IB · DP · Biology

2 hours 15 questions

Structured Questions: Paper 2

# 3.3 Inheritance

3.3.1 Inheritance / 3.3.2 Inheriting Alleles / 3.3.3 Skills: Inheritance / 3.3.4 Inheritance of Genetic Diseases / 3.3.5 Mutations & Disease

| | |
|---|---|
| Easy (5 questions) | /42 |
| Medium (5 questions) | /48 |
| Hard (5 questions) | /52 |
| **Total Marks** | **/142** |

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# Easy Questions

**1 (a)** Huntington's disease is a disease caused by a dominant allele.

State what is meant by the term **dominant**, in the context of alleles.

.....

**(1 mark)**

**(b)** Gregor Mendel conducted experiments that established the basis of modern genetics.

(i) State the type of organism that Mendel used in his studies.

[1]

(ii) State why the organism you named in part (i) was a good choice for Mendel's experiments.

[2]

.....

.....

.....

**(3 marks)**

**(c)** As well as Mendel discovering modern genetics, his experiments also set an important precedent that defines all good scientific experiments. In particular, his methods demonstrated good practice in the collection of reliable data.

Which aspect of Mendel's experimental set-ups can claim to have achieved this?

.....

.....

**(2 marks)**

**(d)** In snapdragon plants, a cross between a red and white flowered plant results in pink flowered offspring due to codominance of alleles.

In the species that Mendel used for his experiments, a cross between a red-flowered plant and a white-flowered plant, did not result in any pink flowered plants in the next generation.

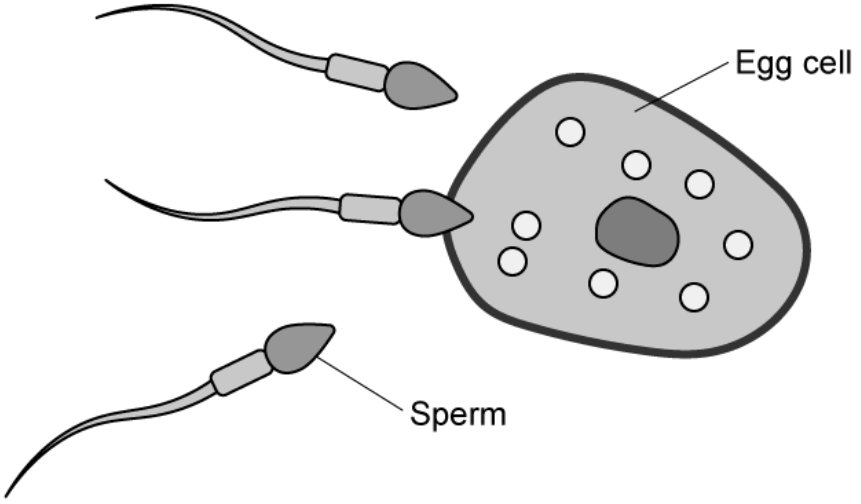
Suggest why.

.....

.....

**(2 marks)**

**2 (a)** The diagram shows a human egg and three sperm cells at the moment of fertilisation.




Suggest why the egg is so much larger than one sperm, even though they carry the same amount of genetic information as each other.

.....

.....

**(2 marks)**

**(b)** State the number of chromosomes in a human egg.

.....

**(1 mark)**

**(c)** Name the cell that forms when a sperm fertilises an egg.

.....

**(1 mark)**

**(d)** In a genetic diagram where **H** denotes the dominant allele responsible for causing Huntington's disease, and **h** denotes the recessive allele, state:

(i) the meaning of the genotype **Hh**

[1]

(ii) the phenotype that **Hh** will display

[1]

.....

**(1 mark)**

**3 (a)** The diploid number of a species of rodent is 64.

The table below has been incorrectly completed; some of the numbers in the second column are correct, while others are not.

| Cell Type | Number of chromosomes |
|---|---|
| Zygote | 64 |
| Sperm cell | 64 |
| Muscle cell | 32 |
| Fur-producing cell | 16 |

Complete the table below with correct numbers in the second column.

| Cell Type | Number of chromosomes |
|---|---|
| Zygote | |
| Sperm cell | |
| Muscle cell | |
| Fur-producing cell | |

**(2 marks)**

**(b)** A genetic cross is performed between two heterozygous parents with the genotype Qq.

Complete the Punnett grid for this cross.

| | | |
|---|---|---|
| | Q | q |
| Q | | |
| q | | |

**(2 marks)**

**(c)** When writing out genetic crosses by hand, which of the following pairs of letters is the best choice for denoting the dominant and recessive alleles?

Give a reason for your answer.

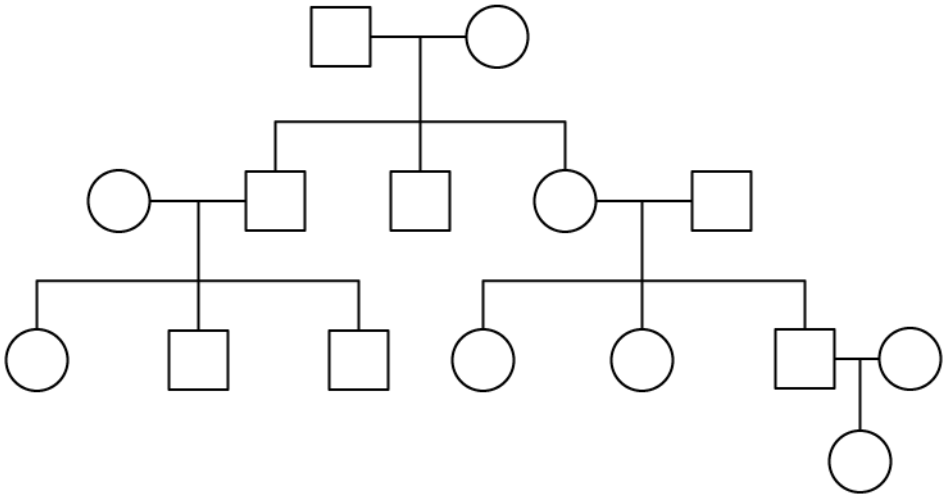
- Cc
- Oo
- Hh
- Vv

**(2 marks)**

**(d)** State the name used to describe different alleles of the same gene, that have a combined effect on the phenotype of the organism.

**(1 mark)**

**4 (a)** A pedigree chart is shown below.



(i) State the number of generations shown in the pedigree chart.

[1]

(ii) State the numbers of males and females shown in the pedigree chart.

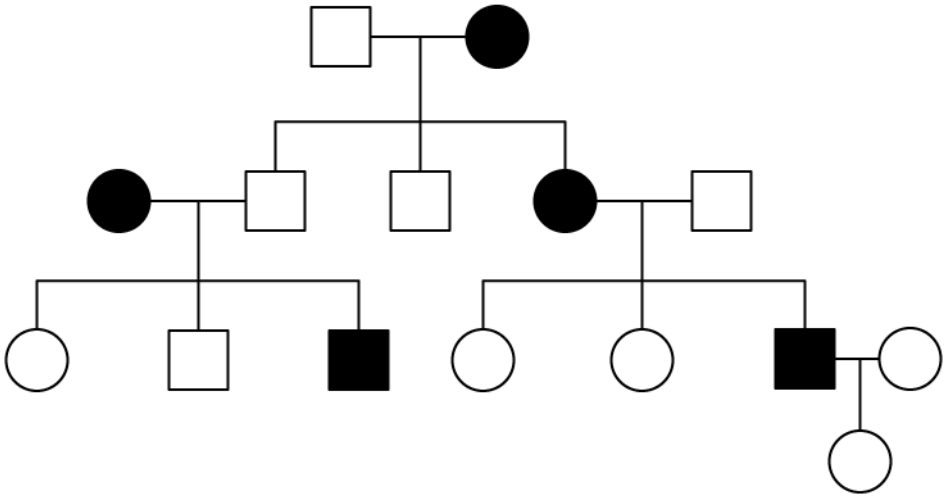
[1]

.....

.....

**(2 marks)**

**(b)** The pedigree chart from part (a) can be adapted with shading as follows:

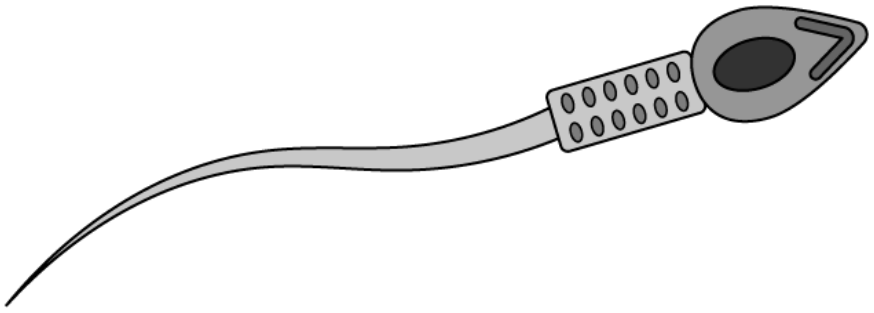


Suggest a meaning for the shaded squares and circles.

.....

**(1 mark)**

**(c)** A sperm cell is shown below.



(i) Label the diagram with an **X** to show the position of mitochondria in this cell.

[1]

(ii) State the purpose of the mitochondria in a sperm cell.

[1]

.....

.....

**(2 marks)**

**(d)** Define the term sex linkage.

.....

.....

**(2 marks)**

**5 (a)** *One mark is available for clarity of communication throughout this question.*

State the differences between the terms phenotype and genotype.

Give **one** example of **each**.

**(4 marks)**

**(b)** 8000 offspring were produced from a cross between two heterozygous parents, Hh and Hh.

Calculate how many of these offspring would have the genotype hh. Show your working.

**(3 marks)**

**(c)** (i) Define the term mutation.

[2]

(ii) List **four** factors that can increase the rate of mutation within cells. Describe the possible consequence of exposure to that factor.

[6]

**(8 marks)**

# Medium Questions

**1 (a)** Human red blood cells can be categorised into different blood groups based on the structure of a surface glycoprotein (antigen). The ABO blood groups are controlled by a single gene with multiple alleles (A, B, O). The table below shows all the genotypes for all the possible blood groups.

| Phenotype | Genotype |
|---|---|
| Blood Group A | $I^AI^A$ $I^Ai$ |
| Blood Group B | $I^BI^B$ $I^Bi$ |
| Blood Group AB | $I^AI^B$ |
| Blood Group O | ii |

A child has blood group AB and their father has blood group A.

Identify the possible phenotypes of the mother.

.....

.....

**(2 marks)**

**(b)** Suggest which pattern of inheritance is exhibited in the AB blood group.

.....

**(1 mark)**

**(c)** A woman with a family history of colour-blindness and a man with normal colour vision wish to start a family but are concerned that all their children will be colour-blind. They decide to speak to a genetic counsellor.

Suggest why the parents are concerned.

.....

.....

**(2 marks)**

**(d)** Genetic testing showed that the woman was carrying the gene for colour-blindness. The genetic counsellor provided information about the chances of having children with colour blindness.

Using the following symbols:

$X^B$ = an X chromosome carrying the normal allele for colour vision
$X^b$ = an X chromosome carrying the allele for colour blindness

(i) Identify all the possible genotypes for female and male offspring.

(ii) Predict the probability of having a child with colour-blindness.

.....

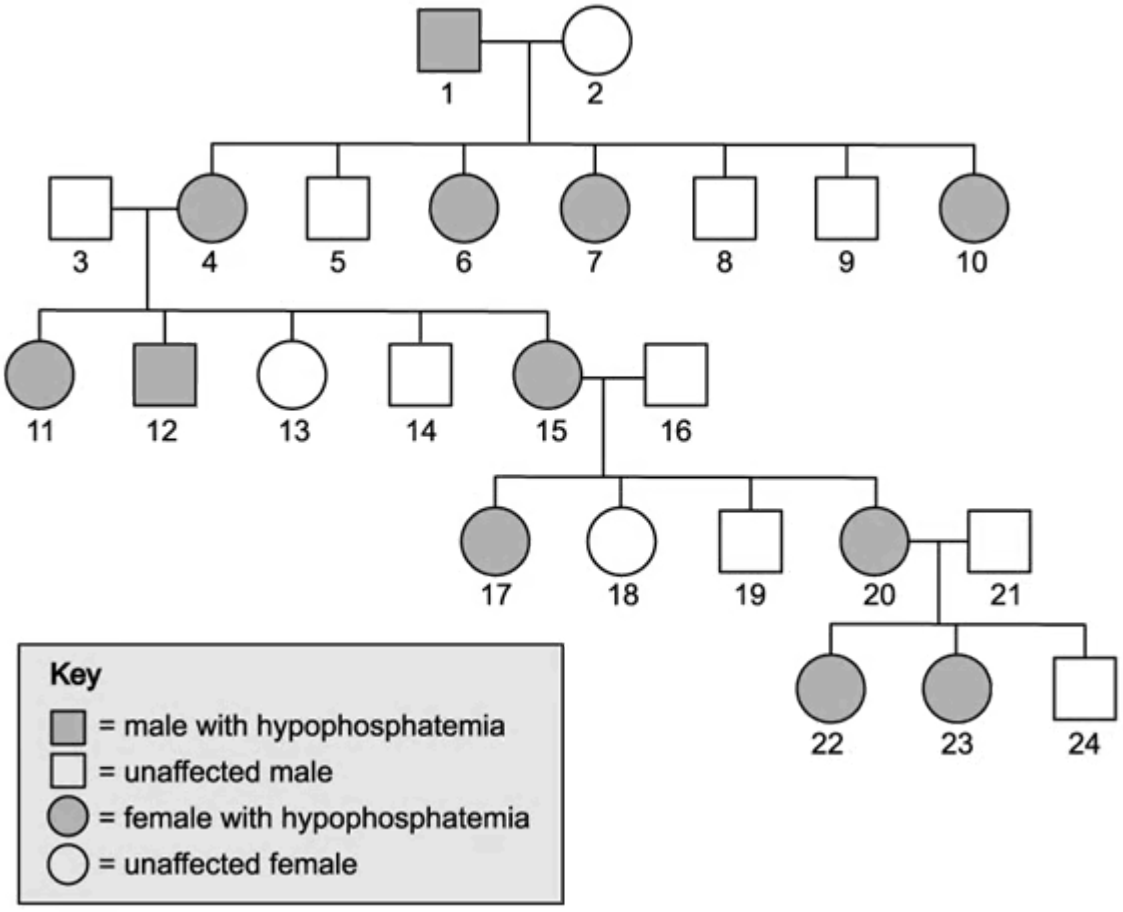
.....

.....

**(3 marks)**

**2 (a)** Hypophosphatemia is a sex-linked inherited condition which results in abnormally low levels of phosphate in the blood which can cause the disease rickets. It is caused by a dominant allele.

The diagram below shows the inheritance of hypophosphatemia in one family.




State the evidence that suggests that hypophosphatemia is a sex-linked, dominant inherited disease.

.....

.....

**(2 marks)**

**(b)** Using the following symbols,

$X^H$ = an X chromosome carrying the allele for hypophosphatemia
$X^h$ = an X chromosome carrying the normal allele
Y = a Y chromosome

Identify all the possible genotypes of each of the following persons from the diagram in part (a):

**1 :**

**4 :**

**5 :**

**13 :**

**(2 marks)**

**(c)** Person 20, from the diagram in part (a), is pregnant for the fourth time. As the family has a history of hypophosphatemia, a test was carried out to discover the sex of the embryo.

Describe what possible observations of the chromosomes would be expected when determining the sex of an embryo.

**(2 marks)**

**(d)** State the probability that the child Person 20 is pregnant with will be a male with hypophosphatemia.

Explain your answer by drawing a genetic diagram, using the following symbols:

$X^H$ = an X chromosome carrying the allele for hypophosphatemia

$X^h$ = an X chromosome carrying the normal allele

Y = a Y chromosome

**(4 marks)**

**3 (a)** A horticulturist investigated the inheritance of flower colour in *Camellia japonica*, a widely cultivated ornamental plant commonly known as Japanese camellia.The horticulturist crossed a homozygous parent with red flowers and a homozygous parent with white flowers. All of the F1 generation had the same colour flowers. Using the following symbols:

$C^R$ = Red flowers
$C^W$ = White flowers

Sketch a genetic diagram / Punnett square to deduce all the genotypes in this cross

**(2 marks)**

**(b)** Each of the F1 generation plants had flowers that were patterned red and white. The horticulturist undertook a self-cross with these F1 hybrids.

(i) State all the possible phenotypes of the F2 hybrids

(ii) Deduce the probability of obtaining a white flower.

**(2 marks)**

**(c)** Describe, with a reason, what pattern of inheritance is exhibited in the horticulturist's experiment.

**(3 marks)**

**4 (a)** FG syndrome is a recessive disorder that can cause a characteristic facial appearance, developmental delays and hyperactivity. FG syndrome is a rare X-linked genetic disorder that occurs almost exclusively in males, it is caused by a mutation in the *MED12* gene on the X chromosome.

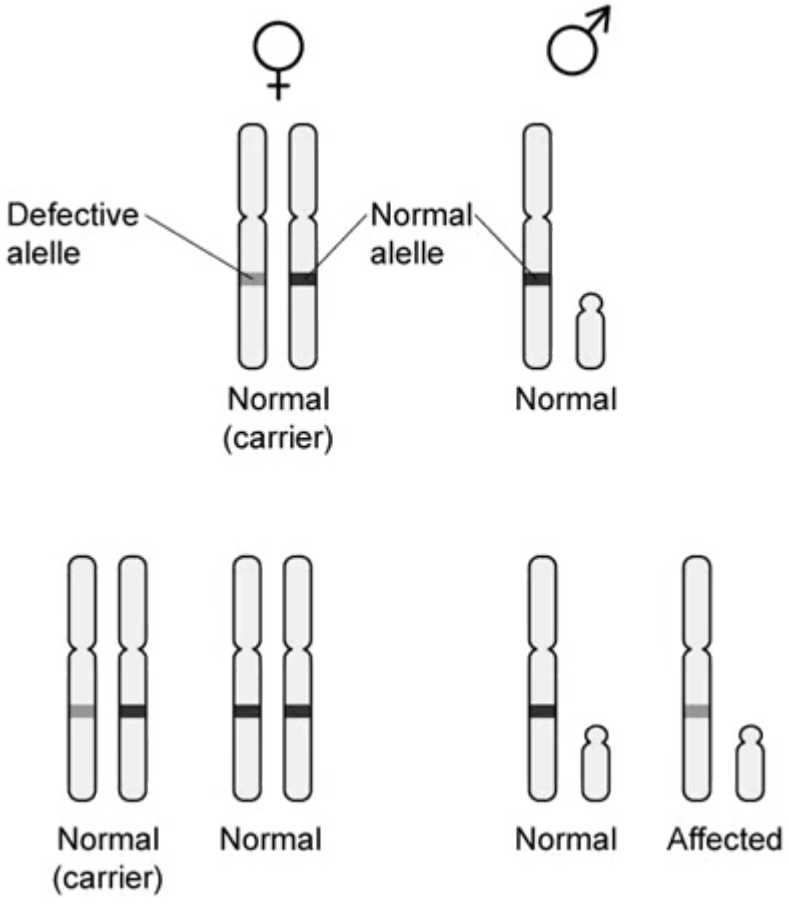
Suggest why FG syndrome occurs almost exclusively in males.

.....

.....

**(2 marks)**

**(b)** The diagram below shows the familial inheritance of an X-linked recessive disease.




Describe the patterns of inheritance that hold true for X-linked conditions.

.....

.....

**(3 marks)**

**(c)** Haemophilia is due to a sex-linked recessive gene $X^h$ whereas the normal gene is $X^H$. A haemophiliac man and a woman, who does not have haemophilia, have two children. Their first child is male and has haemophilia.

Deduce what this tells us about the mother.

**(1 mark)**

**(d)** Their second child is female.

Deduce, with a reason, the probability that their daughter will also have haemophilia.

**(2 marks)**

**5 (a)** *One mark is available for clarity of communication throughout this question.*

Radiation and mutagenic chemicals can cause mutations in DNA that result in new alleles.

Explain how mutations in DNA can affect the final protein product.

**(3 marks)**

**(b)** Outline the consequences of radiation after the Chernobyl power plant accident.

**(5 marks)**

**(c)** Outline the inheritance of colour-blindness.

**(7 marks)**

# Hard Questions

**1 (a)** State and explain **three** features of sweet pea plants that enabled Mendel to make meaningful genetic observations.

**(3 marks)**

**(b)** Aside from his ground-breaking experiments in genetics, Mendel is also credited with establishing one of the most fundamental principles of good experimental practice.

Explain how his experiments allowed him to accomplish that.

**(3 marks)**

**(c)** Human eggs and sperm cells are very different in size to each other.

Explain why, despite this size difference, both contribute equally to the genetic composition of a zygote.

**(1 mark)**

**(d)** Explain the concept of, and the importance of, segregation of alleles.

**(3 marks)**

**2 (a)** Explain why knowledge of blood groups is of critical importance when planning a blood transfusion.

**(2 marks)**

**(b)** A man of blood group **AB** and a woman of blood group **B** have four children together.

- One child is blood group **AB**
- One child is blood group **A**
- Two children are blood group **B**

Assuming that the genotypes of the four children are representative of the expected genotype ratios, deduce the mother's and father's genotypes under the A, B, O blood grouping system.

**(3 marks)**

**(c)** Using your knowledge of the A, B, O blood grouping system, suggest why people of blood group O are sought-after as blood donors.

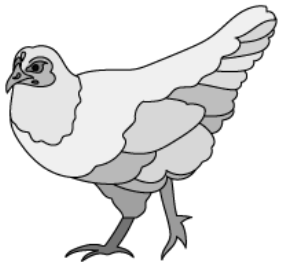
**(2 marks)**

**(d)** As stated in part (c), group O blood is highly valued for transfusions into other patients.

Explain the main **disadvantage** of a person having group O blood.

**(2 marks)**

**3 (a)** Chickens can produce pigmentation in their feathers to make them white, black or speckled, as shown in the diagram below.



White feathers

Black feathers

Speckled feathers

Homozygous white-feathered chickens can be crossed with homozygous black-feathered chickens to produce speckled offspring. This occurs via codominance.

Construct a Punnett grid to show the results of two of the speckled offspring being crossed. Use your Punnett grid to deduce the ratios of the various phenotypes that would come out of the cross.

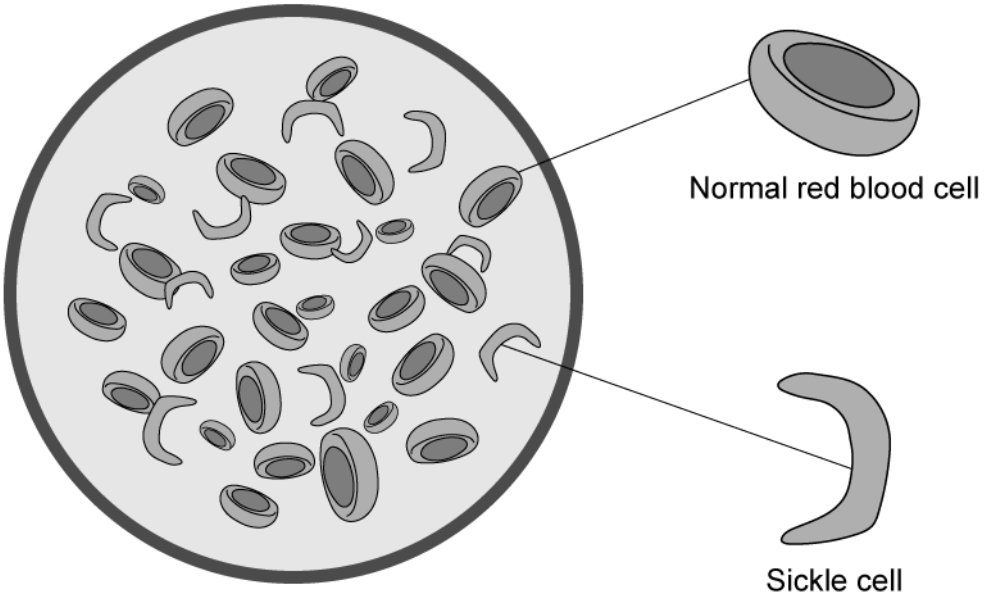
**(4 marks)**

**(b)** Explain why the traits shown in part (a) are referred to as *codominant*.

**(2 marks)**

**(c)** The genetic disease sickle cell anaemia is caused by a faulty allele of the beta-globin gene, needed for the production of functional haemoglobin in red blood cells.

The faulty allele causes red blood cells to adopt a sickle shape when oxygen availability is low, as opposed to the conventional biconcave disc structure, as shown below. Sickle cells cause considerable suffering including severe cramping pains in fingers and toes, and general fatigue.




The following table gives information about the condition in its various forms.

| Genotype | Disease manifestation |
|---|---|
| **Homozygous dominant** | No disease<br><br>All red blood cells are biconcave discs |
| **Heterozygous** | Mild symptoms at worst<br><br>Mixture of biconcave discs and sickle-shaped cells at low oxygen levels |
| **Homozygous recessive** | Severe disease<br><br>All red blood cells sickle-shaped at low oxygen levels, considerable suffering |

Use the information above to explain why the condition is regarded as codominant.

.....

.....

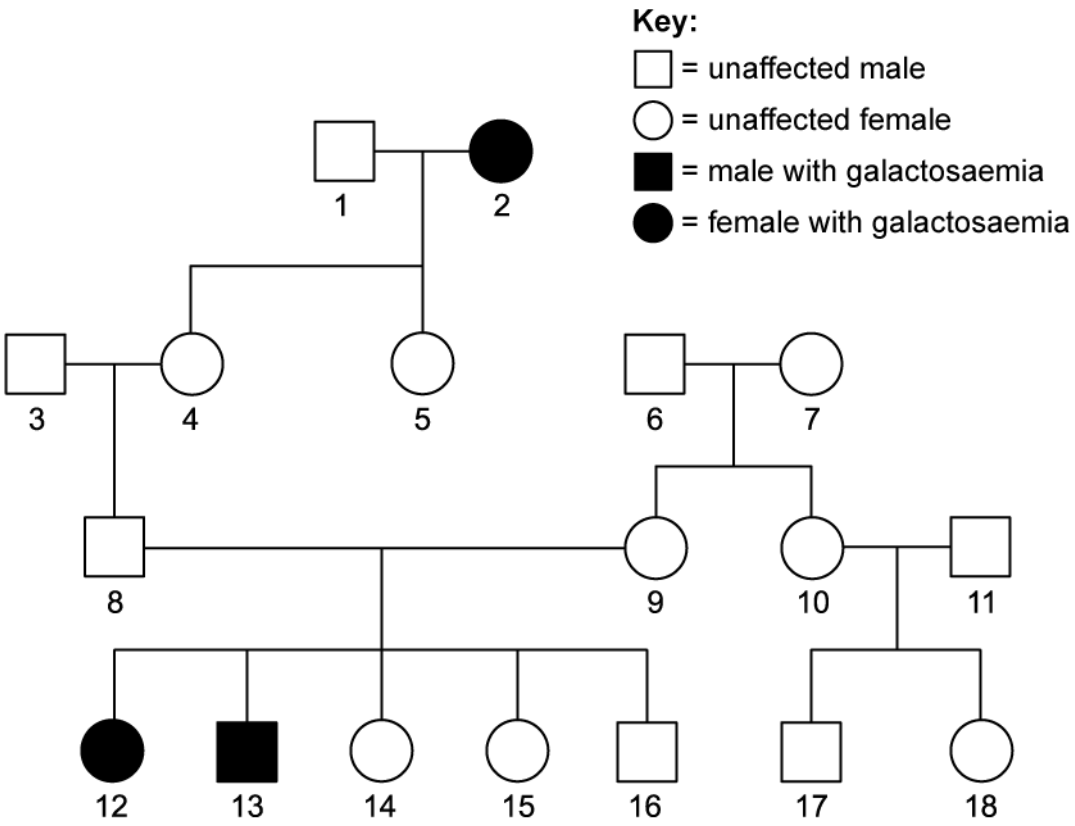
**(2 marks)**

**4 (a)** Explain why mutations only rarely lead to advantageous alleles, but when they do, there is a positive effect on a species.

**(2 marks)**

**(b)** Galactosaemia is a condition that causes sufferers to be unable to metabolise the sugar galactose properly.

The pedigree chart below shows part of a family in which galactosaemia is an inherited condition.




Explain how this pedigree chart indicates whether galactosaemia is recessive, sex-linked or both.

**(3 marks)**

**(c)** (i) Outline the cause of the genetic disease cystic fibrosis, along with its main symptoms.

[3]

(ii) Two individuals, who do not exhibit symptoms of cystic fibrosis, want to have children together and have asked for guidance as to their potential risk of having a child with cystic fibrosis. The parents are not aware of their own genotypes.

What should they be told about their potential risks?

[2]

**(5 marks)**

**5 (a)** *One mark is available for clarity of communication throughout this question.*

(i) A certain species of flower grows with either red or white petals. The allele for red flowers, **R**, is dominant to the allele for white flowers, **r**.

Construct a genetic diagram to predict the outcome of crossing pure-bred red flowers with pure-bred white flowers. State the genotype and phenotype ratios that would be expected in the $F_1$ generation.

[3]

(ii) Plants from the $F_1$ generation were crossed.
Construct a second genetic diagram to predict the outcomes.

State the genotype and phenotype ratios that would be expected in the $F_2$ generation.

[4]

**(7 marks)**

**(b)** After the 1986 nuclear accident at the Chernobyl power plant in northern Ukraine, an exclusion zone of 2,600 $km^2$ was set up around the plant.

Explain why this measure was taken and is still in force, over 35 years after the incident.

**(4 marks)**

**(c)** Huntington's disease is a genetic condition that affects the brain progressively. Problems with coordination worsen over time and can ultimately cause death by, for example, an inability to swallow or by injuries associated with falling.

(i) Huntington's disease is described as an ***autosomal dominant*** disorder. Explain the meaning of this description.

[2]

(ii) The mutation in the Huntington's disease allele contains a higher-than-normal number of repeats of a certain nucleotide sequence coding for a protein called huntingtin.

Suggest the consequence to the protein huntingtin of the extra nucleotide repeats.

[2]

**(4 marks)**