VCE EXAM ESSENTIALS

Unit 3 Biology: How Do Cells Maintain Life?

Area of Study 1

What is the Role of Nucleic Acids and Proteins in Maintaining Life?

Area of Study 2

How Are Biochemical Pathways Regulated?

&

Scientific Investigations/Experimental Design

VCE Accreditation Period
2022 – 2026

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UNIT 3 BIOLOGY

PART 1 – VCE STUDY DESIGN

HOW DO CELLS MAINTAIN LIFE?

PART 2 – AREA OF STUDY 1

WHAT IS THE ROLE OF NUCLEIC ACIDS & PROTEINS IN MAINTAINING LIFE?

PART 3 – AREA OF STUDY 2
HOW ARE BIOCHEMICAL PATHWAYS REGULATED?

PART 4 – UNIT 3 & UNIT 4
SCIENTIFIC INVESTIGATIONS & EXPERIMENTAL DESIGN

PART 5 – ANSWERS

PART 1: VCE STUDY DESIGN

UNIT 3 BIOLOGY

(2022 – 2026)

HOW DO CELLS MAINTAIN LIFE?

SECTION 1: UNIT 3 BIOLOGY STUDY DESIGN
HOW DO CELLS MAINTAIN LIFE?

In this unit students investigate the workings of the cell from several perspectives. They explore the relationship between nucleic acids and proteins as key molecules in cellular processes. Students analyse the structure and function of nucleic acids as information molecules, gene structure and expression in prokaryotic and eukaryotic cells and proteins as a diverse group of functional molecules. They examine the biological consequences of manipulating the DNA molecule and applying biotechnologies.

Students explore the structure, regulation and rate of biochemical pathways, with reference to photosynthesis and cellular respiration. They explore how the application of biotechnologies to biochemical pathways could lead to improvements in agricultural practices.

Students apply their knowledge of cellular processes through investigation of a selected case study, data analysis and/or a bioethical issue. Examples of investigation topics include, but are not limited to: discovery and development of the model of the structure of DNA; proteomic research applications; transgenic organism use in agriculture; use, research and regulation of gene technologies, including CRISPR-Cas9; outcomes and unexpected consequences of the use of enzyme inhibitors such as pesticides and drugs; research into increasing efficiency of photosynthesis or cellular respiration or impact of poisons on the cellular respiration pathway.

The application of ethical understanding in VCE Biology involves the consideration of approaches to bioethics and ethical concepts.

A student-designed scientific investigation related to cellular processes and/or responses to challenges over time is undertaken in either Unit 3 or Unit 4, or across both Units 3 and 4, and is assessed in Unit 4, Outcome 3. The design, analysis and findings of the investigation are presented in a scientific poster format as outlined on Pages 11 and 12 of the VCE Biology Study Design (2022 – 2026).

AREA OF STUDY 1

WHAT IS THE ROLE OF NUCLEIC ACIDS & PROTEINS IN MAINTAINING LIFE?

In this area of study students explore the expression of the information encoded in a sequence of DNA to form a protein and outline the nature of the genetic code and the proteome. They apply their knowledge to the structure and function of the DNA molecule to examine how molecular tools and techniques can be used to manipulate the molecule for a particular purpose. Students compare gene technologies used to address human and agricultural issues and consider the ethical implications of their use.

OUTCOME 1

On completion of this unit the student should be able to analyse the relationship between nucleic acids and proteins, and evaluate how tools and techniques can be used and applied in the manipulation of DNA.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 1 and the related key science skills on Pages 7–9 of the VCE Biology Study Design (2022 – 2026).

KEY KNOWLEDGE

THE RELATIONSHIP BETWEEN NUCLEIC ACIDS & PROTEINS

- Nucleic acids as information molecules that encode instructions for the synthesis of proteins: the structure of DNA, the three main forms of RNA (mRNA, rRNA and tRNA) and a comparison of their respective nucleotides.
- The genetic code as a universal triplet code that is degenerate and the steps in gene expression, including transcription, RNA processing in eukaryotic cells and translation by ribosomes.
- The structure of genes: exons, introns and promoter and operator regions.
- The basic elements of gene regulation: prokaryotic *trp* operon as a simplified example of a regulatory process.
- Amino acids as the monomers of a polypeptide chain and the resultant hierarchical levels of structure that give rise to a functional protein.
- Proteins as a diverse group of molecules that collectively make an organism's proteome, including enzymes as catalysts in biochemical pathways.
- The role of rough endoplasmic reticulum, Golgi apparatus and associated vesicles in the export of proteins from a cell via the protein secretory pathway.

KEY KNOWLEDGE

DNA MANIPULATION TECHNIQUES & APPLICATIONS

- The use of enzymes to manipulate DNA, including polymerase to synthesise DNA, ligase to join DNA and endonucleases to cut DNA.
- The function of CRISPR-Cas9 in bacteria and the application of this function in editing an organism's genome.
- Amplification of DNA using polymerase chain reaction and the use of gel electrophoresis in sorting DNA fragments, including the interpretation of gel runs for DNA profiling.
- The use of recombinant plasmids as vectors to transform bacterial cells as demonstrated by the production of human insulin.
- The use of genetically modified and transgenic organisms in agriculture to increase crop productivity and to provide resistance to disease.

AREA OF STUDY 2

HOW ARE BIOCHEMICAL PATHWAYS REGULATED?

In this area of study students focus on the structure and regulation of biochemical pathways. They examine how biochemical pathways, specifically photosynthesis and cellular respiration, involve many steps that are controlled by enzymes and assisted by coenzymes. Students investigate factors that affect the rate of cellular reactions and explore applications of biotechnology that focus on the regulation of biochemical pathways.

OUTCOME 2

On completion of this unit the student should be able to analyse the structure and regulation of biochemical pathways in photosynthesis and cellular respiration, and evaluate how biotechnology can be used to solve problems related to the regulation of biochemical pathways.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 2 and the related key science skills on Pages 7–9 of the VCE Biology Study Design (2022 – 2026).

KEY KNOWLEDGE

REGULATION OF BIOCHEMICAL PATHWAYS IN PHOTOSYNTHESIS & CELLULAR RESPIRATION

- The general structure of the biochemical pathways in photosynthesis and cellular respiration from initial reactant to final product.
- The general role of enzymes and coenzymes in facilitating steps in photosynthesis and cellular respiration.
- The general factors that impact on enzyme function in relation to photosynthesis and cellular respiration: changes in temperature, pH, concentration, competitive and non-competitive enzyme inhibitors.

KEY KNOWLEDGE

PHOTOSYNTHESIS AS AN EXAMPLE OF BIOCHEMICAL PATHWAYS

- Inputs, outputs and locations of the light dependent and light independent stages of photosynthesis in C_3 plants (details of biochemical pathway mechanisms are not required).
- The role of Rubisco in photosynthesis, including adaptations of C_3, C_4 and CAM plants to maximise the efficiency of photosynthesis.
- The factors that affect the rate of photosynthesis: light availability, water availability, temperature and carbon dioxide concentration.

KEY KNOWLEDGE

CELLULAR RESPIRATION AS AN EXAMPLE OF BIOCHEMICAL PATHWAYS

- The main inputs, outputs and locations of glycolysis, Krebs Cycle and electron transport chain including ATP yield (details of biochemical pathway mechanisms are not required).
- The location, inputs and the difference in outputs of anaerobic fermentation in animals and yeasts.
- The factors that affect the rate of cellular respiration: temperature, glucose availability and oxygen concentration.

KEY KNOWLEDGE

BIOTECHNOLOGICAL APPLICATIONS OF BIOCHEMICAL PATHWAYS

- Potential uses and applications of CRISPR-Cas9 technologies to improve photosynthetic efficiencies and crop yields.
- Uses and applications of anaerobic fermentation of biomass for biofuel production.

SECTION 2: SCHOOL-BASED ASSESSMENT

SATISFACTORY COMPLETION

The award of satisfactory completion for a unit is based on whether the student has demonstrated the set of outcomes specified for the unit. Teachers should use a variety of assessment tasks to provide a range of opportunities for students to demonstrate the key knowledge and key skills in the outcomes.

The areas of study and key knowledge and key skills listed for the outcomes should be used for course design and the development of learning activities and assessment tasks.

ASSESSMENT OF LEVELS OF ACHIEVEMENT

The student's level of achievement in Unit 3 will be determined by School-assessed Coursework. School-assessed Coursework tasks must be part of the regular teaching and learning program and must not unduly add to the workload associated with that program. They must be completed mainly in class and within a limited timeframe.

Where teachers provide a range of options for the same School-assessed Coursework task, they should ensure that the options are of comparable scope and demand.

The types and range of forms of School-assessed Coursework for the outcomes are prescribed within the study design. The VCAA publishes *Advice for teachers* for this study, which includes advice on the design of assessment tasks and assessment of student work for a level of achievement.

Teachers will provide to the VCAA a numerical score representing an assessment of the student's level of achievement. The score must be based on the teacher's assessment of the performance of each student on the tasks set out in the following table.

CONTRIBUTION TO THE FINAL ASSESSMENT

School assessed Coursework for Unit 3 will contribute 20 per cent to the study score.

Outcomes	Marks Allocated	Assessment Tasks
Outcome 1 Analyse the relationship between nucleic acids and proteins, and evaluate how tools and techniques can be used and applied in the manipulation of DNA.	40	*For Outcomes 1 and 2* For each outcome, one task selected from: • Analysis and evaluation of a selected biological case study. • Analysis and evaluation of generated primary and/or collated secondary data. • Comparison and evaluation of biological concepts, methodologies and methods, and findings from three student practical activities. • Analysis and evaluation of a contemporary bioethical issue. Each task type can only be selected once across Units 3 and 4. For each task the time allocated should be approximately 50–70 minutes for a written response and 10 minutes for a multimodal or oral presentation.
Outcome 2 Analyse the structure and regulation of biochemical pathways in photosynthesis and cellular respiration, and evaluate how biotechnology can be used to solve problems related to the regulation of biochemical pathways.	40	
Total Marks	**80**	

PRACTICAL WORK & ASSESSMENT

Practical work is a central component of learning and assessment and may include activities such as laboratory experiments, fieldwork, simulations and other direct experiences as described in the scientific investigation methodologies on Pages 9 and 10 of the VCE Biology Study Design (2022 – 2026). A minimum of ten hours of class time should be devoted to student practical activities and investigations across Areas of Study 1 and 2.

EXTERNAL ASSESSMENT

The level of achievement for Units 3 and 4 is also assessed by an end-of-year examination, which will contribute 50 per cent to the study score.

SCHOOL-ASSESSED COURSEWORK (SACs)

THE VCAA RULES

- Students must ensure that all unacknowledged work is genuinely their own.
- A student must acknowledge all resources used, e.g. text, websites and source material.
- A student must not receive undue assistance from any other person in the preparation and submission of work.
- A student must not submit the same piece of work for assessment in more than one study.
- A student should not knowingly assist other students.
- A student must sign an authentication record for work done outside class at the time of submitting the completed task.
- A student must sign a general declaration stating that they will obey the rules.

Please Note:

Any material in the TSFX Biology Master Class notes or lecture notes that is denoted with an asterix (*) is not required knowledge and will not be examined in the Unit 3 & Unit 4 external Biology examination.

PART 2: AREA OF STUDY 1

WHAT IS THE ROLE OF NUCLEIC ACIDS & PROTEINS IN MAINTAINING LIFE?

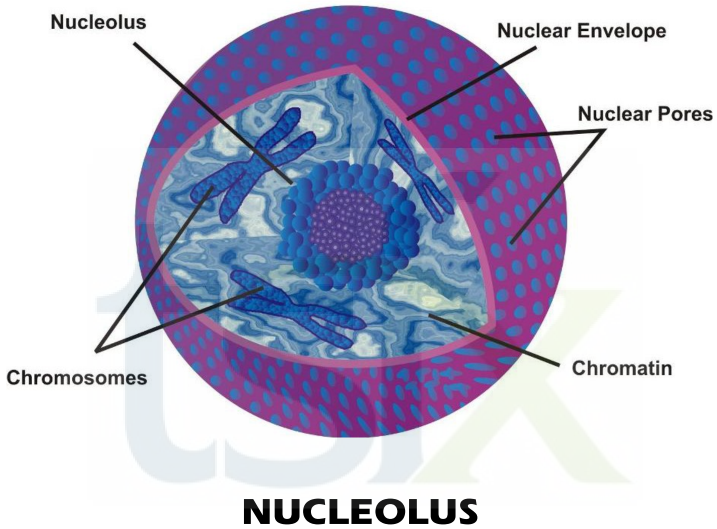
SECTION 1: REVIEW OF CELLULAR ORGANELLES & THEIR FUNCTION

Any persistent structure that carries out a specific function within a cell, such as the nucleus and ribosomes, is referred to as an ***organelle***.

Organelles **do not** have to be membrane-bound. One example are ribosomes.

THE NUCLEUS

- The nucleus is a spherical structure enclosed by a nuclear membrane.
- It is one of the largest organelles jn a cell.
- It contains genetic material in the form of DNA and controls many of the cell's activities.
- The nucleus is the ***control centre*** of a cell.



NUCLEOLUS

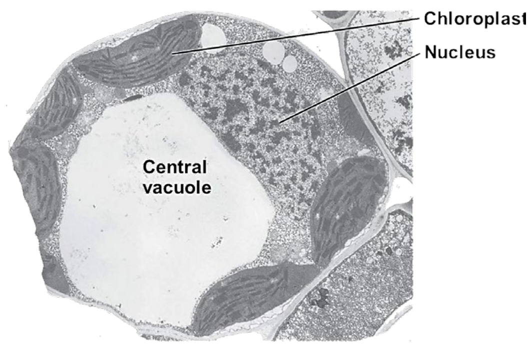
- The nucleolus is a dark, round structure located within the nucleus.
- It is composed of RNA and is the site of ribosome synthesis.

VACUOLES

- A ***vacuole*** is a membrane-bound structure that can store water, minerals, pigments, waste products, organic nutrients and other materials needed by a cell.

- Plant cells usually have one large, permanent, water-filled sac known as the 'large central vacuole'. This vacuole is surrounded by a membrane called the ***tonoplast***.

  The ***large vacuole*** of plants houses large amounts of a liquid called cell sap, composed of water, enzymes, inorganic ions (eg. chloride, calcium etc.), and other substances, including toxic by-products removed from the cytosol so they don't interfere with metabolic processes.

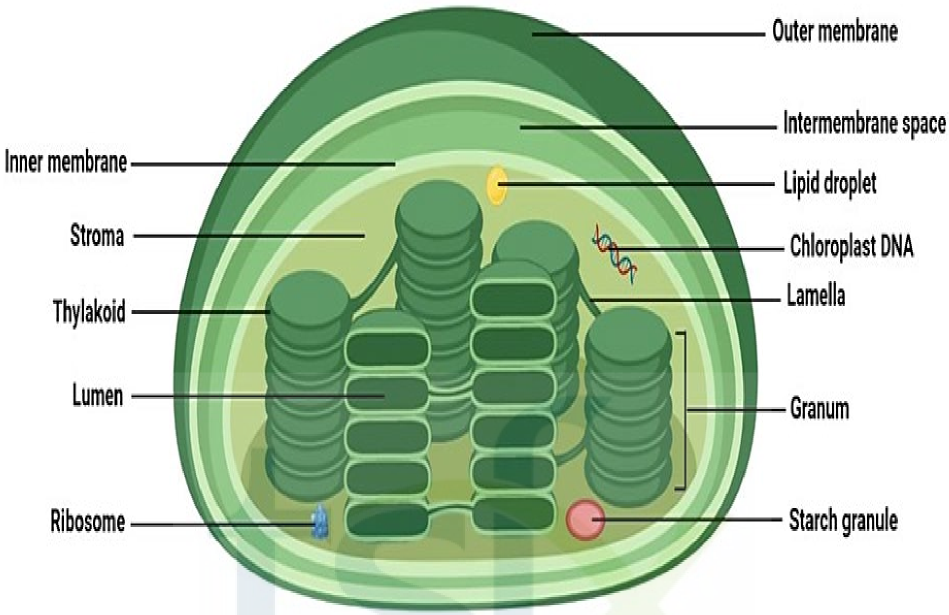


PLASTIDS

Plastids are major organelles found in the cells of plants and algae. They act as the site of manufacturing and storage of important chemical compounds used by the cell.

Plastids often contain pigments used in photosynthesis, and the types of pigments present can change or determine the cell's colour.

CHLOROPLASTS



- Chloroplasts are the sites of ***photosynthesis*** in many plant and protist cells.
- This organelle is bound by two membranes and contains its own DNA and ribosomes.
- Chloroplasts are filled with a green pigment called **chlorophyll.** This pigment is located on internal ***(thylakoid)*** membrane and the ***grana*** of the chloroplast.

  Grana are stacks of thylakoid discs that contain containing light absorbing pigments (chlorophyll, carotenoids, xanthophylls).
- Chlorophyll captures the energy of sunlight to produce carbohydrates that are then used by cells as a source of fuel.
- Chloroplasts divide in two by binary fission.

CELL WALLS

- The cell wall lies outside the cell membrane in plants, fungi, bacteria, and many protists.
- It is a rigid structure that gives support, strength and protection to cells.
- The cell wall varies in composition.

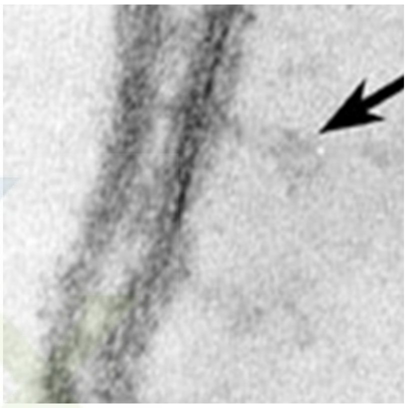
  Cellulose is found in the cell walls of plants and protists except for diatoms.

. Chitin is found in the cell walls of fungi.

  The cell walls of bacteria include a variety of carbohydrates as well as lipid and protein components (peptiglycan).

- Animal cells do not have cell walls.

A Cellulose Cell Wall



A Cell Membrane

CELL MEMBRANE OR PLASMA MEMBRANE

- Cell membranes are thin, flexible barriers that surround cells.
- They contain specific surface molecules allowing for self and non-self recognition.
- Cell membranes are semi-permeable and only allow certain particles to pass through. In this way, cell membranes regulate the movement of substances into and out of a cell.
- All cells have a cell/plasma membrane.

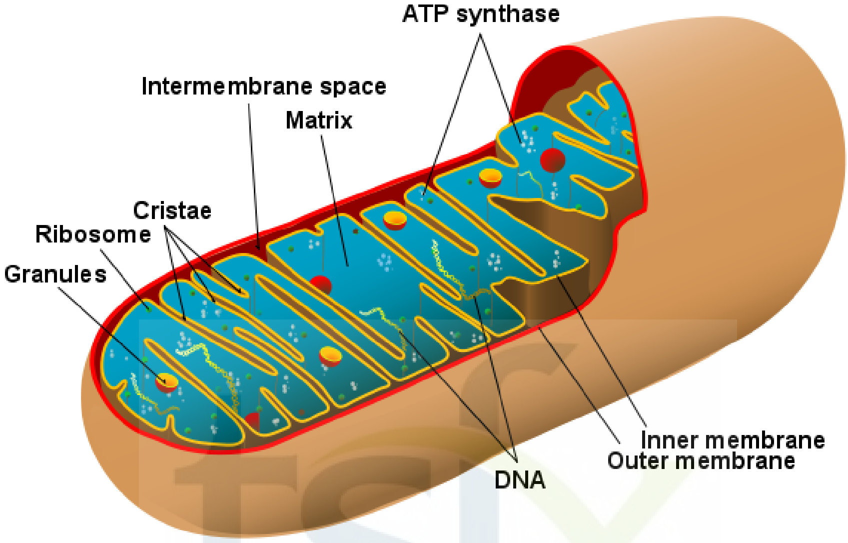
CYTOSOL

- This is the fluid component of the cell.
- The cytosol is composed mainly of water and includes dissolved chemicals (enzymes, nutrients, gases).

CYTOPLASM

- The cytoplasm is composed of cytosol, all organelles and other cell particles, ***except for the nucleus***.
- It is the site of cellular activities.
- Cytoplasm + Nucleus = ***Protoplasm***.

MITOCHONDRIA

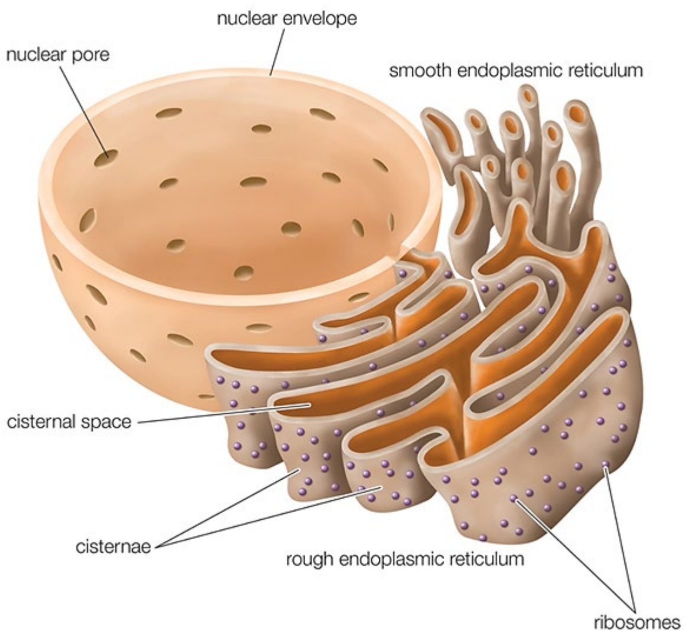


- The mitochondrion is the site for ***aerobic respiration***, providing energy for the cell in the form of ATP.
- It has a smooth outer membrane, a highly folded inner membrane (cristae), and fluid inside (matrix) containing enzymes for respiration.
- It has DNA and ribosomes and is found in high numbers in cells with high energy requirements.

RIBOSOMES

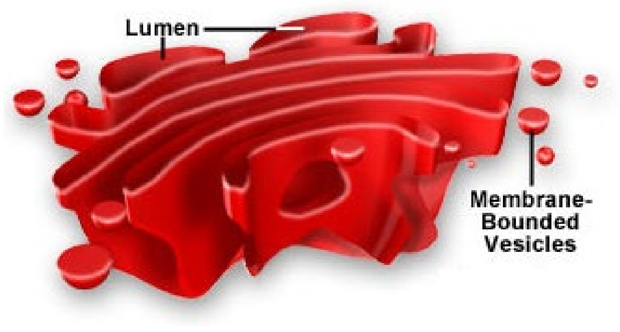
- Ribosomes are the organelles where ***protein synthesis*** occurs.
- They are found free in the cytoplasm (making protein for the cell) or attached to endoplasmic reticulum (making proteins for secretion to other parts of the body).

ENDOPLASMIC RETICULUM (ER)



- Endoplasmic reticulum (ER) is a network of membrane bound channels.
- These organelles process many substances such as proteins and lipids (fats).
- Rough ER has ribosomes attached to it and is involved in the synthesis and transport of proteins.
- Smooth ER isn't associated with ribosomes and is involved in the synthesis and transport of lipids.

GOLGI APPARATUS (BODY/COMPLEX)

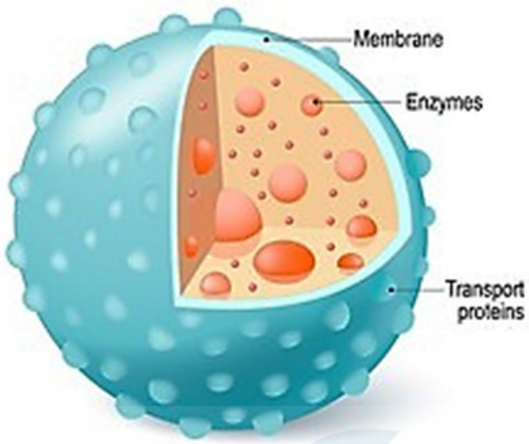


- The Golgi body is a flattened membrane bound sac that stores, packages and secretes cell products such as proteins, which it receives from the endoplasmic reticulum. It distributes these materials to both other parts of the cell and outside the cell.
- The release of contents occurs via ***exocytosis*** when vesicles bud from the membrane of the organelle.

VESICLES

- Vesicles are small fluid filled membrane bound structures found in the cytoplasm of cells.
- Their role is to carry substances in and out of cells and between organelles.

LYSOSOMES



- Lysosomes are formed by the golgi apparatus.
- They are membrane bound structures in the cytoplasm that contain digestive enzymes.
- Their role is to digest invading cells (causing cell death). For example, bacteria are consumed by lysosomes in white blood cells. They also digest worn out organelles and break down larger food particles into smaller ones.
- These organelles are considered to be the ‘recycling centres’ of cells.

DIFFERENCES BETWEEN PLANT AND ANIMAL CELLS

Despite many similarities between animal and plant cells, the following differences consistently exist:

- ***Cell walls (cellulose)*** are present in plants, but not animals.
- Plants contain ***plastids*** (rounded structures surrounded by a membrane). One major type of plastid is the chloroplast – a green plastid that contains chlorophyll.
- Plants have ***large permanent fluid filled vacuoles*** which provide support and storage of ions, pigments etc. Animal cells only have smaller and temporary vacuoles.

QUESTION 1
Complete the table below by summarising the structure and functions of the given organelles.

Organelle	Structure	Function
Mitochondria		
Chloroplasts		
Golgi Bodies		
Lysosomes		
Endoplasmic Reticulum		
Ribosomes		
Nucleus		
Nucleolus		
Cell Membrane		
Cell Wall		

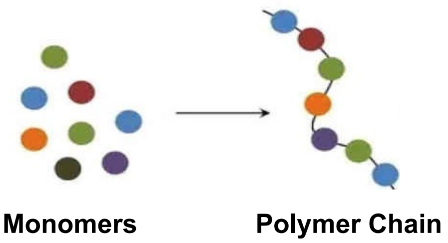
SECTION 2: THE RELATIONSHIP BETWEEN NUCLEIC ACIDS & PROTEINS

NUCLEOTIDES & NUCLEIC ACIDS

- ***Nucleic acids*** (DNA and RNA) store information that determines how organisms develop and function. They carry instructions for making proteins by determining the amino acid sequence of the protein produced at the ribosome.

- Nucleic acids are polymer chains that are made up of individual units called **nucleotides. i.e.**

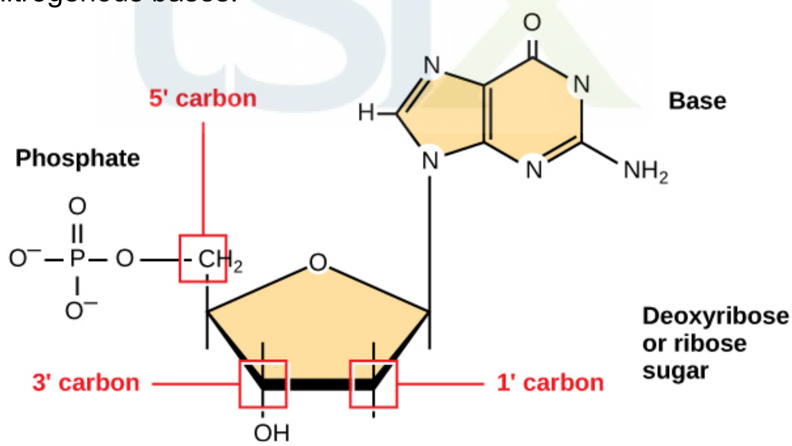
Nucleotides are the monomers of the nucleic acid polymer.



- **Nucleotides** are organic molecules that are made from carbon, hydrogen, oxygen, nitrogen (in the base) and phosphorus (in the phosphate group) i.e. ***CHONP***.

- Each nucleotide consists of the following:

  A phosphate group which is negatively charged.
  A pentose (5-carbon) sugar.
  One of four nitrogenous bases.



- The phosphate group joins to the sugar at the **5' carbon** whereases the nitrogenous base attaches to the sugar at the **1' carbon.**

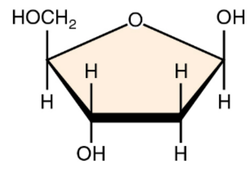
- Nucleotides can link together to form either RNA or DNA. Each time a nucleotide is added to a polynucleotide chain, a water molecule is produced, so these reactions are **condensation reactions.**

- Each polynucleotide has a backbone consisting of phosphates and sugars.
  One of **four** possible nitrogen-containing bases is attached to each sugar molecule.

DNA (DEOXYRIBONUCLEIC ACID)

DNA contains the genetic instructions for all living organisms. It determines all the characteristics of all living organisms, from hair colour, to sex, to the actual type of species under investigation. Its code is ***universal***.

A **gene** is a specific section of the DNA that makes up a chromosome. It is the code for a protein for a cellular function. A single DNA molecule can be very long and may be made of hundreds or thousands of genes.

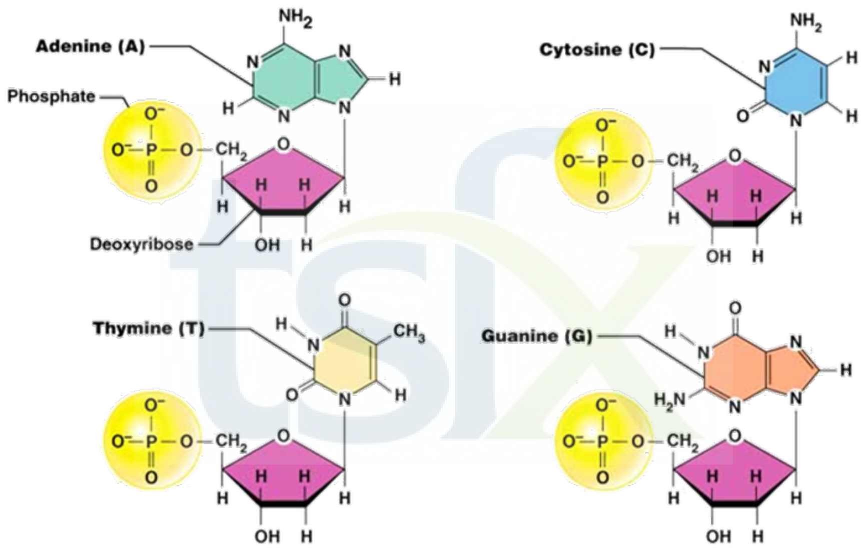


Deoxyribose (in DNA)

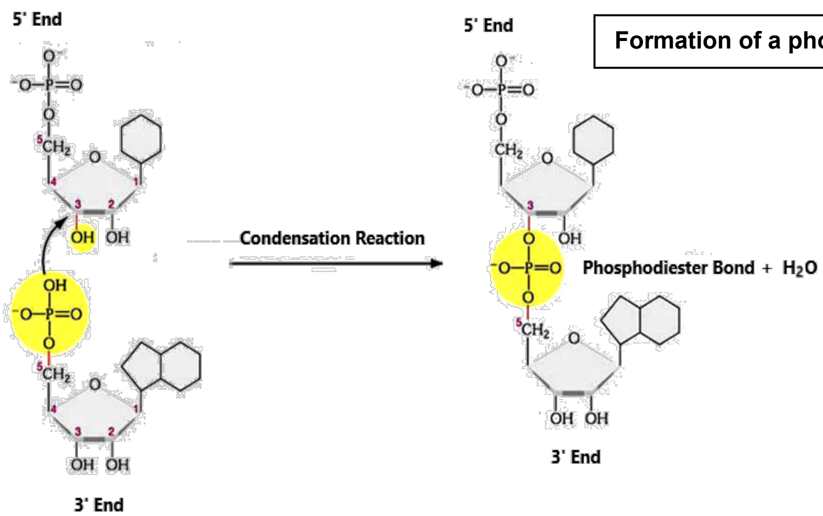
The DNA nucleotide is made up of three units:

- A **phosphate group** which is negatively charged.
- A pentose (5-carbon) sugar called ***deoxyribose.***
- One of the following four nitrogenous bases:

  Adenine (A), thymine (T), guanine (G), or ***cytosine (C).***



- The larger bases (adenine and guanine) are known as ***purines***, while the smaller bases (thymine and cytosine) are called ***pyrimidine*** bases.
- The DNA nucleotide subunits (sugar, base and phosphate) join together through strong covalent bonds known as the **phosphodiester** bond or link.



Formation of a phosphodiester bond

- These links are formed by condensation reactions between the 5’ phosphate group on one nucleotide and the 3’ hydroxyl group on the pentose of the next nucleotide.

- As polymerisation continues, a backbone of alternating sugar and phosphate groups is formed, with the nitrogenous bases pointing out from the backbone.

DNA NUCLEOTIDE BASE PAIRING

In 1953 James Watson and Francis Crick created a visual model of the chemical structure of DNA (which was partly based on Rosalind Franklins X-Ray Crystallography and Linus Paulings prior models) showing DNA as a **double helix.**

- **Each DNA molecule is made up of two nucleotide strands.**

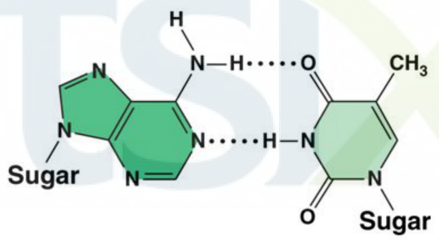
- The two nucleotide strands in DNA molecules are held together by **weak hydrogen bonds** between bases on each chain.

- **Only two base pairing combinations are possible in DNA:**

  Adenine (A) can bind with thymine (T) and visa versa.
  Guanine (G) can bind with cytosine (C) and visa versa.

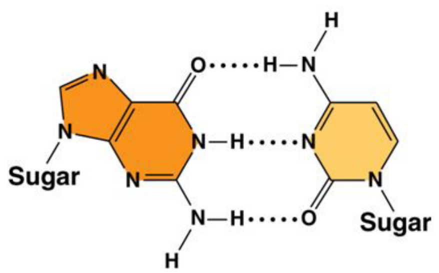
- This feature is known as ***complementary base pairing*** and is determined by the sizes of the bases. Only the given combinations result in the right dimensions to be able to bridge the two backbones of DNA.

- **Two hydrogen bonds** are formed between adenine and thymine.



Adenine (A) **Thymine (T)**

- **Three hydrogen bonds** are formed between guanine and cytosine.



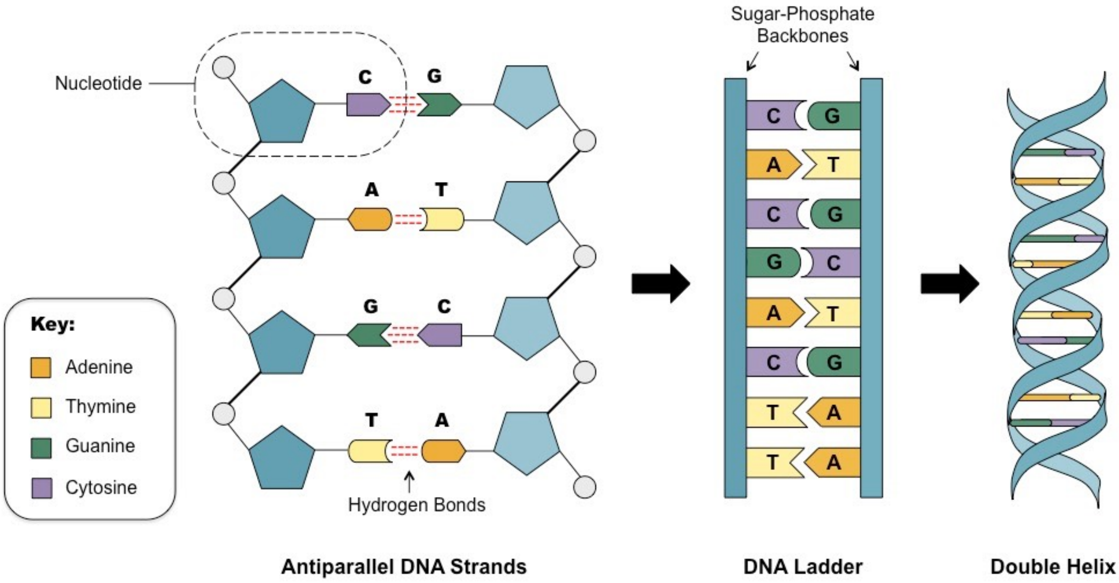
Guanine (G) **Cytosine (C)**

- The two nucleotide stands are aligned in opposite directions – one strand runs from 3’ to 5’ whereas the second strand runs from 5’ to 3’. We say that the nucleotide strands are ***antiparallel***.

3’ ———————————————————— **5’**

5’ ———————————————————— **3’**

- The end of the polymer chain with the **phosphate group** is called the **5' end** whereas the end containing the hydroxyl group is referred to as the 3' end.



- The nucleotide strands wind around one another to form a **double helix** containing around 10 nucleotide units per complete turn.

- If the order of bases on one DNA strand is known, the order of bases on the second strand can be determined using the complementary base pairing rules:

  Adenine (A) can bind with thymine (T) and visa versa.
  Guanine (G) can bind with cytosine (C) and visa versa.

  If the order of bases on one strand of DNA is: A A T G T C G
  Then the sequence of bases on the other strand will be: T T A C A G C

- Only one nucleotide strand in DNA is made up of **genes** (bases that code for characteristics of organisms). This strand is called the ***template strand***.
  The other strand is called the ***complementary*** or ***coding strand.***

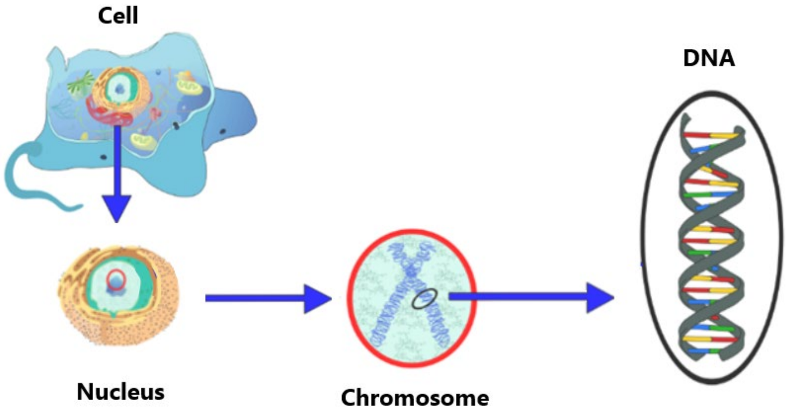
- DNA and RNA are always produced from the **template strand of DNA.**

- **Newly formed** DNA or RNA molecules are always synthesised in the ***5' to 3' direction***.

- The DNA of all living organisms is composed of the same four nucleotides. Each species of organism varies in the amount of DNA it contains, in its base sequences which create different genes, and in the base sequences within genes that might be common to other individuals of the same or different species (creating different alleles).

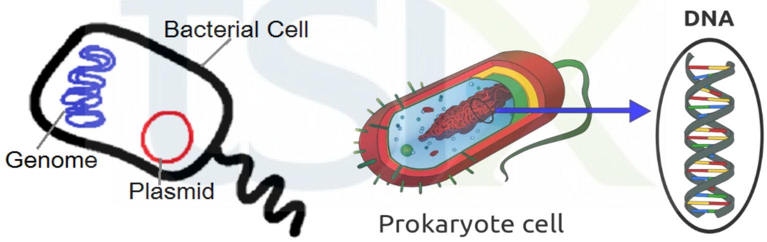
DNA IN EUKARYOTIC & PROKARYOTIC CELLS

- In **eukaryotic cells**, DNA is found within the nucleus, mitochondria, and chloroplasts. It is thought that the mitochondria and chloroplasts were once tiny prokaryotic cells that were engulfed by bigger eukaryotic cells, so they have their own free-floating circular chromosome.



Coding DNA in eukaryotes consists of chromosomes in a membrane bound nucleus

- In **prokaryotic cells** (bacteria) DNA is found in a ***single circular chromosome***. Bacteria also possess small circular rings of double stranded DNA called ***plasmids***.



DNA in prokaryotes consist of a chromosome and plasmids

- Plasmids are not chromosomes and replicate independently of chromosomes.
- The chromosomes contain the essential genes that allow the bacteria to function while the plasmid contains genes that can give it an advantage to survival.
- A plasmid can be used to carry genes from one organism to another.

QUESTION 2
Complete the following table.

SIMILARITIES & DIFFERENCES BETWEEN EUKARYOTIC & PROKARYOTIC DNA

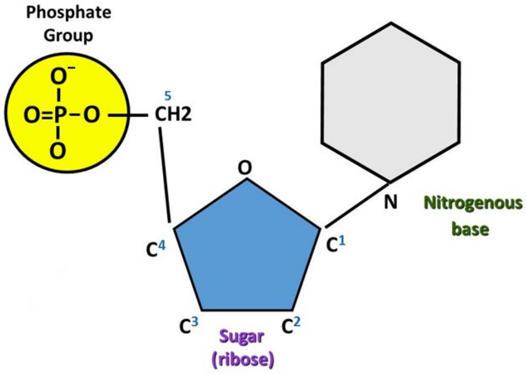
Criteria	Prokaryotes	Eukaryotes
Similarities		
Differences		

RNA (RIBONUCLEIC ACID)

- Ribonucleic acid (RNA) plays a major role in protein synthesis as it is involved in the transcription, decoding, and translation of the genetic code to produce proteins.

- Ribonucleic acid (RNA) is a ***single stranded*** nucleic acid made up of nucleotides similar to those of DNA, however, some differences exist.

- Although RNA is a single stranded structure it usually folds back upon itself, forming helices.

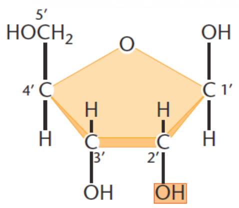


- Similar to the nucleotide monomers that make up DNA, each RNA nucleotide is made up of three units:

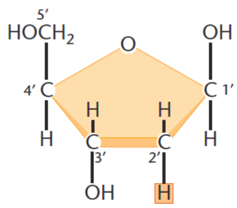
  (a) A **phosphate group** which is negatively charged.

  (b) A pentose (5-carbon) sugar called **ribose** instead of the sugar deoxyribose which is found in DNA nucleotides.

  Note the convention for numbering carbon atoms in sugars



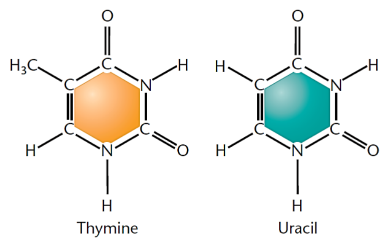
Ribose (in RNA)



Deoxyribose (in DNA)

  (c) One of four nitrogenous bases.

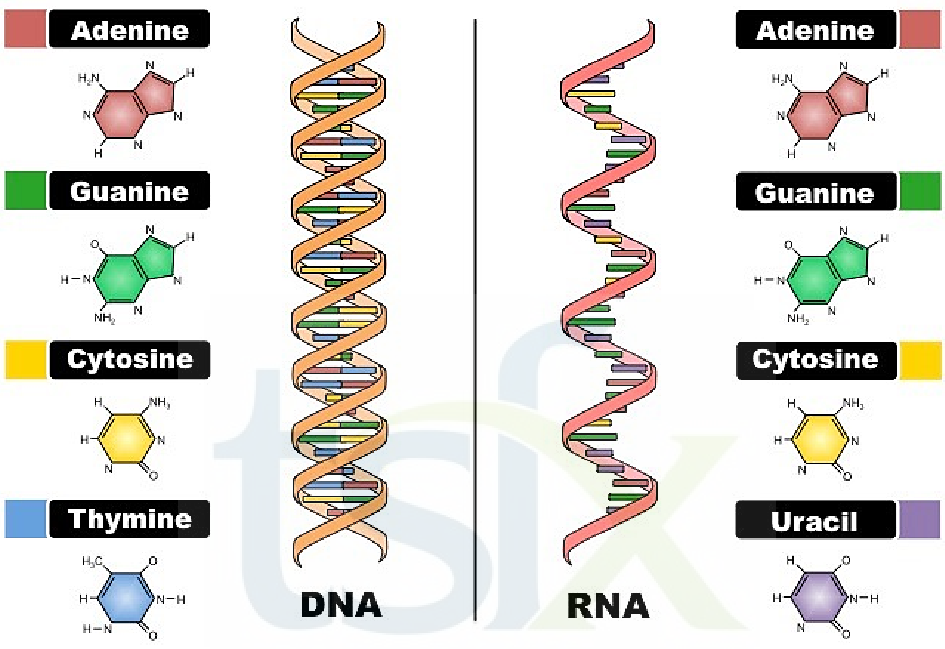
  Three of these bases are the same as those present in DNA, namely adenine, cytosine and guanine. The fourth nitrogenous base in RNA is called ***uracil.*** Uracil (U) is complementary to adenine (A) during transcription during RNA base pairing (whenever RNA pairs with another nucleic acid).



- RNA nucleotides join together in a series of condensation reactions to form long polymer chains.

- RNA molecules are produced from a DNA template during the transcription process. Each RNA molecule is complementary copy of one of the two strands of DNA that are being transcribed i.e. The RNA nucleotide sequence is complementary to the deoxyribonucleotide sequence of DNA that served as the template for their synthesis.

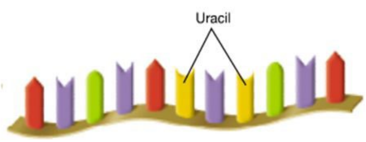
COMPARING THE STRUCTURES OF RNA & DNA



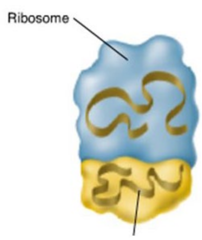
TYPES OF RNA INVOLVED IN PROTEIN SYNTHESIS

- There are different types of RNA that have different functions in a cell. The most common classes of RNA that also play a major role in protein production or gene expression include the following:

  Messenger RNA (mRNA)
  Ribosomal RNA (rRNA)
  Transfer RNA (tRNA)



Messenger RNA (mRNA)

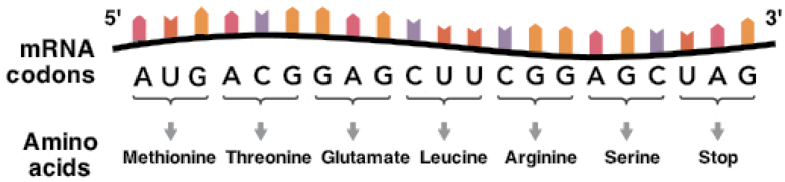


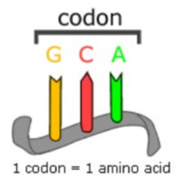
Ribosomal RNA (rRNA)

Transfer RNA (tRNA)

MESSENGER RNA (mRNA)

- Messenger RNA (mRNA) has the main role in ***transcription***, which is the first stage in protein synthesis.
- Messenger RNA molecules carry genetic information from the DNA of a gene to the ribosomes. In more specific terms, mRNA molecules carry a complementary copy of the sequence of codons that determine the order of amino acids in specific protein.
- This genetic information is contained within **DNA** genes in 3 nucleotide base **triplets** that code for a single amino acid. The base sequence of the transcribed **mRNA** is made up of 3 complementary nucleotide base **codons**.

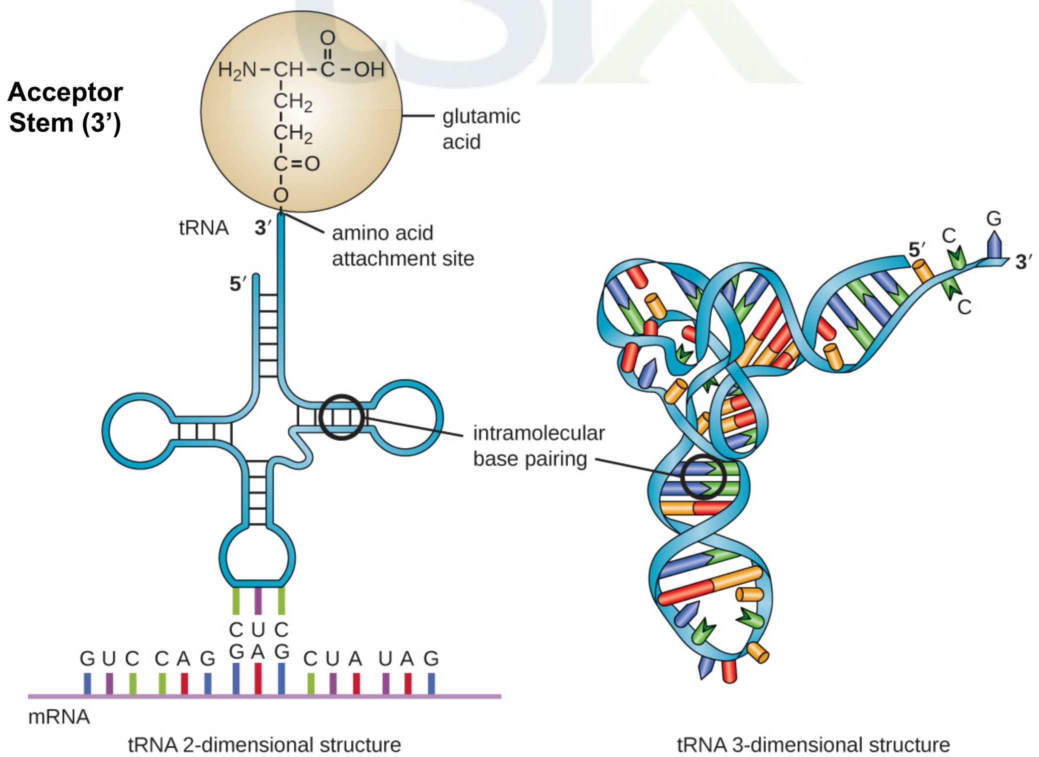




- Unlike DNA, mRNA can leave the nucleus after the completion of the transcription process. It then travels through the cytoplasm to the ribosomes where proteins are made.

TRANSFER (tRNA)

- **Transfer RNA (tRNA)** is responsible for supplying specific amino acids to the growing polypeptide chain at the ribosome and making sure the correct amino acids are presented in the correct order during the process of translation.



During protein construction, transfer RNA (tRNA) transfers amino acids to the ribosomes

- The top end (3' end) of tRNA matches the conformation of one of the 20 amino acids. This amino acid can therefore be covalently attached to the 3' end of this tRNA.

- Each amino acid has its own specific tRNA carrier molecule. i.e 20 different types of tRNA molecules are involved in the translation process.

- The 5' end of tRNA has the anticodon which is complementary to the codon representing the amino acid on the mRNA.

  For example:

  If the codon on the mRNA is AAU, then the anticodon on the tRNA is UUA.

- Complementary base pairing between tRNA anticodons and mRNA codons ensure that amino acids are joined in the correct order.

- Every tRNA carries only one specific type of amino acid. Each **tRNA** therefore has a specific 3 nucleotide base **anticodon** that is complementary to a codon on mRNA.

RIBOSOMAL RNA (rRNA)

- Ribosomal RNA (rRNA) forms the bulk of the structure of ribosomes, where proteins are synthesised during translation.

- Not only is rRNA the main building block of ribosomes and the site of protein synthesis, it plays a very large and important role in translation, holding the single stranded mRNA in place so the tRNA can match up its anticodon with the mRNA codon that codes for a specific amino acid.

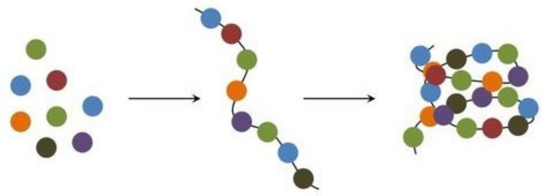
DNA VS RNA

SIMILARITIES & DIFFERENCES

	DNA	RNA
No. of Nucleotide Strands	Double stranded molecule	Single stranded molecule
Sugar	Deoxyribose	Ribose
Bases	Adenine, thymine cytosine, guanine	Adenine, uracil cytosine, guanine
Number of Different Types	One type of DNA	Many forms of RNA including mRNA, rRNA & tRNA
Type of Molecule	Polymer of Nucleotides	Polymer of Nucleotides
Structural Arrangement	Nitrogenous bases supported by a sugar-phosphate backbone	Nitrogenous bases supported by a sugar-phosphate backbone
Primary Function	Stores the genetic material of almost every living organism	Is the genetic material for some viruses
Functional Location	Nucleus	Cytosol
Reactivity	Chemically less reactive than RNA	Chemically more reactive than DNA
Stability	Structurally more stable than RNA	Structurally less stable than DNA
Size	Larger than RNA	Smaller than DNA
Elemental Composition	C, H, O, N, P	C, H, O, N, P

AMINO ACIDS & PROTEINS

PROTEINS



Proteins (and polypeptides) are condensation polymers of amino acids consisting of carbon, nitrogen, hydrogen, oxygen, and sometimes small quantities of sulfur.

Natural proteins are polymers that are based on combinations of 20 amino acids.

Twelve of these amino acids can be synthesised in the human body, the other eight must be supplied in the diet. These amino acids are therefore referred to as **essential amino acids.**

IMPORTANCE OF PROTEINS

Although their functions are diverse, the general role of proteins includes:

- The growth, maintenance and repair of tissue.
- The formation of tissues such as skin, blood, muscles, nerves, enzymes, antibodies and transport proteins.
- Proteins may also function as an energy source when carbohydrate and lipid stores have been depleted.
- Some, not all proteins act as biological catalysts known as **enzymes.**
- Protein is the only major nutrient that provides humans with a source of nitrogen, which is used to produce other proteins, DNA, tissue etc.

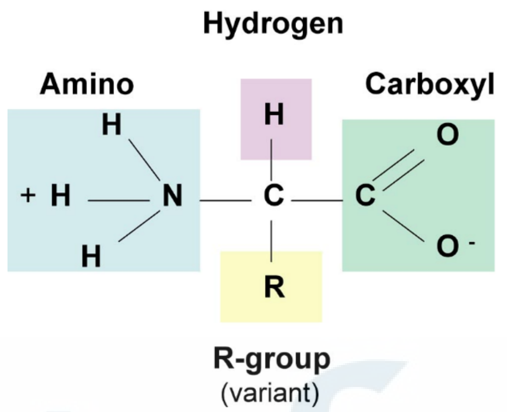
Note: As amino acids are not stored in the body, a regular protein intake is required.

AMINO ACIDS

The amino acid is made up of the following:

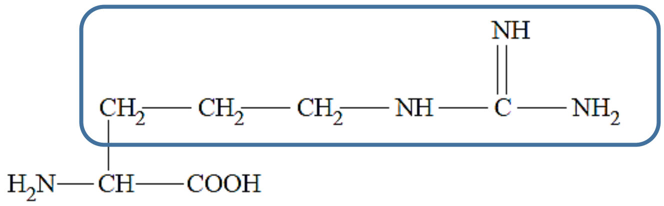
- An amino functional group (NH_2)
- A carboxyl functional group ($COOH$)
- An R group
- A H atom

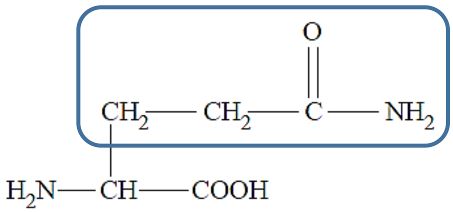
Each of these entities are attached to the same central carbon which is referred to as the carbon atom.

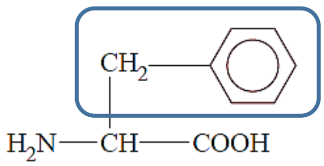


Differences between amino acids arise due to the different ‘R’ groups they contain. Since there are 20 biologically important amino acids, it follows that there are 20 different R entities. Examples include:

- Glycine (H_2NCH_2COOH) where $R = H$.
- Alanine $(H_2NCH(CH_3)COOH)$ where $R = CH_3$.







CLASSIFICATION OF AMINO ACIDS

Amino acids are classified according to their nutritional status (essential vs non-essential) and the polarity and structure of their R group. The different amino acid properties give variation in the folding and the final property of the protein.

Amino acids are divided into two broad groups:

- Those with a polar (hydrophilic) R group
- Those with a non-polar (hydrophobic) R group

R groups that are hydrophilic or polar are classified according to their acid/base behaviour, resulting in three groups:

- Polar & **Neutral** R Group
- Polar & **Acidic** R Group
- Polar & **Basic** R Group

*20 AMINO ACIDS IN THE HUMAN BODY (INFORMATION ONLY)

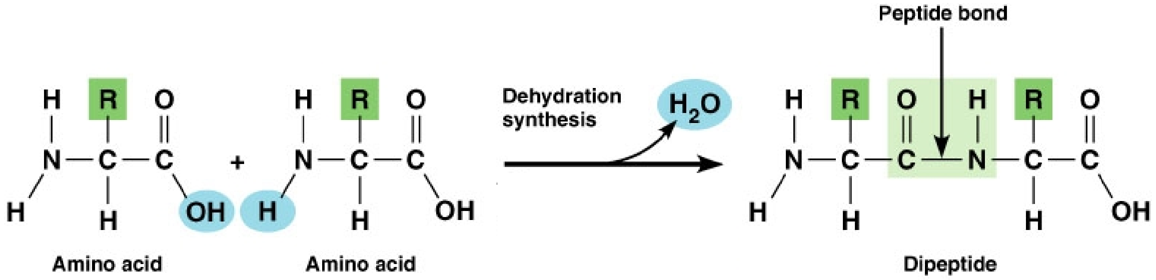
Type of Amino Acid	Amino Acid	Abbreviation
Nonpolar *(Hydrophobic – and tend to cluster on the inside of a protein molecule)*	Glycine	gly
	Alanine	ala
	Valine	val
	Leucine	leu
	Isoleucine	ile
	Methionine	met
	Phenylalanine	phe
	Tryptophan	trp
	Proline	pro
Polar *(Hydrophilic)*	Serine	ser
	Threonine	thr
	Cysteine	cys
	Tyrosine	tyr
	Asparagine	asn
	Glutamine	gln
Electrically Charged *(Acidic & hydrophilic)*	Aspartic Acid	asp
	Glutamic Acid	glu
Electrically Charged *(Basic & hydrophilic)*	Lysine	lys
	Arginine	arg
	Histidine	his

FORMATION OF PROTEINS & POLYPEPTIDES

Amino acids may be linked together to form long unbranched polypeptide chains via **condensation** reactions. Each time two amino acid molecules are joined together, one molecule of water is produced.

During the condensation process, a hydrogen atom is removed from the amino group of one amino acid, a hydroxyl group is removed from the carboxyl group of the second amino acid, and the resulting units are joined together via a covalent bond.

The bond linking amino acids ($CONH$ or CON) is referred to as a peptide link (or amide link) and is covalent in nature.



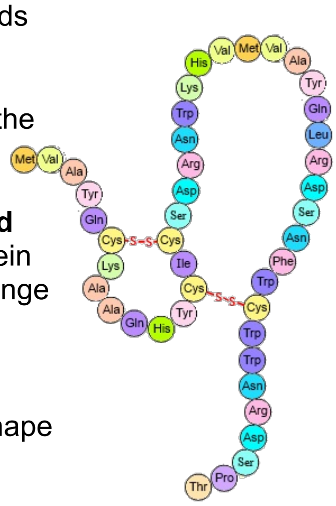
- Proteins differ in the number, type and arrangement of amino acids. Different ordering in amino acids results in different organic products.

PROTEIN STRUCTURE

The shape of a protein is described by four levels – the primary, secondary, tertiary and quaternary structures.

PRIMARY STRUCTURE

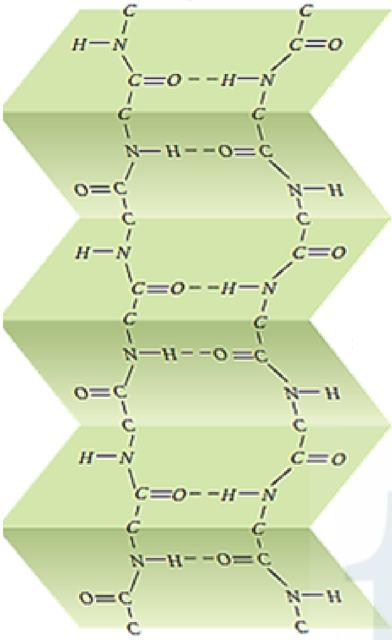
- The primary structure is the linear sequence (chain) of amino acids joined together in a specific order by peptide bonds.
- Amino acids are placed in the correct order by ribosomes under the coded instructions of DNA.
- The primary structure is critical in determining the **properties and function** of a protein. A change in just **ONE** amino acid in a protein sequence gives rise to a different protein and may result in a change in the function and biological activity of the protein, as well as an organism's chance for survival.
- The primary structure ultimately determines the 3-dimensional shape of a protein.



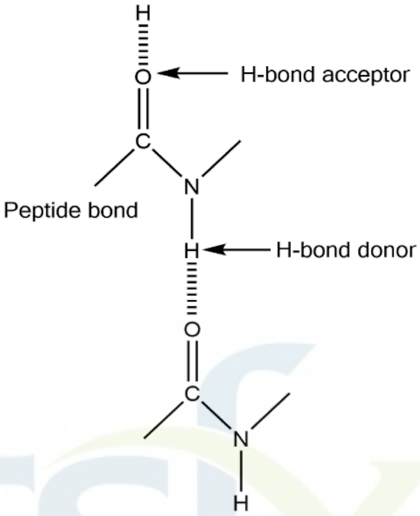
SECONDARY STRUCTURE

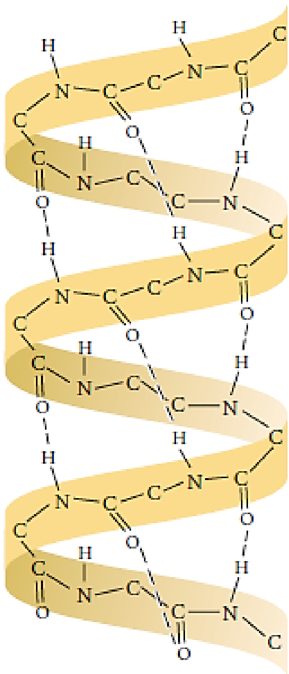
The properties of proteins not only depend on their sequence of amino acids, but also on their shape, which is described by the secondary and tertiary structures.

Within a protein chain there can be regions arranged into regular structures known as **alpha-helices** (alpha-helixes) and **beta-pleated sheets**. These are the **secondary structures** of proteins.



β **Pleated Sheet**





α **Helix**

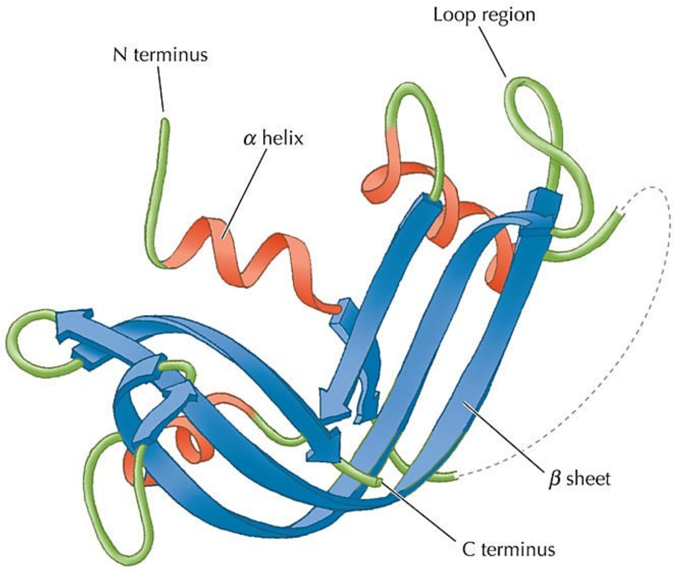
Secondary structures arise when chains of amino acids fold or turn upon themselves in regions maintained by ***hydrogen bonds***. They are formed along many points of the protein chain as the result of the repeating sequence of amino acids in a polypeptide chain.

- The ***alpha (α) helix*** are found in collagen, tissue, skin and cartilage. Haemoglobin and myoglobin are helical in some parts of their chains, but randomly orientated in others.

- The ***beta (ß) pleated sheet*** Hydrogen bonds form between parallel parts of the backbone & hold the structure together. Keratin and silk fibroin have secondary structures which are pleated sheets.

TERTIARY STRUCTURE

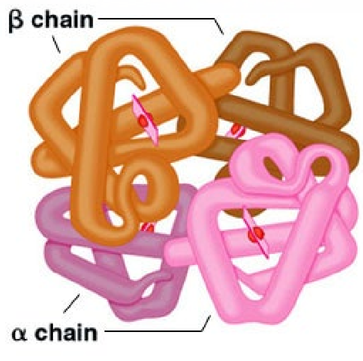
Other forces also contribute to maintaining the protein in a definite three-dimensional shape. These forces are the backbone of a protein's tertiary structure.



The tertiary structure describes the overall 3-dimensional functional shape of a protein and is unique to each different protein.

The tertiary structure is primarily maintained by interactions between the **'R' groups** of amino acids. The tertiary structure is determined by primary structure.

QUATERNARY STRUCTURE



Some proteins are composed of two or more polypeptide chains joined together. The interaction of these subunits forms the quaternary structure and involves hydrogen bonding, disulfide-bridges, hydrophobic interactions and ionic interaction (salt bridges).

Eg, Haemoglobin (4 chains), collagen (3 chains), antibodies (3 chains).