SAMPLE TEXTBOOK ANSWERS

# Chapter 24 Variation in humans

The following are sample answers only. Other answers to the same questions may also be correct.

## Science inquiry

### Activity 24.1 Modelling independent assortment

#### Studying your data

1 Are all your combinations of chromosomes different? Are there any combinations that you think are missing?

*Answer*: Student responses will vary according to their data.

2 How many combinations of these four chromosomes are possible? Remember that each cell receives one of two possible chromosomes four times (see page 338).

*Answer*: There are 16 possibilities.

3 Combine your data with the other groups in the class to obtain a bigger sample. Are all the possible combinations for the four chromosomes now listed?

*Answer*: One would assume all should now be listed.

#### Interpreting your data

1 How has this activity indicated the variability brought about by independent assortment of the chromosomes?

*Answer*: With just eight chromosomes, there are 16 combinations of chromosomes possible in the gametes. That is, 16 combinations in the sperm and 16 combinations in the eggs, which makes 256 possible combinations in offspring. Thus, independent assortment contributes to variation.

2 If you got the same combination of chromosomes more than once, what does this imply about the first stage of meiosis?

*Answer*: Assortment is a matter of chance. By chance, it would be possible to get the same combination.

3 Write a brief statement to summarise the variability brought about by the random assortment of chromosomes.

*Answer*: The members of each pair of chromosomes separate independently of one another, so a large number of combinations of the chromosomes is possible in the gametes. The greater the chromosome number, the greater the number of possible combinations. This large number of possible combinations is just one of the reasons for variation among offspring.

## Activity 24.2 Independent assortment and fertilisation

1 The fruit fly, *Drosophila*, has a chromosome number of 8. How many different combinations of chromosomes would be possible in the gametes of *Drosophila*?

*Answer*: $2^4 = 16$

2 How many different combinations of chromosomes would be possible in the offspring of *Drosophila*?

*Answer*: $16 \times 16 = 256$

3 Kangaroos and the peas on which Mendel worked have 14 chromosomes. How many different combinations of chromosomes would be possible in the gametes of kangaroos and peas?

*Answer*: $2^7 = 128$

4 How many different combinations of chromosomes would be possible in the offspring of kangaroos and peas?

*Answer*: $128 \times 128 = 16\,384$

5 Beans and rock wallabies have a chromosome number of 22. Calculate the number of possible combinations of chromosomes in the gametes and the offspring of rock wallabies and beans.

*Answer*: Gametes: $2^{11} = 2048$

Offspring: $2048 \times 2048 = 4\,194\,304$

6 *Homo sapiens* have a chromosome number of 46. The number of possible combinations of chromosomes in sperm or eggs is therefore $2^{23}$, which is 8 388 608. The number of possible combinations of chromosomes in human offspring is 8 388 608 multiplied by 8 388 608. If crossing over is taken into account, the total number of different ways that human gametes can combine is $2^{52}$ – a number greater than the total number of atoms in the solar system. Explain why no two humans (apart from identical twins) ever have exactly the same combination of alleles.

*Answer*: No two humans (apart from identical twins) have exactly the same combination of alleles, because of a combination of independent assortment, non-disjunction, mutation and random fertilisation. As shown in the question, the number of ways that human gametes can combine is astronomical; so great, in fact, that the chance of two humans having the same set of alleles is effectively zero.

# Review questions

1 What is meant by the term 'variation'? Illustrate your answer with at least two examples.

*Answer*: Variation is the differences shown between individuals within a species. Many examples are possible. Students will probably mention examples such as skin colour, eye colour, hair form and colour, height, weight, build, ear lobes, tongue rolling, blood groups and resistance to disease.

2 Describe the events that take place during meiosis that lead to the random, or independent, assortment of chromosomes.

*Answer*: Chromosome separation during the first division of meiosis is independent for all pairs of chromosomes. During this first division homologous chromosomes pair and then the members of each pair separate. The way one pair separates is independent of every other pair, so the pattern of separation is random.

**3** What is crossing over? Explain how it results in new combinations of characteristics in offspring. Draw a diagram to illustrate your answer.

*Answer*: Crossing over occurs when the chromatids become tangled during the first division of meiosis. This can lead to the chromatids breaking and reattaching to different chromatids. (Essentially, they swap pieces of genetic information.) This recombination leads to different allele combinations along the chromosome. Student diagrams should resemble Figure 24.3 on page 339.

**4** Certain genes, or alleles, are linked. What does this mean?

*Answer*: Linked alleles are those that are found on the same chromosome. As chromosomes separate and combine during meiosis, all the alleles on a particular chromosome tend to be inherited as a group.

**5** Explain how non-disjunction takes place. Give an example of a common instance of this chromosomal defect.

*Answer*: Non-disjunction occurs when a homologous pair of chromosomes in the first meiotic division, or a pair of chromatids in the second meiotic division, fail to separate and both move to the same pole of the dividing cell. This results in two or more gametes having either a greater number or a lesser number of chromosomes than is normal. An example of this is trisomy 21, also known as Down syndrome.

**6** Describe how random assortment contributes to variation in the offspring produced by sexual reproduction.

*Answer*: Random assortment occurs when pairs of homologous chromosomes move apart during the first division of meiosis. When these pairs of chromosomes separate they do so completely independently of all the other pairs of chromosomes present. This results in an egg or sperm receiving one of two possible chromosomes 23 times. This process contributes to the huge number of possible chromosome combinations in the gametes and, when fertilisation takes place, to the large range of variation that occurs in the offspring.

**7** Explain how the joining of gametes at fertilisation contributes to variation.

*Answer*: At fertilisation, there is no way of determining which sperm will unite with the egg. Therefore, fertilisation is a random event – any one of the millions of sperm produced by the male parent is able to fuse with any kind of egg from the female parent. This contributes to the variation observable in offspring.

**8** **a** What is meant by epigenetics?

*Answer*: Epigenetics refers to those inherited characteristics that are not actually encoded in the DNA sequence itself. Although epigenetic factors do not change the genes, they can be inherited when cells divide and are therefore passed on from one generation to the next.

**b** Describe an example of an epigenetic change that has been documented through several generations.

*Answer*: Students may mention:

- the Hunger Winter: German forces occupied Holland during the Second World War and during the winter of 1944-45, they restricted the supply of food to the Dutch to only a quarter of that required for normal health. Babies born during this period were much smaller than average as their mothers were suffering from severe malnutrition. Girls born during the Hunger Winter had babies during the 1960s and these babies were also smaller than average even though their

mothers had normal nutrition. Subsequently, when the underweight 1960s babies grew up and had children in the 1980s, their babies were also underweight. This has been explained by epigenetic changes in the women who gave birth during the Hunger Winter. These changes were passed on to the next two generations.

- smoking: a study of more than 1400 fathers found that 166 had begun smoking before puberty; the sons of those men were shown to be at higher risk of obesity and other health problems than those whose fathers who did not smoke at puberty.

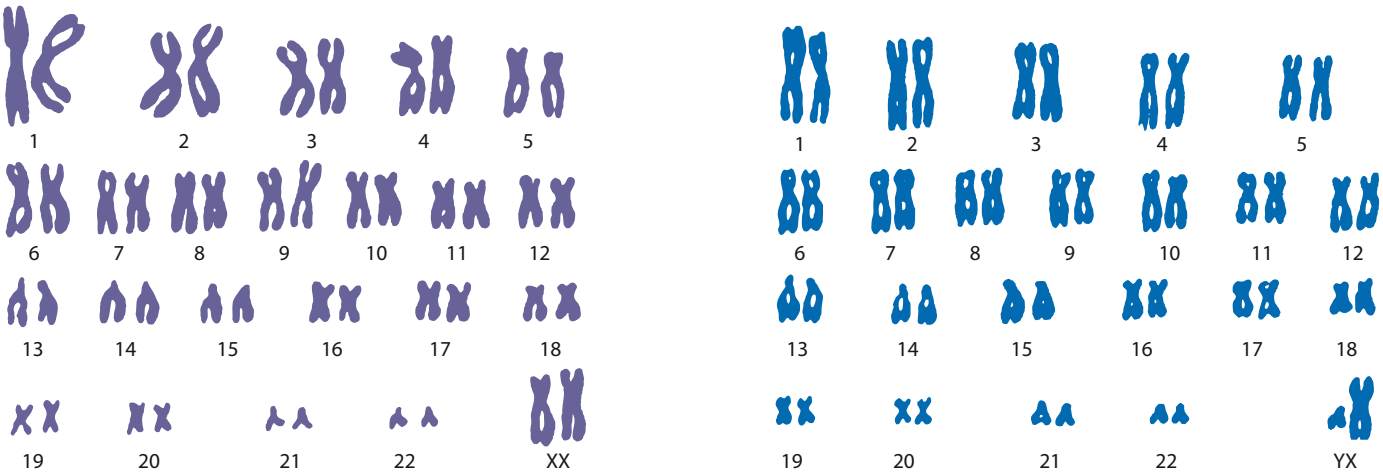
Students who have researched will be able to quote other examples.

## Apply your knowledge

**1** When a sperm fertilises an egg, the resulting fertilised cell contains a combination of genes arranged in an order that, in all probability, has never occurred before and is highly unlikely to occur again. What processes contribute to the uniqueness of the fertilised cell?

*Answer*: The uniqueness of a fertilised egg is due to independent assortment, crossing over, non-disjunction, mutation and random fertilisation.

**2** Look at the picture of human chromosomes in Figure 22.5 (page 308). Which of the human chromosomes would be likely to have the greatest amount of crossing over? Explain the reason for your answer.




*Answer*: The first pair of chromosomes would have the greatest amount of crossing over because they are the longest, and have more length to get tangled up and cross over.

**3** The relative location of genes along a chromosome affects the chances of them being separated by the process of crossing over. Use references to find out which human characteristics are more likely to be affected by crossing over.

*Answer*: Individual research, so answers will vary.

**4** The frequency of non-disjunction of chromosome 21 (Down syndrome) increases with the age of the mother. Find out how it is thought age contributes to non-disjunction.

*Answer*: Individual research, so answers will vary. However, most responses should mention that as women age, meiotic mechanisms erode leading to an increased incidence of trisomy.

**5** In Australia, do you think that selection of a partner is a completely random event? Is there a range of social factors that may influence the choice of a partner and therefore contribute to the phenotypes found in the next generation?

*Answer*: Some possible social factors include socioeconomic status, mutual interests, language spoken, religious beliefs and education level. Place of residence is also an important factor – a person is much more likely to meet a partner from their own town or city rather than from some other part of the country.

**6** Explain why independent assortment of chromosomes occurs at the first meiotic division and not the second.

*Answer*: During the first division of meiosis the homologous chromosomes pair and the members of each pair of chromosomes separate independently. The members of each pair of chromosomes have different alleles. At the second meiotic division the chromatids separate. The chromatids are duplicates – they have the same alleles – so separation of chromatids does not contribute to variation.

**7** Variation only occurs when organisms reproduce sexually. When a single-celled organism like an amoeba reproduces asexually, the two new amoebae are identical to the parent. Explain why asexual reproduction does not produce variation.

*Answer*: Asexual reproduction occurs by mitosis. In mitosis the daughter cells have DNA that is identical to the parent cell, so there can be no variation. Only one parent and one set of DNA are cloned. Therefore, there can be no variation. Students may mention that some variation may occur through mutation.

**8** Mendel studied the inheritance of characteristics that just happened to be controlled by genes on different chromosomes. Explain why he would not have been able to arrive at the principle of independent assortment had he studied characteristics controlled by genes on the same chromosome.

*Answer*: Had Mendel chosen characteristics that were controlled by genes on the same chromosome, the alleles for those characteristics would be inherited as a group. When the chromosome pairs separate at meiosis all the alleles on a chromosome go together. There is no independent assortment, as there is with alleles on different chromosomes.

**9** Medical scientists are very interested in advances in our knowledge of epigenetics. Explain why.

*Answer*: Student answers will vary as the question is quite open to interpretation. Possible responses could be:

Epigenetic changes come about as a result of environmental influences and these changes are passed on to subsequent generations. Such characteristics may be implicated in human conditions such as allergies, asthma and anxiety. A better understanding of how environmental factors affect genes to turn them off or on could help explain why some individuals experience such things as an allergy when other members of the same family do not.

Students may also mention that new and ongoing research is continuously uncovering the role of epigenetics in a variety of human disorders and fatal diseases. There has been research into the relationship between epigenetic changes and a range of disorders including various cancers, intellectual handicaps and associated disorders, immune disorders, neuropsychiatric disorders and paediatric disorders. For example, a number of studies have shown that children born during the period of the Hunger Winter in Holland (see Question 8 in the Review questions) have increased rates of coronary heart disease and obesity after maternal exposure to severe malnutrition during early pregnancy compared to those not exposed.