Edexcel GCSE Biology

Your notes

Reproduction

Contents

Your notes

Types of Reproduction

Sexual Reproduction

- Sexual reproduction is:

The process involving the fusion of the nuclei of two gametes to form a zygote (fertilised egg cell) and the production of offspring that are genetically different from each other

- Fertilisation is defined as the **fusion of gamete nuclei**, and as each gamete comes from a **different parent**, there is **variation** in the offspring

Gametes and zygotes

- A **gamete** is a sex cell (in animals: sperm and ovum; in plants: pollen nucleus and ovum)
- Gametes differ from normal cells as they contain **half the number of chromosomes** found in other body cells - we say they have a **haploid nucleus**
- This is because they only contain **one copy of each chromosome**, rather than the two copies found in other body cells
- In human beings, a normal body cell contains **46 chromosomes** but each gamete contains **23 chromosomes**
- When the male and female gametes fuse, they become a **zygote** (fertilised egg cell)
- This contains the full **46 chromosomes**, half of which came from the father and half from the mother - we say the zygote has a **diploid nucleus**

Advantages and disadvantages of sexual reproduction

- Although there are some clear advantages of sexual reproduction (in comparison to asexual reproduction), there are also a few disadvantages of sexual reproduction

Advantages & Disadvantages of Sexual Reproduction Table

ADVANTAGES	DISADVANTAGES
INCREASES GENETIC VARIATION	TAKES TIME AND ENERGY TO FIND MATES
THE SPECIES CAN ADAPT TO NEW ENVIRONMENTS DUE TO VARIATION, GIVING THEM A SURVIVAL ADVANTAGE	DIFFICULT FOR ISOLATED MEMBERS OF THE SPECIES TO REPRODUCE
DISEASE IS LESS LIKELY TO AFFECT POPULATION (DUE TO VARIATION)	

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Asexual Reproduction

- Asexual reproduction is:

  The process resulting in genetically identical offspring being produced from one parent

- Asexual reproduction does **not** involve **gametes** or **fertilisation**
- **Only one parent is required** so there is no fusion of gametes and no mixing of genetic information
- As a result, the offspring are **genetically identical to the parent and to each other** (they are clones)
- Many **plants** reproduce via asexual reproduction
- **Bacteria** produce exact genetic copies of themselves in a type of asexual reproduction called **binary fission**

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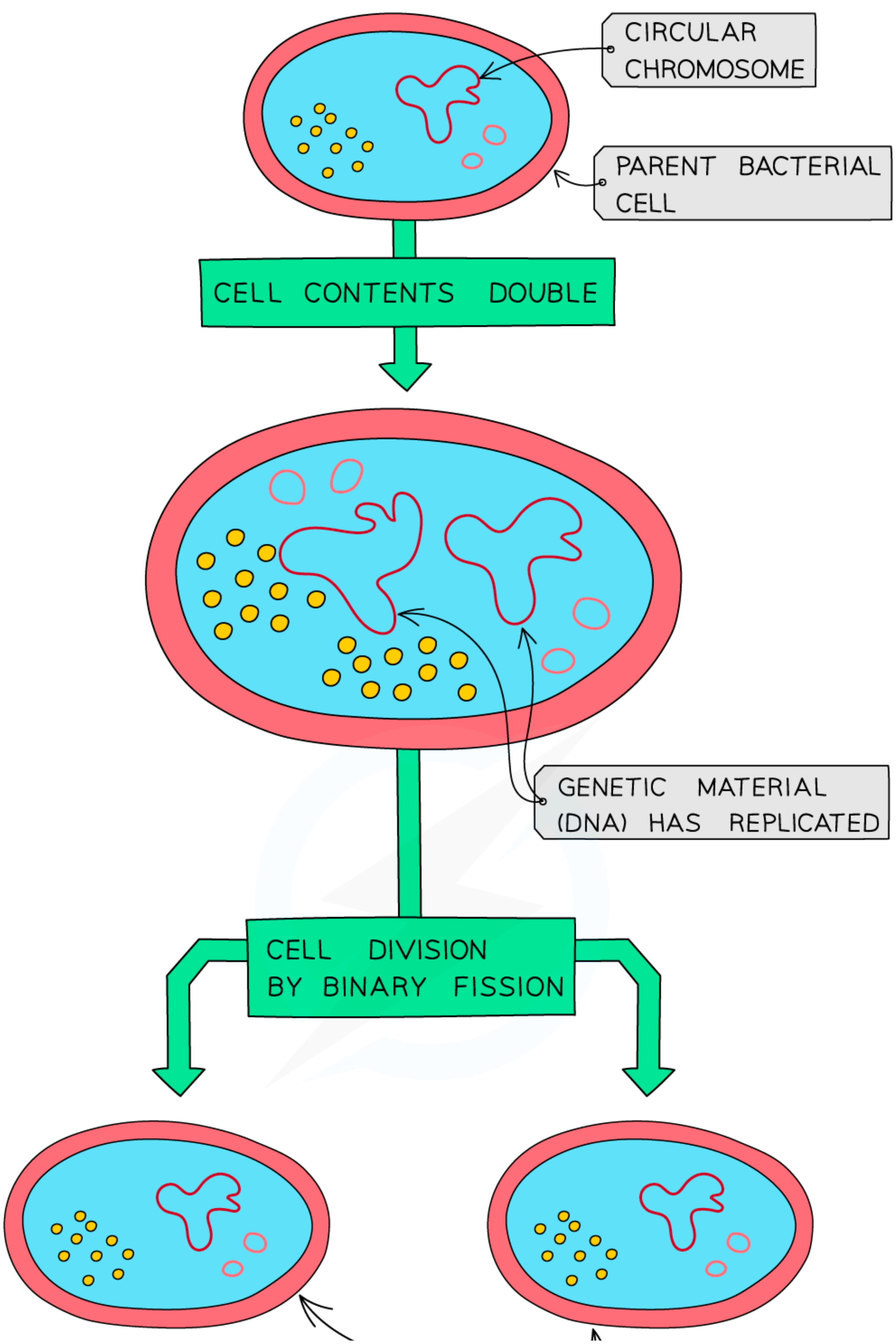
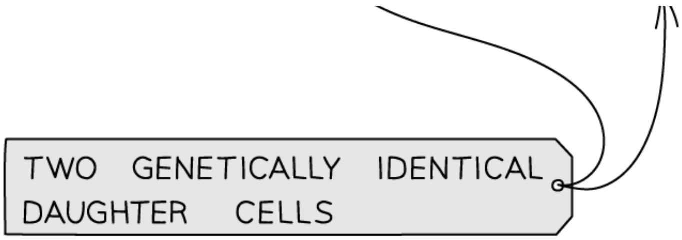

CIRCULAR CHROMOSOME
PARENT BACTERIAL CELL
CELL CONTENTS DOUBLE
GENETIC MATERIAL (DNA) HAS REPLICATED
CELL DIVISION BY BINARY FISSION



Bacteria produce exact genetic copies of themselves in a type of asexual reproduction called binary fission

Advantages and disadvantages of asexual reproduction

- Whilst asexual reproduction has several advantages over sexual reproduction, it also has a few disadvantages

Advantages & Disadvantages of Asexual Reproduction Table

ADVANTAGES	DISADVANTAGES
POPULATION CAN BE INCREASED RAPIDLY WHEN CONDITIONS ARE RIGHT	LIMITED GENETIC VARIATION IN POPULATION – OFFSPRING ARE GENETICALLY IDENTICAL TO THEIR PARENTS
CAN EXPLOIT SUITABLE ENVIRONMENTS QUICKLY	POPULATION IS VULNERABLE TO CHANGES IN CONDITIONS AND MAY ONLY BE SUITED FOR ONE HABITAT
MORE TIME AND ENERGY EFFICIENT	DISEASE IS LIKELY TO AFFECT THE WHOLE POPULATION AS THERE IS NO GENETIC VARIATION
REPRODUCTION IS COMPLETED MUCH FASTER THAN SEXUAL REPRODUCTION	

Comparing sexual and asexual reproduction

- The key differences between sexual and asexual reproduction include:
  - The **number of parent organisms**
  - **How** offspring are produced (the **type of cell division** required)

Your notes

- The **level of genetic similarity** between offspring
- The possible **sources of genetic variation** in offspring
- The **number of offspring** produced
- The **time taken** to produce offspring

Comparing Sexual & Asexual Reproduction Table

Feature	Asexual Reproduction	Sexual Reproduction
Number of parent organisms	One	Two
Type of cell division required	Offspring are produced by mitosis	Offspring are produced from the fusion of two haploid gametes, which are produced by meiosis
Level of genetic similarity between offspring	Offspring are genetically identical to each other (and to the parent)	Offspring are geenetically unique (and genetically different from both parents)
Sources of genetic variation in offspring	Only one source: mutation	Three sources: the contribution of 50% of their DNA from each of the two parents, the production of gametes by meiosis (resulting in new combinations of alleles on the chromosomes), the random distribution of chromosomes into gametes during meiosis
Number of offspring produced	Usually relatively large numbers	Usually relatively limited numbers
Time taken to produce offspring	Usually relatively fast	Usually relatively slowly

The Role of Meiosis

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The Role of Meiosis

- Cells in **reproductive organs** divide by **meiosis** to form **gametes** (sex cells)
- The **number of chromosomes must be halved** when the **gametes** are formed
- Otherwise, there would be double the number of chromosomes after they join at **fertilisation** to form the zygote (fertilized egg)
- This halving occurs during **meiosis**, and so it is described as a **reduction division** in which the chromosome number is **halved from diploid to haploid**, resulting in **genetically different haploid gametes**
- It starts with chromosomes doubling themselves as in mitosis and lining up in the centre of the cell
- After this has happened the cells divide twice so that only one copy of each chromosome passes to each gamete
- We describe gametes as being **haploid** – having **half the normal number of chromosomes**
- Because of this double division, meiosis produces **four haploid daughter cells**

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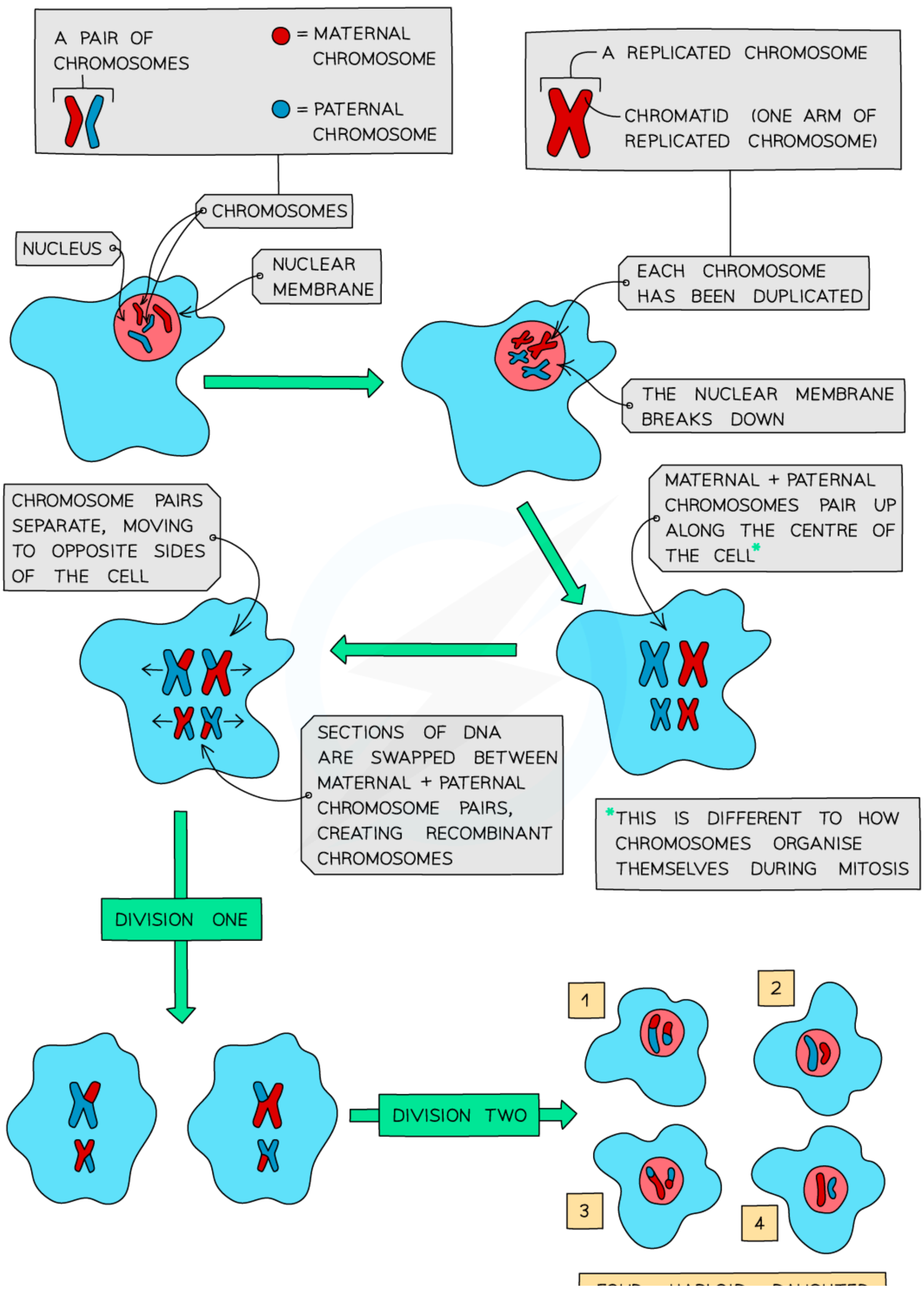
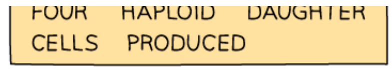

A PAIR OF CHROMOSOMES
= MATERNAL CHROMOSOME
= PATERNAL CHROMOSOME
A REPLICATED CHROMOSOME
CHROMATID (ONE ARM OF REPLICATED CHROMOSOME)
CHROMOSOMES
NUCLEUS
NUCLEAR MEMBRANE
EACH CHROMOSOME HAS BEEN DUPLICATED
THE NUCLEAR MEMBRANE BREAKS DOWN
CHROMOSOME PAIRS SEPARATE, MOVING TO OPPOSITE SIDES OF THE CELL
MATERNAL + PATERNAL CHROMOSOMES PAIR UP ALONG THE CENTRE OF THE CELL*
SECTIONS OF DNA ARE SWAPPED BETWEEN MATERNAL + PATERNAL CHROMOSOME PAIRS, CREATING RECOMBINANT CHROMOSOMES
*THIS IS DIFFERENT TO HOW CHROMOSOMES ORGANISE THEMSELVES DURING MITOSIS
DIVISION ONE
DIVISION TWO
1
2
3
4



The process of cell division by meiosis to produce haploid gamete cells

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The importance of meiosis

- Produces gametes e.g. sperm cells and egg cells in animals or pollen grains and ovum cells in plants
- **Increases genetic variation of offspring**
- Meiosis produces **variation** by forming **new combinations of maternal and paternal chromosomes** every time a gamete is made, meaning that when gametes fuse randomly at fertilisation, each offspring will be **genetically different** from any others

Examiner Tips and Tricks

You are not required to know the **stages** of meiosis for your exam. They are only included here to help with your understanding of the **role** of meiosis (i.e. the production of **four daughter cells**, each with **half** the number of **chromosomes**, which results in **genetically different haploid gametes**).

DNA & the Genome

Your notes

The Genome

- The **entire set of the genetic material** of an organism is known as its **genome**
- In 2003, scientists completed a 13–year project in which they sequenced the **genes** that make up the **whole human genome**
  - This project was named the **human genome project**
- A **gene** is a **section of DNA** that codes for a **particular sequence of amino acids**
- These sequences of amino acids form **proteins**
- Genes control our **characteristics** as they code for proteins that play **important roles** in what our cells do

The Structure of DNA

- DNA, or **deoxyribonucleic acid**, is the **genetic material found in the nucleus** of a cell
- DNA is a **polymer** made up of **two strands** coiled around to make a **double helix**

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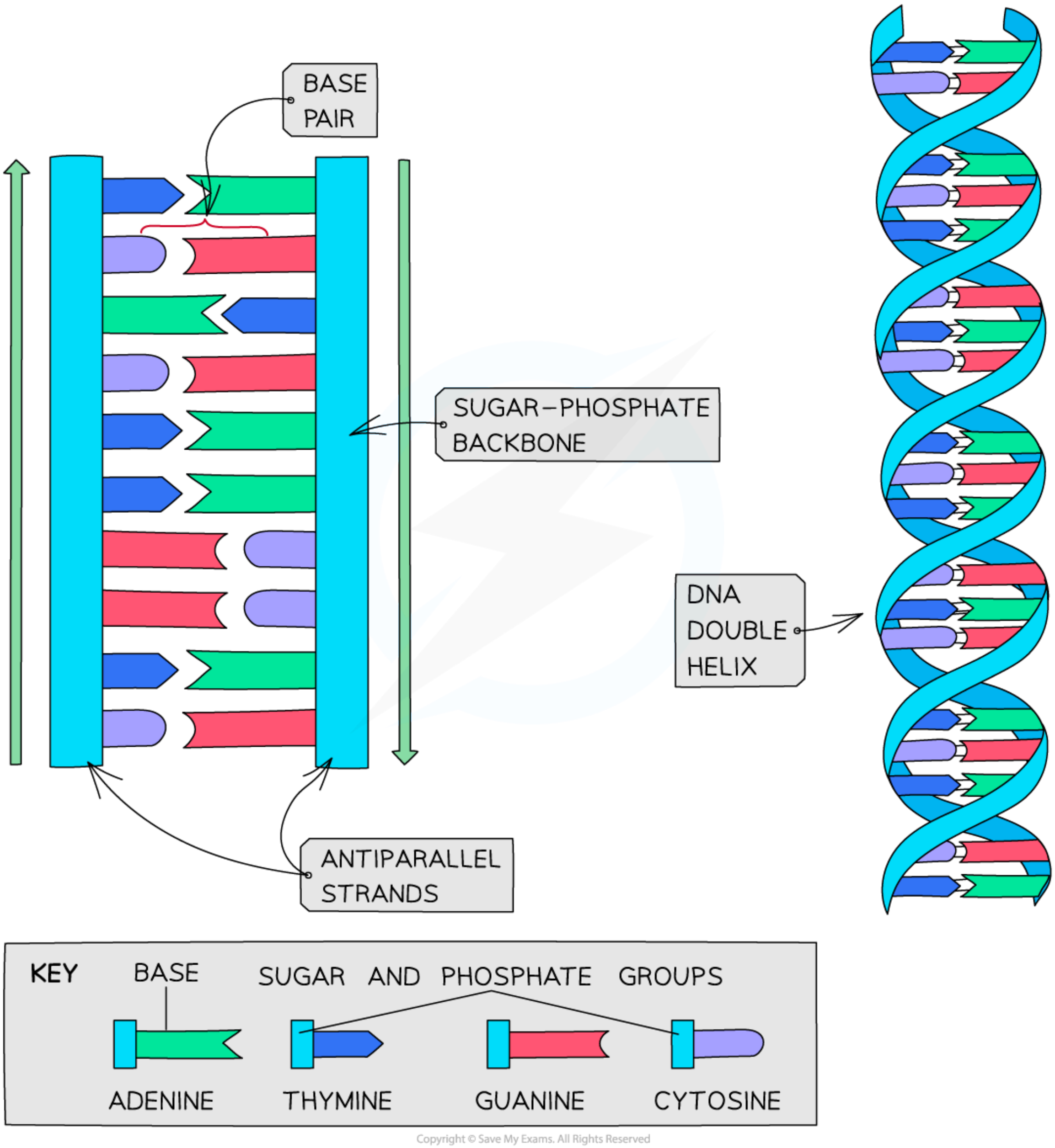
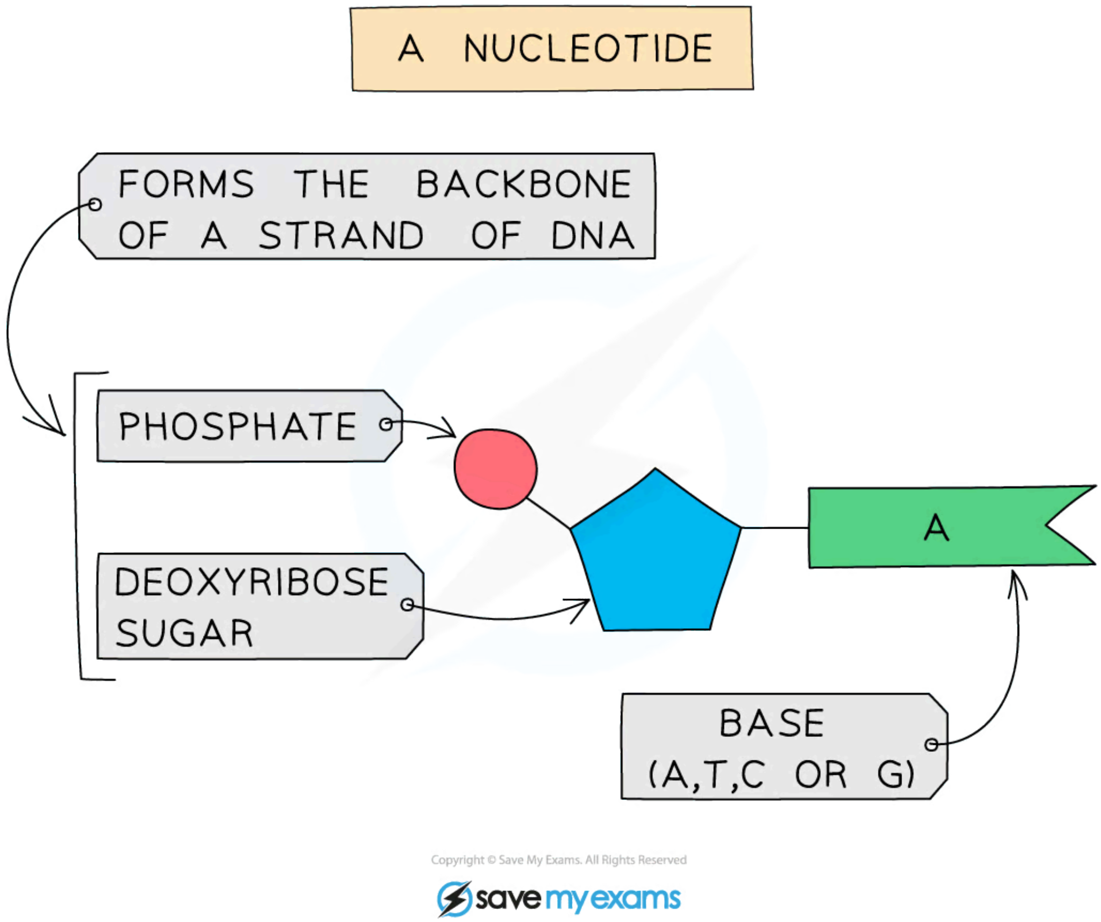


The structure of DNA and complementary base pairs

Nucleotides

- DNA is a **polymer** (a molecule made from many **repeating subunits**)
- These individual subunits of DNA are called **nucleotides**

- Each nucleotide consists of a common **sugar** and **phosphate group** with one of four different **bases** attached to the sugar

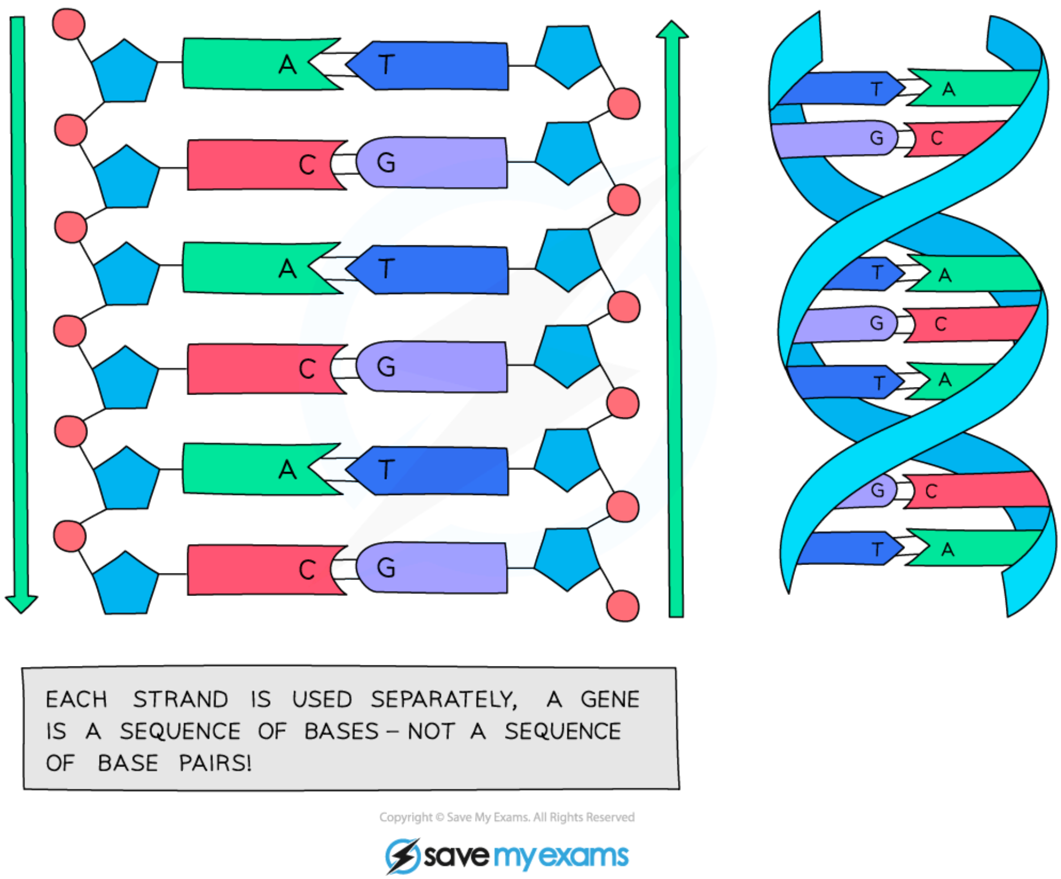


A nucleotide

- The **phosphate and sugar section of the nucleotides** form the **'backbone'** of the DNA strand (like the sides of a ladder) and the base pairs of each strand connect to form the rungs of the ladder

Your notes

Your notes

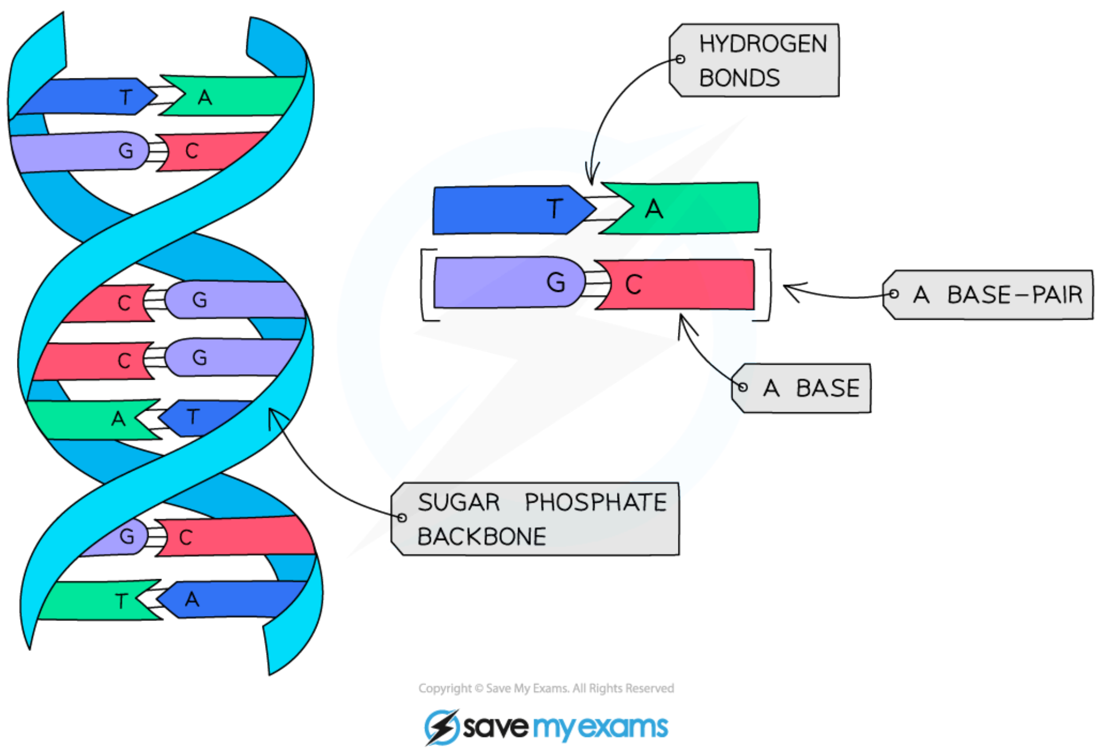


DNA is a polynucleotide – this means it is a polymer made up of many repeating subunits (monomers) known as nucleotides

Base pairing

- There are **four different nucleotides**
- These four nucleotides contain the same phosphate and deoxyribose sugar, but **differ** from each other in the **base** attached
- There are **four different bases**: Adenine (**A**), Cytosine (**C**), Thymine (**T**) and Guanine (**G**)
- The bases on each strand **pair up** with each other, holding the two strands of DNA in the **double helix** together
- The bases always pair up in the same way:
  - Adenine always pairs with Thymine (**A–T**)

- Cytosine always pairs with Guanine (**C-G**)
- This is known as **'complementary base pairing'**
- The **complementary base pairs** (A-T and C-G) pair up by forming **weak hydrogen bonds** with each other



DNA complementary base pairs

Extracting DNA

- DNA can actually be **extracted from fruit** using some basic classroom equipment
- Fruits that have relatively large amounts of DNA in their cells, such as strawberries, bananas and kiwis, can be used

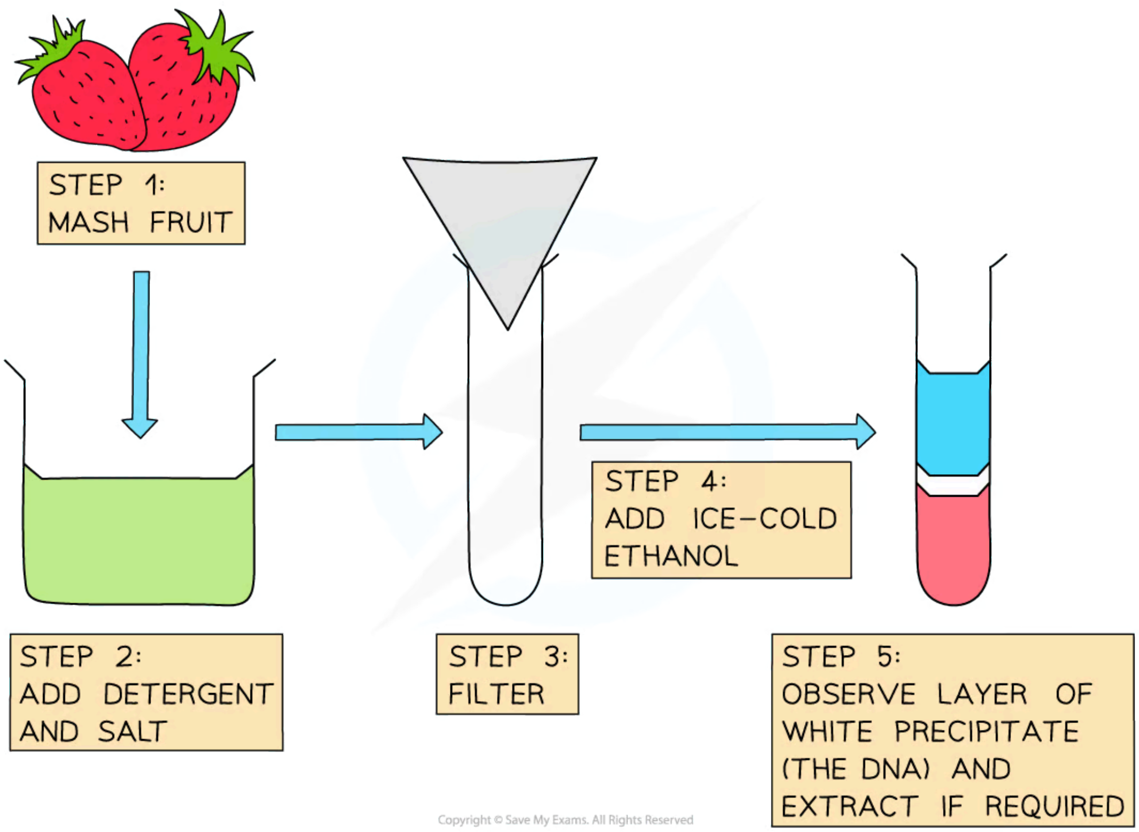
Method

- **Mash the fruit** and **mix** this into a beaker containing a solution of **detergent** (e.g. washing up liquid) and **salt**
  - The detergent **breaks down** the **cell membranes** (and the **nuclear membranes**), causing the fruit cells to **release their DNA**

Your notes

Your notes

- The salt causes the DNA to **stick together**
- **Filter** the mixture into a test tube
  - This **removes any debris** (big, insoluble bits of cell) from the mixture
- Gently add some **ice-cold ethanol** to the filtrate (the filtered mixture) by pouring the ethanol slowly down the side of the test tube
  - This causes the DNA to **precipitate** (i.e. to **come out of solution**) as DNA is not soluble in **cold alcohol**
- The DNA will appear as a **stringy white precipitate** (a solid)
- If needed, this precipitate can be carefully **extracted** using a glass rod



A simple method for extracting DNA from fruit

Protein Synthesis

Your notes

Genes

Higher tier only

- A **gene** is a section of DNA with a **particular sequence of bases** that codes for a **particular sequence of amino acids**
- A sequence of **three bases** is the **code** for a single specific **amino acid**
- The **order of bases** controls the **order** and **different types** of **amino acids** that are eventually **joined together** in a polypeptide chain
- These polypeptide chains (the amino acid sequences) then form a particular type of **protein**
- In this way, it is the **order of bases in the DNA** that eventually **determines which proteins are produced**

Types of proteins

- When the protein chain is complete it **folds up** to form a **unique shape**
- This unique shape enables the proteins to fulfil a **specific function**. For example, proteins can be:
  - **Enzymes** – proteins that act as **biological catalysts** to speed up chemical reactions occurring in the body (e.g. maltase is an enzyme that breaks down maltose into glucose)
  - **Hormones** – proteins that **carry messages** around the body (e.g. testosterone is a hormone that plays an important role in the development of the male reproductive system and development of male secondary sexual characteristics, such as increased muscle mass and growth of body hair)
  - **Structural proteins** – proteins that **provide structure** and are physically strong (e.g. collagen is a structural protein that strengthens connective tissues such as ligaments and cartilage)
- There are also many other types of proteins

Transcription & Translation

Higher tier only

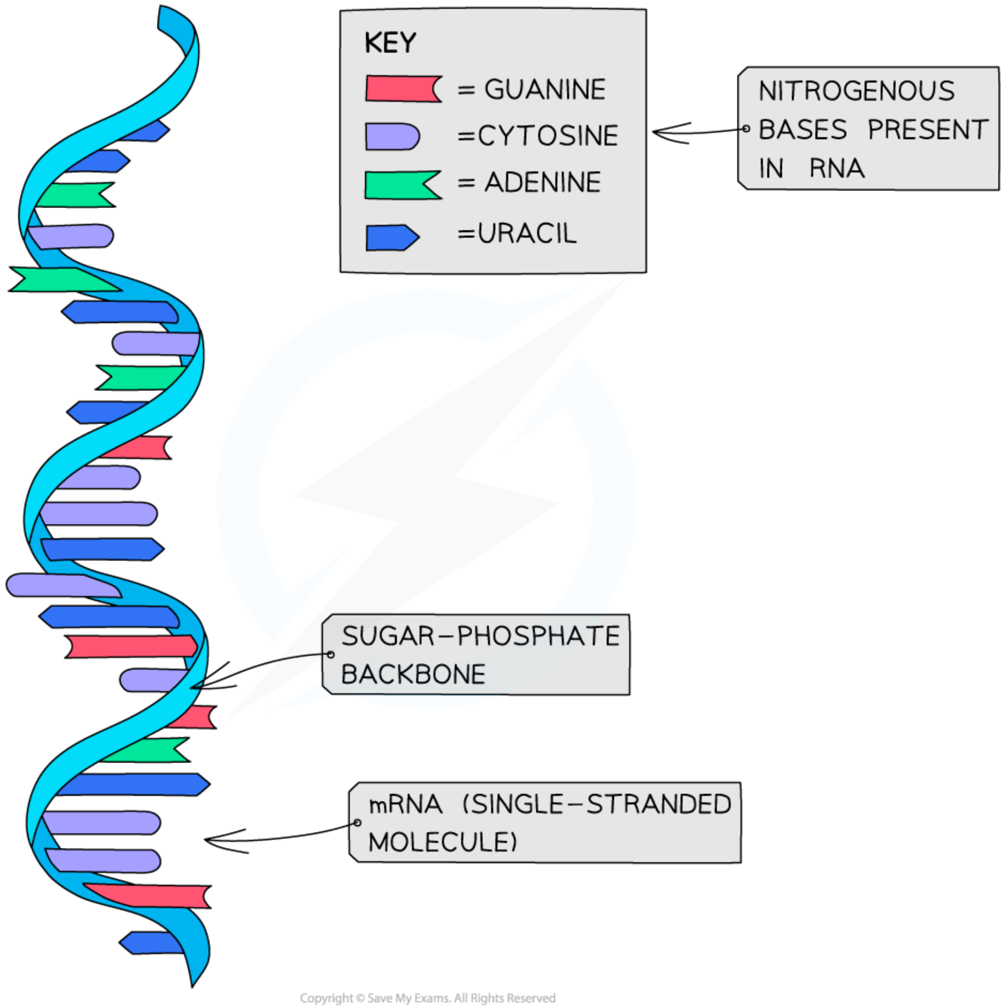
- A **gene** is a **sequence of nucleotide bases** in a DNA molecule that **codes** for the **production** of a **specific sequence of amino acids**, that in turn make up a **protein**
- This process of protein synthesis occurs in **two stages**:
  - **Transcription** – **DNA** is **transcribed** and an **mRNA** molecule is produced
  - **Translation** – **mRNA** (messenger RNA) is **translated** and an **amino acid sequence** is produced

Transcription

Your notes

- This stage of protein synthesis occurs in the **nucleus** of the cell
- Part of a DNA molecule **unwinds** (the hydrogen bonds between the complementary base pairs break)
- This exposes the gene to be transcribed (the gene from which a particular protein will be produced)
- An **enzyme** known as **RNA polymerase** binds to a region of **non-coding DNA** just **in front of the gene**
- RNA polymerase then makes a **complementary** copy of the code from the gene by building a single-stranded nucleic acid molecule known as **mRNA** (messenger RNA)
- The mRNA molecule **leaves the nucleus** via a pore in the nuclear envelope
    - Like DNA, the nucleic acid RNA (ribonucleic acid) is a **polynucleotide** – it is made up of many nucleotides linked together in a long chain
    - **Like DNA**, RNA nucleotides contain the nitrogenous bases **adenine (A), guanine (G) and cytosine (C)**
    - **Unlike DNA**, RNA nucleotides never contain the nitrogenous base thymine (T) – in place of this they contain the nitrogenous base **uracil (U)**
    - **Unlike DNA**, RNA molecules are only made up of one polynucleotide strand (they are **single-stranded**)
    - Each RNA polynucleotide strand is made up of alternating ribose sugars and phosphate groups linked together, with the nitrogenous bases of each nucleotide **projecting out** sideways from the single-stranded RNA molecule
    - One example of an RNA molecule is **messenger RNA** (mRNA), which is the transcript copy of a gene that encodes a specific polypeptide. Two other examples are **transfer RNA** (tRNA) and **ribosomal RNA** (rRNA)

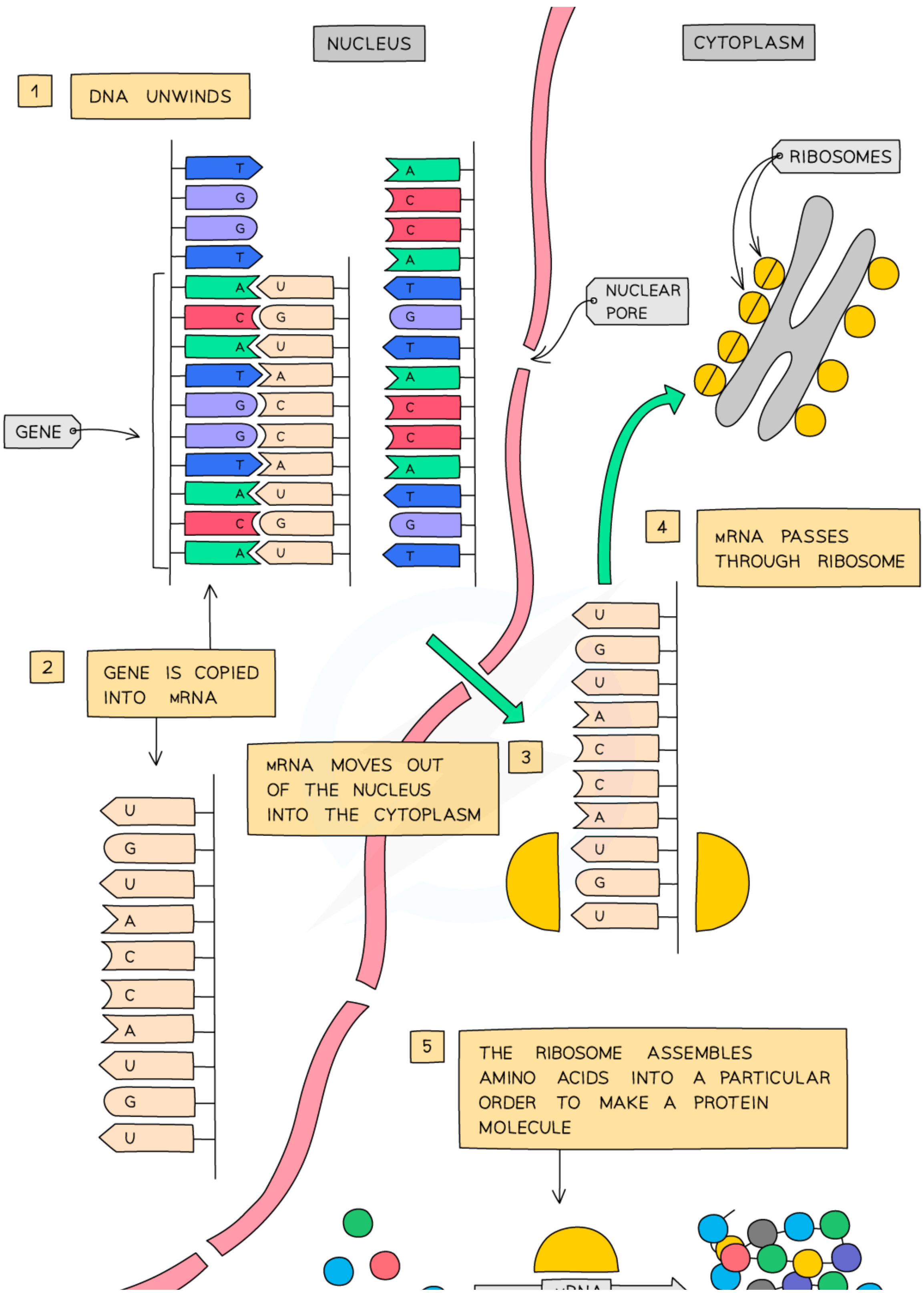
Your notes



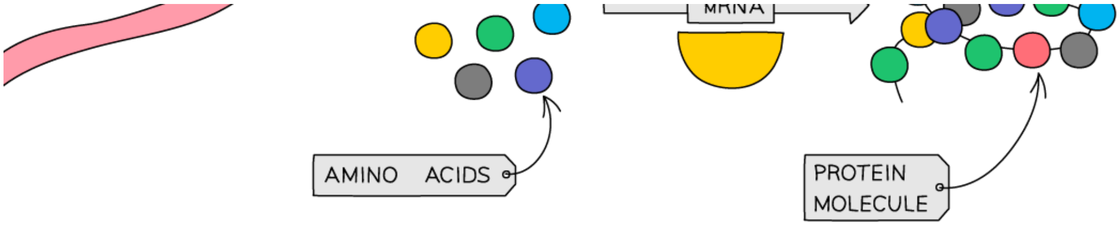
Messenger RNA (mRNA) provides a good example of the structure of RNA

Translation

- This stage of protein synthesis occurs in the **cytoplasm** of the cell
- After leaving the nucleus, the mRNA molecule attaches to a **ribosome**
  - The ribosome '**reads**' the code on the mRNA in groups of **three**
  - Each **triplet of bases** on the mRNA molecule (known as a codon) codes for a **specific amino acid**
  - In this way, the ribosome **translates** the sequence of **bases** into a sequence of **amino acids** that make up a **protein**


NUCLEUS
CYTOPLASM
1
DNA UNWINDS
GENE
NUCLEAR PORE
RIBOSOMES
2
GENE IS COPIED INTO mRNA
3
mRNA MOVES OUT OF THE NUCLEUS INTO THE CYTOPLASM
4
mRNA PASSES THROUGH RIBOSOME
5
THE RIBOSOME ASSEMBLES AMINO ACIDS INTO A PARTICULAR ORDER TO MAKE A PROTEIN MOLECULE

Your notes

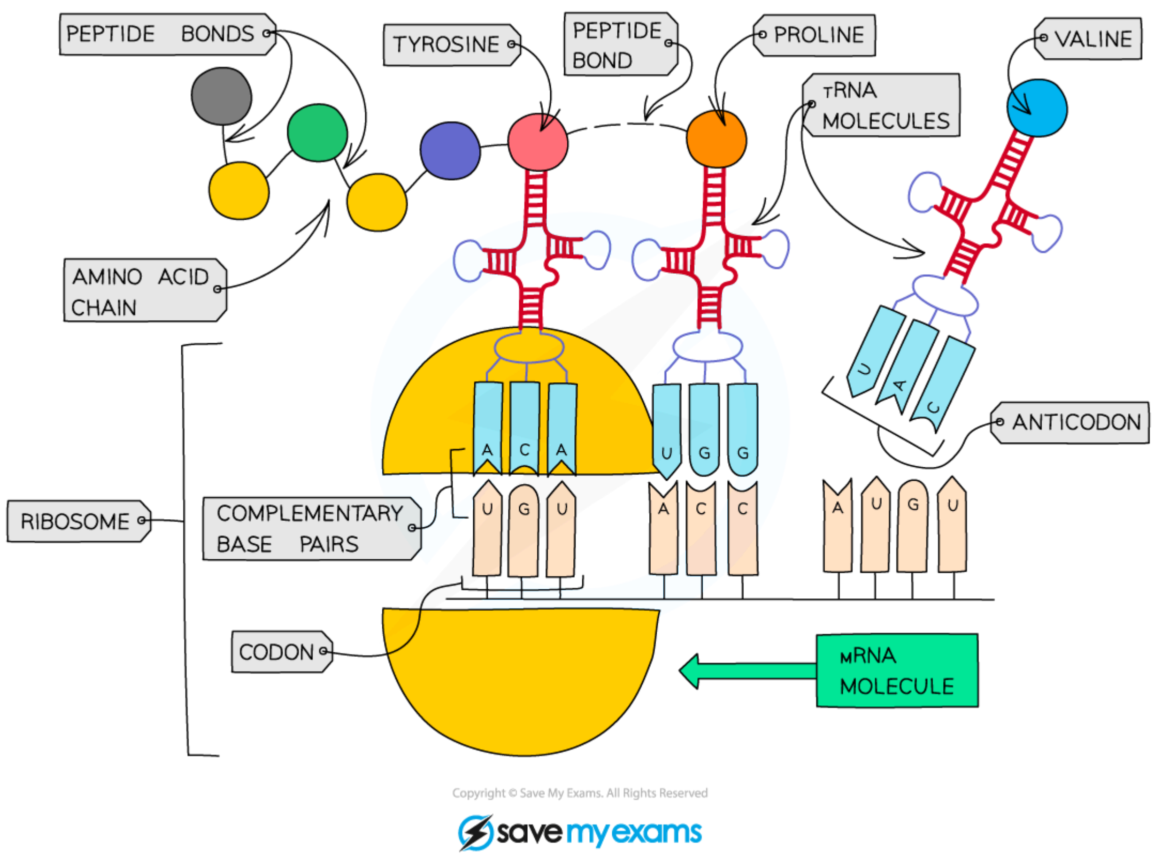


An overview of protein synthesis

- In the cytoplasm, there are free molecules of **tRNA** (transfer RNA)
- These tRNA molecules have a triplet of unpaired bases at one end (known as the **anticodon**) and a region where a **specific amino acid** can attach at the other
  - There are at least 20 different tRNA molecules, each with a specific anticodon and specific amino acid binding site
- The tRNA molecules bind with their specific amino acids (also in the cytoplasm) and bring them to the mRNA molecule on the ribosome
- The triplet of bases (anticodon) on each tRNA molecule **pairs with a complementary triplet (codon)** on the mRNA molecule
- Two tRNA molecules fit onto the ribosome at any one time, bringing the amino acid they are each carrying side by side
- A **peptide bond** is then formed between the two amino acids
- This process continues until a 'stop' codon on the mRNA molecule is reached – this acts as a signal for translation to stop and at this point the amino acid chain coded for by the mRNA molecule is complete
- This amino acid chain (the final polypeptide) will then fold to form a protein

Your notes

Your notes



The triplet of bases (codon) of mRNA is read by the ribosome and amino acids are attached together in a specific sequence to form the protein

Examiner Tips and Tricks

In an exam, you could be asked why DNA must first be transcribed into mRNA before it can be translated into a protein. This is necessary because **DNA cannot travel out of the nucleus to the ribosomes** (it is far **too big** to pass through a nuclear pore) so the base code of each gene is transcribed into an RNA molecule called messenger RNA (mRNA).

Your notes

Genetic Variants

Genetic Variants in Non-coding DNA

Higher tier only

- During transcription, part of a DNA molecule **unwinds**, exposing the gene to be transcribed (the gene from which a particular protein will be produced)
- An **enzyme** known as **RNA polymerase** then binds to a region of **non-coding DNA** just **in front of this gene**
  - Non-coding means that the DNA bases do not code for the production of an amino acid
  - RNA polymerase makes a **complimentary** copy of the gene by building a single-stranded nucleic acid molecule known as **mRNA** (messenger RNA)
- However, **genetic variants** (**different versions of genes caused by mutations**) can be produced if a mutation occurs in the non-coding DNA of a gene
  - A mutation is a random change to the DNA base sequence
- Such genetic variants can **affect phenotype** by **influencing the binding of RNA polymerase** and altering the **quantity of protein** produced:
  - If a **mutation** happens in the non-coding region to which RNA polymerase attaches, this can affect the **ability** of RNA polymerase to **bind** to it
  - In some cases, this might make it **easier** for RNA polymerase to bind. In other cases, it might make it more **difficult**
  - If it makes it more difficult for RNA polymerase to bind, **less mRNA will be transcribed** from the gene and therefore **less protein** (that the gene codes for) **will be produced**
  - Depending on the function of this protein, the phenotype of the organism may be affected by how much of it is produced
  - In this way, genetic variants in the non-coding DNA of a gene can affect phenotype, **even if the coding region of the gene is completely normal**

Genetic Variants in Coding DNA

Higher tier only

- **Genetic variants** (different versions of genes caused by mutations) can also be produced if a **mutation** occurs in the **coding DNA** of a gene

- If a mutation happens in the coding region of a gene, the gene may code for a **different sequence of amino acids**
- As the amino acid sequences are **highly specific** and form **specific shapes and types of proteins**, a change in the sequence may **change** the shape of the final protein and therefore may affect how it **functions**
  - For example, if its amino acid sequence is changed, the activity of a protein such as an enzyme may be **increased**, **decreased** or **stopped altogether**
- This, in turn, could change the **phenotype** (the **characteristics**) of the organism
  - For example, XDH is an enzyme found in fruit flies. Fruit flies with normal genes coding for XDH show normal levels of XDH activity and have red eyes. Fruit flies with genetic variants of the genes coding for XDH (caused by mutations in the coding DNA) show decreased levels of XDH activity and have brown eyes, as they cannot produce the red eye pigment

Your notes