Inheritance, variation and evolution

Model answers and marking points

GCSE science 6-mark questions

This topic online

1 Strawberry plants can reproduce sexually using flowers and seeds. They can also reproduce asexually by growing runners, which are side shoots that put down roots and form new plants.

Compare sexual and asexual reproduction in strawberry plants. (6 marks)

Model answer

In sexual reproduction, a male gamete from pollen fuses with a female gamete, an egg cell, so genetic information comes from two parents. The gametes are made by meiosis. Asexual reproduction by runners only needs one parent plant and involves only mitosis, with no gametes and no fusion.

Because sexual reproduction mixes genetic information from two parents, the seeds grow into plants that vary from each other and from their parents. Asexual reproduction produces clones that are genetically identical to the parent.

The variation from sexual reproduction is an advantage if the environment changes or a new disease appears, because some offspring may have characteristics that help them survive. People can also use the variation to selectively breed new varieties. However, sexual reproduction is slower and depends on pollination.

Asexual reproduction is much faster and does not need pollinating insects. If the parent plant has good features, such as large, sweet fruit, every runner will have them too. The disadvantage is that all the clones are equally likely to be killed by the same disease or change in conditions.

Marking points (credit any 6 relevant points, linked in a sensible order)

- sexual reproduction involves two parents (or two gametes); asexual involves one parent
- sexual reproduction involves the fusion of male and female gametes, pollen and egg cells
- gametes are made by meiosis; asexual reproduction involves only mitosis
- sexual reproduction gives offspring that vary genetically; asexual gives clones
- variation from sexual reproduction gives a better chance of some surviving a change in the environment or a new disease
- variation allows selective breeding for new desirable characteristics
- asexual reproduction is faster and needs no pollination
- asexual reproduction means a plant with good features, such as large fruit, passes them all on
- asexual clones may all be killed by the same disease

How it is marked

- 5-6 marks: compares the processes (gametes, meiosis and mitosis, number of parents) and the outcomes (variation or clones) with advantages and disadvantages of each.
- 3-4 marks: gives correct differences in either the processes or the outcomes, with some comparison.
- 1-2 marks: states one difference, such as one parent or two.

What loses marks

- saying asexual offspring are made by meiosis
- saying runners are seeds
- giving advantages for only one type

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2 Cystic fibrosis is caused by a recessive allele, f. The dominant allele is F.

Sophie and Ravi do not have cystic fibrosis. Their first child, Ellie, has cystic fibrosis.

Use this information to work out the genotypes of Sophie and Ravi. Draw a Punnett square to find the probability that their next child will have cystic fibrosis, and the probability that the next child will be a carrier.

(6 marks)

Model answer

Cystic fibrosis is recessive, so Ellie must have the genotype ff. She received one allele from each parent, so both Sophie and Ravi must have passed on an f allele.

Sophie and Ravi do not have cystic fibrosis, so each must also have a dominant F allele. This means both parents are heterozygous, Ff. They are carriers.

Each parent makes gametes containing either F or f.

	F	**f**
F	FF	Ff
f	Ff	ff

There is 1 ff out of 4 possible outcomes, so the probability that the next child will have cystic fibrosis is 1 in 4, which is 0.25 or 25%.

There are 2 Ff outcomes out of 4, so the probability that the next child will be a carrier is 2 in 4, which is 0.5 or 50%.

The probability is the same for every child they have, so having one child with cystic fibrosis does not change the chance for the next one.

Marking points (credit any 6 relevant points, linked in a sensible order)

- Ellie has cystic fibrosis, so her genotype is ff
- Ellie must have received one f allele from each parent
- Sophie and Ravi do not have the disorder, so each has at least one F allele
- so both parents are heterozygous, Ff, and are carriers
- the gametes from each parent are F or f
- Punnett square gives FF, Ff, Ff, ff
- probability of cystic fibrosis = 1 in 4, 0.25 or 25%
- probability of a carrier (Ff) = 2 in 4, 0.5 or 50%
- each child has the same probability, whatever happened with Ellie

How it is marked

- 5-6 marks: deduces both parents are Ff with reasoning, shows a correct Punnett square and gives both probabilities correctly.
- 3-4 marks: gives the parents as Ff with a correct square but one probability wrong or missing, or little reasoning.
- 1-2 marks: gives Ellie's genotype or a partly correct square.

What loses marks

- giving the parents as FF and ff
- giving the probability as a ratio such as 3:1 when a probability is asked for
- saying the next child cannot have it because the first one does

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3 **Higher tier**

Before genetic engineering, insulin for people with diabetes was extracted from the pancreases of pigs and cattle. Today, most insulin is made by genetically modified bacteria.

Describe the main steps used to produce bacteria that make human insulin. (6 marks)

Model answer

First, scientists identify the gene that codes for human insulin in human DNA.

This gene is cut out of the DNA using enzymes, which cut the DNA at specific places.

Next, a plasmid, which is a small ring of DNA, is taken from a bacterium. The plasmid acts as a vector, carrying the gene into the new cell. The plasmid is cut open using the same enzymes, so it has ends that match the ends of the insulin gene.

The insulin gene is then inserted into the opened plasmid, and other enzymes are used to join it into place.

The modified plasmid is put back into a bacterial cell. This bacterium is now genetically modified and contains the human insulin gene.

The genetically modified bacteria are grown in large numbers in a fermenter. As they divide, every new bacterium has a copy of the plasmid, so they all make human insulin.

Finally, the insulin is extracted and purified so it can be injected by people with diabetes. Because it is human insulin, it is less likely to cause a reaction than insulin from animals.

Marking points (credit any 6 relevant points, linked in a sensible order)

- the human gene for insulin is identified
- the gene is cut out of human DNA using enzymes
- a plasmid is taken from a bacterium to act as a vector
- the plasmid is cut open using the same enzymes
- this gives matching ends so the insulin gene can be inserted
- the gene is joined into the plasmid
- the modified plasmid is put back into a bacterial cell
- the bacteria are grown in large numbers in a fermenter
- the bacteria make human insulin, which is extracted and purified

How it is marked

- 5-6 marks: describes all the main steps in order, including the use of enzymes to cut DNA and the plasmid as a vector.
- 3-4 marks: describes most steps, but with one missing or out of order, or no mention of enzymes.
- 1-2 marks: states that the insulin gene is put into bacteria with no detail.

What loses marks

- saying the insulin protein rather than the gene is put into the bacterium
- leaving out the vector
- saying the gene is put into the bacterium's nucleus

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4 On a group of islands, two species of lizard live on separate islands. Scientists think both species evolved from one population of lizards that lived on a single island. Rising sea levels later split this island into two.

Explain how the two separate species could have evolved.

Separate science only

(6 marks)

Model answer

When the sea level rose and the island split in two, the lizard population was divided into two groups. They were now geographically isolated, so the two groups could not interbreed.

Within each group there was genetic variation, caused by different alleles. New mutations also arose separately in each population.

The conditions on the two islands were different. For example, one island may have had different plants to eat, different predators or a drier climate. On each island, the lizards with characteristics that suited those conditions best were more likely to survive and reproduce. They passed on the alleles for these characteristics to their offspring. This is natural selection.

Because each population was being selected for different characteristics, the two groups gradually became more and more different over many generations.

Eventually the two populations became so different that, even if they met again, they could no longer interbreed to produce fertile offspring. At this point they are two separate species. This process of forming new species is called speciation.

Marking points (credit any 6 relevant points, linked in a sensible order)

- rising sea levels separated the population into two groups, so they became geographically isolated
- the two groups could no longer interbreed
- there was genetic variation within each group
- conditions on each island were different, for example different food, predators or climate
- individuals with characteristics best suited to their island were more likely to survive and breed
- these individuals passed on the alleles for these characteristics to their offspring
- over many generations, natural selection changed each population differently
- new mutations arose in each population independently
- eventually the two populations became so different that they could no longer interbreed to produce fertile offspring
- they are then separate species

How it is marked

- 5-6 marks: explains isolation, variation, different selection pressures and natural selection over generations, ending with the populations unable to interbreed to make fertile offspring.
- 3-4 marks: explains isolation and natural selection, but misses the idea of fertile offspring or of different conditions.
- 1-2 marks: states that the lizards changed to suit their island.

What loses marks

- saying lizards changed on purpose to suit their island
- saying characteristics gained in an animal's life are passed on
- defining a new species without the word fertile

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5 A dairy farmer in Devon wants to increase the amount of milk her herd produces. She reads the following.

Breed	Mean milk yield in litres per year	Information
Selectively bred high-yield breed	9500	Bred for many generations for milk. More likely to have foot and fertility problems.
Traditional breed	5500	Hardy, lives longer, copes well outdoors.

Evaluate the use of selectively bred cattle for her farm. Give a justified conclusion. (6 marks)

Model answer

Selective breeding means choosing parents with a wanted characteristic, such as high milk yield, and breeding them together. The best offspring are chosen and bred again, and this is repeated for many generations until all the offspring have the characteristic.

The selectively bred cows produce 9500 litres per year compared with 5500 litres, which is 4000 litres more per cow, about 73% more. This would greatly increase the farmer's income, or she could keep fewer cows for the same amount of milk.

However, selective breeding reduces variation in the herd and can lead to inbreeding. This makes the animals more likely to inherit defects and makes some diseases more common, as shown by their foot and fertility problems. These would raise vet bills, could shorten the cows' lives and raise welfare concerns. With less variation, a new disease could also affect the whole herd.

The traditional breed makes less milk but is hardy and lives longer, so it may be cheaper to keep.

I would recommend the high-yield breed, because the large increase in milk is likely to outweigh the extra costs, but she must monitor their health closely.

Marking points (credit any 6 relevant points, linked in a sensible order)

- selective breeding: choose parents with the desired characteristic, such as high milk yield
- breed them together and choose the best offspring to breed again, over many generations
- the high-yield breed gives 4000 litres more per cow per year, about 73% more
- more milk per cow means more income or fewer cows needed
- selective breeding reduces variation and leads to inbreeding
- inbreeding makes inherited defects and some diseases more likely
- the table shows more foot and fertility problems, giving vet costs and welfare concerns
- a smaller gene pool means the herd could be more affected by a new disease
- the traditional breed is hardier and lives longer, so may cost less to keep
- a justified conclusion

How it is marked

- 5-6 marks: explains selective breeding, uses the data to weigh the extra yield against health and variation problems and gives a reasoned conclusion.
- 3-4 marks: gives an advantage and a disadvantage using some of the data, with a weak conclusion.
- 1-2 marks: states that the high-yield cows make more milk.

What loses marks

- confusing selective breeding with genetic engineering
- not using any figures from the table
- giving a conclusion with no reason

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