1. Nov/2019/Paper_41/No.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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Calcitonin is a small protein hormone consisting of 32 amino acids. One of its functions is to inhibit the activity of cells, called osteoclasts, that break down bone tissue.

Calcitonin has been used as a therapeutic protein to treat osteoporosis. In osteoporosis too much breakdown of bone tissue in older people leads to reduced bone density and a risk of breaking bones.

(b) Fig. 3.1 shows the amino acid sequences of human calcitonin and calcitonin from the salmon fish, *Salmo salar*.

position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
human	Cys	Gly	Asn	Leu	Ser	Thr	Cys	Met	Leu	Gly	Thr	Tyr	Thr	Gln	Asp	Phe
salmon	Cys	Ser	Asn	Leu	Ser	Thr	Cys	Val	Leu	Gly	Lys	Leu	Ser	Gln	Glu	Leu

position	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
human	Asn	Lys	Phe	His	Thr	Phe	Pro	Gln	Thr	Ala	Ile	Gly	Val	Gly	Ala	Pro
salmon	His	Lys	Leu	Gln	Thr	Tyr	Pro	Arg	Thr	Asn	Thr	Gly	Ser	Gly	Thr	Pro

Fig. 3.1

(i) The two amino acid sequences shown in Fig. 3.1 can be compared. The number of amino acids that occur at the same position in both sequences can be counted and expressed as a percentage of the total number of amino acids present in one sequence. This is called the percentage sequence similarity.

Use Fig. 3.1 to calculate the percentage sequence similarity of human and salmon calcitonin.

Show your working.

..... % [2]

(ii) Compared to human calcitonin, salmon calcitonin is more biologically active. It remains active in the human body for longer and binds to calcitonin receptors more readily.

Bioinformatics was used to identify this more biologically active form of calcitonin to treat osteoporosis.

Explain how bioinformatics helped identify salmon calcitonin as a suitable form of calcitonin to treat human osteoporosis.

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(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.

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

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(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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[Total: 14]

2. Nov/2019/Paper_42/No.3

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

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salmon	Cys	Ser	Asn	Leu	Ser	Thr	Cys	Val	Leu	Gly	Lys	Leu	Ser	Gln	Glu	Leu

position	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
human	Asn	Lys	Phe	His	Thr	Phe	Pro	Gln	Thr	Ala	Ile	Gly	Val	Gly	Ala	Pro
salmon	His	Lys	Leu	Gln	Thr	Tyr	Pro	Arg	Thr	Asn	Thr	Gly	Ser	Gly	Thr	Pro

Fig. 3.1

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Show your working.

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- cut plasmid DNA

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- join the salmon calcitonin gene with plasmid DNA.

..... [2]

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

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(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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[Total: 14]

3. Nov/2019/Paper_43/No.3

Therapeutic proteins are used to treat disease. One example of a therapeutic protein is human growth hormone (hGH).

hGH has important roles in growth during childhood and in regulation of metabolism in adulthood.

Children described as hGH-deficient do not produce enough hGH and grow more slowly than other children. People who were hGH-deficient when they were children have a mean adult height that is 32 cm shorter than the population mean.

Daily injections of hGH are a treatment for hGH-deficient children that can increase growth rate, resulting in an increased adult height.

(a) The growth rate of three children was measured.

- The growth rate of the hGH-deficient child who did **not** receive daily hGH injections was 2.5 cm $year^{-1}$.
- The growth rate of the hGH-deficient child who received daily hGH injections was 10.0 cm $year^{-1}$ in the first year after starting treatment.
- The growth rate of the child who is **not** hGH-deficient was 5.0 cm $year^{-1}$.

Calculate the percentage increase in growth rate of the hGH-deficient child treated with hGH injections compared to the child who is **not** hGH-deficient.

Show your working.

..... % [2]

When this form of treatment started in 1958, hGH could only be obtained from the pituitary glands of people who had died.

In 1981, a plasmid containing hGH cDNA was constructed and inserted into *Escherichia coli* bacteria. This allowed recombinant hGH protein to be produced by the bacteria.

(b) Name the type of enzyme that:

- cuts plasmid DNA

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- makes cDNA from hGH mRNA.

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(c) Identify **and** explain **two** properties of plasmids that allow them to be used as vectors of hGH cDNA into cells of *Escherichia coli*.

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(d) In 1985, several cases of a rare brain disease were discovered in people who had been treated many years previously with hGH obtained from pituitary glands. It was decided, from 1985 onwards, that only recombinant hGH should be used to treat patients.

Explain the advantages of producing human therapeutic proteins, such as hGH, by recombinant DNA technology.

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(e) hGH is one of many proteins in the body whose secretion or production is controlled by a person's sleep-wake pattern.

The sleep-wake pattern describes when, during a 24 hour day, a person is asleep and when they are awake. For example:

- pattern 1 – asleep during the night and awake during the day (normal)
- pattern 2 – asleep during the day and awake during the night.

Researchers used microarray analysis to identify which genes have their expression changed by a person's sleep-wake pattern. They collected mRNA from:

- a group of people with sleep-wake pattern 1
- the same group of people whose sleep-wake pattern was changed to pattern 2.

A summary of the results is shown in Table 3.1.

Table 3.1

sleep-wake pattern	number of genes with increased expression		
	during the day	during the night	all the time
pattern 1	661	733	108
pattern 2	134	95	8

(i) Describe how changing the sleep-wake pattern from pattern 1 to pattern 2 affects the number of genes expressed.

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(ii) Explain how eukaryotic genes can be switched on and off, for example, at certain times of day.

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(iii) Explain how bioinformatics can help to identify whether the genes whose expression is changed by moving from pattern 1 to pattern 2 are important to health.

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[Total: 15]

4. June/2019/Paper_41/No.2

The interpupillary distance (IPD) is the distance in millimetres between the centres of the pupils of the eyes. Fig. 2.1 shows how IPD is measured.

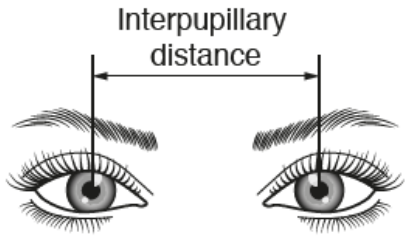

Fig. 2.1

IPD is one example of a characteristic of human facial structure that shows variation.

Fig. 2.2 shows the pattern of variation in IPD in a large sample of adults.

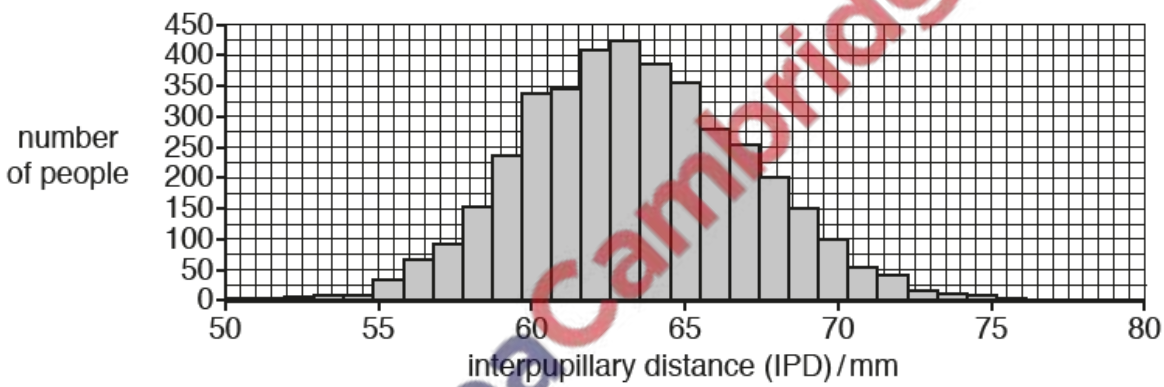

Fig. 2.2

(a) (i) Name the type of variation shown in Fig. 2.2.

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(ii) Suggest **and** explain how genes and the environment contribute to variation in IPD in humans.

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(b) Individuals with an IPD of 70 mm or more have a mutation in the *PAX3* gene that results in less PAX3 protein being made.

The normal role of the PAX3 protein is to increase the expression of many other genes involved in embryonic development. These genes affect a range of phenotypic features such as facial structure, hearing and eye colour.

(i) State the term that is used to describe a gene, such as *PAX3*, that controls the expression of other genes **and** suggest how the PAX3 protein controls the expression of other genes.

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(ii) Describe how microarray analysis could be used to identify the genes switched on by PAX3 in embryonic cells.

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(iii) The chimpanzee, *Pan troglodytes*, has DNA that is 98.5% similar to humans, including possession of the *PAX3* gene. Investigations show that chimpanzees express higher levels of the PAX3 protein during embryonic development than humans.

Fig. 2.3 shows a chimpanzee, *Pan troglodytes*.

Fig. 2.3

Suggest how knowledge of the *PAX3* gene helps scientists explain how humans and chimpanzees are very different in facial structure, even though they have very similar DNA.

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[Total: 15]

5. June/2019/Paper_41/No.6

Maize, *Zea mays*, is an important food crop for human consumption and for feeding to animals.

Two varieties of maize are MON810 and Justina. Justina has been developed in the traditional way by selective breeding (artificial selection) and MON810 is an example of a genetically modified (GM) organism.

(a) MON810 produces a chemical that is toxic to insect pests. It is described as insect-resistant.

Outline how genetic engineering gave MON810 the trait of insect resistance.

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(b) Countries vary in the extent to which they grow GM varieties such as MON810, instead of traditional varieties such as Justina.

- In the USA, 88% of the total maize that is grown is GM.
- In most European countries, 0% of the maize that is grown is GM.

Scientists used computer models to predict the effect of two different changes in agricultural practice on maize crop yields:

- a global ban that reduces the cultivation of GM maize to 0% everywhere
- all countries increasing the cultivation of GM maize to the 88% level of the USA.

Table 6.1 shows the results of this modelling for four countries.

Table 6.1

country	percentage change in yield of maize	
	decrease GM maize cultivation to 0% of total	increase GM maize cultivation to 88% of total
Argentina	–8.86	+2.90
Honduras	–1.26	+16.75
Spain	–3.82	+5.39
USA	–7.63	0.00

Explain what the data in Table 6.1 suggests about the social and ethical implications of growing GM maize.

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[Total:8]

6. June/2019/Paper_42/No.2(c)

(c) **(i)** Describe how microarray analysis can detect differences in the expression of many genes when comparing two samples, such as the offspring of wild and captive-bred fish.

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(ii) Explain how gene expression is controlled in eukaryotes such as fish.

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7. June/2019/Paper_42/No.3(a, b)

Soybean, *Glycine max*, is an important food crop for human consumption and for feeding to animals.

Two varieties of soybean are Vinton 81 and GTS 40-3-2.

Vinton 81 has been developed in the traditional way by selective breeding (artificial selection) and GTS 40-3-2 is an example of a genetically modified (GM) organism.

(a) GTS 40-3-2 is described as herbicide-resistant, as it can withstand the application of glyphosate herbicide. Glyphosate is sprayed on the crop to kill weeds.

Outline how genetic engineering gave GTS 40-3-2 the trait of herbicide resistance.

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(b) Countries vary in the extent to which they grow GM varieties, such as GTS 40-3-2, instead of traditional varieties such as Vinton 81.

- In the USA, 94% of soybeans grown are GM.
- In Europe, 0% of soybeans grown are GM.

Scientists used computer models to predict the effect of two different changes in agricultural practice on soybean crop yields:

- a global ban that reduces the cultivation of GM soybeans to 0% everywhere
- all countries increasing the cultivation of GM soybeans to the 94% level of the USA.

Table 3.1 shows the results of this modelling for four countries.

Table 3.1

country	percentage change in yield of soybeans	
	decrease GM soybean cultivation to 0% of total	increase GM soybean cultivation to 94% of total
Argentina	0.00	+6.23
Bolivia	–10.82	0.00
Brazil	0.00	+6.23
USA	–5.87	0.00

Explain what the data in Table 3.1 suggests about the social and ethical implications of growing GM soybeans.

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8. June/2019/Paper_43/No.4

Rice, *Oryza sativa*, is an important food crop for human consumption.

Two varieties of rice are T2A-1 and Shanyou 2.

Shanyou 2 has been developed in the traditional way by selective breeding (artificial selection) and T2A-1 is an example of a genetically modified (GM) organism.

(a) T2A-1 rice is described as insect-resistant as it produces a chemical that is toxic to insect pests.

Outline how genetic engineering gave T2A-1 rice the trait of insect resistance.

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(b) Countries vary in the extent to which they grow GM varieties instead of traditional crop varieties.

- The USA, Canada and countries in South America plant GM varieties on a large proportion of their crop-growing land, reaching 94% for soybeans in the USA.
- In most European countries, 0% of the crop-growing land is planted with GM varieties.

Scientists used computer models to predict the effects of a global ban that reduced the cultivation of GM crops to 0% everywhere.

Table 4.1 shows the results of this modelling on world crop yields and the purchase price of each crop.

Table 4.1

crop	percentage change in crop yield	percentage change in purchase price
rapeseed	–0.14	+1.96
rice	–0.12	+1.58
soybeans	–1.40	+4.05

(i) Explain what the data in Table 4.1 show about the **social** implications of growing GM crops.

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(ii) A worldwide ban on growing GM crop varieties would mean that more land would be needed to grow traditional crops, such as Shanyou 2. This would involve converting forest and grassland to crop-growing land.

Table 4.2 shows the predicted changes in carbon dioxide emissions associated with this change in use of land.

Table 4.2

change in use of land	change in carbon dioxide emissions /million kg CO_2
forest to crop-growing land	+ 608 726
grassland to crop-growing land	+ 276 042

Discuss what the data in Table 4.2 indicate about the environmental implications of growing GM crops.

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[Total: 8]

9. Feb/2019/Paper_42/No.3(a, d)

During an immune response, only B-lymphocytes with receptors that are specific to the antigens present are activated. Activation occurs when an antigen binds to a receptor of a B-lymphocyte.

Activated B-lymphocytes grow in size and then divide by mitosis. Many further mitotic cell divisions occur, increasing the number of B-lymphocytes with receptors specific to the antigen. Eventually, cells produced in this process will develop into either plasma cells that secrete antibodies or memory B-cells.

Fig. 3.1 is a summary of B-lymphocyte activation and the events that follow.

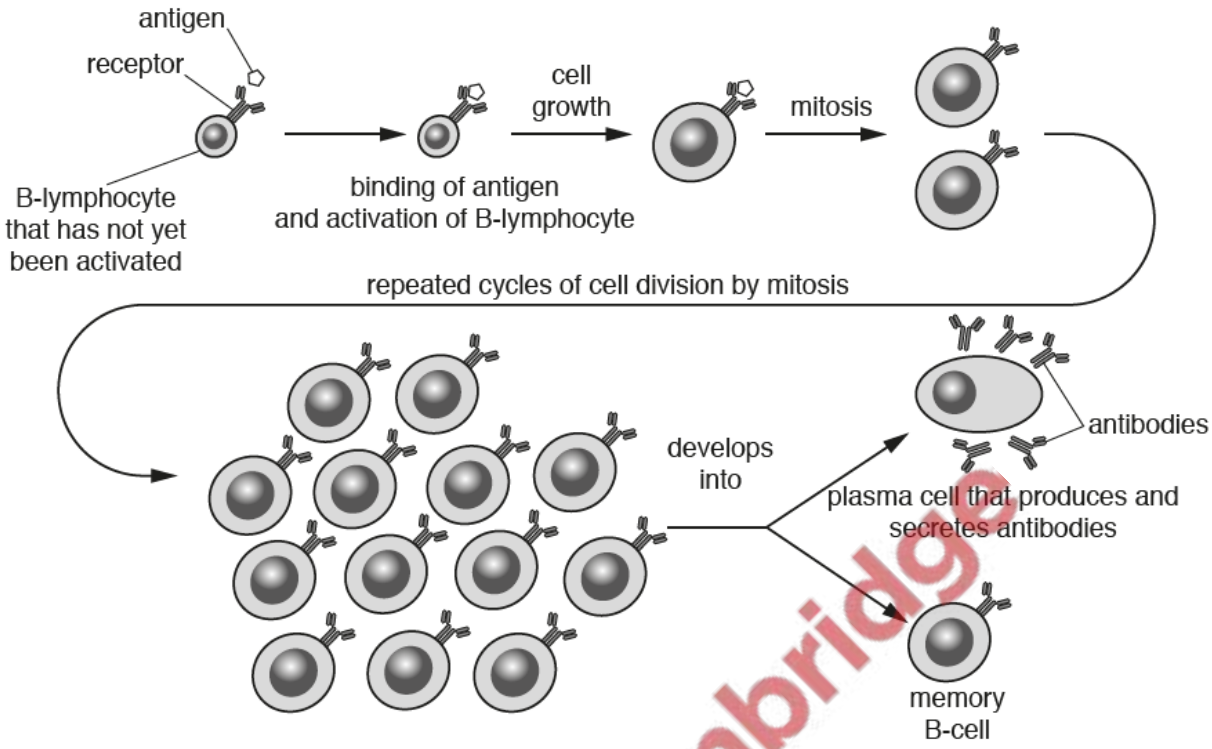

Fig. 3.1

The development of plasma cells and memory B-cells in this process depends on transcription factors.

(a) Explain the role of transcription factors in gene expression in eukaryotic cells.

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(d) Microarrays can be used to analyse the effect of transcription factors, such as BLIMP-1, on gene expression.

(i) Describe how a microarray is used in the study of gene expression.

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(ii) BCL6 is another transcription factor found in B-lymphocytes. The effect of BCL6 on gene expression was compared in two samples of B-lymphocytes.

- Sample 1 consisted of B-lymphocytes that were producing BCL6.
- Sample 2 consisted of B-lymphocytes that were **not** producing BCL6.

Suggest why a microarray is suitable for identifying the function of the transcription factor BCL6 in these two samples.

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10. Feb/2019/Paper_42/No.5

Fig. 5.1 shows the area of land that was used to grow genetically modified (GM) crops in the USA, Brazil, India and China from 2004 to 2015.

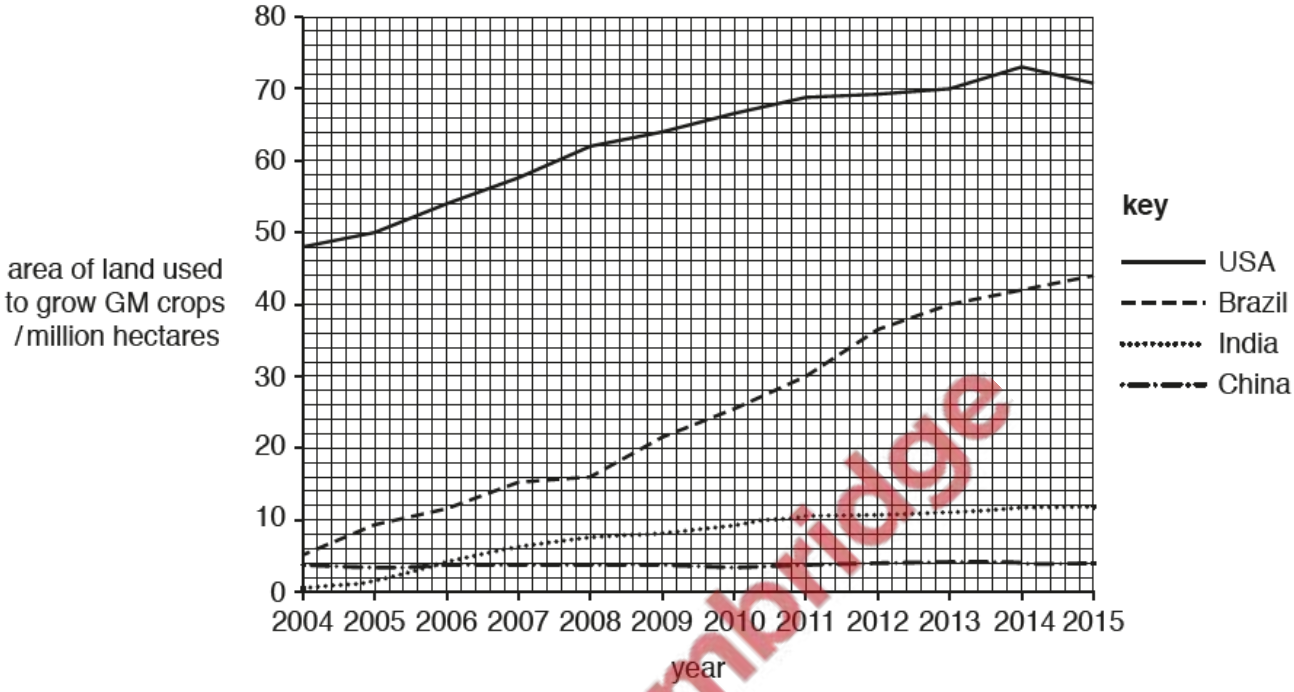

Fig. 5.1

(a) (i) Suggest reasons why the area of land used to grow GM crops in the USA is greater than the area of land used to grow GM crops in Brazil.

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(ii) Describe the differences in the area of land that was used to grow GM crops in China and the area of land that was used to grow GM crops in India, over the time shown in Fig. 5.1.

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(b) **(i)** Genetic modifications in crops can provide resistance to insect pests. Bt maize is one type of GM crop that has been produced to be resistant to insect pests.

State **two** benefits to farmers of insect resistance in crops.

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(ii) Describe the difference between Bt maize and non-GM maize that explains why Bt maize is resistant to insects.

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(c) **(i)** State **two** reasons why people may have objections to the growth of insect-resistant GM crops.

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(ii) In 2015, the percentage of the USA population that objected to the use of GM crops was lower than in 2005.

Suggest why a smaller percentage of the USA population objected to the use of GM crops in 2015.

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[Total: 12]