# Genetics of living systems

## Section Summary

Make sure you know...

- That there are regulatory mechanisms that control gene expression (and therefore protein synthesis) at three different levels: the transcriptional level, the post-transcriptional level and the post-translational level.
- That at the transcriptional level, the control of gene expression in eukaryotes involves transcription factors, and in prokaryotes (e.g. bacteria) it often involves operons (sections of DNA that contain structural genes, control elements and sometimes a regulatory gene).
- How the *lac* operon in *E. coli* controls the production of the enzymes needed to respire lactose — the genes that code for the enzymes are only switched on (transcribed) in the presence of lactose.
- That at the post-transcriptional level, gene expression is controlled by the editing of primary mRNA. Introns are removed from primary mRNA (by a process called splicing) to produce mature mRNA.
- That the post-translational control of gene expression includes some proteins being activated before they can work. An example of this is the activation of proteins by cyclic AMP (cAMP) — cAMP activates proteins by altering their 3D structure.
- That a body plan is the general structure of an organism.
- That the development of the body plan in animals, plants and fungi is controlled in a similar way, by a similar group of genes called Hox genes.
- That the homeobox sequences within Hox genes are very similar in animals, plants and fungi, and these sequences have changed very little during evolution.
- How Hox genes and the homeobox sequences they contain control the development of body plans by regulating transcription.
- That apoptosis (programmed cell death) is a highly controlled process that leads to cells being broken down in stages.
- How mitosis and apoptosis are important mechanisms involved in the development of different parts of the body — mitosis (and cell differentiation) creates the bulk of body parts and then apoptosis can refine these parts by removing unwanted structures.
- That the genes that regulate the cell cycle (including mitosis) and apoptosis are able to respond to internal cell stimuli (e.g. DNA damage) and external stimuli (e.g. stress).
- That gene mutations are changes to the base (nucleotide) sequence of DNA. These can affect protein function by altering the amino acid sequence (primary structure), and whether a protein is produced at all.
- That substitution mutations involve one base being swapped for another, insertion mutations involve one or more nucleotides being added, and deletion mutations involve one or more nucleotides being removed.
- How gene mutations can have neutral, beneficial or harmful effects on an organism.

Genetics of living systems

# Exam-style Questions

1 Which of the following statements is/are true?

**Statement 1:** The homeobox sequences found in Hox genes are highly conserved.

**Statement 2:** Mutations in Hox genes can cause developmental abnormalities.

**Statement 3:** Identical Hox genes are found in all living things.

**A** 1, 2 and 3

**B** Only 1 and 2

**C** Only 2 and 3

**D** Only 1

*(1 mark)*

2 Glucagon is a hormone involved in the regulation of the blood glucose level in humans. It controls protein activation in a cell via the secondary messenger cAMP.

**(a)** Glucagon is a protein.
How is the order of amino acids in glucagon determined?

*(1 mark)*

**(b)** Suggest how glucagon could control the activation of a protein via cAMP.

*(2 marks)*

**(c)** cAMP is also involved in the regulation of the *lac* operon in *E. coli*.

When the concentration of glucose is low, cAMP activates the protein CRP. CRP helps RNA polymerase bind to the promoter at the start of the operon.

Explain how this helps *E. coli* to continue respiring when the concentration of glucose is low, but lactose is present.

*(3 marks)*

3 A mutation in the APC gene is found in the majority of colon cancers. The mutation prevents the protein produced from carrying out its function.

**(a)** Mutations that result in a non-functioning APC protein are usually caused by **base deletions**.

Explain how the deletion of a single base could result in a non-functioning protein.

*(3 marks)*

**(b)** Explain why a single-base **substitution** in a gene may have a less serious effect on the gene's protein structure than a single-base deletion.

*(2 marks)*

**(c)** Mutations in the APC gene that lead to the development of colon cancer have a harmful effect on a person. Explain how other mutations may have a **neutral effect** on an organism.

*(4 marks)*

# Genetics of living systems answers

1 B ***(1 mark)***

Remember, similar Hox genes are found in plants, animals and fungi — they are not identical.

2 a) By the order of bases in the glucagon gene ***(1 mark)***.

b) E.g. glucagon could bind to cell membranes causing the production of cAMP inside the cell ***(1 mark)***. cAMP would then activate the protein inside the cells by changing its three-dimensional structure ***(1 mark)***.

c) Once bound to the promoter, RNA polymerase begins the transcription of the structural genes in the *lac* operon ***(1 mark)***. The structural genes produce proteins/enzymes that help the bacteria to digest lactose ***(1 mark)***. This means the bacteria are able to respire lactose instead of glucose ***(1 mark)***.

3 a) A single-base deletion will cause a frameshift ***(1 mark)*** and this could cause a change in the amino acid sequence/primary structure of the protein ***(1 mark)***. This could change the tertiary structure of the protein and prevent it from functioning ***(1 mark)***.

b) A single-base substitution will only affect one amino acid ***(1 mark)***, whereas a single-base deletion will probably alter all the amino acids after the mutation ***(1 mark)***.

c) Mutations that have a neutral effect on a protein's function won't affect an organism overall ***(1 mark)***. This may happen because the mutation doesn't change the amino acid coded for by a triplet ***(1 mark)*** or because it changes the amino acid to one that is chemically similar to the original ***(1 mark)***. Alternatively, the mutation may affect an amino acid that isn't involved in the protein's function ***(1 mark)***.

# Patterns of inheritance + variation

## Section Summary

Make sure you know...

- That characteristics which show continuous variation are usually polygenic (influenced by many genes), while characteristics that display discontinuous variation are usually monogenic (influenced by one gene).
- That both genotype and the environment contribute to phenotypic variation.
- That genetic variation is generated during meiosis via crossing-over and the independent assortment of chromosomes, and during fertilisation via the random fusion of gametes.
- That examples of environmental contributions to phenotypic variation include diet in animals, and that etiolation and chlorosis in plants are variations in phenotype caused by environmental factors.
- That there can be one or more versions of the same gene and that these are called alleles.
- That most plants and animals have two alleles for each gene and that each one is found at a fixed position (called a locus) on each chromosome in a pair.
- That the genotype of an organism is what alleles it has and that the phenotype of an organism is the characteristics the alleles produce.
- That if an organism has two different alleles for the same characteristic it's heterozygous, but if it has two copies of the same allele it's homozygous.
- That an allele can be dominant (its characteristic is always shown in the phenotype), recessive (its characteristic is only shown in the phenotype if there are two copies of it) or codominant (where two alleles are both shown in the phenotype).
- That a carrier is a person carrying an allele which is not expressed in the phenotype but that can be passed on to offspring.
- How to use genetic diagrams to show the inheritance of a single gene (monogenic inheritance) and the inheritance of codominant alleles.
- That the phenotypic ratio is the ratio of phenotypes in the offspring and that the typical phenotypic ratio for a monogenic cross between two heterozygous parents is 3 : 1 of dominant : recessive characteristic and the typical phenotypic ratio for a cross between two heterozygous parents involving codominant alleles is 1 : 2 : 1 of homozygous for one allele : heterozygous : homozygous for the other allele.
- How to use genetic diagrams showing crosses involving multiple alleles and showing the inheritance of two characteristics controlled by different genes (dihybrid inheritance).
- That a typical phenotypic ratio for a dihybrid cross between two heterozygous parents is 9 : 3 : 3 : 1 (dominant both : dominant first, recessive second : recessive first, dominant second : recessive both).
- How to use genetic diagrams to show the inheritance of sex-linked characteristics (the alleles that code for them are located on sex chromosomes) and recognise that sex linkage alters expected phenotypic ratios in the offspring of crosses.
- How to identify genes linked on autosomes (chromosomes that aren't sex chromosomes) and recognise that autosomal linkage alters expected phenotypic ratios in the offspring of crosses.
- That epistasis is when the allele of one gene masks the expression of the alleles of other genes.
- What recessive epistasis is and that when the epistatic allele is recessive, crossing a homozygous recessive parent with a homozygous dominant parent will produce a 9 : 3 : 4 phenotypic ratio of dominant both : dominant epistatic, recessive other : recessive epistatic in the $F_2$ generation.
- What dominant epistasis is and that when the epistatic allele is dominant, crossing a homozygous recessive parent with a homozygous dominant parent will produce a 12 : 3 : 1 phenotypic ratio of dominant epistatic : recessive epistatic, dominant other : recessive both in the $F_2$ generation.
- How to calculate the chi-squared ($\chi^2$) value for an experiment, how to find the critical value from a chi-squared table and how to use these values to determine whether the difference between observed and expected results is significant or not, and whether or not to reject the null hypothesis.

Pa[redacted] of in[redacted]

## Exa[redacted]-style [redacted]

1 In mice, the allele for wild-type speckled coat colour, [redacted] (A), is dominant to the allele for solid coloured fur (a).

(a) Several pairs of heterozygous agouti [redacted] are crossed, producing 256 offspring. Assuming this is a normal case of monogenic inheritance with no linkage involved, how many of these offspring would you expect to have agouti coat colour?

*(1 mark)*

(b) The alleles for coat colour (A and a) are [redacted] actually controlled by another gene (P). If a mouse is homozygous recessive for this gene, it is unable to produce any pigmentation and so will be albino. Give the possible genotype(s) that will produce the albino phenotype.

*(1 mark)*

(c) A student produces a genetic diagram to show the phenotypic ratio of offspring produced in the $F_2$ generation if a homozygous dominant agouti mouse (PPAA) breeds with a homozygous recessive albino mouse (ppaa). The results are shown in **Table 1.1** below.

**Table [redacted]**

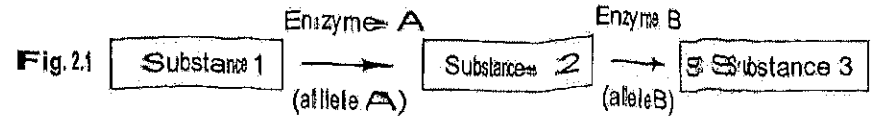
| | PA | pA | Pa | pa |
|---|---|---|---|---|
| PA | PPAA | PpAA | PPAa | PpAa |
| pA | PpAA | ppAA | PpAa | ppAa |
| Pa | PPAa | PpAa | PPaa | Ppaa |
| pa | PpAa | ppAa | Ppaa | ppaa |

The student concludes that this cross produces a phenotypic ratio of 9 : 3 : 3 : 1. This is incorrect. Give the phenotypic ratio that would be expected and explain why the student's conclusion is wrong.

*(3 marks)*

2 Yeast cells can convert substance 1 to substance 3 via the enzymatic pathway shown in **Fig. 2.1**. Two different gene loci control the pathway and each has two alleles. Having the dominant versions of alleles A and B means that the yeast cell will produce enzymes A and B as shown in **Fig. 2.1**.

**Fig. 2.1**




Yeast cells that lack either enzyme A or enzyme B cannot convert substance 1 to substance 3 and so cannot grow in media containing substance 1.

# Patterns of inheritance + variation

**(a)** Complete **Table 2.1** by putting a tick (✓) or a cross (✗) in the correct boxes below to show whether or not yeast cells with the following genotypes could grow on substance 1. The first one has been done for you

**Table 2.1**

| Genotype | Growth on substance 1 |
|---|---|
| AaBb | ✓ |
| aaBb | |
| AAbb | |
| AABb | |

*(1 mark)*

**(b)** Some of the cells that could not grow on substance 1 will grow if supplied with substance 2. Suggest why (with reference to their genotype).

*(3 marks)*

**(c)** Yeast cells with genotype AaBb were crossed with yeast cells homozygous recessive for both alleles. Draw a genetic diagram to show the expected ratio of offspring genotypes for this cross. Predict the percentage of $F_1$ cells that would not be able to grow in medium containing substance 1.

*(4 marks)*

**3** Haemophilia is a sex-linked genetic disorder. It is caused by a faulty allele on the X-chromosome. The faulty allele ($X^h$) is recessive to the normal allele ($X^H$). A study was carried out into the inheritance of haemophilia. The phenotypes of children in families where the mother was a carrier of the disease (genotype $X^HX^h$) and the father was a haemophiliac (genotype $X^hY$) were recorded.

**(a)** Draw a genetic diagram to show why a 1 : 1 : 1 : 1 phenotypic ratio of haemophiliac male : haemophiliac female : carrier female : unaffected male was expected in the results of this study.

*(3 marks)*

**(b)** Of the 272 children in this study, 130 were boys and 142 were girls. 61 of the boys and 70 of the girls had haemophilia. A chi-squared test was used to analyse the results.

**(i)** Calculate the chi-squared value ($\chi^2$) for this study.

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

O = observed result
E = expected result

*(3 marks)*

**(ii)** Use your calculated value of $\chi^2$ and **Table 3.1** to determine whether or not the difference between the observed and expected results is significant.

**Table 3.1**

| Degrees of freedom | Probability (P) | | | | | |
|---|---|---|---|---|---|---|
| | 0.50 | 0.20 | 0.10 | 0.05 | 0.01 | 0.001 |
| 1 | 0.46 | 1.64 | 2.71 | 3.84 | 6.64 | 10.83 |
| 2 | 1.39 | 3.22 | 4.61 | 5.99 | 9.21 | 13.82 |
| 3 | 2.37 | 4.64 | 6.25 | 7.82 | 11.34 | 16.27 |

*(1 mark)*

# Patterns of inheritance + variation

## Exam-style Questions — pages 188-189

1 a) Number of agouti offspring = (256 ÷ 4) × 3 = **192** ***(1 mark)***

A normal case of monogenic inheritance would give a phenotypic ratio of 3 : 1 of agouti : solid coloured. So three-quarters of the offspring would have agouti coat colour.

b) ppAA, ppAa, ppaa ***(1 mark)***

The allele for pigmentation is controlled by the gene (P) — you need to have a gene for coat colour as well as the control gene to get the albino phenotype.

c) A cross between PPAA and ppaa parents will give a 9 : 3 : 4 phenotypic ratio in the $F_2$ generation of agouti : solid coloured : albino ***(1 mark)***. This is because the P gene has a recessive epistatic allele (p) and two copies of the recessive epistatic allele (pp) will mask the expression of the pigmentation gene ***(1 mark)***.

A dihybrid cross will only give a phenotypic ratio of 9 : 3 : 3 : 1 in the $F_2$ generation if the two genes do not interact and are not linked ***(1 mark)***.

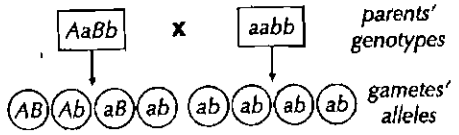
2 a)

| Genotype | Growth on substance 1 |
|---|---|
| AaBb | ✓ |
| aaBb | ✗ |
| AAbb | ✗ |
| AABb | ✓ |

***(1 mark for all three correct)***

b) They must have the genotype aaBb or aaBB ***(1 mark)***. They can't produce enzyme A but can produce enzyme B ***(1 mark)***, so if they're given substance 2 they can convert it to substance 3 ***(1 mark)***.

c) E.g.




| | ab | ab | ab | ab |
|---|---|---|---|---|
| AB | AaBb | AaBb | AaBb | AaBb |
| Ab | Aabb | Aabb | Aabb | Aabb |
| aB | aaBb | aaBb | aaBb | aaBb |
| ab | aabb | aabb | aabb | aabb |

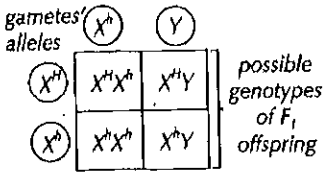
***(1 mark for correct gametes, 1 mark for correct $F_1$ genotypes)***

The ratio of genotypes AaBb : Aabb : aaBb : aabb is 1 : 1 : 1 : 1 ***(1 mark)***.

(12 ÷ 16) × 100 = 75% ***(1 mark)***

Offspring with the genotype Aabb, aaBb and aabb would not be able to grow in medium containing substance 1.

3 a) $X^hY$ — *haemophiliac male*
$X^HX^h$ — *female carrier*




Possible phenotypes of $F_1$ offspring: carrier female ($X^HX^h$), unaffected male ($X^HY$), haemophiliac female ($X^hX^h$) and haemophiliac male ($X^hY$).

***(1 mark for correct gametes, 1 mark for correct $F_1$ genotypes, 1 mark for $F_1$ phenotypes matched to correct $F_1$ genotypes.)***

b) i)

| Phenotype | Ratio | E | O | O − E | $(O-E)^2$ | $\frac{(O-E)^2}{E}$ |
|---|---|---|---|---|---|---|
| Carrier female | 1 | 68 | 72 | 4 | 16 | 0.24 |
| Haemophilic female | 1 | 68 | 70 | 2 | 4 | 0.06 |
| Unaffected male | 1 | 68 | 69 | 1 | 1 | 0.02 |
| Haemophilic male | 1 | 68 | 61 | −7 | 49 | 0.72 |
| | | | | | $\chi^2 = \Sigma\frac{(O-E)^2}{E} =$ | 1.04 |

Therefore $\chi^2$ = **1.04**.

***(3 marks for correct answer, otherwise 1 mark for correct expected results, 1 mark for correct $(O-E)^2 \div E$ calculation.)***

ii) The difference between the observed and expected results is not significant at the 0.05 probability level ***(1 mark)***.

This is because the critical value for this test is 7.82 and the chi-squared value (1.04) is less than this.

Patterns of Inheritance + evolution

## Section Summary

Make sure you know...

- That evolution is a change in allele frequencies in a population over time, and can occur due to natural selection and genetic drift.
- Why variation is essential for natural selection — because organisms vary, some individuals will be better adapted to selection pressures than others. These organisms are more likely to survive, reproduce and pass on their beneficial alleles than others. This will increase the frequency of the beneficial allele in the population over many generations.
- That in a stable environment, selection will favour alleles for characteristics towards the middle of the range (stabilising selection).
- That in a changing environment, selection will favour alleles for characteristics of an extreme type (directional selection).
- That in evolution by genetic drift, alleles become more common in a population by chance.
- That genetic drift has a bigger effect in small populations than in large populations.
- That genetic bottlenecks occur when a population shrinks rapidly, e.g. due to a natural disaster.
- That the founder effect describes what happens when a few organisms from a population start a new population so there is only a small number of different alleles in the initial gene pool.
- That genetic bottlenecks and the founder effect make populations more susceptible to genetic drift.
- That the Hardy-Weinberg principle predicts that allele frequencies in a population won't change between one generation and the next, provided that certain conditions are met.
- How to use the Hardy-Weinberg equations ($p + q = 1$ and $p^2 + 2pq + q^2 = 1$) to calculate allele and genotype frequencies.
- How artificial selection is used to produce plants and animals with desirable traits.
- Why preserving 'wild type' organisms is important for maintaining resources of genetic material for use in the future.
- That there are ethical considerations concerning the use of artificial selection.
- That speciation is the development of a new species and it happens when populations of the same species become reproductively isolated (unable to interbreed to produce fertile offspring).
- That allopatric speciation can occur when populations of the same species are geographically isolated and differences in the gene pools develop that eventually lead to reproductive isolation.
- That sympatric speciation occurs when a random mutation causes reproductive isolation without geographic isolation.
- The different ways in which reproductive isolation can occur.

Patterns of inheritance + evolution

# Exam-style Questions

1 A species of insectivorous bird usually breeds in mid-April, although there is variation between individuals in breeding date. Individuals that breed earlier in the year have difficulties finding sufficient food to feed their young, and the offspring of individuals that breed later are less likely to survive the following winter.

**(a)** State the kind of selection that is acting on this species.

*(1 mark)*

**(b)** It is thought that climate change may cause the insects that this species feeds on to increase in abundance earlier in the year. Describe and explain the possible effect of this selective pressure on the bird species.

*(2 marks)*

2 Chickens that are farmed for their meat are known as broiler chickens. Broiler chickens grow faster than normal chickens, so can be slaughtered at a younger age, are more efficient at converting food into body mass, and produce a higher proportion of breast meat. However, their rapid growth to large sizes means broiler chickens are more vulnerable to cardiovascular problems than normal chickens, and can have problems with walking.

**(a) (i)** State the name of the process by which farmers developed broiler chickens from normal chickens.

*(1 mark)*

**(ii)** Describe how this process may have occurred.

*(2 marks)*

**(b)** Discuss the ethical issues around the development of broiler chickens for meat.

*(3 marks)*

3 A forest is home to a population of a species of flightless beetle. A new motorway is built, separating an area of woodland from the main body of the forest, and isolating a small population of the beetle from the larger population in the main forest. The beetles will not cross open spaces, due to increased visibility to predators, so the motorway acts as a barrier between the two populations. There is no immigration into either woodland from the wider area.

Scientists study the two populations, collecting data on the size and colour of individuals, and how likely they are to survive (which they estimate from recapture rates). Over time, they notice that the beetles in the small fragment of woodland have evolved to become significantly smaller than the beetles in the main body of the forest. The size of the beetles in the main body of the forest remains unchanged.

**(a)** Suggest two possible mechanisms for this evolutionary change.

*(2 marks)*

**(b)** Describe how the scientists could distinguish between these two mechanisms using the data they have collected.

*(2 marks)*

Patterns of inheritance + evolution

4 The Amish population of North America descended from a small group of migrants. They live isolated from the surrounding population, and it is rare for people to migrate into the Amish community.

The Amish population has an unusually high incidence of genetic disorders, including a rare form of dwarfism called Ellis-van Creveld syndrome, which can lead to health problems and death in childhood.

(a) Ellis-van Creveld syndrome is caused by a recessive allele (e). In some Amish communities, the frequency of Ellis-van Creveld syndrome may be as high as 5 births in every 1000.
The Hardy-Weinberg equations are:

$$p + q = 1$$
$$p^2 + 2pq + q^2 = 1$$

Use the Hardy-Weinberg equations to calculate the percentage of these communities that are **carriers** of Ellis-van Creveld syndrome (genotype Ee). Show your working. Give your answer to **two decimal places**.

*(2 marks)*

(b) What process is likely to have led to the high frequency of the Ellis-van Creveld allele in some Amish communities? Give a reason for your answer.

*(2 marks)*

5 In the early 1970s, ten lizards of the species *Podarcis sicula* were introduced to the island of Pod Mrcaru in the Adriatic Sea from the nearby island of Pod Kopiste. Pod Mrcaru has denser vegetation than Pod Kopiste.

Thirty-six years later, researchers returned to the islands. They found that *P. sicula* on Pod Kopiste ate a diet mainly consisting of insects, whilst the diet of *P. sicula* on Pod Mrcaru had changed to include a high proportion of plant material. The *P. sicula* lizards on Pod Mrcaru had larger heads than the *P. sicula* on Pod Kopiste, and were able to bite with more force. *P. sicula* lizards on Pod Mrcaru had also developed chambers in their intestines, which are associated with fermenting cellulose in order to produce fatty acids, and which were absent in *P. sicula* from Pod Kopiste.

(a)* Explain how the differences between lizards on the two islands may have arisen in the 36 years since their introduction to Pod Mrcaru.

*(9 marks)*

(b) It is possible that these changes may be early stages of speciation.

(i) State the name for this kind of speciation.

*(1 mark)*

(ii) State what would need to occur for these two populations to become separate species.

*(1 mark)*

* The quality of your response will be assessed in this question.

# Patterns of inheritance + evolution

1 a) stabilising selection
b) Birds could evolve to breed earlier in the year ***(1 mark)***, as sufficient food will be available to allow them to breed earlier in the year, and offspring that hatch earlier in the year are more likely to survive ***(1 mark)***.

2 a) i) artificial selection / selective breeding ***(1 mark)***
ii) E.g. males and females which grew quickly, converted food into body mass efficiently and produced a high proportion of breast meat were selected and bred together. Their offspring that showed these traits most strongly were then selected and bred together ***(1 mark)***. This process continued over multiple generations, to give chickens that grew quickly and efficiently to produce a high proportion of breast meat ***(1 mark)***.
b) E.g. because broiler chickens grow quickly and can be slaughtered at a younger age, producing chicken is quicker, meaning a large volume of meat can be generated easily ***(1 mark)***. The fact that broiler chickens are efficient at converting food to body mass also reduces costs, and means raising broiler chickens uses fewer resources than normal chickens (which is good for the environment) ***(1 mark)***. However, selective breeding appears to have increased broiler chickens' vulnerability to some health problems, such as cardiovascular problems and walking issues, and many people don't think it's fair to artificially select traits that cause the organism to suffer ***(1 mark)***.

3 a) The change may be due to genetic drift ***(1 mark)*** or it may be due to natural selection for smaller body size in the smaller forest fragment ***(1 mark)***.
b) Genetic drift is random, but natural selection increases the frequency of traits that increase an organism's chances of survival, so the scientists could distinguish between the two possibilities by looking at whether smaller beetles in the small forest fragment have a higher chance of survival ***(1 mark)***. If they do, then the change is likely to be due to natural selection ***(1 mark)***.

4 a) $q^2 = 5 \div 1000 = 0.005$
$q = \sqrt{0.005} = 0.0707$
$p = 1 - 0.0707 = 0.9293$
$2pq = 0.1314$
$0.1314 \times 100 =$ **13.14%**
***(2 marks for the correct answer, otherwise 1 mark for identifying 2pq as the frequency of heterozygotes in the population.)***.
b) Genetic drift ***(1 mark)***. The syndrome does not increase a person's chance of surviving, so the allele must have become more common in the population by chance ***(1 mark)***.

5 a) ***7-9 marks:***
The answer gives a detailed discussion of the selection pressures on both islands, and how the population sizes on the two islands will have affected their ability to respond to the selection pressures. Scientific terminology is used correctly, and the answer demonstrates a detailed understanding of the process of evolution, including the founder effect and genetic drift. The answer has a clear and logical structure. The information given is relevant and detailed.
***4-6 marks:***
The selection pressures on both islands are discussed, but no reference is made to the effect of population size. Scientific terminology is used correctly, and the answer is mostly well-structured. Most of the information given is relevant and there is some detail involved.
***1-3 marks:***
The selection pressures on Pod Mrcaru are discussed, but no comparisons are made to Pod Kopiste. Use of scientific terminology is poor. The answer has no clear structure. The information given is basic and lacking in detail. It may not all be relevant.
***0 marks:***
No relevant information is given
***Here are some points your answer may include:***
On Pod Mrcaru, more vegetation is available to eat than on Pod Kopiste. This has acted as a selection pressure on Pod Mrcaru, favouring individuals with alleles that make them better able to eat and digest vegetation. The individuals introduced to Pod Mrcaru included some individuals who were better able to eat vegetation, due to having stronger jaws, and individuals who were better able to digest vegetation due to the structure of their gut. These individuals were more likely to survive and reproduce, and pass on their alleles, leading to an increase in the frequency of these alleles over time and a change in jaw strength and gut structure across generations. The speed of this change may have been increased by the effect of genetic drift, and also by the founder effect, as the population of Pod Mrcaru was initially very small.
On Pod Kopiste, on the other hand, as less vegetation is present, the selection pressure to be able to eat and process vegetation will have been lower. The population of lizards on Pod Kopiste will also have initially been larger, meaning that there was less of a chance of alleles for features that would make it easier to eat and digest vegetation increasing in frequency by chance via genetic drift. This weaker selection pressure and lack of drift will have meant that the ability to eat and digest vegetation efficiently has not evolved on Pod Kopiste within the same timescale as on Pod Mrcaru.
b) i) allopatric speciation ***(1 mark)***
ii) The two populations would need to become reproductively isolated ***(1 mark)***.

# Manipulating genomes

## Section Summary

Make sure you know...

- That millions of identical copies of a DNA fragment can be made using the polymerase chain reaction (PCR).
- That fragments of DNA can be isolated using restriction enzymes. These enzymes recognise and cut DNA at different, specific palindromic sequences (called recognition sequences).
- That DNA fragments, RNA fragments or proteins can be run on an electrophoresis gel to separate them according to size (length).
- How to carry out electrophoresis.
- That an organism's genome contains repetitive, non-coding base sequences.
- That electrophoresis can be used to analyse the number of times a non-coding sequence is repeated in a person's genome, creating a DNA profile for that individual. DNA profiles can be used in forensics and to analyse the risk of genetic disorders.
- That genetic engineering involves isolating a gene from one organism, and placing the gene into another organism, using a vector, and that it produces transformed organisms.
- The techniques involved in genetic engineering — using restriction enzymes to isolate a DNA fragment containing a desired gene, creating recombinant DNA from the DNA fragment and vector DNA using DNA ligase, and using electroporation to get bacteria to take up the vector and produce transformed cells (cells that have taken up the recombinant DNA).
- That soybean plants can be genetically modified to be resistant to insects, and the ethical issues relating to this, including positive issues (e.g. reducing the amount of harmful chemical pesticides used on the crops) and negative issues (e.g. encouraging monoculture, which decreases biodiversity).
- How 'pharming' (producing drugs from genetically modified organisms, such as animals) works, and the ethical issues relating to this, including positive issues (e.g. being able to make the drugs more available by producing them in large quantities) and negative issues (e.g. that the manipulation of an animal's genes could cause harmful side-effects for the animal).
- That pathogens are genetically engineered for research into treatments for disease, and the ethical issues relating to this, including positive issues (e.g. the ability to treat previously untreated diseases) and negative issues (e.g. the possibility of a mass outbreak of the disease).
- What technology transfer is, and why scientists or companies may patent genetically modified products.
- The ethical issues surrounding patenting and technology transfer, including the issues of making genetically modified seed available to farmers in poorer countries.
- That gene therapy involves altering defective alleles inside body cells (somatic gene therapy) or sex cells (germ line gene therapy), to attempt to treat or cure genetic disorders.
- The positive and negative ethical issues raised by gene therapy.
- That DNA sequencing is used to determine the order of bases in a section of DNA (e.g. a fragment of a gene) and that the chain termination method is one way this can be carried out.
- That whole genomes can be sequenced using bacterial artificial chromosomes (BACs) and the chain termination method.
- That advancements in sequencing techniques, such as high-throughput sequencing, have increased the speed of sequencing so that whole genome sequencing can happen much more quickly.
- That gene sequencing allows the amino sequences of amino acids to be predicted.
- That gene sequencing has allowed for the development of synthetic biology in which biological molecules can be made from scratch.
- That the results of whole genome sequencing can be used to compare genomes between and within species.
- How computational biology and bioinformatics are contributing to biological research into genotype-phenotype relationships, epidemiology and the understanding of evolutionary relationships.

Manipulating Genomes

# Exam-style Questions

1 The following steps describe processes involved in genetic engineering. They are **not** in the correct order.

1 DNA ligase joins the sugar-phosphate backbones together.

2 The desired DNA fragment is isolated using restriction enzymes.

3 The plasmid is cut open using restriction enzymes.

4 The bacterial cells take in the plasmid.

5 Bacterial cells are mixed with the plasmid and placed in an electroporator.

6 The DNA fragment and plasmid are mixed together with DNA ligase.

Which of these is the correct order for producing genetically engineered cells?

**A** 5, 3, 2, 1, 4, 6

**B** 2, 3, 6, 1, 5 ,4

**C** 5, 4, 6, 3, 2, 1

**D** 2, 5, 4, 3, 6, 1

*(1 mark)*

2 A prize-winning racehorse has been stolen from its stables. Police suspect it has been taken to a stud farm where it has previously gone to breed. The police have obtained DNA samples from four similar-looking horses at the stud farm and used them to produce DNA profiles to compare against a DNA profile from the stolen animal. The DNA profiles are shown in **Fig. 2.1**.

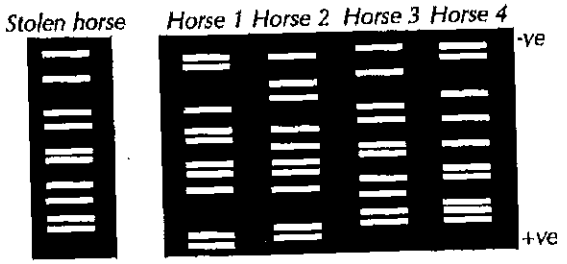



**Fig. 2.1**

**(a)** Describe and explain how the DNA profiles have been produced from the DNA samples.

*(4 marks)*

**(b)** Use your understanding of the biology behind DNA profiling technology to explain why the chances of two DNA profiles matching by chance are so small.

*(3 marks)*

**(c)** Is the stolen animal at the stud farm? Explain your answer.

*(1 mark)*

**(d)** Give **one** other use for DNA profiling technology other than in forensic science.

*(1 mark)*

# Manipulating Genomes

3 An organic soybean farmer is concerned that his crop of non-GM soybean plants may have become cross-contaminated with a gene (called a transgene) from nearby GM soybean plants. One way to find out if the farmer's soybean plants contain the transgene is to first take a DNA sample from one of his plants and then use PCR to obtain DNA fragments of the region of DNA that would contain the transgene.

**(a)** Explain how the process of PCR works.

*(5 marks)*

The next step is to compare the DNA fragments produced to those from a sample of the GM soybean plant tissue, using gel electrophoresis. The GM soybean plant acts as a positive control.

**(b)** What would the gel show if the farmer's soybean plant did have the transgene?

*(1 mark)*

**(c)** What could be used as a negative control in this experiment?

*(1 mark)*

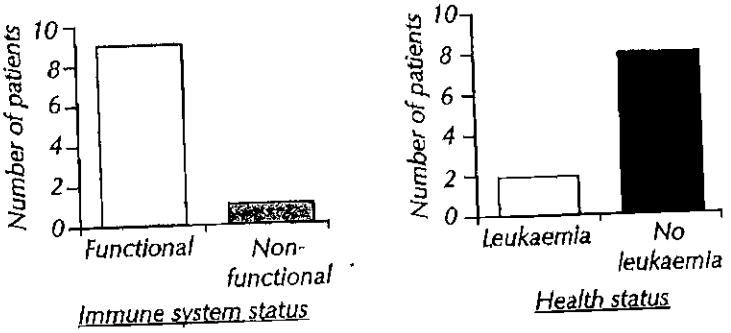
**(d)** Apart from cross-contamination, suggest and explain **one** other negative ethical issue associated with growing genetically modified plants.

*(2 marks)*

4 A study was carried out to investigate the effectiveness of gene therapy in patients with X-linked severe combined immunodeficiency disease (SCID). SCID is an inherited disorder that affects the immune system. It is caused by a mutation in the IL2RG gene.

Ten patients were treated with a virus vector carrying a correct version of the IL2RG gene. After gene transfer, the patients' immune systems were monitored for at least three years and noted as functional (good) or not. Their health was also monitored for the same time. **Fig. 4.1** shows the results.

**Fig. 4.1**




**(a)** Besides viruses, give **one** other example of a type of vector they could have used.

*(1 mark)*

**(b) (i)** Describe the results shown in **Fig. 4.1**.

*(2 marks)*

**(ii)** Suggest **two** ways the study could be improved.

*(2 marks)*

**(c)** Outline **one** negative issue that may be raised by using gene therapy.

*(1 mark)*

# Manipulating Genomes - Answers

1 B ***(1 mark)***

2 a) PCR is used to amplify multiple areas containing different sequence repeats in each DNA sample ***(1 mark)***. The PCR products from each sample are run on an electrophoresis gel ***(1 mark)***. Shorter DNA fragments move faster and travel further through the gel, so the DNA fragments separate according to length, with longer pieces nearer the top ***(1 mark)***. The fragments are stained before electrophoresis so that the bands produced for each sample can be seen — these are the DNA profiles ***(1 mark)***.

b) DNA profiling technology involves comparing the number of times repetitive, non-coding base sequences ***(1 mark)*** are repeated at a number of different, specific places (loci) in a genome ***(1 mark)***. The probability of two individuals having the same DNA profile is very low because the chance of two individuals having the same number of sequence repeats at each locus tested is very low ***(1 mark)***.

c) Yes. The DNA profile of the stolen horse and DNA profile of horse 3 have exactly the same band pattern, so the DNA that produced both DNA profiles must have come from the same horse ***(1 mark)***.

d) It can be used in medical diagnosis to analyse the risk of genetic disorders ***(1 mark)***.

3 a) A reaction mixture is set up that contains the plant DNA sample, free nucleotides, primers and DNA polymerase ***(1 mark)***. The DNA mixture is heated to 95 °C to break the hydrogen bonds between the two strands of DNA ***(1 mark)***. The mixture is then cooled to 50-65 °C so that the primers can bind to the strands ***(1 mark)***. The reaction mixture is heated to 72 °C, so that DNA polymerase can create new DNA strands ***(1 mark)***. Two new copies of the DNA fragment are formed and then the cycle of heating and cooling is repeated many times ***(1 mark)***.

b) It would show a band at the same point on the gel as that for the GM soybean plant ***(1 mark)***.

c) The farmer's non-GM soybean plant ***(1 mark)***.

d) E.g. there may be concerns that growing a genetically modified crop could encourage monoculture ***(1 mark)***. Monoculture decreases biodiversity and could leave the whole crop vulnerable to disease, because all the plants are genetically identical ***(1 mark)***.

4 a) E.g. plasmids / BACs/bacterial artificial chromosomes / liposomes ***(1 mark)***

Bacteriophages are vectors too, but they are a type of virus that infects bacteria, so this doesn't answer the question. Make sure you read the question carefully before and, if you've time, after you answer it.

b) i) Nine out of the ten patients had a functional immune system after gene therapy ***(1 mark)***. However, two out of the ten patients developed leukaemia within 3 years of the treatment ***(1 mark)***.

ii) Any two from: e.g. a larger sample size could be used ***(1 mark)***. / The patients could be followed for longer than three years after treatment ***(1 mark)***. / Indicators other than developing leukaemia could be used to check the health status of the patients ***(1 mark)***.

c) E.g. the technology could be used in ways other than for medical treatment, e.g. to reverse the cosmetic effects of aging ***(1 mark)***. / There's the potential to do more harm than good by using the technology, e.g. by causing the overexpression of genes ***(1 mark)***. / Gene therapy is expensive and the resources may be better spent on treatments that have already passed clinical trials ***(1 mark)***.

# Cloning and Biotechnology

## Section Summary

Make sure you know...

- That cloning is the process of producing genetically identical cells or organisms from the cells of an existing organism.
- That vegetative propagation is the natural production of plant clones from non-reproductive tissues.
- That plants produce natural clones via different methods of vegetative propagation (e.g. rhizomes, stolons/runners, suckers, tubers, bulbs) and that plant growers also use methods of vegetative propagation to produce clones (e.g. growing cuttings, grafting, layering).
- How to dissect plant material (e.g. the stem, roots or leaves) to produce cuttings, which can then be grown to produce plant clones.
- How plants can be artificially cloned using tissue culture and micropropagation (which is used to produce a large number of clones very quickly).
- The advantages and disadvantages of artificially cloning plants in agriculture and horticulture.
- How natural animal clones (e.g. twins) are produced — a fertilised egg splits in the very early stages of development and develops into multiple identical embryos, which leads to offspring that are clones.
- How artificial animal clones can be made by artificial embryo twinning and somatic cell nuclear transfer (SCNT).
- How artificial cloning of animals can be used, e.g. in agriculture and medicine.
- The arguments for and against the artificial cloning of animals.
- That biotechnology is the industrial use of living organisms to produce food, drugs and other products.
- That the organisms used in biotechnology are mostly microorganisms because their ideal growth conditions can be easily created, they have a short life-cycle so grow quickly under the right conditions, they can grow on inexpensive materials so are economical and they can be grown at any time of the year.
- The roles that microorganisms play in brewing, baking, cheese making, yoghurt production, penicillin production, insulin production and bioremediation.
- The advantages and disadvantages of using microorganisms to produce food for human consumption, e.g. foods made from single-cell protein.
- How microorganisms can be produced on an industrial scale for use in biotechnology using fermentation vessels.
- How growing conditions (i.e. pH, temperature, oxygen supply, nutrient concentration and contamination risk) in batch and continuous fermentation can be manipulated to maximise the yield of the desired product.
- What the standard growth curve for a population of microorganisms in a closed culture looks like, and what's happening during the lag, exponential (log), stationary and decline phases.
- How to culture microorganisms, and the aseptic techniques that need to be used when doing so.
- How to carry out an investigation into the effect of factors such as temperature, pH and nutrient availability on the growth of microorganisms.
- How enzymes can be immobilised for use in biotechnology.
- The advantages and disadvantages of using immobilised enzymes for industrial processes.

# Cloning and Biotechnology

## Exam-style Questions

**1** A group of scientists are manufacturing insulin for use in the treatment of diabetes.

**(a)** The researchers genetically modify bacteria to produce the human insulin protein and grow the cells by continuous fermentation in the fermentation vessel shown in **Fig. 1.1**.

**(i)** Identify **three** features of the fermentation vessel in **Fig. 1.1** which help to increase the yield of protein produced. For each feature explain how it helps to increase the yield.

*(3 marks)*

**(ii)** Explain why it's important that the air entering the fermentation vessel is sterile.

*(2 marks)*

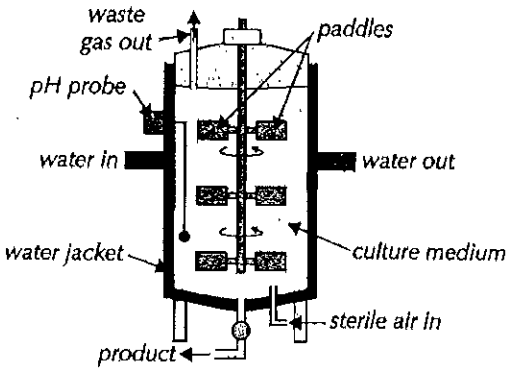



**Fig. 1.1**

**(b)** The growth curve of the bacterial population is shown in **Fig. 1.2**. It has been plotted on a logarithmic scale.

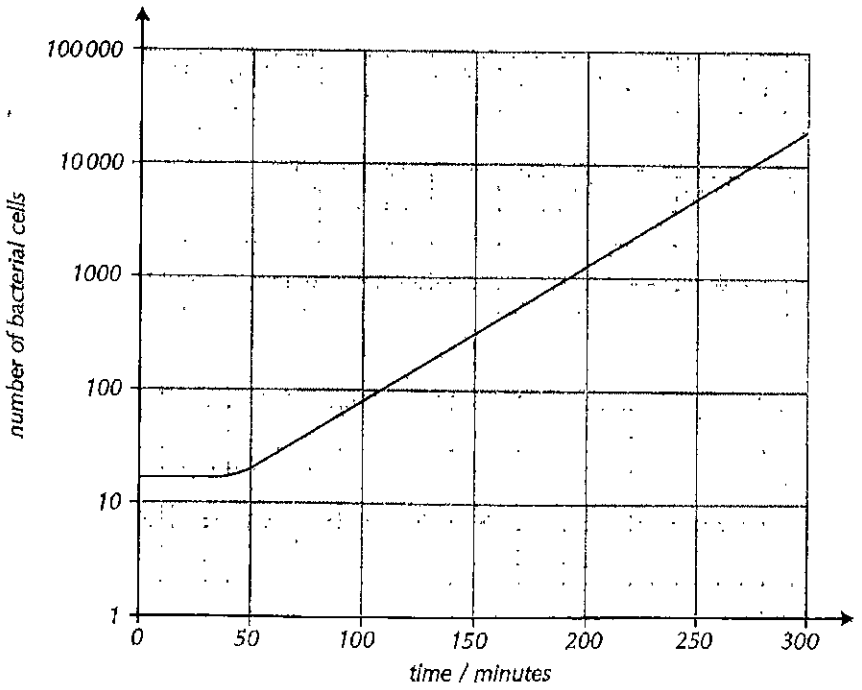



**Fig. 1.2**

**(i)** Using **Fig. 1.2**, estimate the time between each cellular division of the bacteria during the exponential growth phase.

*(1 mark)*

# Cloning and Biotechnology

(ii) Explain why there is no increase in the number of bacterial cells between 0 and 40 minutes.

*(1 mark)*

(iii) Sketch out the growth curve you would expect to see if the bacteria had been grown by **closed culture**.

*(1 mark)*

(iv) Explain the differences between the growth curve of a bacterial population in a closed culture and the growth curve in **Fig. 1.2.**

*(4 marks)*

(c) The scientists believe that, in the future, diabetes could be cured using cloning to produce embryonic stem cells from the patient's own cells. Describe how embryonic stem cells could be produced from a human body cell using somatic cell nuclear transfer.

*(4 marks)*

2 Plant cloning can occur naturally via vegetative propagation or can be carried out artificially with human intervention. Both produce genetically identical copies of the parent plant.

(a) Name and describe **two** natural methods of vegetative propagation used by plants to produce clones of themselves.

*(2 marks)*

(b) A gardener wants to take cuttings to produce a clone of his blueberry plant. Describe how he could produce a clone from a cutting from a stem of the plant.

*(3 marks)*

(c) A company decides to use tissue culture to produce clones of the gardener's blueberry plant after the normal growing season has ended.

(i) When performing tissue culture, explain why the cells that are removed from the original plant are usually taken from the stem and root tips.

*(2 marks)*

(ii) In addition to being able to produce plants out of season, give **two** further advantages of cloning plants.

*(2 marks)*

(d) When inspecting clones grown from the same culture, a scientist working for the company notices that one of the clones has a bacterial infection.

(i) Suggest why this could be major problem.

*(1 mark)*

(ii) An antibiotic against the bacteria causing the infection is produced by a fungus. The fungus can be cultured using batch fermentation or continuous fermentation. Explain **two** reasons why fungi are commonly used in the biotechnology industry.

*(2 marks)*

# Ecosystems

## Section Summary

Make sure you know:

- That an ecosystem is all the organisms living in a certain area and all the non-living conditions (factors) found there, and that it's a dynamic system — it's changing all the time.
- That biotic factors (e.g. the presence of predators and food) are all the living features of an ecosystem and that abiotic factors (e.g. temperature, soil) are all the non-living features of an ecosystem.
- The biotic and abiotic factors that affect ecosystems of different sizes, for example a rock pool, a playing field and a large tree.
- That biomass (stored energy) is transferred in an ecosystem through food chains and food webs from producers to primary consumers, then to secondary consumers and tertiary consumers by feeding.
- That not all of the energy that's available to the organisms in a trophic level is transferred to the next trophic level and that you can work out the total amount of energy that can be passed from one trophic level to the next using the equation: net productivity = gross productivity – respiratory loss.
- How to work out percentage efficiency of biomass transfer using the equation:
  (net productivity of trophic level ÷ net productivity of previous trophic level) × 100
- That the efficiency of biomass transfer increases as you move up the food chain but that energy is still lost at each level, and this limits the number of organisms that can exist in a particular environment.
- That you can measure the amount of energy in an organism by measuring its dry mass (biomass) and that you can use this to measure biomass transfers between trophic levels.
- That farming activities such as using herbicides, fungicides, insecticides, natural predators, fertilisers and intensively rearing livestock can increase the efficiency of energy transfer through an ecosystem.
- That the carbon cycle is important because all organisms need carbon to make essential compounds.
- That organisms play an important role in the carbon cycle — carbon in the air becomes carbon compounds in plants by photosynthesis, these carbon compounds are passed on through the food chain by feeding and are broken down by microorganisms during decomposition, and carbon is released back into the atmosphere by respiration.
- That physical and chemical processes also have a role in the carbon cycle and that they eventually return carbon to the atmosphere through combustion, weathering and via volcanoes.
- The four main processes of the nitrogen cycle and the microorganisms involved: nitrogen fixation (*Rhizobium*, *Azotobacter*), ammonification, nitrification (*Nitrosomonas*, *Nitrobacter*) and denitrification.
- That succession is the process by which an ecosystem changes over time, and how this happens.
- That succession begins with a pioneer species and ends with a climax community.
- That at each stage in succession, species change the abiotic conditions, so that the environment becomes more suitable for other species, increasing species diversity.
- That human activities can artificially stop succession from occurring, or can deflect succession from its natural course, leading to the formation of a plagioclimax.
- How samples of populations can be taken and recorded to investigate the distribution and abundance of organisms in different ecosystems.
- How the abundance and distribution of organisms can be measured using different methods such as frame quadrats, point quadrats, line transects, belt transects and interrupted transects.

Ecosystems

# Exam-style Questions

1 **Fig. 1.1** below shows the carbon cycle.

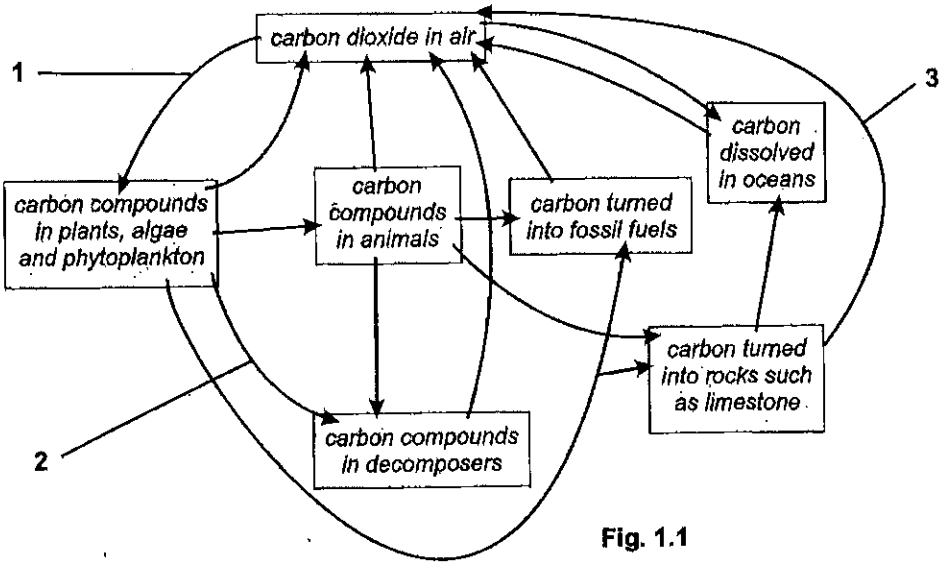



**Fig. 1.1**

Which of the following numbered processes is the result of action by organisms?

**A** Only 1

**B** Only 1 and 2

**C** Only 2 and 3

**D** 1, 2 and 3

*(1 mark)*

2 The process of primary succession leads to the development of ecosystems.
Which of the following statements about primary succession is/are correct?

1 Primary succession starts on land where there is no soil or organic material.

2 Pioneer species make the abiotic conditions in an ecosystem less hostile.

3 The climax community is the largest and most complex community an ecosystem can support.

**A** Only 1

**B** Only 1 and 2

**C** Only 2 and 3

**D** 1, 2 and 3

*(1 mark)*

# Ecosystems

3 A team of scientists are investigating the distribution of marsh marigolds across a field that is directly next to a stream.

(a) (i) Suggest and describe a method the scientists could use to investigate the distribution of marsh marigolds.

*(2 marks)*

(ii) The team decide they want to record the percentage cover of marsh marigolds. Describe how they could measure the percentage cover **and** give **two** advantages of measuring species abundance this way.

*(3 marks)*

(b) Abiotic factors were investigated at the same places as the data on marsh marigolds was recorded. Explain what is meant by the term 'abiotic factors'.

*(1 mark)*

(c) Sheep frequently graze in the field that the scientists are investigating. Explain how this may result in deflected succession.

*(2 marks)*

4 **Fig. 4.1** shows the net productivity of some organisms in a food web. All the figures are in $kJm^{-2}yr^{-1}$.

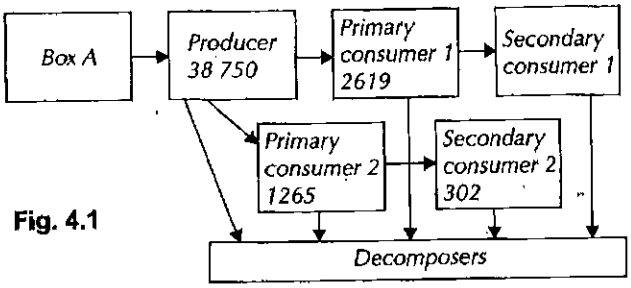



**Fig. 4.1**

(a) What source of energy is represented by Box A?

*(1 mark)*

(b) 476 $kJm^{-2}yr^{-1}$ of biomass energy is lost from primary consumer 1 to the decomposers. The respiratory loss of secondary consumer 1 is 1571 $kJm^{-2}yr^{-1}$. Calculate the net productivity of secondary consumer 1.

*(2 marks)*

(c) Give **two** reasons why the energy absorbed by secondary consumer 2 will not equal 1265 $kJm^{-2}yr^{-1}$.

*(2 marks)*

(d) Calculate the difference in the percentage efficiency of energy transfer between the producer and primary consumer 1, and the producer and primary consumer 2.

*(3 marks)*

(e) Nitrogen is passed on in a food web when organisms eat each other. Describe how nitrogen compounds in organisms are recycled back to atmospheric nitrogen.

In your answer, you should describe the specific roles of named microorganisms.

*(4 marks)*

# Ecosystems

1 B ***(1 mark)***

2 D ***(1 mark)***

3 a) i) E.g. they could set up a belt transect / place quadrats next to each other along a transect ***(1 mark)*** leading from the edge of the field that's next to the stream into the middle of the field ***(1 mark)***.

ii) E.g. they could count how many squares of each quadrat are covered by marsh marigolds by counting a square if it's more than half-covered ***(1 mark)***. Measuring percentage cover is a quick way to investigate the abundance of marsh marigolds ***(1 mark)*** and they wouldn't have to count all the individual marsh marigolds ***(1 mark)***.

b) The non-living features of an ecosystem ***(1 mark)***.

c) Regular grazing would prevent the normal climax community from developing ***(1 mark)***, so succession would be deflected from its natural course ***(1 mark)***.

4 a) Light / the Sun ***(1 mark)***

b) gross productivity (secondary consumer 1)
= net productivity (primary consumer 1) – energy lost
$= 2619 - 476 = 2143$ kJm$^{-2}$yr$^{-1}$
net productivity = gross productivity – respiratory loss
net productivity = 2143 – 1571 = **572 kJm$^{-2}$yr$^{-1}$**
***(1 mark for correct working only, 2 marks for correct answer)***

c) E.g. because some parts of food, e.g. roots or bones, aren't eaten by organisms so the energy isn't taken in ***(1 mark)***. Also, some parts of food are indigestible so pass through organisms and come out as waste, e.g. faeces ***(1 mark)***.

d) percentage efficiency of energy transfer =
(net productivity of trophic level ÷ net productivity of previous trophic level) × 100
between the producer and primary consumer 1 =
$(2619 \div 38750) \times 100 = 6.76\%$
between the producer and primary consumer 2 =
$(1265 \div 38750) \times 100 = 3.26\%$
$6.76 - 3.26 = \mathbf{3.5\%}$
***(1 mark for each correct percentage efficiency of energy transfer or 3 marks for correct answer)***

e) Nitrogen compounds from dead organisms and animal waste are turned into ammonia by decomposers (e.g. bacteria or fungi), which goes on to form ammonium ions (ammonification) ***(1 mark)***. *Nitrosomonas* change ammonium ions into nitrites ***(1 mark)***. *Nitrobacter* change nitrites into nitrates (nitrification) ***(1 mark)***. Nitrates are converted into nitrogen gas by denitrifying bacteria (denitrification) ***(1 mark)***.

# Populations and Sustainability

## Section Summary

Make sure you know:

- That the size of a population varies because of the effect of abiotic factors (such as the temperature of the surroundings) and biotic factors (which include interspecific competition, intraspecific competition and predation).
- That interspecific competition is when individuals of different species compete with each other for the same resources.
- That intraspecific competition is when individuals of the same species compete with each other for the same resources.
- That the carrying capacity of an ecosystem is the maximum stable population size of a species that it can support.
- That population sizes of predators and prey are interlinked and have negative feedback effects on each other — as the prey population increases, there's more food for predators, so the predator population grows. As the predator population increases, more prey is eaten, so the prey population then begins to fall. This means there's less food available for predators, causing the predator population to decrease and allowing the prey population to increase once more.
- That limiting factors (e.g. amount of shelter) stop the population size of a species increasing.
- That conservation is the protection and management of ecosystems.
- How conservation is important for economic, social, ethical and ecological reasons.
- That preservation is the protection of ecosystems so that they're kept exactly as they are.
- That ecosystems (such as temperate woodland and oceans) can be managed in a sustainable way to make sure there are enough resources to meet the needs of people today and in the future.
- That human activities affect the environment, and that environmental resources can be managed to limit these effects.
- That ecosystems can be managed to balance the conflict between conservation and preservation and human needs, as in the Maasai Mara, the Terai Arc and peat bogs in the UK.
- That human activities have had an effect on environmentally sensitive ecosystems, such as the Galapagos Islands, Antarctica, Snowdonia National Park and the Lake District, and some of the ways that these effects can be controlled.

# Populations and Sustainability

## Exam-style Questions

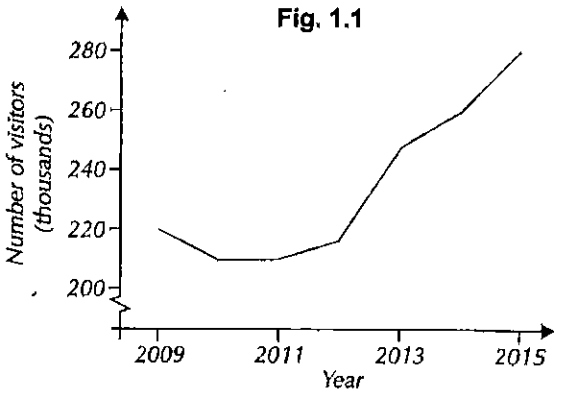
1 Coral reefs are environmentally sensitive ecosystems that are popular with tourists. **Fig. 1.1** shows the annual number of tourists visiting a particular area of coral reef between 2009 and 2015.

What was the percentage increase in visitor numbers between 2009 and 2015?

**A** 21% **B** 27%

**C** 33% **D** 25%

**Fig. 1.1**




*(1 mark)*

2 An investigation has been conducted on two species of grasshopper, species A and species B, in an area of grassy fields. **Fig. 2.1** shows changes in the population sizes of species A and B in the area under investigation.

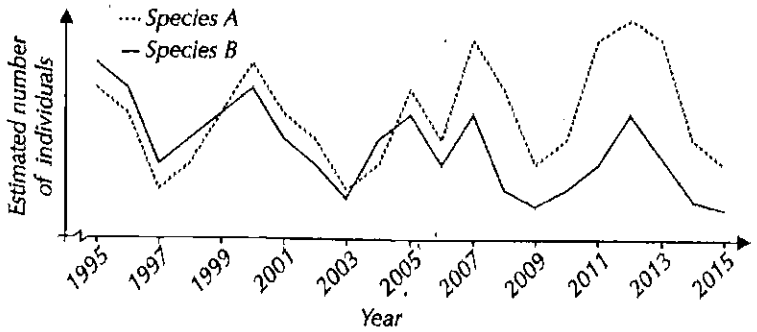



**Fig. 2.1**

(a) Describe **and** explain the trend shown by **Fig. 2.1**, with reference to the type of competition it shows.

*(3 marks)*

(b) The amount of food available prevents the population size of each grasshopper species from increasing further.

What term is used to describe the amount of food available in this case?

*(1 mark)*

(c) In a second area, species A is present but species B is not. The population of species A in this area remains roughly stable, with some smaller fluctuations.

State the name given to this stable population size.

*(1 mark)*

# Populations and sustainability

**3** Mangrove swamps are found in coastal areas in the tropics and sub-tropics. These swamps provide a unique habitat for many species of plant and fish. They also absorb wave energy, protecting the coastline behind them from storms.

Mangrove swamps have been cleared to make room for farming, settlements and tourist resorts. In some areas, wood is harvested from mangrove swamps at unsustainable levels. Mangrove swamps are globally threatened ecosystems.

**(a)** Suggest why the conservation of mangrove swamps is considered important by some people.

*(2 marks)*

A conservation charity is investigating methods for protecting a mangrove swamp in a Less Economically Developed Country in East Asia, where the swamp is threatened by overexploitation from the local population for charcoal making. Possible methods of protecting the swamp suggested by the charity include:

- Creating a nature reserve around the mangrove swamp and restricting access to the swamp to everyone except for conservation workers and scientists.
- Paying local people to only take wood from the mangrove swamp at sustainable levels.
- Promoting ecotourism in the area, based around the mangrove swamp.

**(b)*** Compare these options, giving the advantages and disadvantages of each.

*(9 marks)*

**(c)** Ecosystems can be protected through conservation or preservation.

**(i)** Explain the difference between conservation and preservation.

*(1 mark)*

**(ii)** State which of the methods outlined above represents a preservation method.

*(1 mark)*

**4** Many areas of woodland around the world are part of conservation projects.

**(a)** Outline **one** ethical reason for the conservation of woodland.

*(1 mark)*

**(b)** Ecosystems such as woodland can be managed in a sustainable way. Briefly describe what this means.

*(1 mark)*

**(c)** Complete the table below to give **two** different methods used to manage timber production in temperate woodland in a sustainable way **and** explain how each method works.

| *Method* | *Explanation* |
|---|---|
| | |
| | |

*(4 marks)*

* The quality of your response will be assessed in this question.

# Populations and sustainability

1 B ***(1 mark)***
visitor numbers in 2015: 280 000
visitor numbers in 2009: 220 000
280 000 – 220 000 = 60 000
(60 000 ÷ 220 000) × 100 = 27.27... = 27%

2 a) The population sizes of species A and B rise and fall cyclically over the 20 year period ***(1 mark)***. The population sizes increase when resources are plentiful but decrease when resources become limited ***(1 mark)***. This is because of intraspecific competition / organisms of species A are competing with each other for the same resources, and organisms of species B are competing with each other for the same resources ***(1 mark)***.
b) (biotic) limiting factor ***(1 mark)***
c) The carrying capacity of the ecosystem ***(1 mark)***.

3 a) E.g. mangrove swamps are a unique ecosystem, and some people believe we have an ethical duty to protect them ***(1 mark)***. People may also believe it is important to preserve mangrove swamps because of the protection they give the coastline, which could protect other ecosystems and people ***(1 mark)***.

You don't actually need to know anything about mangrove swamps to answer this question — the command word 'suggest' means that you're expected to use your scientific knowledge of the benefits of conservation to come up with possible reasons. So your answer could include any sensible economic, social, ethical or ecological reasons that people may have for supporting conservation.

b) ***7-9 marks:***
The answer gives a detailed discussion of all three methods for protecting the mangrove habitat, giving well-explained disadvantages and advantages of each. Scientific terminology is used correctly, and the answer demonstrates a detailed understanding of the conservation of ecosystems.
The answer has a clear and logical structure.
The information given is relevant and detailed.
***4-6 marks:***
The answer includes a discussion of each of the three methods for protecting the habitat, but it may not include both advantages and disadvantages for all three, so the comparison of the methods is limited. Scientific terminology is used correctly, and the answer is mostly well-structured.
Most of the information given is relevant and there is some detail involved.
***1-3 marks:***
The answer doesn't consider all of the habitat protection methods mentioned, and the discussion of the advantages and disadvantages of any of the methods is very limited. Use of scientific terminology is poor.
The answer has no clear structure. The information given is basic and lacking in detail. It may not all be relevant.
***0 marks:***
No relevant information is given.

# Populations + Sustainability

***Here are some points your answer may include:***
Creating a nature reserve and heavily restricting access would be an effective way of preserving the mangrove swamp, as it would prevent any further damage to the ecosystem by local populations. However, this suggestion doesn't take the needs of the local population into account, so doesn't represent an ethical solution to the problem. In addition, maintaining restrictions to access in the long term will require continued investment from the charity, so the solution isn't economically sustainable.

On the other hand, paying local people to limit their use of the mangrove swamp to sustainable levels may represent an effective way of conserving the ecosystem whilst taking the needs of the local population into account. It allows them to continue using resources from the swamp, but at a reduced level, and offers them financial compensation. However, like the nature reserve suggestion, this solution requires a continued investment from the charity, so doesn't represent an economically sustainable solution. It may also be hard to enforce, as it requires constant monitoring of what is being taken from the swamp.

The final suggestion, of developing ecotourism in the area, may be an effective way of protecting the mangrove swamp. By providing an alternative income for local populations it could reduce their need to take wood from the swamp to make charcoal, and gives the local population an incentive to conserve the swamp effectively. Unlike the other two suggestions, it may not require long-term investment from the conservation charity, so may be self-sustaining. It would, however, require careful management to make sure that tourists did not damage the ecosystem. Of these suggestions, ecotourism therefore seems like the best long-term solution for conserving the mangrove swamp, as it takes the needs of local people into account and doesn't require indefinite investment from the charity.

c) i) Preservation keeps ecosystems exactly as they are, so nothing is removed, and human activity is limited. Conservation, on the other hand, does allow the removal of resources from ecosystems ***(1 mark)***.

ii) Creating a nature reserve and restricting access ***(1 mark)***.

4 a) E.g. it's the right thing to do, especially if the ecosystem is at risk because of human activity. / There is a moral responsibility to conserve ecosystems for future generations, so they can enjoy and use them. ***(1 mark)***

*If the question tells you to 'outline' a reason for something (like this one), you need to give a bit more than a one word answer — make sure you include a little bit of detail.*

b) It means taking enough resources from the woodland to meet the needs of people today without reducing the ability of people in the future to meet their own needs ***(1 mark)***.

c) Any two from: e.g.

| *Method* | *Explanation* |
|---|---|
| Trees cleared in strips or patches. | Woodland grows back more quickly in smaller areas between bits of existing woodland than it does in larger, open areas. |
| Cleared strips or patches of woodland aren't too large or exposed. | Lots of soil erosion can occur on large areas of bare ground. If the soil is eroded, newly planted trees won't be able to grow. |
| Timber is harvested by coppicing/cut down in a way that lets them grow back. | New trees don't need to be planted. |
| Native species are preferentially planted. | Native species are better for biodiversity. |
| Planted trees are attached to posts / grown in plastic tubes. | This makes it more likely the trees will survive to become mature adults as they're supported/protected. |
| Trees aren't planted too close together. | The trees aren't competing with each other for space or resources, so they're more likely to survive. |

***(Maximum of 4 marks available — 1 mark for each correct method up to a maximum of 2 marks and 1 mark for each correctly matched explanation of how the method works).***