ST ANDREW'S SECONDARY SCHOOL

Secondary 4 Biology (6093)

Chapters 20: Molecular Genetics

Name: ________________________ ( ) Class: _________ Date: __________

14. Molecular Genetics

Content

- The Structure of DNA
- The Role of DNA in Protein Synthesis
- Genes
- Genetic Engineering and Medical Biotechnology

Learning Outcomes

Candidates should be able to:

(a) outline the relationship between DNA, genes and chromosomes

(b) state the structure of DNA in terms of the bases, sugar and phosphate groups found in each of their nucleotides

(c) state the rule of complementary base pairing

(d) explain why observed ratios often differ from expected ratios, especially when there are small numbers of progeny

(e) state that DNA is used to carry the genetic code, which is used to synthesise specific polypeptides (details of transcription and translation are not required)

(f) state that each gene is a sequence of nucleotides, as part of a DNA molecule

(g) explain that genes may be transferred between cells. Reference should be made to the transfer of genes between organisms of the same species or different species – transgenic plants or animals

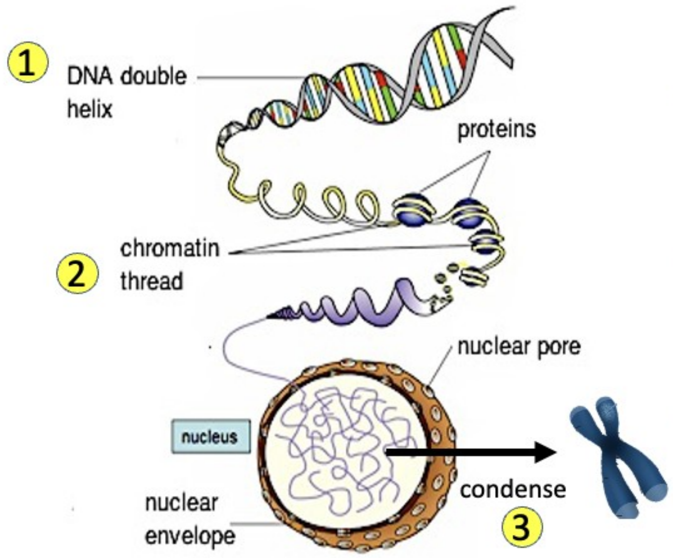
(h) briefly explain how a gene that controls the production of human insulin can be inserted into bacterial DNA to produce human insulin in medical biotechnology

(i) discuss the social and ethical implications of genetic engineering, with reference to a named example (k) state that variation and competition lead to differential survival of, and reproduction by, those organisms best fitted to the environment

Use the knowledge gained in this section in new situations or to solve related problems.

20.1 DNA

Organisation of DNA

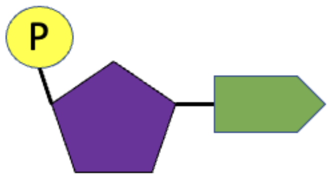


1. DNA consists of two polynucleotide strands, twisted around each other to form a double helix
2. DNA is wrapped around proteins to form chromatin threads
3. During cell division, chromatin threads condense to form chromosomes

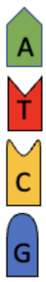
Basic units of DNA

- DNA is made up of basic units known as nucleotides.

  A nucleotide is made up of:
  - a sugar called deoxyribose,
  - a phosphate group, and
  - a nitrogen-containing bases (also referred to as nitrogenous base)

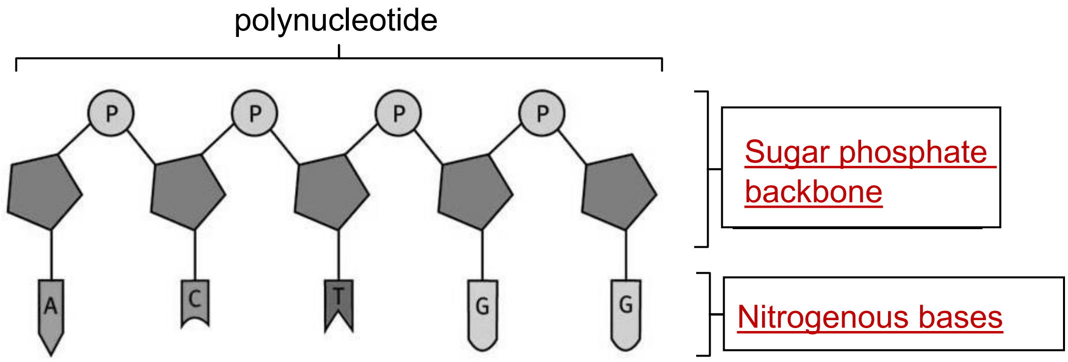


- The four types of bases found in a DNA molecule are:
  - adenine (A)
  - thymine (T)
  - cytosine (C)
  - guanine (G)



- Nucleotides join together to form polynucleotides.
- The DNA molecule is made up of two anti-parallel polynucleotide chains that run in opposite directions.

- A polynucleotide consists of:



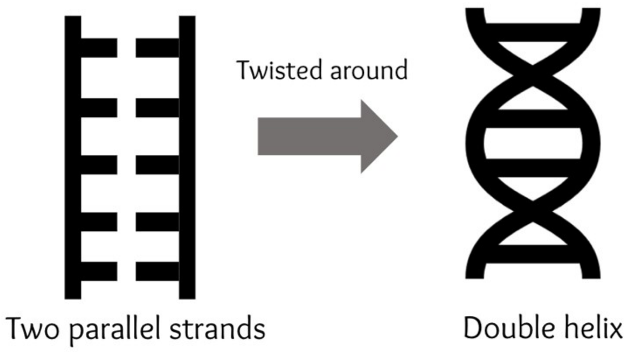
- The bases from one strand form hydrogen bonds with the bases on the other strand according to the rule of complementary base pairing. This rule states that:

adenine $\xrightarrow{\text{bonds with}}$ thymine

cytosine $\xrightarrow{\text{bonds with}}$ guanine

- As a result of this, the ratio of A-T and C-G is **1:1**

- The two antiparallel polynucleotide strands twist and coil about each other to form a double helix.



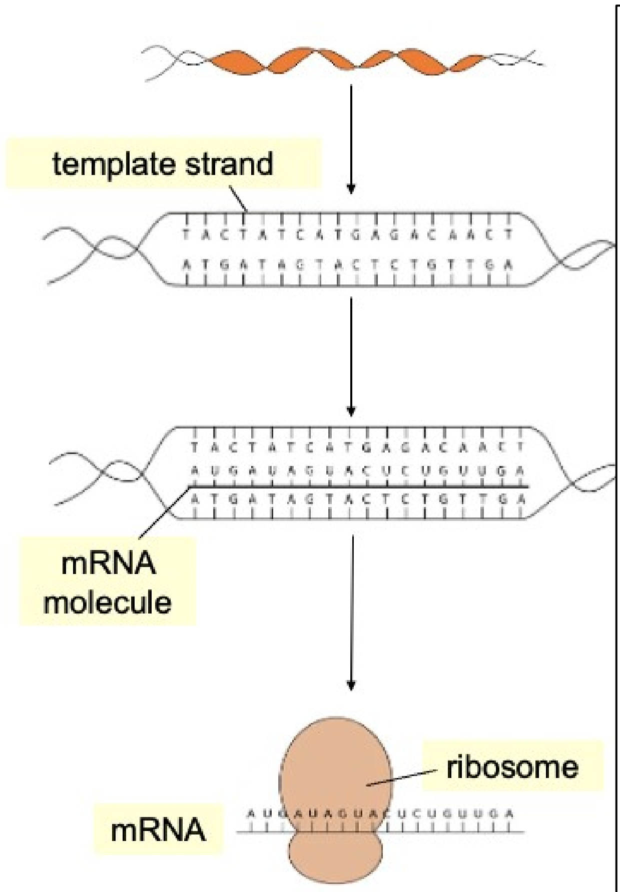
20.2 Genes

How proteins are made from genes

DNA → mRNA → polypeptide

Process: ____________ ____________

Location: ____________ ____________



Region of DNA carrying the gene unwinds and unzips. The two DNA strands are separated.
One of the DNA strands called the template is then used to make the messenger RNA (mRNA).
The mRNA has a base sequence complementary to that of the DNA template, however it contains uracil (U) instead of thymine (T).
It carries the message from DNA out of the nucleus to the

Transcription

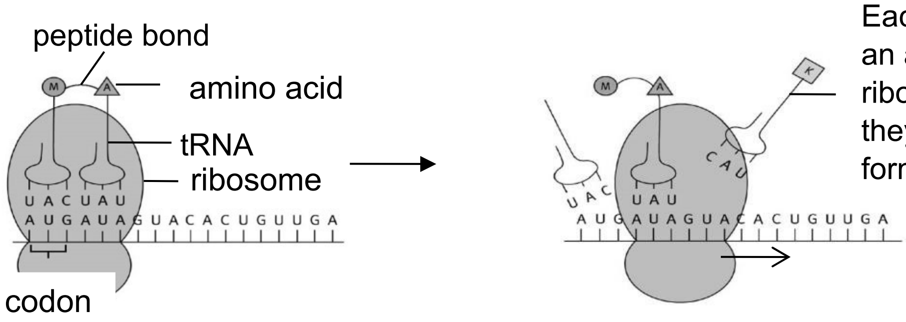
- Process by which the DNA template is used to make a single-stranded molecule called the messenger RNA (mRNA).

Translation

- Process by which the sequence of mRNA is used to make a polypeptide.
- The biological molecules involved are:

  a. Amino acids c. messenger RNA (mRNA)

  b. ribosomes d. transfer RNA (tRNA)
- Translation starts with an mRNA attaching to a ribosome:



Each tRNA carries an amino acid to the ribosome, where they are linked to form proteins.

- As the ribosome moves along the mRNA, the polypeptide produced gets longer as more amino acids are joined together by peptide bonds.
- At the end of the mRNA strand, the ribosome detaches from the mRNA and the polypeptide is released.

Comparison between DNA and RNA molecules:

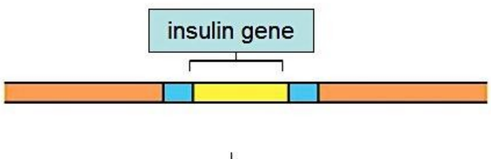
DNA	RNA
The sugar unit in the nucleotide is deoxyribose.	The sugar unit in the nucleotide is ribose.
The nitrogen-containing bases are adenine (A), thymine (T), guanine (G), and cytosine (C).	The nitrogen-containing bases are adenine (A), uracil (U), guanine (G), and cytosine (C).
The ratio of A:T and G:C is 1:1	There is no fixed ratio between A and U and between C and G.
It is a permanent molecule in the nucleus.	It is a temporary molecule that is made when it is needed and can move out of the nucleus.

20.3 Transferring Genes between Organisms

- Genetic engineering is a technique used to transfer genes from one organism to another by cutting the gene of interest from the cell of one organism, and inserting it into the cell of another organism of the same or different species.
- A vector is required for the transfer of genes.
  E.g. of a vector: plasmid - small circular DNA obtained from bacteria

Producing human insulin

1. Type I diabetes is caused by the inability of the islet of Langerhans to produce sufficient insulin.
2. The process:

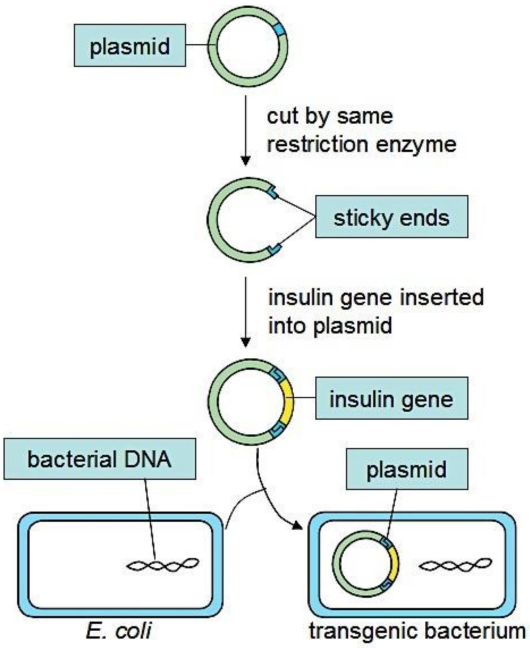


Isolate desired gene

DNA segment that contains insulin gene is cut by restriction enzymes.

Insert gene into vector

Plasmid is cut with the same



Large scale production of human insulin

- To produce large amounts of human insulin, large amounts of recombinant bacteria needs to be cultured. This is done through the use of a fermenter under optimum conditions for growth and reproduction.
- Features include:
  - Nutrient broth containing glucose water and essential mineral salts
  - Cooling jacket that maintains an optimum temperature
  - pH controller that maintains an optimum pH
  - aeration system that ensures sufficient oxygen for aerobic respiration

Other applications of genetic engineering include:

✓ Creation of transgenic plants that are resistant to herbicides.

✓ Creation of transgenic plants that are pest-resistant.

✓ Gene therapy – Healthy genes from a person can be transferred to the cells of another person with defective genes.

***Note:** Genes can be transferred between organisms of same species and between organisms of the different species.

20.4 Effects of Genetic Engineering on Society

1. Advantages of genetic engineering:

Applications of genetic engineering	Benefits to society
Low cost production of medicine	Drugs such as human insulin become more affordable.
Production of crops that grow in extreme conditions	Farmers are able to grow crops even when environmental conditions that are not suitable for cultivating most crops.
Development of crops that produce toxins that kill insect pests	The use of pesticides that may damage the environment is reduced. (e.g. Bt gene)
Development of foods designed to meet specific nutritional goals	Nutritional quality of food is improved. (e.g. golden rice)

2. Social and ethical issues of genetic engineering

Health	1. New proteins in GM food might cause allergies in humans
	2. GM food may prove to be toxic or cancer-causing to humans. Modification of a single gene in plants could alter their metabolic processes, resulting in the production of toxins.
Economic	1. If the price of GM crop seeds are not regulated, poorer farmers may not benefit from the technology while their richer competitors will continue to get richer through the technology.
Environmental	1. Genetically modified crops that produce insect toxins may result in the loss of insect biodiversity.
Ethical	1. Some groups object to consuming animal genes in plants -

	vegetarians may object to the transfer of animal genes into crop plants.
	2. Some animal rights groups feel that it is morally wrong to exploit animals for medical research, especially when the animals are engineered to suffer.
Social	1. New combinations of genes may be deliberately created for use in chemical or biological warfare