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Answers

Chapter 9 DNA determines the structure and function of cells

Questions 9.1

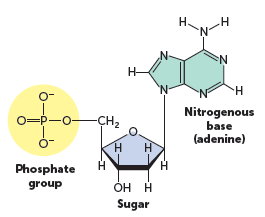
Recall knowledge

**1** State the location of DNA in the cell.

Answer*:* Nucleus and mitochondria

**2** Draw a labelled diagram of a nucleotide.

Answer: Refer to Figure 9.4 on page 231 of the student book.



**3** Name the four nitrogenous bases found in DNA.

Answer: Adenosine, Thymine, Cytosine, Guanine

**4** Describe the double helix structure of DNA.

Answer: Each strand of DNA is composed of repeating units of nucleotides. The sugar bonds with the phosphate, which in turn bonds with another sugar, so the backbone of the DNA molecule is alternating sugar and phosphate groups. The nitrogenous bases are attached to the sugar group; they form weak bonds to the complementary nitrogenous base. The two stands are twisted into a spiral shape called a double helix.

**5** Describe the structure of chromatin and chromosomes.

Answer: Chromatin is the tangled network of coiled DNA. Chromosomes are tightly/super-coiled chromatin that are large enough to be seen with a light microscope.

**6** Outline the steps of DNA replication.

Answer:

1 – The two strands of DNA separate under the influence of the enzyme helicase

2 – Each strand provides the template for the nucleotides that will form the new half.

3 – DNA polymerase attaches the complementary nucleotide (A – T and C – G). DNA polymerase proofreads the DNA.

4 – DNA ligase seals the strands up (joins the hydrogen bonds)

5 – The two DNA molecules wind up.

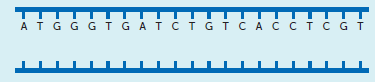
Apply knowledge

**7** State two similarities and two differences between nuclear DNA and mitochondrial DNA.

Answer: Similarities: Both have the same four nitrogenous bases, both code for proteins, both contain genes (coding sections of DNA).

Differences: Mitochondrial DNA is circular in shape, opposed to the double helix of nuclei DNA, mitochondrial only contains 37 genes, mitochondrial DNA is inherited from the maternal line as opposed to nucleic DNA, which is equally inherited from both parents.

**8** Write the missing bases on the diagram below.



Answer*:* T A C C C A C T A G A C A G T G G A G C A

**9** Explain the relevance of nucleosomes.

Answer*:* Nucleosomes are the basic packing unit of DNA, built from 8 histone proteins with DNA coiled around them. They allow the long DNA molecule to be coiled into chromatin so that it can fit into the small space of the nucleus. Nucleosomes also have a regulatory role in gene expression.

Questions 9.2

Recall knowledge

**1** List the types of RNA.

Answer: Messenger RNA (mRNA); Transfer RNA (tRNA); Ribosomal RNA (rRNA)

**2** Complete the following table to compare DNA and RNA.

Answer:

|  |  |  |
| --- | --- | --- |
|  | **DNA** | **RNA** |
| Type of sugar | Deoxyribose | Ribose |
| Number of strands | Two | One |
| Bases | A C T G | A C G U |

**3** The sequence of three bases in DNA, mRNA and tRNA determines the amino acid in a protein. State the name of the three bases in each of the molecules.

Answer*:* DNA: Codon; mRNA: Codon; tRNA: Anti-codon

**4** Name the enzyme that:

**a** separates the strands of DNA

Answer*:* DNA helicase

**b** transcribes the bases on the DNA molecule to produce mRNA.

Answer*:* RNA polymerase

**5** Describe the role of anticodons in the process of protein synthesis.

Answer*:* Anticodons are located at the base of the tRNA molecule and are complementary to the codon found in the mRNA molecule. The anticodon will bind to the codon on the mRNA, allowing the tRNA to release the attached amino acid. The amino acid is added to the peptide chain and the protein grows.

**6** Describe the structure of mitochondrial DNA.

Answer*:* Mitochondrial DNA is circular in shape, is double-stranded, but not attached to proteins.

Apply knowledge

**7** Explain why messenger RNA is needed for protein synthesis.

Answer*:* DNA is too large to leave the nucleus through the nuclear pores. mRNA, as a single stranded and shorter molecule, is able to pass through the nuclear pores into the cytosol.

**8** Explain why the base sequence of mRNA is the same as the coding strand.

Answer*:* The template strand of DNA is used to provide the code to build mRNA. As nucleotides bond in a complementary fashion, the coding strand will read the same as the mRNA molecule (replacing the thymine with uracil).

**9** Explain why gene expression must be controlled.

Answer: DNA contains the instructions to make all proteins. Since cells are specialised for their function, they only need to make certain proteins at any one time. Gene expression must be controlled so that only the relevant genes for that cell are activated/switched on and the other genes are switched off.

Questions 9.3

Recall knowledge

**1** Define ‘epigenetics’.

Answer*:* The changes in gene expression that result from mechanisms other than changes in the DNA.

**2** List the ways in which the structure of chromatin may be altered.

Answer*:* Acetylation and methylation

**3** Describe acetylation.

Answer*:* The addition of an acetyl group (CH3CO) to a histone protein. This relaxes the chromatin, promotes transcription and therefore enhances gene expression.

Apply knowledge

**4** Explain how the environment may affect gene expression.

Answer*:* Environmental stimuli, including severe stress, nutritional factors, exposure to toxins or drugs, can change the amount of acetyl groups or methyl groups that attach on the DNA. The level of acetylation can enhance gene expression, methylation acts to silence genes. The different exposure levels to environmental stimuli goes some way to explain the relationship between the environment and phenotype.

**5** Explain why gene expression increases when the chromatin structure is relaxed.

Answer*:* The addition of acetyl groups relaxes the interaction between the chromatin and the histones, pushing the histones further apart. This exposes more of the DNA for transcription, or ‘switches on’ genes that were previously unreadable.

**6** Explain why identical twins are used when studying epigenetics.

Answer*:* Identical twins have an identical genome but can be seen to have different phenotypes. Using identical twins in epigenetic studies helps explain how the environment can influence gene expression resulting in different phenotypes. Studying identical twins’ genomes allows the comparison of DNA methylation. Essentially, identical twins have different epigenomes.

**7** Compare and contrast acetylation and methylation.

Answer: Compare: Both acetylation and methylation act to influence gene expression without changing the individual’s genome.

Contrast: Methylation is the addition of a methyl group at a CpG island. It results in switching off the gene. Acetylation is the addition of an acetyl group onto a histone tail. The addition of the acetyl group acts to enhance transcription, thereby switching on genes for translation.

**8** Suggest why the number of epigenetic changes in our cells increases as we get older.

Answer*:* As we age, there is more exposure to the environmental stimuli including stress, pollutants, alcohol consumption, psychological stress and infectious diseases. These culminate in more epigenetic changes seen in cells.

Chapter 9 activities

Activity 9.1 Modelling DNA structure and replication

Studying your observations

**1** How does the order of the base pairs of your two new molecules compare with the sequence of the original molecule? Explain why this happens.

Answer*:* The base pairs of the two new molecules should be the same as the original that the student wrote down. The two halves were used as templates to form the two new molecules. Because the shape of the adenine molecule is complementary to that of the thymine molecule only adenine can pair with thymine. Similarly, only cytosine can pair with guanine so that the two new molecules are identical to each other and to the original.

**2** Why are the numbers of adenine and thymine bases in a DNA molecule always equal?

Answer*:* Adenine only bonds with thymine, so wherever there is a thymine there must be an adenine.

**3** Would there be equal numbers of thymine and cytosine bases? Explain your answer.

Answer*:* Thymine and cytosine cannot pair, so there are likely to be different numbers of thymine and cytosine bases.

**4** Explain how, when a cell divides, the two daughter cells contain the same genetic information as the parent cell.

Answer*:* Before a cell divides, the DNA has replicated – it has formed an exact copy of itself. DNA is able to replicate because adenine can only pair with thymine and cytosine can only pair with guanine. Each daughter cell receives one of the DNA copies so both cells get identical DNA. DNA carries the genetic information.

Chapter 9 review questions

Recall

**1** Describe the difference between a gene and a chromosome.

Answer*:* At cell division, DNA is coiled into structures called chromosomes, while genes are sections of the DNA that are the code for making a specific protein.

**2** Draw a labelled diagram to illustrate the structure of DNA.

Answer*:* Refer to Figure 9.4 on page 231 of the student book.

**3** List the nitrogenous bases found in RNA.

Answer*:* Adenine, Uracil, Cytosine, Guanine

**4** Describe the role of the ribosomes in protein synthesis.

Answer*:* Ribosomes read the code on messenger RNA and join the amino acids determined by the code. The joined amino acids form the protein.

**5** Define ‘gene expression’.

Answer*:* Gene expression is when the DNA code for a protein results in production of that protein. Information from the gene in the DNA is copied onto messenger RNA and amino acids are joined at a ribosome in the sequence determined by the mRNA.

**6** List the functions of mitochondrial DNA.

Answer*:* mtDNA contains 37 genes. 24 genes contain the code to make transfer RNA, 13 genes contain the instructions to make some of the enzymes needed for the reactions of cellular respiration.

Explain

**7** Explain the difference between:

**a** DNA and RNA

Answer*:* The difference between DNA and RNA is that where DNA is double-stranded and contains the base thymine, RNA is single-stranded and contains the base uracil in the place of thymine.

**b** messenger RNA and transfer RNA

Answer*:* The difference between messenger RNA and transfer RNA is that messenger RNA carries the DNA code out of the nucleus to the ribosomes in the cytoplasm, while transfer RNA brings its corresponding amino acid molecule to the messenger RNA at the ribosome. In addition, an mRNA molecule may have hundreds of bases that are the code for a protein, but of the bases that make up a tRNA molecule, only three, which form the anticodon, determine the amino acid carried by the tRNA.

**c** transcription and translation.

Answer*:* Transcription is the process of making a strand of messenger RNA (mRNA) based on the code in the DNA molecule. Transcription is needed as the DNA molecule is too large to leave the nucleus through a nuclear pore. Translation is the production of a protein using the information coded in the mRNA molecule that was previously made.

**8** Explain how a DNA molecule is able to form an exact replica of itself.

Answer*:* A DNA molecule is able to form an exact replica of itself because the two strands separate and a complementary copy is made from each strand, resulting in two molecules of DNA that are identical to the original. The two molecules are identical because the base adenine will only bond with thymine, and the base cytosine will only bond with guanine.

**9** Explain the role of mRNA in protein synthesis.

Answer*:* mRNA contains a copy of the code to build a protein that is held in the DNA molecule within the nucleus. It is small enough to leave the nucleus, where it can be ready by the ribosome in the cytosol. As each codon is read on the mRNA molecule a transfer RNA (tRNA), with the matching anticodon, brings the corresponding amino acid to the ribosome.

**10** How does DNA control the synthesis of carbohydrates and lipids in a cell?

Answer*:* DNA encodes for protein and enzymes are proteins. Thus, DNA has the code for the enzymes that are required to synthesise lipids and carbohydrates.

**11** Histones affect both the structure and function of DNA. Explain how they achieve each of these effects.

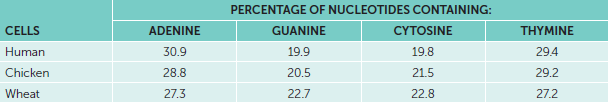
Answer*:* Histones are used structurally to coil the DNA around to form chromatin, which enables the DNA to fit into the small space of the nucleus. Histones affect the function of DNA if they have the addition of an acetyl group or methyl group. Acetylation of histone proteins acts to enhance gene expression, methylation of the histone proteins can either enhance or inhibit gene expression.

Apply

**12** Explain how a person’s genome is different from their epigenome.

Answer*:* A person’s genome is the inherited information that is encoded in their DNA – their genes. Their epigenome determines which of the genes are active in a cell at any particular time.

**13** The table below shows the results of analysing the nucleotides found in the cells of humans, chickens and wheat plants. What do these percentages tell us about the structure of DNA?



Answer*:* The table showing the percentage of nucleotides containing the four different bases demonstrates that the amount of adenine is equal to the amount of thymine and the amount of guanine is equal to the amount of cytosine. This is consistent for all species shown. (This relationship is known as Chargaff’s rule.) It demonstrates that in a DNA molecule adenine pairs with thymine and cytosine pairs with guanine.

**14** Approximately how many bases would there be in a messenger RNA molecule that coded for a protein 250 amino acids long? Explain your answer.

Answer*:* Three bases comprise the code for one amino acid, so, for 250 amino acids:

250 × 3 = 750 plus a start and stop codon = at least 756

**15** A DNA molecule has the following sequence of bases on the template strand: CTC CCC TTA GTC GAT AGT.

**a** What would be the sequence of bases on the coding strand of the DNA molecule?

Answer*:* GAG GGG AAT CAG CTA TCA

**b** What sequence of bases would be found in a strand of messenger RNA?

Answer*:* GAG GGG AAU CAG CUA UCA

**16** Explain how the discovery of epigenetic factors has changed the way we think about characteristics that can be passed from one generation to another.

Answer*:* It used to be thought that inherited characteristics were only passed on through DNA. This meant that environmental influences on a person would have no effect on the characteristics inherited by their children. We now know that a parent’s experiences can result in epigenetic changes that are passed on to offspring.

Extend

**17** Geneticist Danielle Reed from the Monell Chemical Senses Center in Philadelphia, Pennsylvania, has said: ‘Things written in pen you can’t change. That’s DNA. Things written in pencil you can. That’s epigenetics.’ Explain what you think Reed meant by this statement.

Answer*:* The statement means that a person’s genes (DNA) do not change, but the expression of the genes may change depending on environmental and other factors. Epigenetics involves changes in the functioning of genes without any change in the code in the DNA.

**18** Gene expression is a complex process, far more involved than the simple explanation given in this chapter. Use the Internet to research the control of gene expression. In your research, you may come across the following terms: enhancers, insulators, operators, promoters, repressors and silencers. Find out how these various elements are involved in the process of gene expression. Use a table to summarise your findings.

Answer:

Many of these are transcription factors, which are proteins that regulate the transcription of genes.

|  |  |
| --- | --- |
| **Term** | **Role in gene expression** |
| Enhancers | Transcription factor that acts to turn a gene on. They are located further away from the gene and are clusters of binding sites for activators. |
| Activators | They act to help the general transcription factors and RNA polymerase assemble. These attach to an activator site that is in or near the promotor region of the gene. |
| Promoters | The promotor is a section of DNA that is ‘upstream’ of the gene that is going to be transcribed. It is the site where transcription of a gene is initiated. In humans the RNA polymerase will only bind to the promotor with the help of general transcription factors (activators, repressors) |
| Insulators | Insulators are DNA sequences that are functional units of gene expression. They can form boundaries that block inappropriate action of regulators (such as enhancers) |
| Operators | The operator is a region of DNA that is downstream from the promoter region. Repressers bind to this region and prevent the RNA polymerase from assembling the mRNA. |
| Repressors | Decreases transcription by blocking the general transcription factors and RNA polymerase. Repressors bind to the operator region that is downstream from the promoter and prevents RNA polymerase from moving along the template strand, preventing transcription. |
| Silencers | Transcription factor that acts to turn a gene off. They are located further away from the gene and are clusters of binding sites for repressors. |

**19** Antibiotics, such as tetracycline, streptomycin and erythromycin, work by blocking translation during the process of protein synthesis. Suggest how this stops the bacteria replicating.

Answer: Bacteria replicate by binary fission, a form of asexual reproduction. Prior to binary fission, the DNA within the bacteria needs to replicate (similar to the process seen in mitosis). Significant protein synthesis is required during DNA replication in preparation for division. Antibiotics that block the attachment of the tRNA to the ribosomal acceptor sites prevent extensive protein synthesis. Therefore, the DNA is unable to replicate in full, and the division of the bacterium will result in non-viable cells.