MODULE 4: PROTEINS AND NUCLEIC ACIDS

UNIT 1: PROTEINS AND THEIR STRUCTURES

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1.0 INTRODUCTION

Proteins vary both in structure and function. They are constructed from a set of 20 amino acids and have distinct three-dimensional shapes. The structure of a protein determines its function. For example, collagen has a super-coiled helical shape. It is long, stringy, strong, and resembles a rope. This structure is great for providing support. Hemoglobin on the other hand, is a globular protein that is folded and compact. Its spherical shape is useful for maneuvering through blood vessels. In this unit, we shall discuss the structures of proteins.

2.0 A: OBJECTIVES

By the end of this unit, you should be able to:

- Define proteins
- List the 20 amino acids found in proteins
- Distinguish the various types of proteins based on their structure

2.0 B: HOW TO STUDY THIS UNIT

1. You are expected to read carefully through this unit twice before attempting to answer the activity questions. Do not look at the solution or guides provided at the end of the unit until you are satisfied that you have done your best to get all the answers.

2. Share your difficulties in understanding the unit with your mates, facilitators and by consulting other relevant materials or internet.
3. Ensure that you only check correct answers to the activities as a way of confirming what you have done.
4. Note that if you follow these instructions strictly, you will feel fulfilled at the end that you have achieved your aim and could stimulate you to do more.

3.0 MAIN CONTENTS

3.1 Definition and Diversity of Proteins

When we look at a cell through a microscope or analyze its electrical or biochemical activity, we are, in essence, observing proteins. Proteins constitute most of a cell's dry mass.

They are not only the building blocks from which cells are built; they also execute nearly all cell functions. Thus, enzymes provide the intricate molecular surfaces in a cell that promote its many chemical reactions. Proteins embedded in the plasma membrane form channels and pumps that control the passage of small molecules into and out of the cell. Other proteins carry messages from one cell to another, or act as signal integrators that relay sets of signals inward from the plasma membrane to the cell nucleus. Yet others serve as tiny molecular machines with moving parts: kinesin, for example, propels organelles through the cytoplasm; topoisomerase can untangle knotted DNA molecules. Other specialized proteins act as antibodies, toxins, hormones, antifreeze molecules, elastic fibers, ropes, or sources of luminescence. Before we understand how genes work, muscles contract, nerves conduct electricity, how embryos develop, or how our bodies function, we must attain a deep knowledge of proteins.

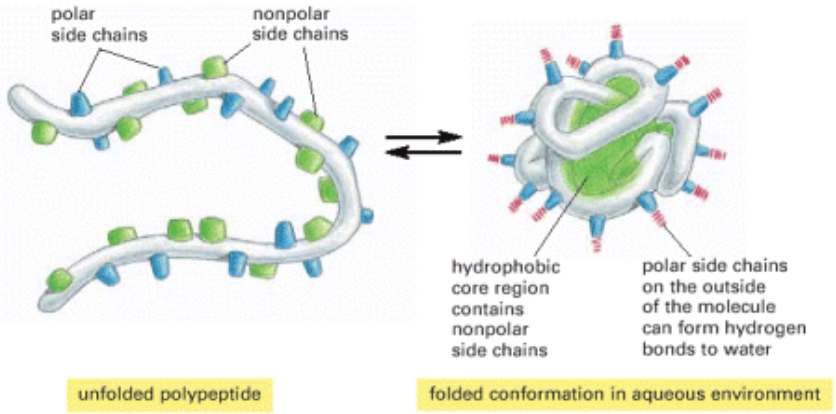


Fig.46 A peptide bond
(Source: Alberts, B., Johnson, A., Lewis, J. Raff, M. Roberts, K. and Walter, P. 2002).

How does a protein folds into a compact conformation? The polar amino acid side chains tend to gather on the outside of the protein, where they can interact with water; the nonpolar amino acid side chains are buried on the inside to form a tightly packed hydrophobic core of atoms that are hidden from water. The twenty essential amino acids are listed (Fig. 47).

AMINO ACID			SIDE CHAIN
Aspartic acid	Asp	D	negative
Glutamic acid	Glu	E	negative
Arginine	Arg	R	positive
Lysine	Lys	K	positive
Histidine	His	H	positive
Asparagine	Asn	N	uncharged polar
Glutamine	Gln	Q	uncharged polar
Serine	Ser	S	uncharged polar
Threonine	Thr	T	uncharged polar
Tyrosine	Tyr	Y	uncharged polar

POLAR AMINO ACIDS

AMINO ACID			SIDE CHAIN
Alanine	Ala	A	nonpolar
Glycine	Gly	G	nonpolar
Valine	Val	V	nonpolar
Leucine	Leu	L	nonpolar
Isoleucine	Ile	I	nonpolar
Proline	Pro	P	nonpolar
Phenylalanine	Phe	F	nonpolar
Methionine	Met	M	nonpolar
Tryptophan	Trp	W	nonpolar
Cysteine	Cys	C	nonpolar

NONPOLAR AMINO ACIDS

Fig. 47. The 20 amino acids found in proteins. Both three-letter and one-letter abbreviations are listed. As shown, there are equal numbers of polar and nonpolar side chains.
(Source: Alberts et al 2002).

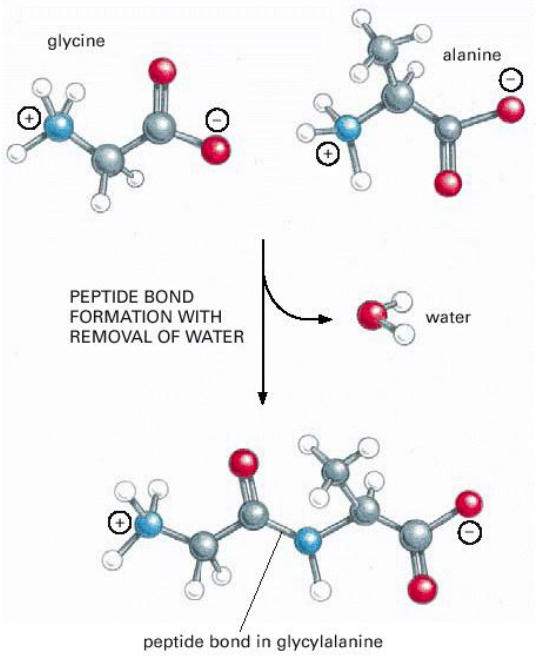


Fig. 48 A peptide bond. This covalent bond forms when the carbon atom from the carboxyl group of one amino acid shares electrons with the nitrogen atom (blue) from the amino group of a second amino acid. As indicated, a molecule of water is lost in this condensation reaction.
(Source: Alberts et al 2002).

3.2 Protein structure

Proteins are an important class of biological macromolecules present in all biological organisms, made up of such elements as carbon, hydrogen, nitrogen and oxygen. Some proteins contain sulphur in addition. All proteins are polymers of amino acids. The polymers, also known as polypeptides, consist of a sequence of 20 different L-α-amino acids, also referred to as residues. For chains under 40 residues the term peptide is frequently used instead of protein. To be able to perform their biological function, proteins fold into one, or more, specific spatial conformations (Fig. 46 and Fig. 48), driven by a number of noncovalent interactions such as hydrogen bonding, ionic interactions, Van Der Waals forces and hydrophobic packing. A number of residues are necessary to perform a particular biochemical function, and around 40-50 residues appear to be the lower limit for a functional domain size. Protein sizes range from this lower limit to several thousand residues in multi-functional or structural proteins. However, the current estimate for the average protein length is around 300 residues. Very large aggregates can be formed from protein subunits, for example many thousand actin molecules assemble into a microfilament. It is often necessary to determine the three dimensional structure of proteins.

3.2.1 Primary Structure

Primary structure of a protein refers to the sequence of amino acids in the chain.

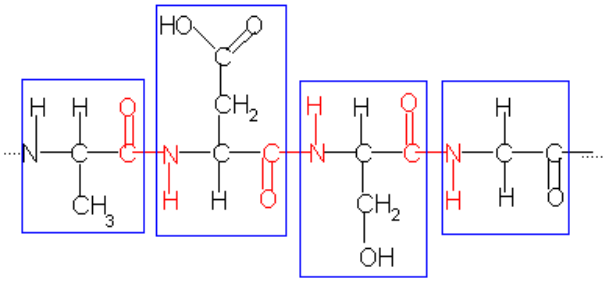


Fig. 49a: The primary structure of a protein.
(Source: Alberts et al 2002).

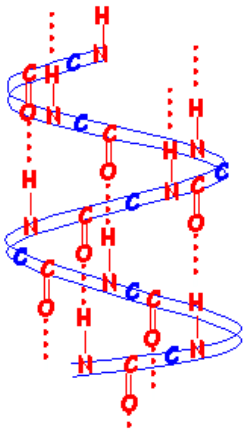
The boxes surround individual amino acids. The text shows the position of the peptide bonds (peptide or amide linkages) joining the amino acids together (Fig. 49). Proteins are made up of many amino acids, so a short-hand system has been developed to show the primary structure of proteins.

Fig. 49b
Source: Andrew Rader 1997

As proteins are being built, they begin as a straight chain of amino acids. This chain structure is called the primary structure. Sometimes chains can bond to each other with two sulfur (S) atoms. Those bonds would be called a disulfide bridge.

3.2.2 Secondary Structure

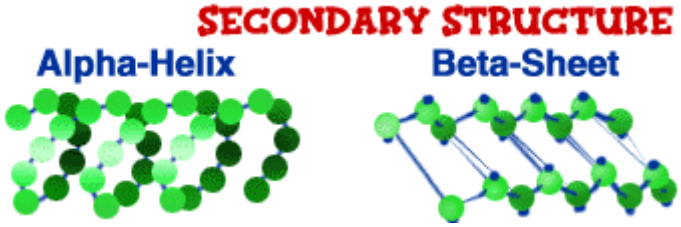
Secondary structure of a protein is the shape of the protein molecule caused by hydrogen-bonding between -C=O and -N-H groups within the chain, the two main shapes are α helix and β sheet (Fig. 50 and 51).



(a)

Fig. 50: Schematic diagram of an α helix such as is found in wool fibres.
(Source: Alberts et al., 2002).

The red dotted lines show the hydrogen bonds between amino acids along the chains maintaining the helical structure.



(b) (c)

Fig. 50 (Source: Andrew Rader 1997)

After the primary structure comes the secondary structure. The original chain begins to twist. It is as if you take a piece of string and twist one end. It slowly begins to curl up. In the amino acid chain, each of the amino acids interacts with the others and it twists like a corkscrew or a flat folded sheet.

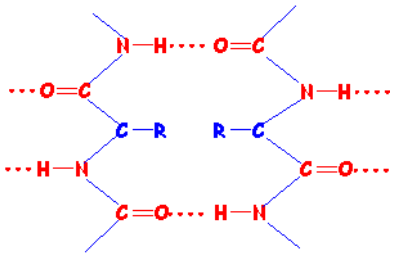


Fig. 51: Schematic diagram of a β sheet such as is found in silk.
(Source: Alberts et al., 2002).

The red dotted lines show the hydrogen bonds between amino acids along the chains maintaining the sheet structure.

3.2.3 Tertiary Structure

Tertiary structure of a protein is the folding and bending of the protein molecule caused by interaction of the R groups. This interaction may be a result of hydrogen bonding, dipole-dipole interactions, covalent bonding or ionic bonding (salt bridges) depending on the polarity of the R groups. The -SH group in cysteine (Cys) can form disulfide links, -C-S-S-C- , between neighbouring groups in the presence of an oxidant (Fig. 52).

(a) (b)

Fig. 52 Two representations of parts of protein molecules showing disulfide bonds (disulfide links) in blue resulting in the molecule folding and bending.
(Source: Alberts et al 2002).

(c)
Fig. 52 (Source: Andrew Rader 1997)

Let us move on to the tertiary structure of proteins. By now you are getting the idea that proteins do a lot of folding and twisting. The third step in the creation of a protein is the tertiary structure when the amino acid chains begin to fold even more and bond using more bridges (the disulfide bridges).

3.2.4 Quarternary Structure

Quarternary structure of a protein is the interactions between protein subunits that result in the protein being classified as fibrous, globular or conjugated.

Fig. 53
(Source: Andrew Rader 1997)

We can finally cover the quaternary structure of proteins. Quaternary means four. This is the fourth phase in the creation of a protein. In the quaternary structure, several amino acid chains from the tertiary structure fold together in a blob. They wind in and out of each other. You heard it right. Blob is the scientific term.

4.0 CONCLUSION

As diverse as proteins are, a protein is determined by the sequence of its amino acids, the more complex the structure, the tougher is the protein.

5.0 SUMMARY

In this unit we have learnt that:

- Proteins are the building blocks of cells

- A protein is a natural polymer, made up of amino acid monomers joined together by peptide bonds (peptide or amide linkages).
- Proteins are made up of: carbon, hydrogen, oxygen, nitrogen and some proteins contain sulfur.
- A peptide bond (peptide or amide linkage) is a covalent bond formed between the carbon of the carboxyl group of one amino acid and the nitrogen of the amine group of another amino acid.
- There are four types of protein structure:
- Primary structure is the sequence of amino acids in the chain.
- Secondary structure is the shape of the protein molecule caused by hydrogen-bonding between -C=O and -N-H groups within the chain.
- Tertiary structure is the interaction between R-groups that causes folding and bending.
- Quarternary structure: interactions between protein subunits that result in the protein being classified as fibrous, globular or conjugated.

6.0 TUTOR MARKED ASSIGNMENT

1. Define proteins and list the 20 amino acids found in proteins.
2. Distinguish between the primary, secondary, tertiary, and quaternary structures of a protein?

7.0 Further Reading and Other Resources

Pelczar, M.J., Chan, E.C.S. & Krieg, N.R. (1986).*Microbiology*, International Edition, McGraw Hill International editions.ISBN 0-07-Y66494-3.

Snyder, L. &Champness, W. (2003).Molecular Genetics of Bacteria, Second Edition, Washington, D.C. 566 pp.

UNIT 2: TYPES AND FUNCTIONS OF PROTEINS

1.0 Introduction
2.0 A Objectives
2.0 B How to Study this Unit
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- 3.1 Protein Composition
- 3.2 Examples of Protein and Their Functions
  - 3.2.1 Antibodies
  - 3.2.2 Contractile Proteins
  - 3.2.3 Hormonal Proteins
  - 3.2.4 Structural Proteins
  - 3.2.5 Storage Proteins
  - 3.2.6 Transport Proteins
  - 3.2.7 Enzymes
- 3.3 The Four steps of an Enzyme reaction and Denaturation

4.0 Conclusion
5.0 Summary
6.0 Tutor Marked Assignment
7.0 Further Reading and Other Resources

1.0 INTRODUCTION

In unit 1, we learnt that proteins constitute most of the cells, therefore proteins are building blocks. Proteins are very important molecules in the cells of our body. They are involved in virtually all cell functions. Each protein within the body has a specific function. Some proteins are involved in structural support; others are involved in bodily movement, or in defense against germs. In this unit, we shall discuss the different proteins and their functions.

2.0 A OBJECTIVES

By the end of this unit, you should be able to:

- State the various types of proteins
- Know their functions
- Define enzyme
- Justify protein as enzymes

2.0 B: HOW TO STUDY THIS UNIT

1. You are expected to read carefully through this unit twice before attempting to answer the activity questions. Do not look at the solution or guides provided at the end of the unit until you are satisfied that you have done your best to get

all the answers.
2. Share your difficulties in understanding the unit with your mates, facilitators and by consulting other relevant materials or internet.
3. Ensure that you only check correct answers to the activities as a way of confirming what you have done.
4. Note that if you follow these instructions strictly, you will feel fulfilled at the end that you have achieved your aim and could stimulate you to do more.

3.0 MAIN CONTENTS

3.1 Protein Composition

As discussed in unit 5, you were told that proteins are organic macromolecules made up of linear chains of amino acids. However, while a protein's basic structure is a linear amino acid chain, the final structure of a protein is not linear. Instead, the protein's amino acid sequence and the physical and chemical properties of the amino acids and of the entire protein molecule influence how it folds into a three dimensional shape. The amino acid sequence of a protein is determined by the base pair sequence in the gene which codes for the protein.

3.2 Examples of Protein and Their Functions

3.2.1 Antibodies

Antibodies (also called immunoglobulins) are specialized proteins involved in defending the body from antigens (foreign invaders). One way antibodies destroy antigens is by immobilizing them so that they can be destroyed by white blood cells. Antibodies are present in the blood serum, tissue fluids and mucosal surfaces of vertebrate animal.

3.2.2 Contractile Proteins

Contractile proteins are responsible for movement. Examples include actin and myosin. These proteins are involved in muscle contraction and movement.

3.2.3 Hormonal Proteins

Hormonal proteins are messenger proteins which help to coordinate certain bodily activities. Examples include insulin, oxytocin, and somatotropin. Insulin regulates glucose metabolism by controlling the blood-sugar concentration. Oxytocin stimulates contractions in women during childbirth. Somatotropin is a growth hormone that stimulates protein production in muscle cells.

3.2.4 Structural Proteins

These proteins are less 'active' than those involved in catalyzing reactions or those signaling cells, and transporting molecules, but are no less important. They confer strength and rigidity to biological components which would otherwise be unable to support themselves. They tend to have very specific shapes. They are long, thin fibers or other shapes which, when allowed to form polymers, provide strength and support. They are essential components of collagen, cartilage, nails and hair, feathers, hooves, and other such structure.

They are also essential components of muscles, and are necessary to generate the force which allows muscles to contract and move. They are fibrous and stringy and provide support. Examples include keratin, collagen, and elastin.

Keratins strengthen protective coverings such as hair, quills, feathers, horns, and beaks. Collagens and elastin provide support for connective tissues such as tendons and ligaments.

3.2.5 Storage Proteins

Storage proteins store amino acids. Examples include ovalbumin and casein. Ovalbumin is found in egg whites and casein is a milk-based protein.

3.2.6 Transport Proteins

Proteins are also involved in molecular transport of cells. Transport proteins are carrier proteins which move molecules from one place to another around the body. Examples include haemoglobin and cytochromes. Haemoglobin transports oxygen through the blood. Hemoglobin binds iron molecules and transports them in the blood from the lungs to organs and tissues throughout the body. Cytochromes operate in the electron transport chain as electron carrier proteins.

3.2.7 Enzymes

The function of proteins as enzymes is perhaps their best known function. Enzymes are proteins that facilitate biochemical reactions. They are often referred to as organic catalysts because they speed up chemical reactions. Examples include lactase and pepsin. Lactase breaks down the sugar lactose found in milk. Pepsin is a digestive enzyme that works in the stomach to break down proteins in food. The enzyme, however, is itself unchanged at the end of the reaction. Enzymes are responsible for catalyzing reactions in processes such as metabolism, DNA replication, and food digestion. In fact, enzymes are known to be involved in some 4,000 bodily reactions.
Enzymes and their substitutes are similar to locks and keys. When a door is locked can it open itself? No. You need a key that is just the right shape to fit in that lock.

Enzymes work in a similar way. Enzymes complete very specific reactions and do nothing else. They are very specific locks and the substrates they work with are the special keys (Fig. 54). In the same way there are door keys, car keys, and bike-lock keys, there are enzymes for neural cells, intestinal cells, and even in our saliva.

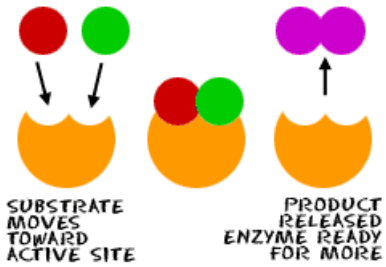

Fig. 54 (Source: Pelczar M.J. et al., 1986 Microbiology. McGraw-Hill International Editions)

3.3 The Four steps of an Enzyme reaction and Denaturation

1. An enzyme and a substrate are in the same area. The substrate is the biological molecule that the enzyme attacks.
2. The enzyme gets onto the substrate with its own special area called the active site. The active site is a specially shaped area of the enzyme that fits around the substrate. The active site is the keyhole of the lock.
3. A process called catalysis happens. Catalysis is when the substrate is changed. It could be broken down or combined with another molecule to make something new. The substrate is no longer the same. The substrate is now called the product.
4. The enzyme reverts to its former state and it is, ready to carry out another reaction.

Can the catalytic actions of enzymes be stopped?
Good question! We know what you are thinking. What if enzymes just kept going and converting every molecule in the world? They would never stop…. like a monster! There are many factors that can regulate enzyme activity. They include temperature, activators, pH levels, inhibitors, substrate concentration etc.

If the pH, salt concentration, temperature or other aspects of enzyme environment are altered, the protein as enzymes may unravel and lose its native conformation, a changed called denaturation (Fig. 55). The denatured protein becomes biologically inactive if the factor is high temperature (Fig. 55). The heat agitates (affects0 the polypeptide chain enough to overpower the weak interactions that stabilize conformation.

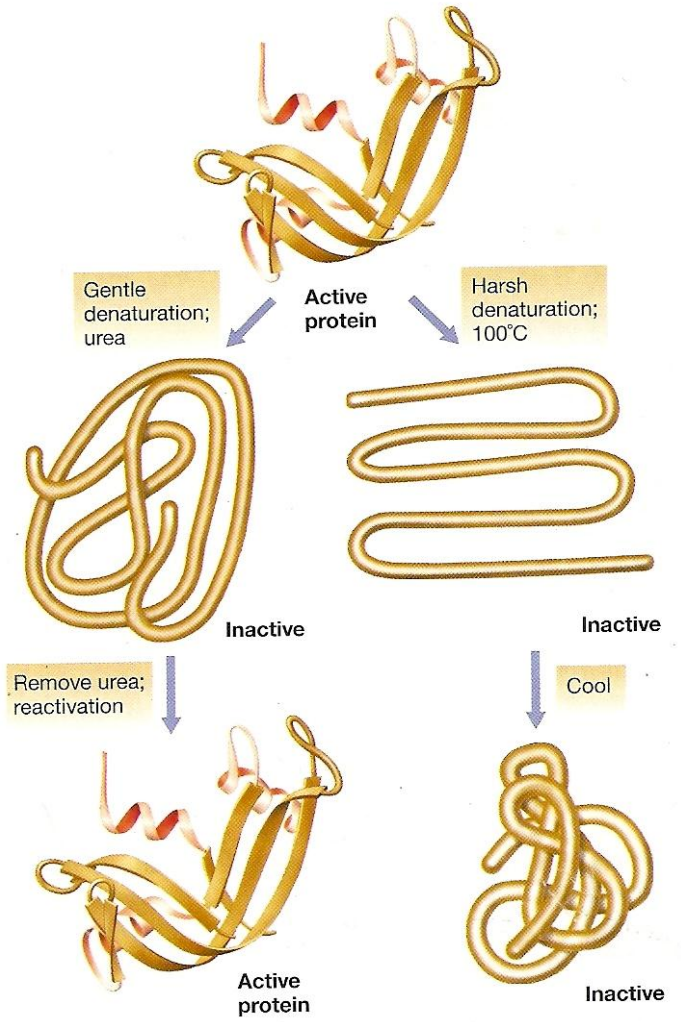

Fig. 55: Protein Denaturation
(Source: Madigan, M.T., et al., 2009 Brock Biology of microorganisms. 12th edition. Pearson International Edition).

4.0 CONCLUSION

Proteins are diverse in functions and they carry out fundamental and basic cellular actions that affect life.

5.0 SUMMARY

In this unit we have learnt that:

- Proteins are of different types.
- Proteins serve various functions in the body.
- Enzymes are proteins and are specific in actions.
- Proteins are required for building and repair of body tissues (including muscle)

- Proteins, like most other essential nutrients, absolutely crucial for overall good health.
- Proteins can be denatured

6.0 Tutor Marked Assignment

1. With examples and their locations in the human body, describe the different proteins that you have studied.
2. What are enzymes? Justify proteins as enzymes.

7.0 FURTHER READING AND OTHER RESOURCES

Pelczar, M.J., Chan, E.C.S. & Krieg, N.R. (1986).*Microbiology*, International edition, McGraw Hill International editions.918pp.ISBN 0-07-Y66494-3.

Snyder, L. &Champness, W. (2003).Molecular Genetics of Bacteria, Second Edition, Washington, D.C. 566.

Madigan, M.T., Martinko, J.M., Dunlap, P.V., & Clark, D.P. (2009).Brock Biology of Microorganisms.12th edition.Pearson International Edition.

UNIT 3: PROTEIN SYNTHESIS

Contents

1.0 Introduction
2.0 A Objectives
2.0 B How to Study this Unit
3.0 Main Contents
3.1 The Basis for Protein Synthesis
3.1.1 The Central Dogma and Transcription
3.1.2 Translation
4.0 Conclusion
5.0 Summary
6.0 Tutor Marked Assignment
7.0 Further Reading and Other Resources

1.0 INTRODUCTION

Can you still recollect our earlier discussion on the two nucleic acids, DNA and RNA? In module 3 unit 2, references were made to them. It is also important for you to know that genes are the instructions for making specific proteins. However a gene does not build a protein directly. The bridge between genetic information and protein synthesis is the RNA. Thus RNA, DNA and proteins contain information written in two different chemical languages; transcription and translation. They will form the bases of our discussion.

2.0 A: OBJECTIVES

By the end of this unit, you should be able to:

- Identify the two chemical languages in which genetic information is written.
- Describe transcription
- Explain translation

2.0 B: HOW TO STUDY THIS UNIT

1. You are expected to read carefully through this unit twice before attempting to answer the activity questions. Do not look at the solution or guides provided at the end of the unit until you are satisfied that you have done your best to get all the answers.
2. Share your difficulties in understanding the unit with your mates, facilitators and by consulting other relevant materials or internet.
3. Ensure that you only check correct answers to the activities as a way of confirming what you have done.
4. Note that if you follow these instructions strictly, you will feel fulfilled at the end that you have achieved your aim and could stimulate you to do more.

3.0 MAIN CONTENTS

3.1 The Basis for Protein Synthesis

The genetic information stored in DNA molecules is used as a blueprint for making proteins. Why proteins? Because these macromolecules have diverse primary, secondary and tertiary structures that equip them to carry out the numerous functions necessary to maintain a living organism. As noted in unit 2, these functions include:

- Structural integrity (hair, horn, eye lenses etc.)
- Molecular recognition and signaling (antibodies and hormones)
- Catalyses of reactions (enzymes)
- Molecular transport (hemoglobin transports oxygen)
- Movement (pumps and motors)

The critical importance of proteins in life processes is demonstrated by numerous genetic diseases, in which small modifications in primary structure produce debilitating and often disastrous consequences. Such genetic diseases include Tay-sachs, phenylketonuria (PKU), sickle cell anemia, achondroplasia and Parkinson disease. Transcription and translation are two important processes that lead to the synthesis of proteins.

3.1.1 The Central Dogma and Transcription

Francis Crick proposed that information flows from DNA to RNA in a process called transcription, and is then used to synthesize polypeptides by a process called translation. Transcription takes place in a manner similar to DNA replication. Characteristic sequence nucleotides marks the beginning of a gene on the DNA strand, and this region binds to a promoter protein site, and one of the strands serves as a template for RNA formation, as depicted in the following diagram (Fig. 56). The RNA molecule thus formed is single stranded, and serves to carry information from DNA to the protein synthesis machinery called ribosome. These RNA molecules are therefore called messenger –RNA (mRNA).

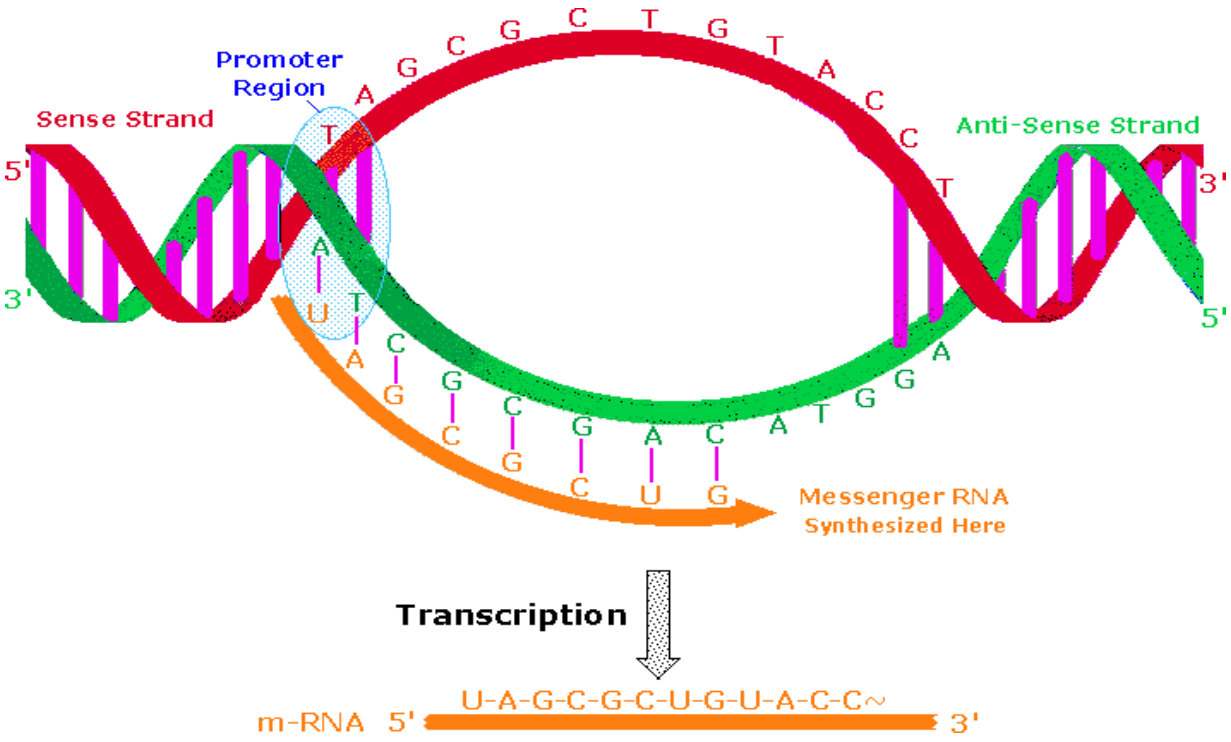

Fig. 56: Transcription
(Source: Ursula Goodenough, 1978, Genetic, 2nd Edition)

An important distinction must be made here. One of the DNA strands in the double helix holds the genetic information used for protein synthesis. This is called the sense strand, or information strand (colored red above). The complementary strand that binds to the sense strand is called the anti-sense strand (colored green), and it serves as a template for generating an mRNA molecule that delivers a copy of the sense strand information to a ribosome. The promoter protein binds to a specific nucleotide sequence that identifies the sense strand, relative to the anti-sense strand. RNA synthesis is the initiated in the 3' direction, as nucleotide triphosphates bind to complementary bases on the template strand, and are joined by phosphate diester linkages. A characteristic "stop sequence" of nucleotides terminates the RNA synthesis. The messenger molecule (colored orange, Fig. 56) is released into the cytoplasm to find a ribosome, and the DNA then rewinds to its double helix structure.

The central dogma of molecular biology, which at first was formulated as a simple linear progression of information from DNA to RNA protein, is summarized in the following illustration (Fig. 57). The replication process on the left consists of passing information from a parent DNA molecule to an mRNA molecule. Finally, this information is used by the chemical machinery of the ribosome to make polypeptides.

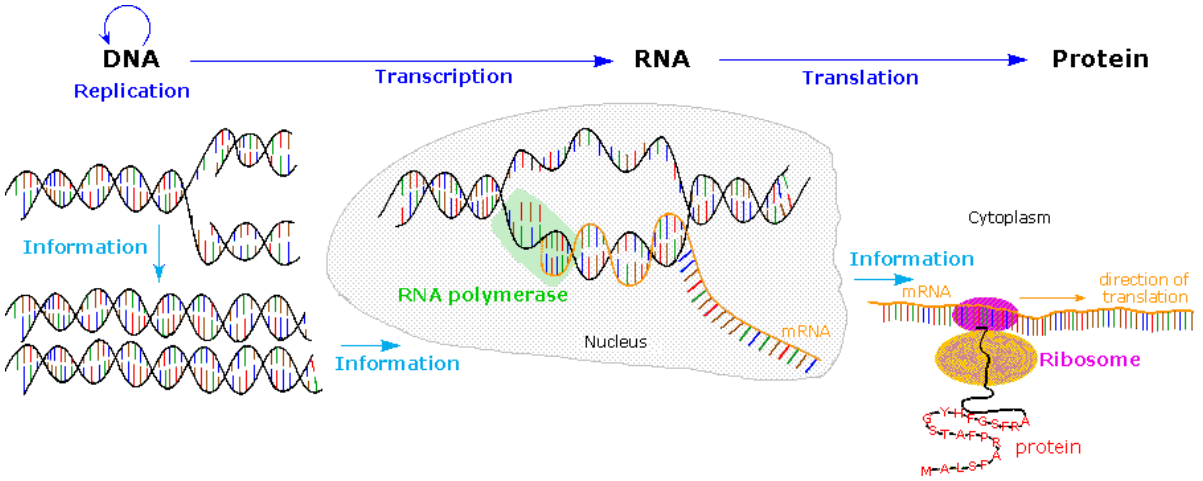

Fig. 57: Replication, transcription and translation.
(Source: William Reusch, 1999)

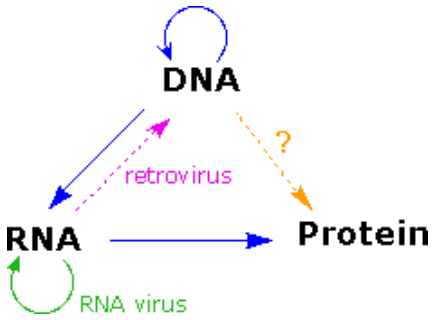

Fig. 58: A molecular chain of command: DNA-RNA-protein
(Source: William Reusch, 1999)

As more has been learned about these relationships, the central dogma has been refined to the representation displayed on the right. The dark blue arrows show the general, well demonstrated, information transfers noted above. It is now known that RNA-dependent DNA polymerize enzyme, known as a reverse transcriptase, is able to transcribe a single-stranded RNA sequence into a double-stranded DNA (figure.58) (magenta arrow). Such enzymes are found in all cells and are an essential component of retroviruses (e.g. HIV), which require RNA replication of their genomes (green arrow). Direct translation of DNA information into protein synthesis (orange arrow) has not yet been observed in a living organism. Finally, proteins appear to be an informational dead end, and do not provide a structural blueprint for either RNA or DNA. In the following section the last fundamental relationship, that of structural information, translation from mRNA to protein, will now be described.

3.1.2 Translation

This is the actual synthesis of a polypeptide that occurs under the direction of mRNA. Translation is a more complex process than transcription. This would, of course, be

expected. DNA replication is simply a complementary base pairing exercise, but the translation of four letter (bases) alphabet code of RNA to the twenty letter (amino acids) alphabet of protein literature is far from trivial. Clearly, there could not be a direct one-to-one correlation of bases to amino acids, so the nucleotide letters must form short words or codons that define specific amino acids.

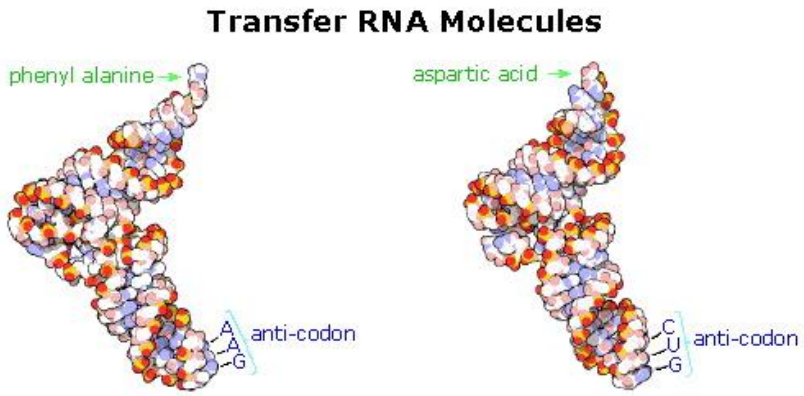

Fig. 59 transfer RNA molecules
(Source: William Reusch, 1999)

The translation process is fundamentally straight forward. The mRNA strand bearing the transcribed code for synthesis of a protein interacts with relatively small RNA molecules (about 70-nucleotides) to which individual amino acids have been attached by an ester bond at the 3'-end.

These transfer RNA's (tRNA) have distinctive three dimensional structure (Fig. 59) consisting of loops of single-stranded RNA connected by double stranded segments. This cloverleaf secondary structure is further wrapped into an "L-shaped" assembly, having the amino acids at the end of one arm, and a characteristic anti-codon region at the other end. The anti-codon consists of a nucleotide triplet that is the complement of the amino acids codon(s). Models of two such tRNA molecules are shown to the right. When read from the top to bottom, the anti-codons depicted here should complement a codon in the previous table (Fig 59). A cell's protein synthesis takes place in the organelle called ribosome. Ribosomes are complex structures made up of two distinct and separable subunits (one about twice the size of the other). Each subunit is composed of one or two RNA molecules (60-70%) associated with 20 to 40 small proteins (30-40%). The ribosome accepts a mRNA molecule, binding initially to a characteristic nucleotide sequence at the 5'-end. This unique binding assures that polypeptide synthesis starts at the right codon. A tRNA molecule with the appropriate anti-codon then attaches at the starting point and this is followed by a series of

adjacent tRNA attachments, peptide bond formation and shifts of the ribosome along the mRNA chain to expose new codons to the ribosomal chemistry. The following diagram is designed as a slide show illustrating these steps (Fig.60). The outcome is synthesis of a polypeptide chain corresponding to the mRNA blueprint. A "stop codon" at a designated position on the mRNA terminates the synthesis by introduction of a "Release Factor".

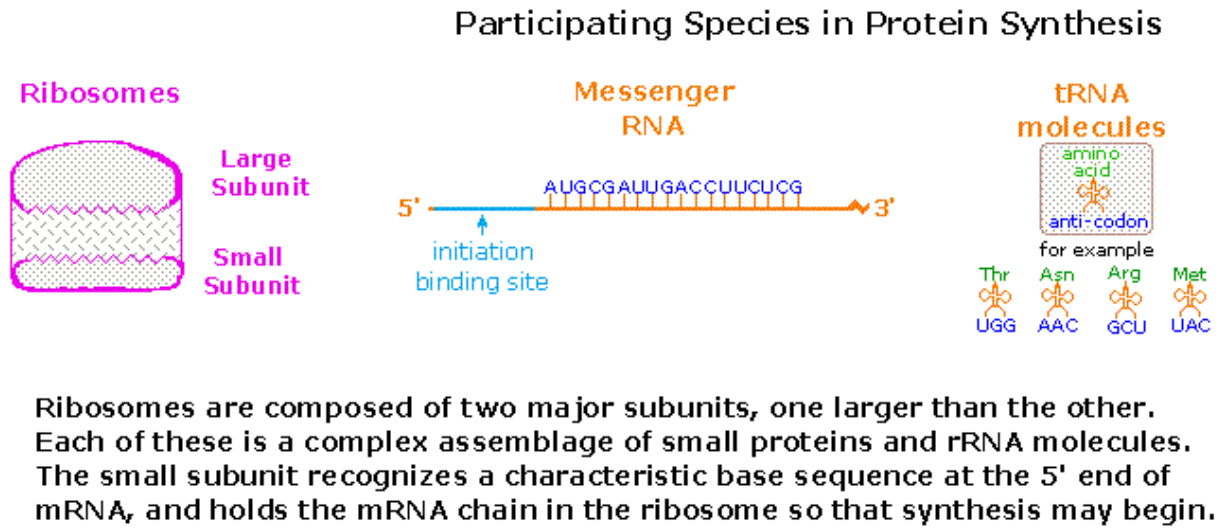

Figure 60: steps involved in the synthesis of a polypeptide chain
(Source: William Reusch, 1999)

4.0 CONCLUSION

Transcription is the synthesis of the RNA by the DNA; while translation is the actual synthesis of a polypeptide under the direction of mRNA during protein synthesis.

5.0 SUMMARY

In this unit we have learnt that:

- Transcription is the process by which a DNA sequence is copied to produce complementary strand of RNA.
- Transcription is the transfer of genetic information from DNA into RNA.
- The process of transcription is similar to replication, but in this case, RNA is being built, rather than DNA.
- Transcription is the beginning of the process that ultimately leads to the translation of the genetic code into a peptide or protein.
- Translation is the synthesis of a polypeptide under the direction of mRNA.

6.0 TUTOR MARKED ASSIGNMENT

1. Outline the process of protein synthesis.

7.0 FURTHER READING AND OTHER RESOURCES

Pelczar, M.J Chan, E.C.S & Krieg N.R. (1986).*Microbiology*, International Edition McGraw Hill International editions. 918 ISBN 0-07-Y66494-3

Snyder, L. &Champness, W. (2003).*Molecular Genetics of Bacteria*, Second Edition, Anon (1970). Washington D.C 556 pp

Anon (1970).The mechanism of protein synthesis."Cold Spring Harbor symp.*Quant. Biol*., Vol. 34. New York: Cold Spring Harbor Laboratory

UNIT 4: INTRODUCTION TO NUCLEIC ACIDS

Contents

1.0 Introduction
2.0 A Objectives
2.0 B How to Study this Unit
3.0 Main Contents
  3.1 Types of nucleic acids
    3.1.1 Ribonucleic acid
    3.1.2 Deoxyribonucleic acid
  3.2 Nucleic Acid Structure
    3.2.1 Phosphate-Sugar Backbone
    3.2.2 The Nucleic Acid "Ladder"
    3.2.3 Organisation of Nucleotides in the Nucleic Acids
  3.3 Chemical structure
4.0 Conclusion
5.0 Summary
6.0 Tutor Marked Assignment
7.0 Further Reading and Other Resources

1.0 INTRODUCTION

Elemental analysis of nucleic acids (RNA and DNA) showed the presence of phosphorus, in addition to the usual carbon, hydrogen, nitrogen and oxygen. Unlike proteins, nucleic acids contained no sulphur.

2.0 A: OBJECTIVES

By the end of this unit, you should be able to:

- List and describe the two types of nucleic acids
- Differentiate between the two nucleic acids

2.0 B: HOW TO STUDY THIS UNIT

1. You are expected to read carefully through this unit twice before attempting to answer the activity questions. Do not look at the solution or guides provided at the end of the unit until you are satisfied that you have done your best to get all the answers.
2. Share your difficulties in understanding the unit with your mates, facilitators and by consulting other relevant materials or internet.
3. Ensure that you only check correct answers to the activities as a way of confirming what you have done.
4. Note that if you follow these instructions strictly, you will feel fulfilled at the end that you have achieved your aim and could stimulate you to do more.

3.0 MAIN CONTENTS

3.1 Types of nucleic acids

3.1.1 Ribonucleic acid

Ribonucleic acid, or RNA, is a nucleic acid polymer consisting of nucleotide monomers, which plays several important roles in the processes of transcribing genetic information from deoxyribonucleic acid (DNA) into proteins. RNA acts as a messenger between DNA and the protein synthesis complexes known as ribosomes, forms vital portions of ribosomes, and serves as an essential carrier molecule for amino acids to be used in protein synthesis.

3.1.2 Deoxyribonucleic acid

Deoxyribonucleic acid is a nucleic acid that contains the genetic instructions used in the development and functioning of all known living organisms. The main role of DNA molecules is the long-term storage of information and DNA is often compared to a set of blueprints. It contains the instructions needed to construct other components of cells, such as proteins and RNA molecules. The DNA segments that carry this genetic information are called genes, but other DNA sequences have structural purposes, or are involved in regulating the use of this genetic information.

DNA is made of four types of bases namely cytosine, thymine, guanine and adenine, which are linked together to form a chain. The bases are attached to each other in this chain by a sugar-phosphate backbone. Two of these chains then coil around each other, forming the DNA double helix.

3.2 Nucleic Acid Structure

Nucleotides are the building blocks of these nucleic acids. Each nucleotide is a monomer of nucleic acid and consists of 3 portions:

- a pentose sugar
- one or more phosphate groups
- one of five cyclic nitrogenous bases

3.2.1 Phosphate-Sugar Backbone

Nucleotides are linked together by covalent bonds between phosphate of one nucleotide and sugar of next. These linked monomers become the phosphate-sugar backbone of nucleic acids. Nitrogenous bases extend from this phosphate-sugar backbone like teeth of a comb.

3.2.2 The Nucleic Acid "Ladder"

Hydrogen bonds form between specific bases of two nucleic acid chains, forming a stable, double-stranded DNA molecule, which looks like a ladder.

Three H bonds form between bases cytosine (C) and guanine (G), which always pair up together between two nucleic acid chains. Two H bonds form between adenine (A) and thymine (T) in DNA or adenine and uracil (U) in RNA molecules.

The structure is analogous to a ladder, with the two deoxyribose-phosphate chains as side rails and the base pairs, linked by hydrogen bonds, forming the rungs

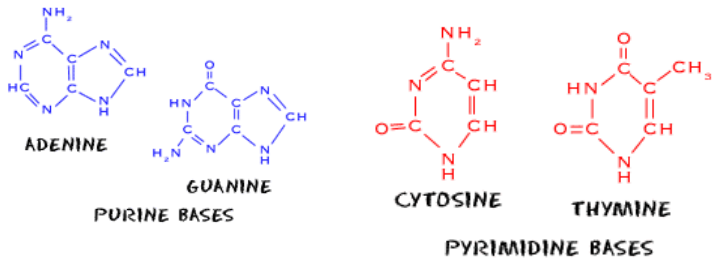

Fig. 61Structure of the nitrogen bases
(Source: Brock Biology of Microorganism 12th edition Madigan M.T. et al.)

3.2.3 Organisation of Nucleotides in the Nucleic Acids

The construction of a nucleic acid is an anabolic polymerization process. Anabolic reactions build bigger molecules. Polymerization is the process of taking nucleotide monomers and putting them together into polymers (large molecules composed of many monomers).

These three-phosphate nucleotide building blocks of DNA bring their own energy for polymerization within their phosphate bonds. When the triphosphate bond of the nucleotide is broken, it contributes the energy required add another nucleotide to the growing nucleic acid.

3.3 Chemical structure

The term "nucleic acid" is the generic name for a family of biopolymers, named for their role in the cell nucleus. The monomers from which nucleic acids are constructed are called nucleotides.

Each nucleotide consists of three components: a nitrogenous heterocyclic base, which is either a purine or a pyrimidine (Fig. 61); a pentose sugar; and a phosphate group. Nucleic acid types differ in the structure of the sugar in their nucleotides - DNA contains 2-deoxyribose while RNA contains ribose (where the only difference is the

presence of a hydroxyl group). Also, the nitrogenous bases found in the two nucleic acid types are different: adenine, cytosine, and guanine are found in both RNA and DNA, while thymine only occurs in DNA and uracil only occurs in RNA. Other rare nucleic acid bases can occur, for example inosine in strands of mature transfer RNA.
Nucleic acids are usually either single-stranded or double-stranded, though structures with three or more strands can form. A double-stranded nucleic acid consists of two single-stranded nucleic acids held together by hydrogen bonds, such as in the DNA double helix. In contrast, RNA is usually single-stranded, but any given strand may fold back upon itself to form secondary structure as in tRNA and rRNA. Within cells, DNA is usually double-stranded, though some viruses have single-stranded DNA as their genome. Retroviruses have single-stranded RNA as their genome.

The sugars and phosphates in nucleic acids are connected to each other in an alternating chain, linked by shared oxygens, forming a phosphodiester bond. In conventional nomenclature, the carbons to which the phosphate groups attach are the 3' end and the 5' end carbons of the sugar. This gives nucleic acids polarity.

In unit 1, you have already been given some information about amino acids. Proteins are made of amino acids. Even though a protein can be very complex, it is basically a long chain of amino acids, all twisted around like a knot.

4.0 CONCLUSION

Both RNA and DNA are macromolecules and differ in their sugar and nitrogenous bases. RNA can fold into various configurations to obtain secondary structure.

5.0 SUMMARY

In this unit we have learnt that:

- RNA is usually single stranded
- DNA is double stranded
- RNA and DNA each consists of a sugar, phosphate, and nitrogenous bases
- RNA has a ribose sugar, phosphate, uracil, adenine, cytosine and guanine
- DNA consists of deoxyribose sugar, phosphate, thymine, adenine, cytosine and guanine.

6.0 TUTOR MARKED ASSIGNMENT

1. Differentiate between the nucleic acids discussed in this chapter.
2. Define the terms primary, secondary, and tertiary with respect to protein structure.
3. Write short note on types of nucleic acid.

7.0 FURTHER READING AND OTHER RESOURCES

Roberts, K., Raff, M., Alberts, B., Walter, P., Lewis, J. & Johnson, A. (2002).*Molecular Biology of the Cell* 4th Edition, Routledge, 1616 pages, ISBN 0-8153-3218-1

Pelczar, M.J., Chan, E.C.S. &Krieg, N.R. (1986).*Microbiology*, International Edition, McGraw Hill International editions.918pp.ISBN 0-07-Y66494-3.

Snyder, L. &Champness, W. (2003).Molecular Genetics of Bacteria, Second Edition, Washington, D.C. 566pp.

Saenger, W. (1984).*Principles of Nucleic Acid Structure*. Springer-Verlag New York Inc.

UNIT 5: NUCLEIC ACID COMPONENTS AND FUNCTIONS

Contents

1.0 Introduction
2.0 A Objectives
2.0 B How to Study this Unit
3.0 Main Contents
  3.1 Nucleic acid components
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    3.1.2 Nucleosides
    3.1.3 Nucleotides
  3.2 Functions of Nucleic Acids
    3.2.1 Functions of DNA (deoxyribonucleic acid)
    3.2.2 Functions of RNA (ribonucleic acid)
    3.2.3 Functions of Some Nucleotides
    3.2.4 Duplication Abilities of RNA and DNA
4.0 Conclusion
5.0 Summary
6.0 Tutor Marked Assignment
7.0 Further Reading and Other Resources

1.0 INTRODUCTION

The nucleic acids (RNA and DNA) are wonderful discoveries of the modern times. They are universally present in the nucleus and in the cytoplasm of all living cells, and are now definitely known to form the chemical basis of life. This unit examines the complex organic compounds made of phosphate, pentose sugar and nitrogen bases which constitute the components of the two nucleic acids.

2.0 A: OBJECTIVES

By the end of this unit, you should be able to:

- Recognise nucleic acid components;
- State the functions of nucleic acids.

2.0 B: HOW TO STUDY THIS UNIT

1. You are expected to read carefully through this unit twice before attempting to answer the activity questions. Do not look at the solution or guides provided at the end of the unit until you are satisfied that you have done your best to get all the answers.
2. Share your difficulties in understanding the unit with your mates, facilitators and by consulting other relevant materials or internet.
3. Ensure that you only check correct answers to the activities as a way of

confirming what you have done.

4. Note that if you follow these instructions strictly, you will feel fulfilled at the end that you have achieved your aim and could stimulate you to do more.

3.0 MAIN CONTENTS

3.1 Nucleic acid components

Adenine, guanine, cytosine and phosphate group are common to both RNA and DNA. Ribose sugar and uracil are found in RNA while thymine and deoxyribose are in the DNA (Fig. 62).

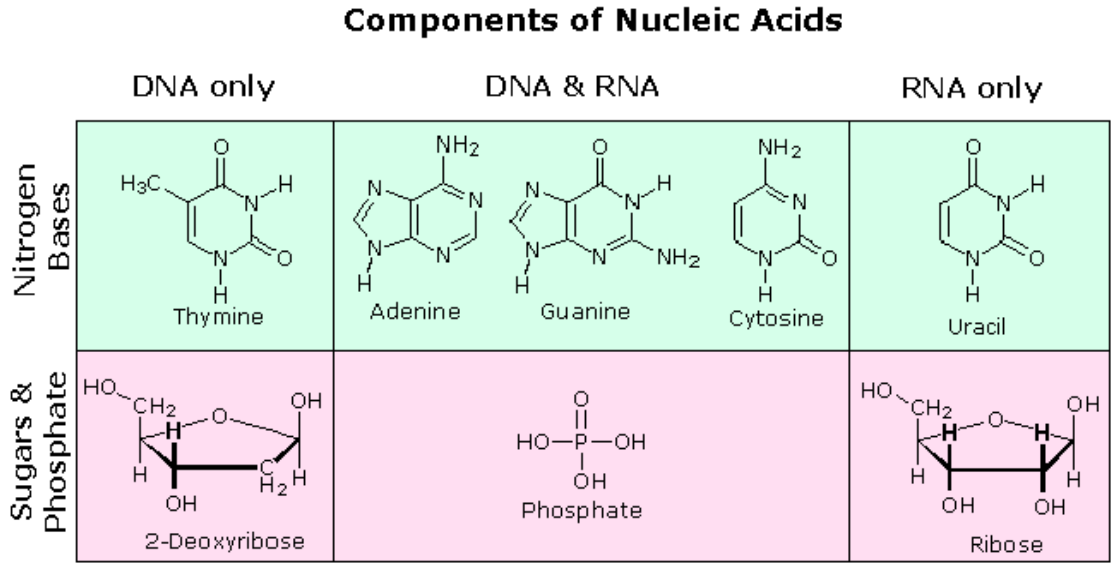

Fig. 62: Components of the Nucleic Acids
(Source: Snyde,r L. and Champness, W. 2003. Molecular Genetics of Bacteria.2nd edition.ASM press, Washington, D.C.).

3.1.1 Nucleobases

Nucleobases are heterocyclic aromatic organic compounds containing nitrogen atoms. Nucleobases are parts of RNA and DNA involved in base pairing. Cytosine, guanine, adenine, thymine are found predominantly in DNA, while in RNA uracil replaces thymine. These are abbreviated as C, G, A, T, U, respectively.

Nucleobases are complementary, and when forming base pairs, must always join accordingly: cytosine-guanine, adenine-thymine (adenine-uracil when RNA). The strength of the interaction between cytosine and guanine is stronger than between adenine and thymine because the former pair has three hydrogen bonds joining them

while the latter pair has only two. Thus, the higher the GC content of double-stranded DNA, the more stable the molecule and the higher the melting temperature.

Two main nucleobase classes exist, named for the molecule which forms their skeleton. These are the double-ringed purines and single-ringed pyrimidines (Fig. 61 unit 4). Adenine and guanine are purines (abbreviated as R), while cytosine, thymine, and uracil are all pyrimidines (abbreviated as Y).

3.1.2 Nucleosides

Nucleosides are glycosylamines made by attaching a nucleobase (often referred to simply as bases) to a ribose or deoxyribose (sugar) ring. In short, a nucleoside is a base linked to sugar. The names derive from the nucleobase names. The nucleosides commonly occurring in DNA and RNA include cytidine, uridine, adenosine, guanosine and thymidine. When a phosphate is added to a nucleoside (by a specific kinase enzyme), a nucleotide is produced.

3.1.3 Nucleotides

A nucleotide consists of a nucleoside and one phosphate group. Nucleotides are the monomers of RNA and DNA, as well as forming the structural units of several important cofactors - CoA, flavin adenine dinucleotide, flavin mononucleotide, adenosine triphosphate and nicotinamide adenine dinucleotide phosphate. In the cell nucleotides play important roles in metabolism, and signaling.

Nucleotides are named after the nucleoside on which they are based, in conjunction with the number of phosphates they contain. For example: adenine bonded to ribose forms the nucleoside adenosine. Adenosine bonded to a phosphate forms adenosine monophosphate. As phosphates are added, adenosine diphosphate and adenosine triphosphate are formed, in sequence. The ATP, adenosine triphosphate is a nucleotide

3.2 Functions of Nucleic Acids

The main function of nucleic acids is to store and transmit genetic information and use that information to direct the synthesis of new protein. The DNA (deoxyribonucleic acid) is the permanent storage place for genetic information in the nucleus of a cell. DNA controls the synthesis of RNA (ribonucleic acid). RNA transmits genetic information from DNA to the protein synthesizers in the cell. RNA is also responsible for directing the production of the new protein by transmitting the genetic information to the protein building structures. The nucleotide, ATP (adenosine triphosphate), which is closely related to DNA and RNA, is the short-term energy storage for all life processes. The function of the sequence of bases (adenine, cytosine, guanine, and thymine) in the backbone of DNA determine what proteins are being synthesized and

in what order (note that in RNA, thymine is replaced by uracil). The function of the double helix formation of DNA molecules is to ensure that no disorders occur if genetic information is lost or damaged. Examples of disorders related to damaged or lost genetic information are Down's syndrome and sickle cell anemia.

3.2.1 Functions of DNA (deoxyribonucleic acid)

- DNA is a permanent storage place for genetic information.
- DNA controls the synthesis of RNA (ribonucleic acid).
- The sequence of nitrogenous bases in DNA determines the protein development in new cells.
- The function of the double helix formation of DNA is to ensure that no disorders occur. This is because the second identical strand of DNA that runs anti-parallel to the first is a backup in case of lost or destroyed genetic information.

3.2.2 Functions of RNA (ribonucleic acid):

- RNA is synthesized by DNA for the transportation of genetic information to the protein building apparatus in the cell.
- RNA also directs the synthesis of new proteins using the genetic information it has transported.
- mRNA (messenger ribonucleic acid) is used to transfer genetic information through plasma membranes.

3.2.3 Functions of Some Nucleotides

- The nucleotide, ATP (adenosine triphosphate) is the short-term energy storage for all living organisms. Nucleic acids can be used to create energy in the form of ATP. ATP is formed with the nitrogenous bases adenosine and ribose.
- Three phosphates are combined with the above nitrogenous bases to form ATP. But how does ATP provide the energy? To provide energy, ATP goes through the process of hydrolysis, producing energy, as well as a phosphate molecule.
- It is important to note that, during cellular respiration, ATP can be accessed either through aerobic (with oxygen) system and anaerobic (without oxygen) system. Aerobic access of ATP energy is much more efficient, creating 36 ATP instead of the 2 with anaerobic.
- cAMP (cyclic adenosine monophosphate) is a messenger in hormone regulation .
- Nucleotide derivatives such as NAD + (nictinamide adenine dinucleotide) is used as a coenzyme in photosynthesis.

3.2.4 Duplication Abilities of RNA and DNA

Nucleic acids (specifically DNA) carry out a vital role in the human body. In particular, nucleic acids play an essential role in both mitosis and meiosis

In mitosis, the chromosomes (or genetic information) contained inside the nucleus of the parent cell is duplicated. The two resulting daughter cells have identical genetic information to the parent cell. This is possible only through nucleic acid's remarkable ability to create identical copies of itself.

It is the only molecule known to have this ability. Mitosis is essential to life because it replaces damaged or dead cells, repairs tissues, and allows the body to grow (in mass and size).

Another use for nucleic acid's duplication ability is meiosis. Meiosis is the process in which sex cells are created. Without nucleic acids, meiosis would be impossible, and therefore there would be no reproductive processes in living organisms.

4.0 CONCLUSION

The nucleic acids, deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) consist of nitrogen bases, sugars and phosphate groups and carry out vital functions in the living cells of organisms

5.0 SUMMARY

In this unit we have learnt that:

- DNA and RNA are the genetic materials of cells, their names derived from the type of sugar, contained within the molecules.
- The strength of the interaction between cytosine and guanine is stronger than between adenine and thymine.
- The higher the GC content of double-stranded DNA, the more stable the molecule and the higher the melting temperature.
- Nucleotides are the monomers of RNA and DNA
- The main function of nucleic acids is to store and transmit genetic information and use that information to direct the synthesis of new protein.
- DNA or RNA has a sugar, nitrogen base and a phosphate group
- ATP (a nucleotide) is related to RNA and DNA and is the short-term energy storage of the cell.

6.0 TUTOR MARKED ASSIGNMENT

1. What are the three parts of a nucleotide?
2. How does a nucleoside differ from a nucleotide?
3. State the functions of the DNA and RNA

7.0 Further Reading and Other Resources

Pelczar, M.J., Chan, E.C.S. *and* Krieg, N.R. (1986).*Microbiology*, International Edition, McGraw Hill International Editions.918pp.ISBN 0-07-Y66494-3.

Snyder, L. &Champness, W. (2003).*Molecular Genetics of Bacteria*, Second Edition, Washington, D.C. 566pp.

UNIT 6: REVIEW OF PROTEINS AND NUCLEIC ACID

Contents

1.0 Introduction
2.0 A Objectives
2.0 B How to Study this Unit
3.0 Main Contents
- 3.1 Relationship between proteins, RNA and DNA
- 3.2 Amino Acids and Proteins
  - 3.2.1 Making Chains
  - 3.2.2 Side Groups
  - 3.2.3 DNA Details
- 3.3 The Rules of Protein Structure
- 3.4 The twenty Amino Acids Found in Proteins
- 3.5 Levels of protein structure

4.0 Conclusion
5.0 Summary
6.0 Tutor Marked Assignment
7.0 Further Reading and Other Resources

1.0 INTRODUCTION

We have already considered the functions of proteins (unit 3) while certain features of protein synthesis in unit 3 have been discussed. In the units that follow, we introduce nucleic acid, their components and functions. Some missing linkages may exist. In this unit, a review of proteins and nucleic acid is presented.

2.0 A: OBJECTIVES

By the end of this unit, you should be able to:

1. Explain the relationship between proteins and DNA;
2. Distinguish between levels of protein structure;
3. Explain amino acids found in proteins (Fig. 64).

2.0 B: HOW TO STUDY THIS UNIT

1. You are expected to read carefully through this unit twice before attempting to answer the activity questions. Do not look at the solution or guides provided at the end of the unit until you are satisfied that you have done your best to get all the answers.
2. Share your difficulties in understanding the unit with your mates, facilitators and by consulting other relevant materials or internet.
3. Ensure that you only check correct answers to the activities as a way of confirming what you have done.

4. Note that if you follow these instructions strictly, you will feel fulfilled at the end that you have achieved your aim and could stimulate you to do more.

2.1 MAIN CONTENTS

2.2 Relationship between proteins, RNA and DNA

There is a relationship between proteins, RNA and DNA. Remember that the DNA synthesizes RNA and mRNA is involved in protein synthesis (Fig. 63).

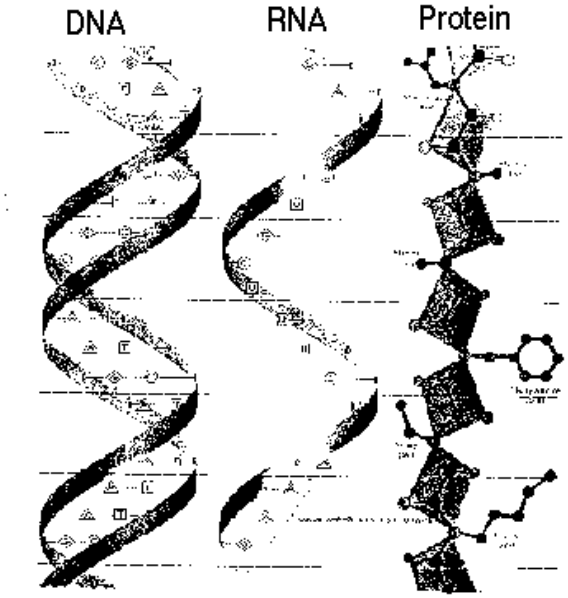

Figure 4.6.1. Linear relationship between DNA, RNA and Protein Sequence
Source: Snyder L. and Champness W. 2003. Molecular Genetics of Bacteria.2nd edition.

- DNA encodes amino acids of a protein using 3 letter codons.
- DNA is transcribed to make mRNA.
- mRNA is translated by ribosomes to make the protein.

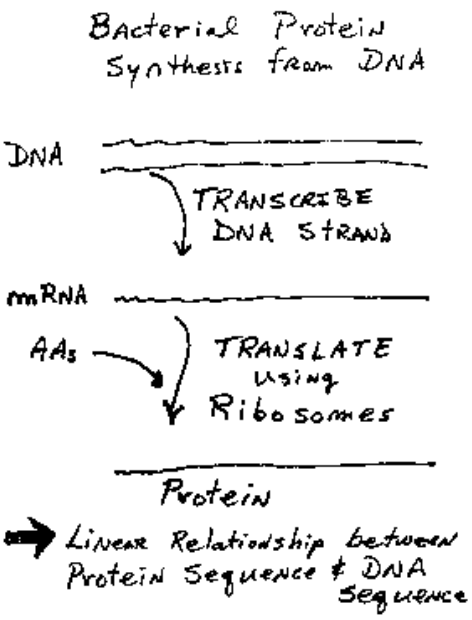

Fig. 64 Bacterial Protein Synthesis.

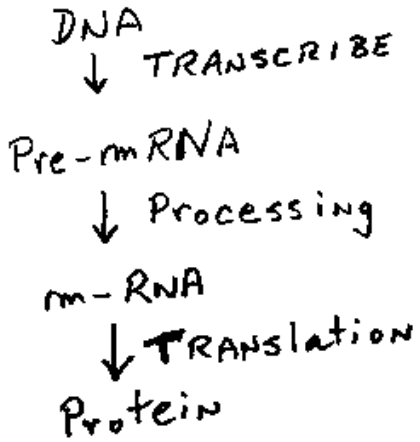

Fig. 65. Eukaryotic Protein Synthesis

- Eukaryotic DNA is transcribed to make a pre-mRNA, then the pre-mRNA is processed (Fig. 65).
- Processing removes the intervening sequences found in eukaryotic DNA, which are called Introns.
- During processing, the exons containing the coding region for the protein are joined.
- Also some modifications of the ends of the mRNA are made and it goes into the cytosol.
- In the cytosol, ribosomes translate the mRNA to make protein in manner very similar to prokaryotes (Fig. 65).

3.2 Amino Acids and Proteins

The first thing you might be asking is, "What is an amino acid?" There are over twenty, and each one of them is different from the other amino acids. Amino acids are used in every cell of your body and are used to build the proteins needed to survive. All organisms need some proteins, whether they are used in muscles or as simple structures in the cell membrane. Even though all organisms have differences, they still have one thing in common, the need for basic chemical building blocks. Amino acids have a two-carbon bond. One of the carbons is part of a group called the carboxyl group. A carboxyl group is made up of one carbon (C), two oxygen atoms (O), and one hydrogen atom (H). The carboxyl group is acidic. The second carbon is a part of the amino group. Amino means there is an NH_2 group bonded to the carbon atom.

3.2.1 Making Chains

Even though scientists have discovered over 50 amino acids, only 20 are used to make proteins in our body. Of those twenty, eight are defined as essential. The other twelve can be synthesized by an adult body.

Thousands of combinations of those twenty are used to make all of the proteins in our body. Amino acids bond together to make long chains and those long chains of amino acids are also called proteins.

3.2.2 Side Groups

The side groups are what make each amino acid different from the others. Of the 20 used to make proteins, there are three groups. The three groups are ionic, polar and non-polar. These names refer to the way the side groups (sometimes called "R" groups) interact with the environment. Polar amino acids like to adjust themselves in a certain direction. Non-polar amino acids are different (please refer to unit 1, Fig. 47).

3.2.3 DNA Details

DNA stands for deoxyribonucleic Acid. It is special because it holds the code for every cell in our body. This means that every cell in your body uses DNA for an instruction manual. In other words DNA is just a long spiral chain of nucleotides. But it's more. So you get all of those nucleotides in two long chains that twist around each other. That twisting shape is called a double-helix. The spiral ladder has the ability to wind and unwind so that the nucleic acid chain can duplicate itself. That duplication process happens every time a cell divides.

When a cell is in its normal state, the DNA is not duplicating and it just looks like a blob of white strands. This nucleic acid chains usually sit around uncoiled and as loose strands called chromatin. When it is time for the cell to reproduce, they

condense and wrap up very tightly. The tightly wound DNA is called a chromosome. Chromosomes appear like long, limp hot dogs. They are also found in pairs.

In most organisms, you will find DNA in the nucleus. Chromosomes work with other nucleic acids in the cell to build proteins and help in duplication. You will most likely find mRNA (messenger-ribonucleic acid) in the nucleus with the DNA. The dispersed tRNA (transfer-ribonucleic acid) is found outside of the nucleus, floating in the cell. In a few organisms called prokaryotes, there is no defined nucleus and the DNA is found throughout the cell.

3.3 The Rules of Protein Structure

The sequence of amino acids in a protein is determined by the sequence of nucleotides in the gene (DNA) encoding it. The function of a protein (except when it is serving as food) is absolutely dependent on its three-dimensional structure. A number of agents can disrupt this structure thus denaturing the protein.

- changes in pH (alters electrostatic interactions between charged amino acids)
- changes in salt concentration (does the same)
- changes in temperature (higher temperatures reduce the strength of hydrogen bonds)
- presence of reducing agents (break S-S bonds between cysteines)

None of these agents breaks peptide bonds, so the primary structure of a protein remains intact when it is denatured. When a protein is denatured, it loses its function.
Examples:

- A denatured enzyme ceases to function.
- A denatured antibody no longer can bind its antigen.

Often when a protein has been gently denatured and then is returned to normal physiological conditions of temperature, pH, salt concentration, etc., it spontaneously regains its function (e.g. enzymatic activity or ability to bind its antigen). When denaturation is not gentle like hike high temperature, the protein loses its structure and functions. This tells us that the protein has spontaneously resumed its native three-dimensional shape. Its ability to do so is intrinsic; no outside agent was needed to get it to refold properly.

However, there are:

- enzymes that add sugars to certain amino acids, and these may be essential for proper folding;

- proteins, called molecular chaperones, that may enable a newly-synthesized protein to acquire its final shape faster and more reliably than it otherwise would.

3.4 The twenty Amino Acids Found in Proteins

There are twenty amino acids required for human life to exist. Adults have eight essential amino acids that they cannot synthesize. The other twelve can be produced within our bodies. There are some other amino acids found in nature (and some very small amounts in humans). These twenty amino acids are found in proteins (Table 4).

Table 4: List of Twenty Amino Acids

Alanine	Leucine
Arginine	Lysine
Asparagine	Methionine
Aspartic Acid	Phenylalanine
Cysteine	Proline
Glutamic Acid	Serine
Glutamine	Threonine
Glycine	Tryptophan
Histidine	Tyrosine
Isoleucine	Valine

3.5 Levels of protein structure

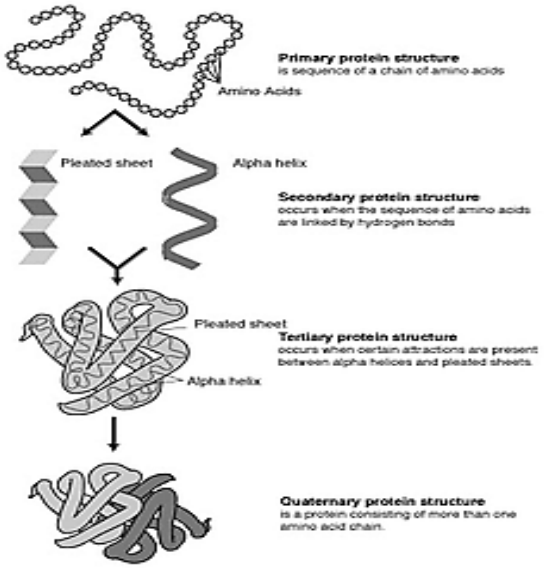

Fig. 66.Protein structure, from primary to quaternary structure.
(Source: Snyder L. and Champness W. 2003.Molecular Genetics of Bacteria.2nd edition).

Primary structure - the amino acid sequence of the peptide chains. The primary structure is held together by covalent or peptide bonds, which are made during the process of protein biosynthesis or translation. These peptide bonds provide rigidity to the protein. The two ends of the amino acid chain are referred to as the C-terminal end or carboxyl terminus (C-terminus) and the N-terminal end or amino terminus (N-terminus) based on the nature of the free group on each extremity.

Secondary structure - highly regular sub-structures (alpha helix and strands of beta sheet) which are locally defined, meaning that there can be many different secondary motifs present in one single protein molecule. The various types of secondary structure are defined by their patterns of hydrogen bonds between the main-chain peptide groups. However, these hydrogen bonds are generally not stable by themselves, since the water-amide hydrogen bond is generally more favorable than the amide-amide hydrogen bond. Thus, secondary structure is stable only when the local concentration of water is sufficiently low.

Tertiary structure - three-dimensional structure of a single protein molecule; a spatial arrangement of the secondary structures. It also describes the completely folded and compacted polypeptide chain.

Quaternary structure - complex of several protein molecules or polypeptide chains, usually called protein subunits in this context, which function as part of the larger assembly or protein complex.
In addition to these levels of structure, a protein may shift between several similar structures in performing its biological function. This process is also reversible. In the context of these functional rearrangements, these tertiary or quaternary structures are usually referred to as chemical conformation, and transitions between them are called conformational changes.

4.0 CONCLUSION

RNA, DNA and proteins are closely related in terms of structure and synthesis. Amino acids are found in all of them.

5.0 SUMMARY

In this unit we have learnt that:

- Eukaryotic protein synthesis is more complex than prokaryotic
- Amino acids are found in proteins
- All organisms have the need for basic chemical building blocks.

- Amino acids bond together to make long chains and those long chains of amino acids are also called proteins.
- DNA holds the code for every cell in human body.
- In prokaryotes, there is no defined nucleus and the DNA is found throughout the cell.
- The primary structure of a protein remains intact when it is denatured
- When a protein is denatured, it loses its function.
- A relationship exists between proteins, RNA and DNA.

6.0 TUTOR MARKED ASSIGNMENT

1. What is an amino acid?
2. List the essential features of the protein structures
3. Give a short account of the DNA

7.0 FURTHER READING AND OTHER RESOURCES

Pelczar, M.J., Chan, E.C.S. & Krieg, N.R. (1986).*Microbiology,* International Edition, McGraw Hill International editions.918pp.ISBN 0-07-Y66494-3.

Snyder, L. &Champness, W. (2003).*Molecular Genetics of Bacteria*, Second Edition, Washington, D.C. 566pp.