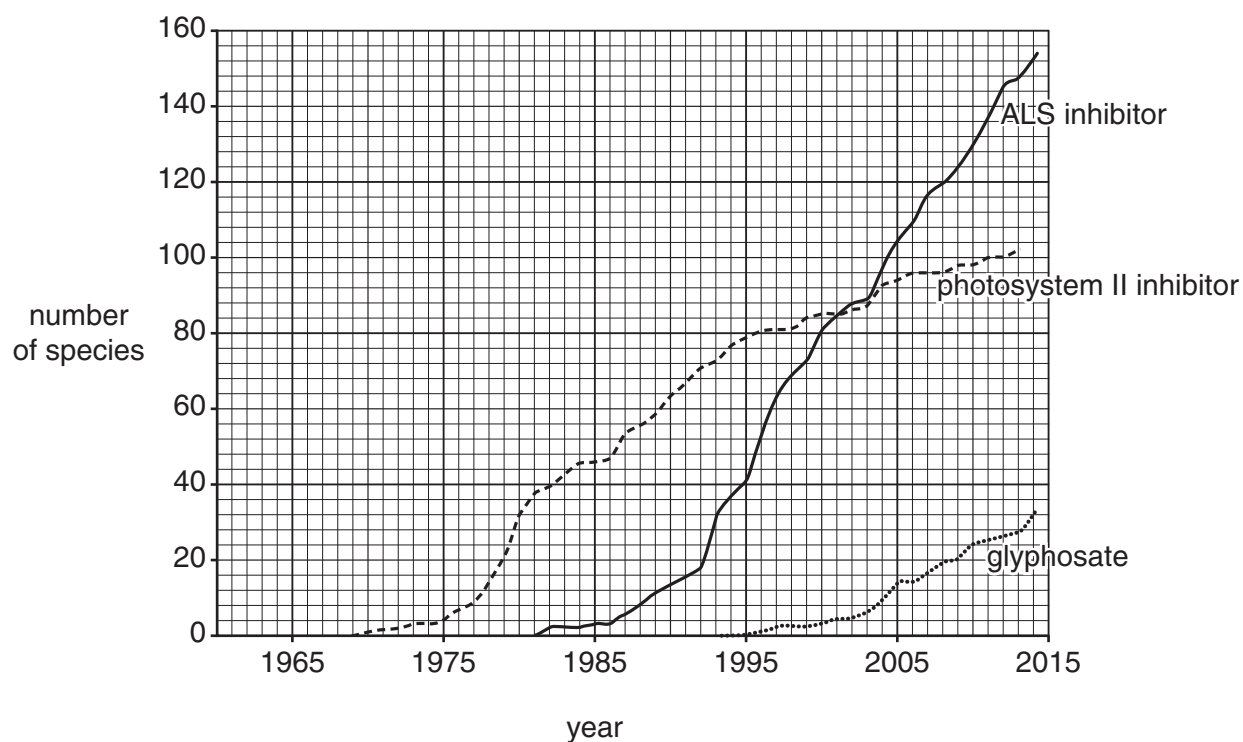
[Total: 14]

- 4 Weeds reduce crop yields by competing with crop plants for space, light, water and minerals. The modes of action of three different types of herbicide are summarised in Table 4.1.

**Table 4.1**

type of herbicide	mode of action	year of first widespread use
photosystem II inhibitor	prevents photophosphorylation	1960
ALS inhibitor	prevents synthesis of the amino acids isoleucine, leucine and valine	1980
glyphosate	prevents synthesis of the amino acids phenylalanine, tryptophan and tyrosine	1990

Fig. 4.1 shows the cumulative number of species of weeds that have become resistant to these three types of herbicide since 1960.



**Fig. 4.1**

- (a) (i)** Describe how the number of weed species resistant to herbicides has changed since 1960.

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- (ii)** Explain how a weed species becomes resistant to a herbicide.

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- (b) ALS inhibitor herbicides work by binding to an enzyme present in chloroplasts called acetolactate synthetase (ALS). ALS is a globular protein consisting of four identical polypeptides each composed of 668 amino acids.

The primary structure of the ALS polypeptide of each weed species resistant to ALS inhibitor herbicides has been sequenced. Amino acid substitutions at positions as far apart as position 122 and position 574 can result in resistance.

- (i) The gene that codes for the ALS polypeptide does not contain any non-coding sections (introns). The first amino acid in the final polypeptide is methionine.

State the number of base pairs in the gene that codes for an ALS polypeptide.

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- (ii) Explain why resistance to ALS inhibitor herbicide can result from substitutions of amino acids that are **far apart** in the primary sequence.

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(c) Genetic modification is one method used to develop herbicide resistance in crop plants. Other methods include:

method 1: crossing a crop plant with a herbicide-resistant wild plant belonging to the same genus and then applying the herbicide

method 2: causing mutations in the crop plants and then applying the herbicide.

State **two** benefits of using method 1 **and two** benefits of using method 2 to develop herbicide resistance in crop plants.

*method 1* .....

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*method 2* .....

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[Total: 14]

- 5 Cancer is a disease in which normal controls over cell division are lost and malignant tumours form. An early diagnosis of many types of cancer can result in successful treatment.

The BRCA2 protein is involved in suppressing the development of tumours. The gene that codes for this protein is on chromosome 13.

Several different dominant alleles of this gene, *BRCA2*, code for faulty versions of the protein. The presence of any one of these faulty alleles leads to an increased chance of developing several types of cancer, including breast cancer. Not everyone with one of these alleles develops cancer. This is because environmental factors, including lifestyle, are also involved.

Fig. 5.1 is a pedigree (family tree) showing the occurrence of cancers in four generations of a family. The presence of a faulty *BRCA2* allele was confirmed in person 15. The other individuals with cancer were not tested for the presence of the allele. Individuals 24–30 are all under twelve years old.

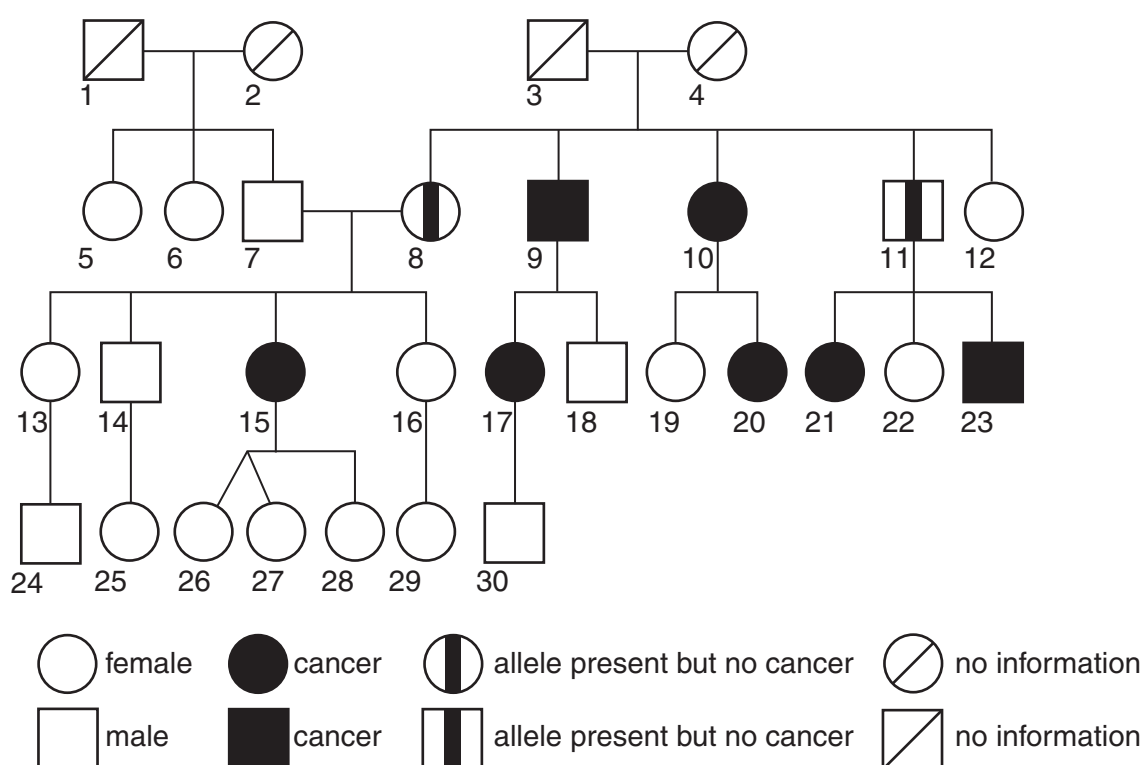


Fig. 5.1

- (a) Discuss the extent to which Fig. 5.1 provides evidence that a faulty *BRCA2* allele increases the risk of a person developing cancer.

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- (b) People whose families are suspected of having a faulty *BRCA2* allele may choose to be tested for its presence in their own genome.

A company based in the USA sells a microarray containing DNA probes for 20 different alleles that are associated with an increased risk of cancer, including the faulty *BRCA2* alleles. This microarray can be used in a medical facility or research laboratory to test blood samples for the presence of these alleles.

- (i) Explain the meaning of the term *genome*.

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- (ii) Suggest a type of cell from a blood sample that is suitable for testing for the presence of this allele **and** explain your choice.

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(iii) Outline how a microarray enables the detection of particular alleles.

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(iv) Suggest **one** advantage and **one** disadvantage of screening for faulty alleles of *BRCA2* before any symptoms occur.

*advantage* .....

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*disadvantage* .....

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[Total: 12]

## Mark scheme abbreviations

<b>;</b>	separates marking points
<b>/</b>	alternative answers for the same point
<b>A</b>	accept (for answers correctly cued by the question, or by extra guidance)
<b>R</b>	reject
<b>AW</b>	alternative wording (where responses vary more than usual)
<b><u>underline</u></b>	actual word given must be used by candidate (grammatical variants accepted)
<b>max</b>	indicates the maximum number of marks that can be given
<b>ora</b>	or reverse argument
<b>mp</b>	marking point (with relevant number)
<b>ecf</b>	error carried forward
<b>I</b>	ignore
<b>AVP</b>	alternative valid point

Question	Answers	Marks
3(a)	<i>max 2 of:</i> 1 can, kill / control, weeds ; <b>R</b> kill, insects / pests 2 reduce competition / increase yield (of rape) ; 3 AVP ; e.g. manual weeding / hoeing, difficult / expensive ref. to glufosinate converted to non-toxic compound	<b>2</b>
3(b)(i)	circle of / circular, DNA ; <b>I</b> loop <b>R</b> single-stranded small / supplementary ;	<b>2</b>
3(b)(ii)	<i>max 3 of:</i> 1 small so can be taken up by, cells / bacteria ; 2 replicate, independently / fast ; <b>A</b> have <i>ori</i> / origin of replication / high copy number 3 (DNA) has restriction site(s) / can be cut by restriction enzymes ; <b>A</b> have polylinker 4 have, marker genes / genes for resistance (for screening) ; 5 AVP ; e.g. circular so, increased stability / reduced host cell degradation	<b>3</b>

3(b)(iii)	<p><i>max 2 of:</i></p> <p>1 <u>RNA polymerase</u> binds ;</p> <p>2 so, transcription / mRNA synthesis, begins / occurs / allowed ;</p> <p>3 AVP ; e.g. correct / template, strand is transcribed <i>ref. to</i> tissue-specific / inducible, expression</p>	2
3(c)(i)	28 ;	1
3(c)(ii)	<p><i>max 1 of:</i></p> <p>spray with herbicide <b>and</b>, those that die did not have the <i>bar</i> gene / those that survive did have the <i>bar</i> gene ;</p> <p>add gene for fluorescence with <i>bar</i> gene and test plants under UV / use PCR with primer complementary to <i>bar</i> gene / use (gene) probe (on Southern blot) of electrophoresis gel ;</p>	1
3(c)(iii)	<p><i>max 3 of:</i></p> <p><i>advantage of male sterile GM variety</i></p> <p>1 avoid transferring, <i>bar</i> / resistance, gene to wild, radish / relations ; <b>ora</b></p> <p>2 avoid superweeds ; <b>ora</b></p> <p>3 avoid <u>type 2</u> hybrids ; <b>ora</b></p> <p><i>disadvantage of <b>type 2 hybrids</b> (from GM variety that produces pollen)</i></p> <p>4 taller (than wild radish) ; <b>A</b> very tall / 88 cm / 95 cm</p> <p>5 produce, more / many, seeds (than wild radish) ; <b>A</b> 3958 / 443 more</p> <p>6 may (out)compete, wild radish / crops ;</p>	3
		<b>Total: 14</b>

Question	Answers	Marks
4(a)(i)	1. no resistance to any herbicide at start of use ; 2. resistant to photosystem II inhibitors – increases, to 101–103 <b>or</b> from 1969 to 2013 ; 3. resistant to ALS inhibitors – increase to 153 – 155 <b>or</b> from 1981 to 2014 ; 4. resistant to glyphosate - increase to 32 / 33 <b>or</b> from 1993 - 1995 to 2014 ; 5. comparative point described ; e.g. ALS steepest gradient / ALS has highest number of species	<b>max 3</b>
4(a)(ii)	1. random / spontaneous, mutation ; 2. herbicide is selection pressure ; 3. mutant / resistant, individuals, survive / reproduce ; ora 4. pass on, mutant / resistance, allele ; ora 5. (mutant / resistance) allele increases in frequency (in population) ; ora 6. <i>ref. to</i> many generations ;	<b>max 4</b>
4(b)(i)	$(668 \cdot 3) + 3$ (stop codon) = 2007 bp <b>or</b> $668 \cdot 3 = 2004$ bp ;	<b>1</b>
4(b)(ii)	1. after folding substituted amino acids are close together ; 2. <i>ref. to</i> different bonding ; 3. (substituted amino acids) causes change to protein, 3D / tertiary / quaternary / globular, structure ; 4. herbicide / inhibitor, unable to bind to, active / allosteric, site ;	<b>max 2</b>

4(c)	<p><i>method 1 benefits max 3</i></p> <ol style="list-style-type: none"> <li>1. hybrid vigour / reduces inbreeding depression ;</li> <li>2. increase in, genetic variation / gene pool / variety of alleles ;</li> <li>3. increase in heterozygosity ; ora</li> <li>4. <i>idea that</i> low tech / easy to do / cheaper ;</li> </ol> <p><i>method 2 benefits</i></p> <ol style="list-style-type: none"> <li>5. no need to find a suitable (wild) plant / can proceed even if no resistant (wild) plant exists ;</li> <li>6. will not introduce, unwanted alleles / poor characteristics, from (wild) plant ;</li> <li>7. no chance of disease transfer ;</li> </ol>	<b>max 4</b>
<b>Total: 14</b>		



Question	Answer	Marks
5(a)	<p>1. individual 8 or 11 has, BRCA2 / allele, but does not have cancer ;</p> <p>2. no evidence / unknown, that individuals (apart from 15) with cancer have, <i>BRCA2</i> / allele</p> <p><b>or</b></p> <p>individuals with cancer (apart from 15) may have a different mutation ;</p> <p>3. no children of individual 15, (known to) have the allele / have cancer ;</p> <p>4. individuals in fourth generation / children of individual 15, may develop cancer later in life ;</p> <p>5. individual 15 has cancer and, <i>BRCA2</i> / allele ;</p> <p>6. (some) individuals with cancer in third generation had a parent with cancer</p> <p><b>or</b></p> <p>(some) individuals with cancer in third generation had a parent with, <i>BRCA2</i> / allele ; ora</p> <p>7. individual 3 or 4 may have had the, BRCA2 / allele</p> <p><b>or</b></p> <p>any individual from 8 to 11 may have inherited, <i>BRCA2</i> / allele, from 3 or 4 ;</p> <p>8. <i>idea that</i> overall data inconclusive ;</p>	<b>max 4</b>
5(b)(i)	all the, DNA / genetic material (in a person's cell) ;	<b>1</b>
5(b)(ii)	(named) white cell, <b>because</b> it contains a nucleus ;	<b>1</b>

Question	Answer	Marks
5(b)(iii)	<p>1. <i>ref. to</i> probes are (short) lengths of ssDNA ;</p> <p>2. complementary to the, alleles / DNA, being tested for ;</p> <p>3. many copies of one type of probe placed in each cell (of the microarray) ;</p> <p>4. (target), alleles / DNA, made single-stranded</p> <p><b>or</b></p> <p>single-stranded DNA made from mRNA ;</p> <p>5. (target), alleles / DNA, labelled, (with fluorescent 'tags') ;</p> <p>6. (target), alleles / DNA, hybridises / binds, with, probes / ssDNA ;</p> <p>7. unbound (target), alleles / DNA, washed off</p> <p><b>or</b></p> <p>bound (target), alleles / DNA, will not be washed off ;</p> <p>8. laser / UV light, used to detect presence of, fluorescence / hybridised probes / alleles / DNA ;</p>	<b>max 4</b>
5(b)(iv)	<p><i>advantage</i> max 1</p> <p>1. if present, enables lifestyle change / early treatment / regular check-ups ;</p> <p>2. if not present removes worry ;</p> <p>3. preventative treatment may be cheaper than treating disease itself ;</p> <p><i>disadvantage</i> max 1</p> <p>4. if present may cause worry ;</p> <p>5. if present person may not develop cancer ;</p> <p>6. test is expensive ;</p> <p>7. may have implications for life insurance / AW ;</p> <p>8. may decide to not have children / may be tested after they have children ;</p>	<b>max 2</b>
<b>Total: 12</b>		