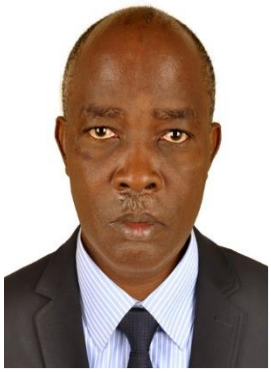


Dr. Bbosa Science

Nature of the gene and Protein synthesis

Specific objectives

(i) Describe the composition of chromosomes and structure of nucleotides
(ii) Describe the structure of DNA and RNA
(iii) Distinguish between DNA and RNA
(iv) Explain the Watson Crick hypothesis of the nature of DNA
(v) Explain DNA replication.
(vi) Describe the nature of the gene
(vii) Describe the structure of the genetic code
(viii) Describe formation of RNA
(ix) State the role of DNA and RNA in protein synthesis. Describe protein synthesis.

Gene

This is a segment of DNA that tell the body how to produce specific proteins – contain the genetic information that is passed from parents to their offspring. These genes are found in structures called chromosomes, which are passed to the embryo during conception. Because the DNA passed from one human to another helps determine gender and physical characteristics, this nucleic acid is necessary for the survival of the species.

Evidences that DNA is the hereditary material

1. DNA is a stable molecule
2. The amount of DNA in a given species is constant for all cells.
3. Mutation or changes in the composition of DNA alter the organisms' characteristics.

4. Purified DNA rather than proteins from dead virulent bacterium Pneumococcus strain which causes pneumonia was shown to transform the non-virulent form into a virulent form. The ability of DNA to transform nonvirulent form was stopped by addition of an enzyme that breaks DNA in the dead virulent form before DNA was purified.
5. DNA rather than proteins of bacteriophage (T_2 phage) that infect E. coli was shown to be the hereditary material because it enabled the E. coli to synthesize the new T_2 phages viruses.

Nucleic acids

This is a form of genetic material in all living organisms including the simplest viruses. Nucleic acids are **polymers** made of subunits called **nucleotides.**

Types

1. Deoxyribonucleic acid (**DNA**) is found in the nucleus
2. Ribonucleic acid (**RNA**) is found in both nucleus and cytoplasm.

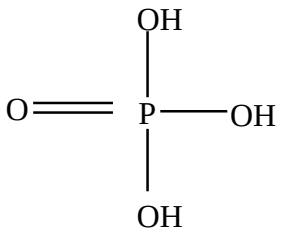
A **nucleotide** is made up of three molecules:

(i) Phosphate group
(ii) Pentose sugar – either Deoxyribose (in DNA) or Ribose (in RNA)
(iii) Nitrogen base – any purine (Adenine, Guanine) or pyrimidine (Cytosine and either Thymine in DNA or Uracil in RNA)

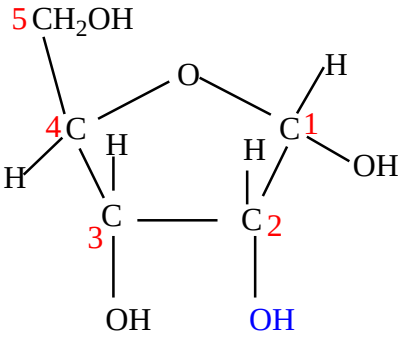
Structure of nucleotide

It is made of phosphoric acid, sugar and an organic base.

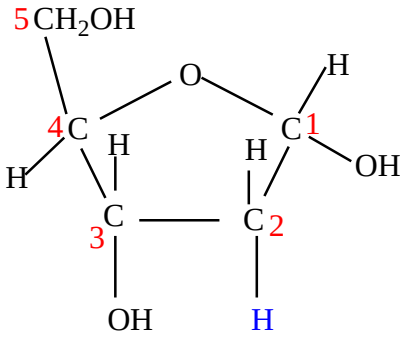
(a) Phosphoric acid



(b) **Sugar:** the pentose sugar in RNA is ribose while that of DNA is deoxyribose sugar. Deoxyribose sugar lacks an oxygen atom on the second carbon atom



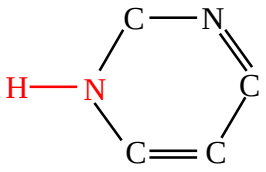
Ribose sugar

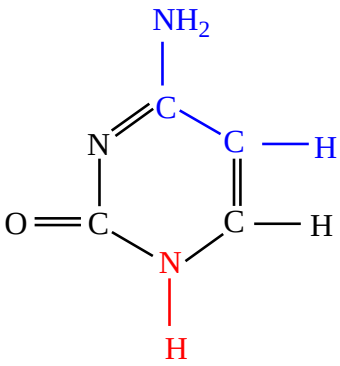


Deoxyribose sugar

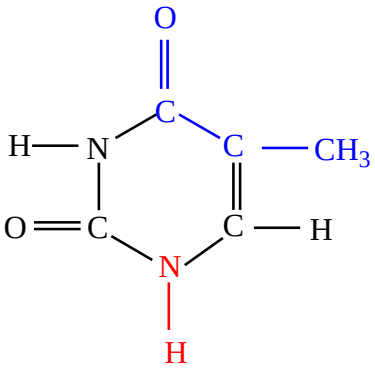
(c) **Organic Bases**: DNA contains four different organic bases; adenine (A), guanine (G) cytosine (C) and thymine (T). RNA also contains adenine (A), guanine (G), cytosine (C) and Uracil (U). all these bases are ring compounds, made of carbon and nitrogen.

(i) **Pyrimidines** (cytosine, uracil and thymine; CUT) have a six-membered ring.

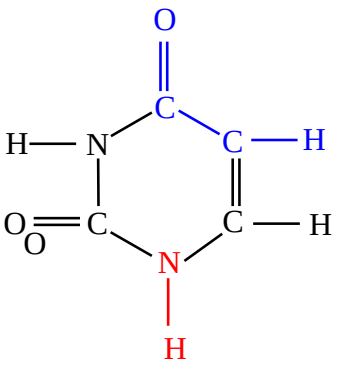




Cytosine

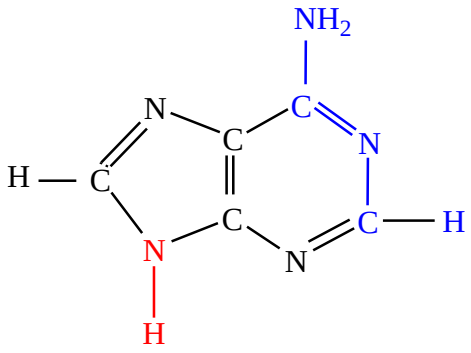


Thymine

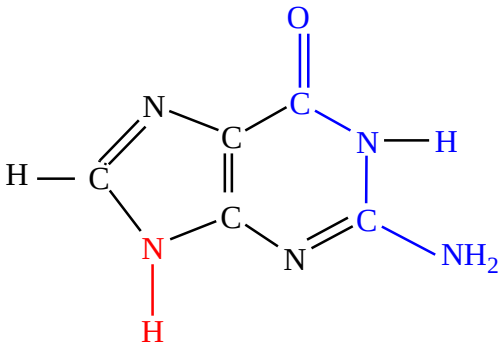


Uracil

(ii) Purine (Guanine and Adenine (GA) have a two membered ring)



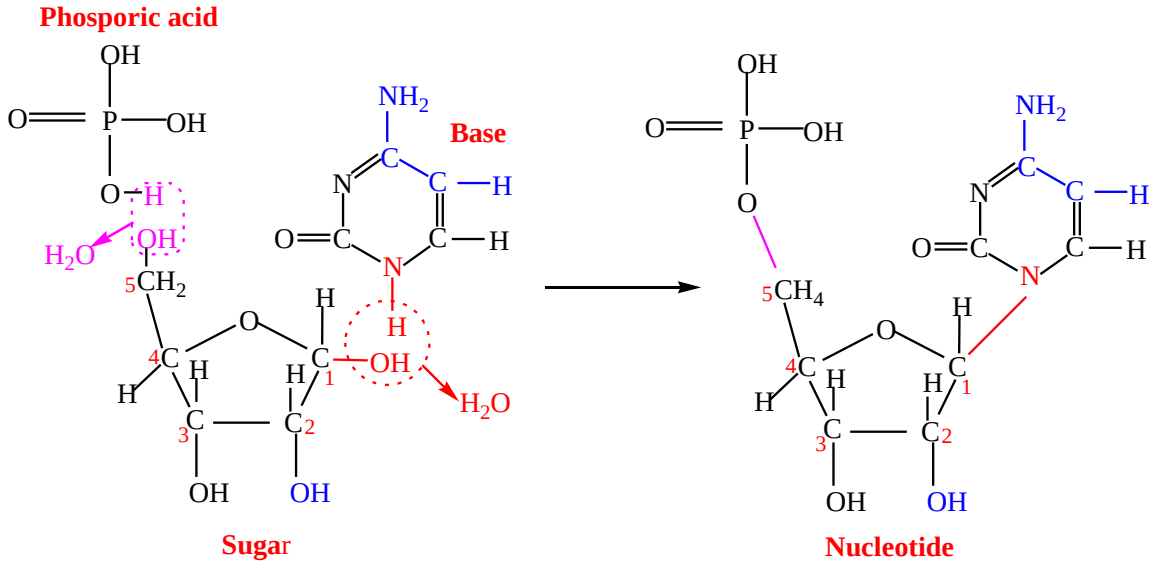
Adenine



Guanine

Nucleoside forms when a pentose sugar joins an organic base by **condensation reaction** (a **water molecule** is lost**)**.

Nucleotide forms when a **nucleoside** (pentose sugar + organic base) joins a phosphate by loss of **second water molecule.**

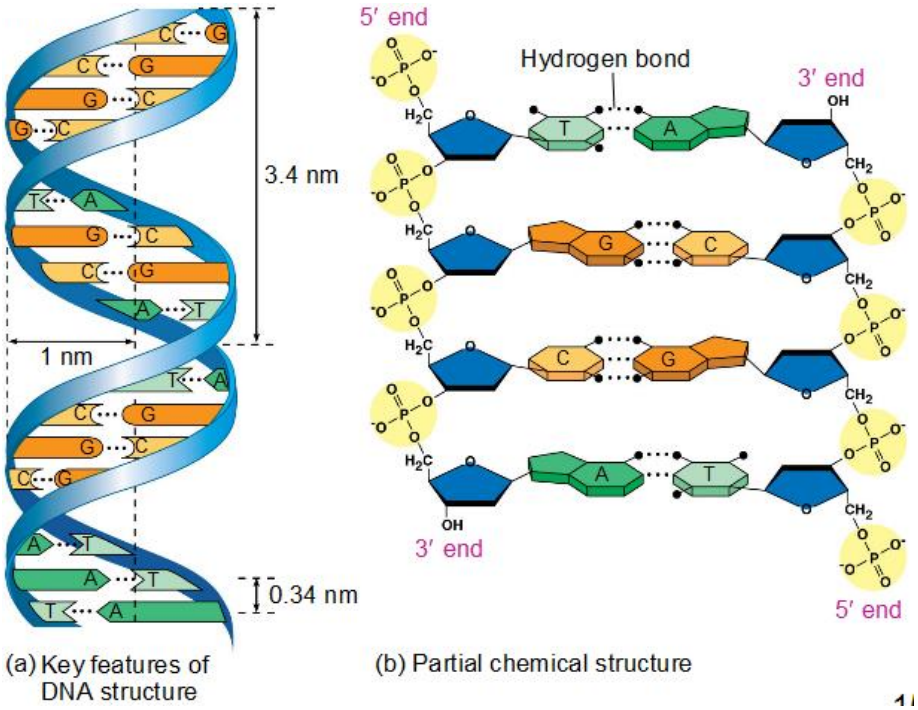


The **sugar-phosphate-sugar backbone** is formed when the 3’ carbon on one sugar joins to the 5’ carbon on the next sugar by **phosphodiester bonds** repeatedly to form a **polynucleotide** (long chain of nucleotides) with organic bases protruding sideways from sugars.

Nitrogen base

DNA structure according to Watson and Crick

1. DNA consist of two polynucleotide strands.
2. The polynucleotide stands are antiparallel (face in opposite directions) i.e. one runs from 3' to 5' direction while another one runs from 5' to 3' direction.
3. A DNA **nucleotide** is made up of three molecules:
   - **(i)** Phosphate group
   - **(ii)** Deoxyribose sugar
   - **(iii)** Nitrogen base - either adenine **(A)**, guanine **(G)**, thymine **(T)** or cytosine **(C)**.
4. Untwisted DNA is ladder-like, in which the sugar-phosphate backbones represent the handrails while the nitrogen base pairs represent the rungs.
5. Twisted DNA forms a double helix of major and minor grooves.
6. The sugar-phosphate-sugar backbone is held by covalent **phosphodiester bonds,** while the nitrogen bases from the two strands form **weak hydrogen bonds** by complimentary base pairing i.e. A with T, C with G.



ADAPTATIONS OF DNA

(i) Sugar-phosphate backbone is held together by strong covalent phosphodiester bonds to provide stability.

(ii) The two sugar-phosphate backbones are antiparallel which enables purine and pyrimidine nitrogen bases to project towards each other for complimentary pairing.

(iii) Sugar-phosphate backbones are two / it is double stranded to provide stability.

(iv) The two sugar-phosphate backbones form a double helix to protect bases/hydrogen bonds.
(v) Long/large molecule for storage of much information.
(vi) Double helical structure makes the molecule compact to fit in the nucleus.
(vii) Base sequence allows information to be stored.
(viii) Double stranded for replication to occur semi- conservatively/ strands can act as templates.
(ix) There are many hydrogen bonds which increase stability of DNA molecule.
(x) There is complementary base pairing / A-T and G-C for accurate replication/identical copies can be made;
(xi) Weak hydrogen bonds enable unzipping /separation of strands to occur readily.

Theories of DNA replication

DNA replication is the process by which the parent DNA molecule makes another copy of itself.

1. Fragmentation hypothesis (Dispersive hypothesis)

The parent DNA molecule breaks into segments and new nucleotides fill in the gaps precisely.

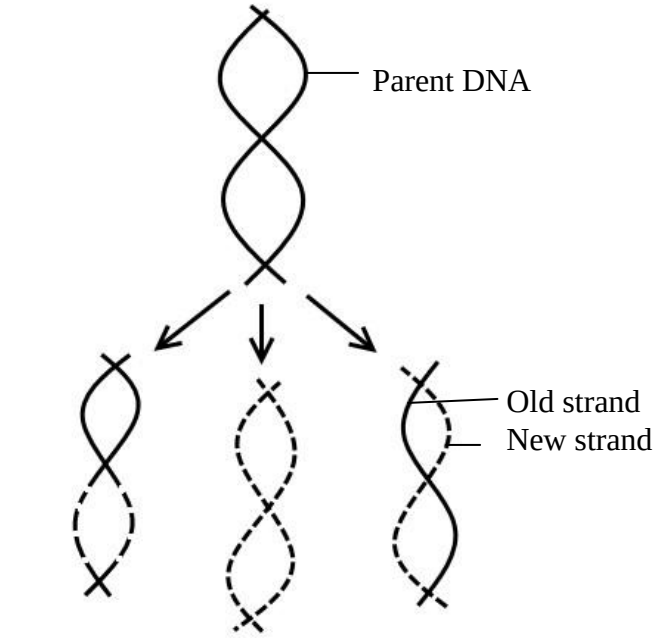
2. Conservative hypothesis

This suggests that the DNA strands remain intact but in some way initiate the synthesis of new but exact copies of DNA to the parent DNA.

3. Semi-conservative hypothesis

The parent DNA molecule separates into its two component strands, each of which acts as a template for the formation of a new complementary strand. The two daughter molecules therefore contain half the parent DNA and half new DNA. **The semi conservative hypothesis was shown to be the true mechanism by the work of Meselsohn and Stahl (1958) in their experiment on bacterium *E.coli* using radioactive ^{15}N.**

Illustration of three possible theories of DNA replication

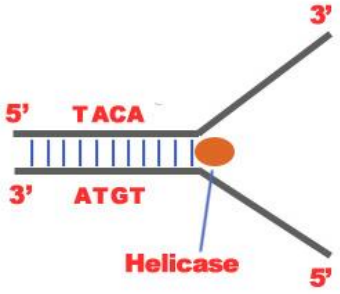


Necessities of DNA replication

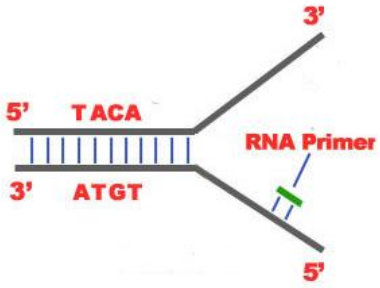
1. Free nucleotides to bond with complementary bases on the separated DNA strands.
2. Energy source in form of ATP
3. Complementary DNA strand
4. Enzymes such as DNA polymerase, DNA helicase and DNA lingaze.

Steps of DNA Replication

1. DNA unwinds and then split open by a Helicase enzyme to expose the bases on either strand. The initiation point is a place rich in A-T probably because these are held by two hydrogen bonds as oppose to the three hydrogen bonds between C and G. The structure that is created is known as "**Replication Fork**".

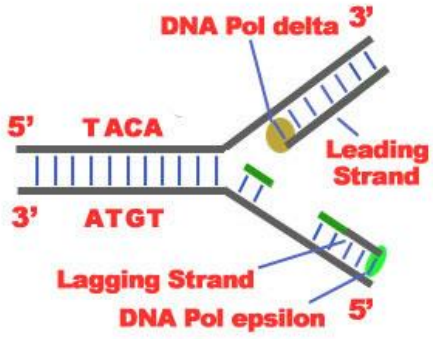


2. An enzyme RNA Primase bind to DNA at the initiation point and attracts the first nucleotide of the 3'-5' strand



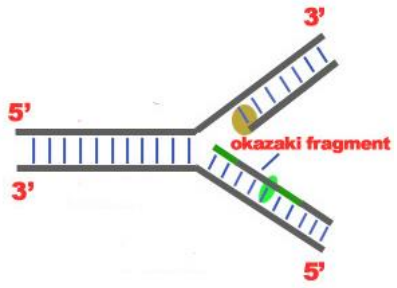
3. The **elongation** process involves the alignment of complementary nucleotides against the bases on open stands and then joined into new strands by the DNA polymerase. However, it occurs differently for the 5'-3' and 3'-5' template.

   a. **5'-3' Template**: The 3'-5' proceeding daughter strand -that uses a **5'-3' template**- is called **leading strand** because **DNA Polymerase ä** can "read" the template and continuously adds nucleotides (complementary to the nucleotides of the template, for example Adenine opposite to Thymine etc.).



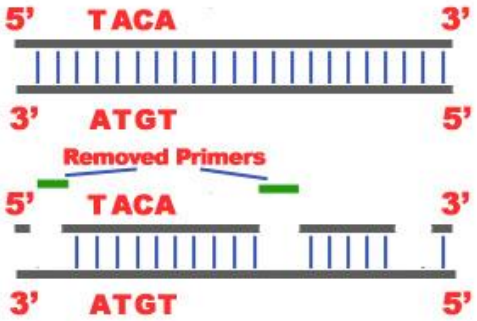
   b. **3'-5'Template**: The **3'-5' template** cannot be "read" by DNA Polymerase ä. The replication of this template is complicated and the new strand is called **lagging strand**. In the lagging strand the RNA Primase adds more RNA Primers. **DNA polymerase å** reads the template and lengthens the bursts. The gap between two RNA primers is called "**Okazaki Fragments**".

   The RNA Primers are necessary for DNA Polymerase å to bind Nucleotides to the 3'-5' end of them. The daughter strand is elongated with the binding of more DNA nucleotides.



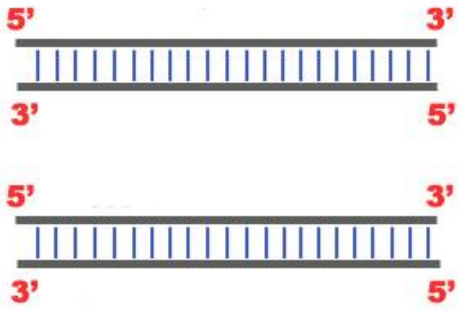
4. In the lagging strand the **DNA Pol I -exonuclease-** reads the fragments and removes the RNA Primers. The gaps are closed with the action of DNA Polymerase (adds complementary nucleotides to the gaps) and DNA Ligase (adds phosphate in the remaining gaps of the phosphate - sugar backbone).

   Each new double helix is consisted of one old and one new chain. This is what we call **semiconservative replication**.



5. The last **step of DNA Replication** is the **Termination**. This process happens when the DNA Polymerase reaches to an end of the strands.

6. The DNA Replication is not completed before a **mechanism of repair** fixes possible errors caused during the replication. Enzymes like **nucleases** remove the wrong nucleotides and the DNA Polymerase fills the gaps.



General structure of RNA

a RNA molecules are small/short, single stranded (rRNA and mRNA) but may be coiled around such that bases of the same strand pair with each other.

b RNA **nucleotide** is made up of three molecules:

(i) Phosphate group

(ii) Ribose sugar

(iii) Nitrogen base - either adenine **(A)**, guanine **(G)**, cytosine **(C)** or uracil **(U)**

c The sugar-phosphate-sugar backbone is held by covalent **phosphodiester bonds.**

d RNA occurs in three types whose sizes, shapes, amounts/abundance and roles vary:

Types of RNA

1. **Ribosomal RNA** (rRNA)

Makes the highest percentage of RNA. It is a single strand with a double helical region. Its function are:

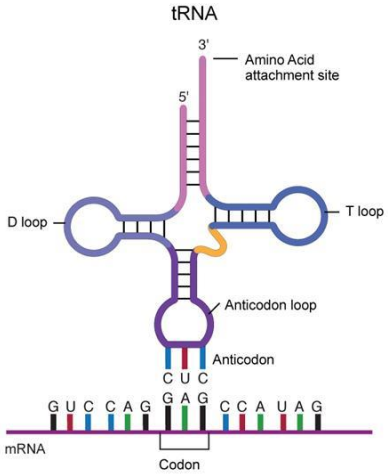
a. integral component to ribosome structure i.e when removed from ribosome, ribosomes structure collapses
b. it serve as a temperate partner for synthesis of ribosomal proteins

2. **Messenger RNA** (mRNA)

Forms 3-5% of the total RNA in a cell. mRNA carries coded information from DNA to ribosomes in the cytoplasm

3. tRNA

is an adaptor molecule composed of RNA, typically 76 to 90 nucleotides in length,[2] that serves as the physical link between the mRNA and the amino acid sequence of proteins. tRNA does this by carrying an amino acid to the protein synthetic machinery of a cell (ribosome) as directed by a three-nucleotide sequence (codon) in a messenger RNA (mRNA). As such, tRNAs are a necessary component of translation, the biological synthesis of new proteins in accordance with the genetic code.



Comparison of DNA and RNA

Similarities

Both:

(1) are polymers of nucleotides
(2) carry genetic information
(3) have same purine bases adenine and guanine plus pyrimidine bases cytosine
(4) originate from the nucleus

Differences

Aspect	Deoxyribonucleic Acid (DNA)	Ribonucleic Acid (RNA)
Function	Stores genetic information for a long time and transmits it.	Transfers genetic code needed for the creation of proteins from the nucleus to the ribosome.
Structure	(i) Double-stranded. (ii) High molecular mass (iii) Pentose sugar is deoxyribose (iv) Quantity is fixed in a cell	(i) Single-stranded. (ii) Low molecular mass (iii) Pentose sugar is ribose (iv) Quantity is variable
Base Pairing	(v) Organic bases are guanine, adenine, cytosine, and thymine	(v) Organic bases are guanine, adenine, cytosine, and uracil
Location	(vi) Much of DNA is in the nucleus of a cell, little in mitochondria and chloroplasts.	(vi) Much of RNA is in the cytoplasm, little in the nucleus.
Stability	(vii) stable	(vii) less stable
Propagation	(xiii) DNA is self-replicating.	(xiii) RNA is synthesized from DNA when needed.
Unique Features	(xiv) DNA is protected in the nucleus, as it is tightly packed.	(xiv) RNA strands are continually made, broken down and reused.
Types	(xvii) Only two types: intra nuclear and extra nuclear DNA	(xviii) Three different types: mRNA, tRNA and rRNA

The central dogma of molecular biology

It states that **DNA makes RNA makes proteins**

PROTEIN SYNTHESIS

Protein synthesis is the process by which individual cells construct proteins. Protein synthesis occurs in separate but interrelated steps as follows:

1. Transcription

Transcription is the process whereby the DNA code of a gene is copied to make messenger RNA (mRNA).

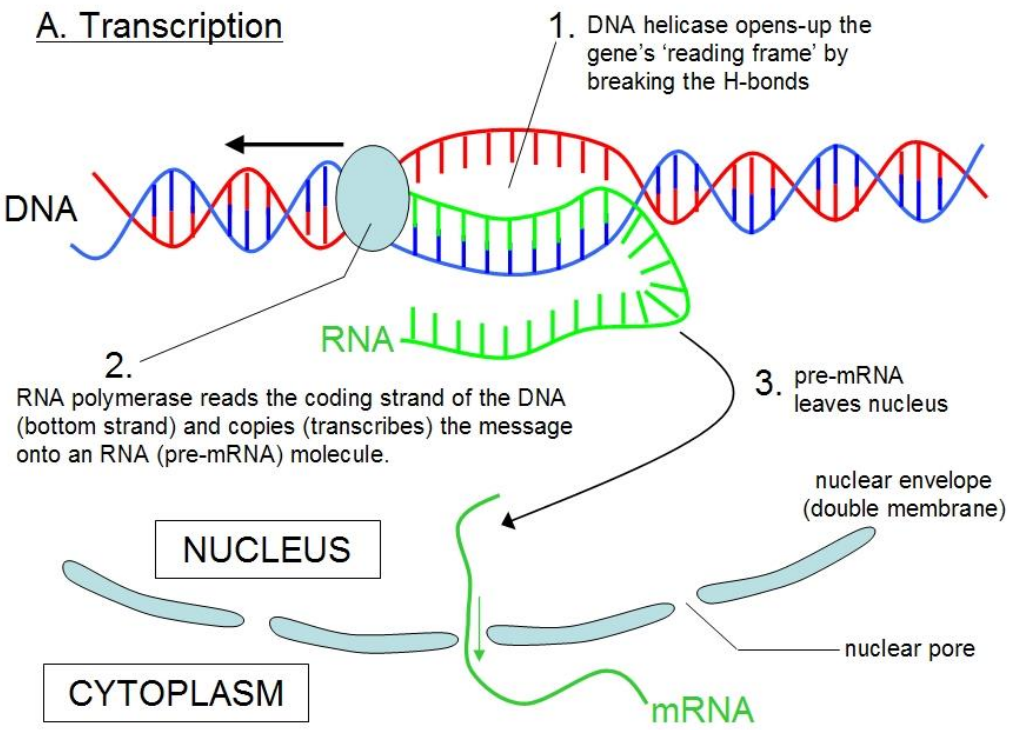
Importance of transcription

(i) DNA is too large to fit through the nuclear pores, yet mRNA being small can readily exit the nucleus.

(ii) DNA contains many codes that aren't always needed at a given time, so m-RNA only carries that code needed to make specific proteins out of the nucleus to the ribosome.

Stages in transcription

1. A specific region of DNA called a cistron unwinds to expose bases on each strand.
2. Each base on one strand attracts its complementary RNA nucleotide, for example. a dree guanine base on DNA attracts an RNA nucleotide with cytosine and adenine attracts uracil.
3. The enzyme RNA polymerase moves along the DNA adding one complementary RNA nucleotide at a time to a newly unwound portion of DNA.
4. The region of base pairing between the DNA and RNA is only around 12 base pairs at a time as the DNA helix reforms behind the RNA polymerase.
5. The DNA acts as a **template** against which mRNA is constructed.



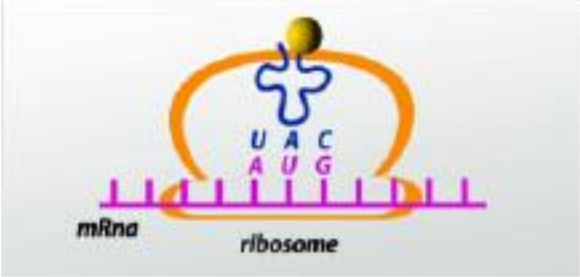
Translation

This describes how the genetic code is converted into amino acids.

It occurs in three stages

The beginning step is called **initiation**, a middle step, called **elongation**, and a final step, called **termination**.

Initiation



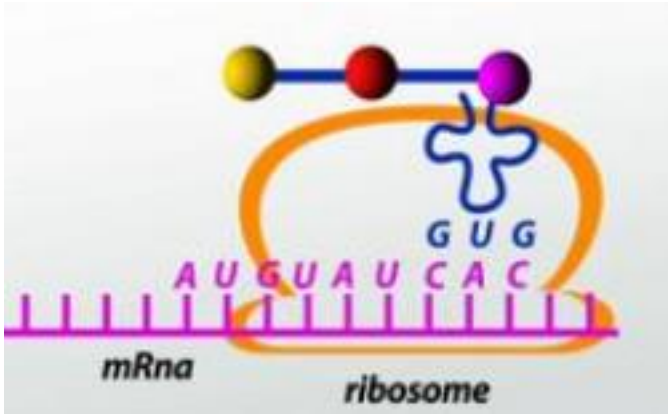
In initiation, mRNA is attached to tRNA, which is attached to the specified amino acid.

During initiation, the mRNA, the tRNA, and the first amino acid all come together within the ribosome. The mRNA strand remains continuous, but the true initiation point is the start codon, AUG that specifies amino acid methionine. So, methionine is first the amino acid that is brought into the ribosome.

Elongation

The next step makes up the bulk of translation. It's called elongation, and it's the addition of amino acids by the formation of peptide bonds. Elongation is just what it sounds like: a chain of amino acids grows longer and longer as more amino acids are added on. This will eventually create the polypeptide.

The mRNA shifts a little through the ribosome so that the next codon exposed to attract the next tRNA with a matching anticodon. A peptide bond forms between the two amino acids on the tRNA . one codon is exposed a time to attract activated tRNA with appropriate anticodon until all the mRNA has moved through the ribosome and each case a peptide bond is formed between the amino acid on the arriving tRNA and the peptide chain already formed.



Termination occurs when all the codons on mRNA are read. The ribosome reaches one or more stop codons on mRNA (UAA, UAG, UGA). The ribosome detaches from the mRNA and splits into its small and large sub-units, while the new protein floats away

Note:

1. Several ribosomes can attach to a molecule of mRNA (to form **polysomes/polyribosomes**) one after another so that several proteins of the same type can be made from one mRNA at the same time.
2. Newly synthesized proteins are packaged and sent to Golgi complex for modification/processing. This is called p**ost translation processing of the protein.**

Comparison between DNA replication and transcription

Similarities

Both:

(1) involve unwinding the helix
(2) involve separating the two strands
(3) involve breaking hydrogen bonds between bases
(4) involve complementary base pairing

(5) involve C pairing with G
(6) work in a 5` to 3` direction
(7) involve linking/ polymerization of nucleotides
(8) DNA or RNA polymerase require a start signal

Differences

DNA replication	**Transcription**
Involves DNA nucleotides, where the pentose sugar is deoxyribose, and the base adenine pairs with thymine	Involves RNA nucleotides where the pentose sugar is ribose, and the base adenine pairs with uracil
Both strands are copied	Only one strand copied not both
Ligase enzyme / no Okazaki fragments are involved	No ligase enzyme / no Okazaki fragments
Has multiple starting points	Has only one starting point
replication gives two DNA molecules	whilst transcription gives mRNA

Compare DNA transcription with translation
Both: **(1)** Occur in 5' to 3' direction **(2)** Require ATP
Differences
(i) DNA is transcribed while mRNA is translated
(ii) Transcription produces RNA while translation produces polypeptides/ protein
(iii) RNA polymerase for transcription while ribosomes for translation/ ribosomes in translation only
(iv) Transcription occurs in the nucleus (of eukaryotes) while translation occurs in the cytoplasm/ at ER
(v) tRNA is needed for translation but not transcription

Explain briefly the advantages and disadvantages of the universality of the genetic code to humans.
(i) Genetic material can be transferred between species/ between humans
(ii) One species could use a useful gene from another species
(iii) Bacteria/ yeasts can be genetically engineered to make a useful product
(1) Viruses can invade cells and take over their genetic apparatus e.g. HIV (**2)** Viruses cause disease

GENETIC CODE
The genetic code is the set of rules by which information encoded in genetic material (DNA or RNA sequences) is translated into proteins (amino acid sequences) by living cells.

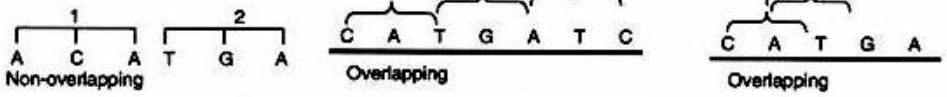
THE GENETIC CODE CHART / TABLE

FIRST BASE	SECOND BASE U	SECOND BASE C	SECOND BASE A	SECOND BASE G	THIRD BASE
U	UUU: Phenylalanine	UCU: Serine	UAU: Tyrosine	UGU: Cysteine	U
	UUC: Phenylalanine	UCC: Serine	UAC: Tyrosine	UGC: Cysteine	C
	UUA: Leucine	UCA: Serine	UAA: Stop	UGA: Stop	A
	UUG: Leucine	UCG: Serine	UAG: Stop	UGG: Tryptophan	G
C	CUU Leucine	CCU: Proline	CAU: Histidine	CGU: Arginine	U
	CUC: Leucine	CCC: Proline	CAC: Histidine	CGC: Arginine	C
	CUA: Leucine	CCA: Proline	CAA: Glutamine	CGA: Arginine	A
	CUG: Leucine	CCG: Proline	CAG: Glutamine	CGG: Arginine	G
A	AUU: Isoleucine	ACU: Threonine	AAU: Asparagine	AGU: Serine	U
	AUC: Isoleucine	ACC: Threonine	AAC: Asparagine	AGC: Serine	C
	AUA: soleucine	ACA: Threonine	AAA: Lysine	AGA: Arginine	A
	AUG: Methionine	ACG: Threonine	AAG: Lysine	AGG: Arginine	G
G	GUU: Valine	GCU: Alanine	GAU: Aspartic acid	GGU: Glycine	U
	GUC: Valine	GCC: Alanine	GAC: Aspartic acid	GGC: Glycine	C
	GUA: Valine	GCA: Alanine	GAA: Glutamic acid	GGA: Glycine	A
	GUG: Valine	GCG: Alanine	GAG: Glutamic acid	GGG: Glycine	G

MOST IMPORTANT PROPERTIES OF GENETIC CODE

1. **The code is a triplet codon**
   The nucleotides of mRNA are arranged as a linear sequence of codons, each codon consisting of three successive nitrogenous bases, i.e., the code is a triplet codon.

2. **The code is non-overlapping**
   In translating mRNA molecules, the codons do not overlap but are "read" sequentially.



3. **The code is comma less**
   This means that no codon is reserved for punctuations. After one amino acid is coded, the second amino acid will be automatically, coded by the next three letters and that no letters are wasted as the punctuation marks.
4. **The code is non-ambiguous**
   A particular codon will always code for the same amino acid. The same codon shall never code for two different amino acids.

5. The code has polarity

The code is always read in a fixed direction, i.e., in the 5'→3′ direction.

6. The code is degenerate

More than one codon may specify the same amino acid; For example, except for tryptophan and methionine, which have a single codon each, all other 18 amino acids have more than one codon.

Biological advantages of degeneracy

(i) It permits essentially the same complement of enzymes and other proteins to be specified by microorganisms varying widely in their DNA base composition.

(ii) It provides a mechanism of minimizing mutational lethality. E.g. Substitution of the third base-**U** in **GUU (**for valine**)** with **C/A/G** does not change the amino acid coded for.

7. Some codes are start codons

In most organisms, **AUG** codon is the start or initiation codon, i.e., the polypeptide chain starts either with methionine (eukaryotes) or N-formylmethionine (prokaryotes).

8. Some codes are stop codons

Three codons **UAG, UAA** and **UGA** are the chain stop or termination codons. They do not code for any of the amino acids. These codons are also called **nonsense codons**, since they do not specify any amino acid.

9. The code is universal

Same genetic code is found valid for all organisms ranging from bacteria to man.

Sample questions

1. If a messenger RNA has a base sequence of CUGACGAGU, which one of the following would be the possible maximum number of amino acids coded for, if the code is overlapping?
   A. 7 C.4
   B.6 D.3

2. The two strands of DNA easily separate during replication because of the
   A. helical nature of the nucleotide
   B. the closeness of the base pairs
   C. weak hydrogen bonds between the base pairs
   D. the week hydrogen bonds between phosphate and sugars.
3. Which one of the following is the mRNA strand that corresponds to the DNA strand TAGGCT?
   A. AUCCGA
   B. UUCCGU
   C. CGAAUC
   D.UAGGCU
4. Which one of the following bas triplet pair with ACG triplet base?
   A. TGC B. AAT C. GTG D. ACC

5. Which one of the following is confined within the nucleus?
   A. DNA molecules B. Ribosome
   C. Messenger RNA D. Transfer RNA
6. Which of the following are purines?
   A. Adenine and cytosine
   B. Thymine and Adenine
   C. Thymine and cytosine
   D Adenine and guanine
7. Which one of the following statement correctly describes the transcription of DNA?
   A. It produces amino acids
   B. it results in and increased DNA synthesis
   C. It produces messenger RNA
   D. It occurs at the surface of the ribosome
8. Which of the following is found in both DNA and messenger RNA?
   A. double helix structure
   B. ribose
   C. sugar-phosphate chain
   D Thymine

9. Which base sequence below pair with AGU?
   A. TGC B. TCA C. GCC D ATT
10. What is the maximum number of triplets of nucleotides that could code for 20 amino acids?
   A. 3 B. 6 C. 48 D. 64
11. Which one of the following tRNA anti-codons will correspond to the mRNA base triplets CAT?
   A. GUA B.GUC C. GTC D. GTA

12. The synthesis of mRNA may be described as a
   A. Replication
   B. Transcription
   C. translocation
   D. transduction

13. Which of the following is the correct sequence of combination forming a double helix of DNA?
   A. Phosphate- sugar- guanine-hydrogen bond- cytosine-sugar - phosphate
   B. Thymine-sugar-phosphate-hydrogen bond-adenine-sugar-phosphate
   C. Sugar- phosphate-cytosine-hydrogen bond-guanine-sugar- phosphate
   D. Phosphate-sugar-guanine-hydrogen bond-thymine-sugar-phosphate

14. Hyroxylamine, a mutagen, converts cytosine to a compound which pairs with adenine. If DNA is treated with hydroxylamine, the resulting mutation is
   A. a deletion
   B. a substitution
   C. an insertion
   D. an inversion
15. Name the bases that may be synthesized of the t-RNA from strand (ii) of the DNA indicated in the diagram below

A. G.U.A
B. C.A.T
C. C.A.U
D. C.T.A

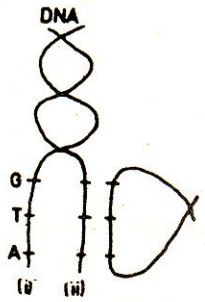


Fig.1

16. If the bases on t-RNA are ACU, what would be the corresponding bases on original DNA coding strand during protein synthesis?
   A. ACT B. UGA C. TGA D. ATG

17. When DNA replicate, it thought to unwind and ‘unzip” along
    A. bonds between the deoxyribose and phosphate units
    B. Phosphate to phosphate bonds
    C. hydrogen bonds between base pairs
    D. ribose to deoxyribose sugars.

18. Which of the following carries the triplet nucleotide code?
    A. ribosome RNA (r-RNA)
    B. Transfer RNA (t-RNA)
    C. Messenger (mRNA)
    D. Nuclear (n-RNA)

19. The nucleotide is attached to another in DNA strand by bridge
    A. Base to Base
    B. Sugar to Base
    C. Phosphate to Base
    D. phosphate to Sugar

20. Which one of the following show the correct coding sequence during protein synthesis?
    A. DNA, mRNA, tRNA, rRNA, amino acids
    B. rRNA, tRNA, mRNA, polypeptide
    C. DNA, mRNA, tRNA, amino acids
    D. DNA, mRNA, rRNA, tRNA, amino acids

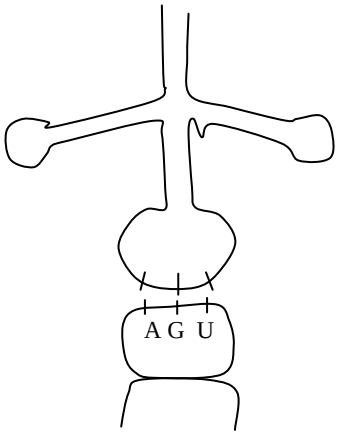
21. Transfer RNA of function in
    A. Carrying RNA from the ribosome to mRNA
    B. Attaching RNA to ribosome
    C. Carrying amino acids to the correct site on mRNA
    D. Carrying nucleotide to mRNA on the ribosome

22.The genetic code is most directly related to the sequence of
    A. Ribose unit
    B. Deoxyribose unit
    C. Nitrogen bases
    D. Phosphates and pentose sugar

23. Any change in the sequence of bases of a DNA molecule by addition, deletion or substation always result in a
    A. Lethal gene
    B. mutation of the gene
    C. visible change in offspring
    D. variation in the new individual making it more capable of adaptation

24. In the Watson-Crick model of double helix, the “rugs” of the “twisted ladder” are composed of
    A. Sugar
    B. A purine and a pyrimidine
    C. Two purines
    D. Two pyrimidine

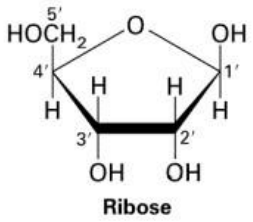
25. The figure below shows a stage in protein synthesis. A mutation in DNA template strand involving substitution of the original base G on the mRNA codon was transcribed with match with a complementary anticodon having the following base triplet code



    A. UUA B. TCU C. GCA D. UCA

26. Analysis of a sample of DNA showed that 33% of the bases were adenine. The percentage of guanine bases in the sample was
    A. 34
    B. 33
    C. 17
    D. 28

27. The figure below represents the structure of



Ribose

    A. Amino acid
    B. Glucose
    C. Ribose
    D. Fatty acid

28. Some bacteria when infected with microphages, may make a particular amino acid they could make before. This is due to
    A. Transformation
    B. Mutation
    C. Transduction
    D. conversion

29. In a non-dividing cell, the percentage of guanine is 40%. The percentage of adenine in the cell is.
    A. 30
    B. 20
    C. 40
    D. 10

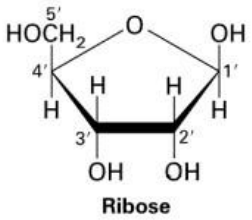
30. In an outline for protein synthesis,

DNA $\xrightarrow{\text{Stage 1}}$ mRNA $\xrightarrow{\text{stage 2}}$ polypeptide

Stage 2 represents
    A. Transcription
    B. Translation
    C. Transduction
    D. transformation

31. If the triplet of mRNA is AAG, what is the complementary triplet of the base on tRNA molecule?
    A. TTC
    B. UUC
    C. CCT
    D. CCU

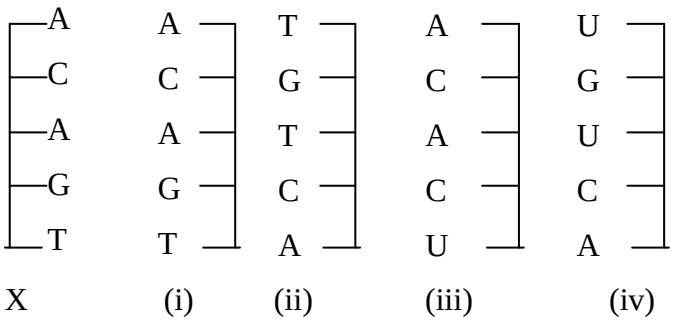
32. Which of th following molecules is represented in figure below



Ribose

    A. Fattay acid
    B. Deoxyribose
    C. Glucose
    D. ribose

33. Which two of the following strands of nucleotide would pair with strand X in the figure?



A. (i) and (iii)
B. (ii) and (iv)
C. (i) and (ii)
D. (iii) and (iv)

34. A biochemical analysis of a DNA sample showed that 34% of the bases were guanine. The percentage of adenine bases in the sample is
A. 32
B. 16
C. 17
D. 34

35. The process of changing the information on mRNA into formation of polypeptides is known as
A. Transcription
B. Translation
C. Transduction
D. transformation

36. Which one of the following shows he correct coding sequence during protein synthesis?
A. DNA → mRNA → tRNA → rRNA → amino acid
B. rRNA → tRNA → mRNA → polypeptide
C. RNA → mRNA → tRNA → proteins
D. DNA → mRNA → rRNA → tRNA → amino acid

37. During protein synthesis, the anticodon base of tRNA is AUG. What is th base sequence on the template DNA strand?
A. UAU
B. ATG
C. AUG
D. TAC

38. Analysis of a sample of DNA showed that 33% of the bases were adenine. The percentage of guanine bases in the sample was

A. 34
B. 33
C. 17
D. 28

39. (a) Biochemical analysis of sample of DNA showed that 33% of the nitrogenous base were guanine. Calculate the percentage of the bases in the sample which would be adenine. Explain how you arrived at your answer
(b) What name is given to the triplet of bases which designate individual amino acid?
(c) If the triplet of mRNA base which designate the amino acid lysine is AAG, what is the complementary triplet of bases on the tRNA

40. (a) state where each of the following is found in a cell
DNA ……
RNA ……..
(b) give three structural differences between DNA and RNA (3marks)
(c) What is the genetic significance of DNA replication? (2marks)
(d) Give two ways that suggest that DNA is hereditary material (4marks)

41. Describe the process of protein synthesis (20marks)

42. (a) Describe the biological function of amino acids (05marks)
(b) Describe how amino acids form a polypetide (09marks)
(c) How do inhibitors change the rate of enzyme controlled reaction? (06marks)

43. (a) Describe the structure of DNA (11marks)
(b) Using examples, explain an effect of gene in humans (6marks)
(c) What is the signifince of mutation in crop hasbandary? 06marks)

44. (a)Compare DNA and RNA (10marks)
(b) Describe the role of mRNA protein synthesis in a cell(5marks)
(c) How does molecular structure of proteins relate to their functions? (05marks)

Suggested answers

1	B	6	D	11	B	16	A	21	C	26	C	31	B	36	D
2	D	7	C	12	B	17	C	22	B	27	C	32	D	37	B
3	A	8	C	13	A	18	B	23	B	28	C	33	B		
4	A	9	D	14	B	19	A	24	B	29	D	34	B		
5	A	10	D	15	A	20	D	25	D	30	B	35	B		

39. (a) Percentage of adenine = 17%
(b) codon
(c) UUC

40. (a)(i) DNA is found in the cell nucleus
RNA is found in both nucleus and cytoplasm

(b)

DNA	RNA
Double helix	Single
Has thymine	Has no thymine
Has no uracil	Contains uracil
Has hydrogen bonds between base pairs	Had no hydrogen bond
High molecular weight	Low molecular weight

(c)

a. it allows maintenance of a constant amount of genetic information within organisms of a population
b. it allows passing over of genetic information from parents to offsprings in constant amounts, generation after generation

(d)

c. ability to replicate
d. it the major component of chromosomes believed to transmit genetic material

41. Process of protein synthesis

(i) Protein synthesis occurs in the cells of living organism controlled by DNA which reside in the nucleus

(ii) (ii) In the nucleus, DNA unwinds to form two separate DNA strands of which one acts as a template for synthesis of mRNA strand in the process called transcription.

(iii) mRNA molecule leaves the nucleus through nuclear pores to the cytoplasm where it attaches to ribosome which consists of rRNA and proteins on the rough endoplasmic reticulum.

(iv) The ribosome reads the sequence of codons in mRNA, and molecules of tRNA bring amino acids to the ribosome in the correct sequence.

(v) rRNA helps bonds peptide bonds form between the amino acids starting with methionine until the entire genetic code on mRNA is read to form a polypeptide.

(vi) The polypeptide molecule then peels off from the ribosome and released into the cytoplasm

(vii) After a polypeptide chain is synthesized, it may undergo additional processing to form the finished protein

42. Solution:

(a) (i) Amino acids are used to build up proteins, which have functional roles such as enzymes and hormones, and structure roles such as keratin and collagen.

(ii) The amino and carboxylic group of amino acids act as buffers, resisting changes in pH in the body fluids.

(iii) Amino acids can be used substrate in cell respiration to provide energy in cases of starvation.

(iv) They are also used to synthesize neurotransmitters. For example, tyrosine is used to synthesize adrenaline and norepinephrine.

(v) Amino acids are regulators of gene expression. They do so by modulating the translation of mRNA

(b) The order and nature of amino acids used in the assembly of polypeptide chain is dictated by the sequence of bases in the mRNA molecule, in a process called translation, it occurs in ribosomes.

- First, the mRNA attaches to the ribosome.
- The amino acids are then activated and attached to their specific tRNA molecules in a reaction catalyzed by the enzymes aminoacyl –RNA synthetase.
- The first mRNA codon then binds the tRNA molecule having the complementary anticodon and carrying the first amino acid (usually methionine)
- The second mRNA codon then also binds the second tRNA molecules bearing the complementary anticodon and carrying a specific amino acid.
- The ribosome holds the mRNA, tRNA and associated enzymes controlling the process until a peptide bond forms between adjacent amino acids.

- Once the new amino acid has added to the growing polypeptide chain, the ribosome moves one codon along the mRNA.
- The tRNA previously attached to the polypeptide chain leaves the ribosome and returns to the RNA pool in the cytoplasm. another tRNA molecule binds to the new codon.
- This process continues until the ribosome comes to a terminating codon (no sense codon), signaling 'stop'
- At this point, the polypeptide chain detaches from the ribosome and is released into the cytoplasm.
- The necessary energy for the synthesis of the polypeptide chain comes from ATP.
- Note: translation is the mechanism by which the sequence of bases in a mRNA molecule is converted into a sequence of amino acids in a polypeptide chain. It is the second steps in protein synthesis
- The first is transcription where the base sequence of a section of DNA representing a gene converted into the complementary base sequence of mRNA. this occurs in the nucleus and is influenced by the enzymes RNA polymerase.
- The last step of protein synthesis involves modification in the protein structure. This may occur in the Golgi apparatus in the cytoplasm.

(c) Inhibitors reduces the rate of enzyme controlled reactions.

They do so two mechanisms competitive inhibition and non-competitive inhibition

Competitive inhibition

- Substance inhibitors' which are structurally similar to the substrate compete with the substrate for the active site on the enzyme.
- This result in fewer enzyme-substrate complex formation and therefore the rate of reaction reduces.
- This type of inhibition is reversible.

Non- competitive inhibitions.

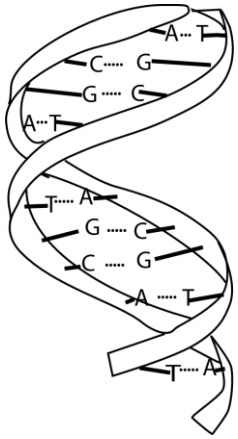
- Substance (inhibitors) bearing no structural resemblance to the substrate bind with the enzymes or it cannot be released from it.
- This types of inhibitions can be reversible or irreversible.

Note: in competitive inhibition, an increase in substrate concentration increases the rate of the reaction. This is because the chances of the substrate molecules binding to the active site are then higher.

However, in non-competitive inhibition, increasing the substrate concentration has no effect on the rate of reaction since the inhibitors does not bind to the active site. The degree of inhibition only depends on the concentration of the inhibitor.

43. Solution

(a) In this question you should outline the structural components of DNA and show how they are linked to form the DNA molecule.



- A DNA molecule is composed of two antiparallel polynucleotide chains as shown above.
- Each chain consists of repeated units of deoxyribonucleotides formed by a deoxyribose sugar phosphate backbone with nitrogenous bases as side branches.
- The two polynucleotide chains are twisted around a common axis to form a right handed double helix.
- These two chains are held together by hydrogen bonds between the nitrogenous bases from either chain. Adenine in one chain is always pairs with thymine of the other by two hydrogen bonds while cytosine pairs with Guanine by three hydrogen bonds.
- The arrangement of these nitrogen bases gives DNA its identity.
- DNA in eukaryotes is wound around histone proteins to form chromosomes.
- In prokaryotes, it occurs in a circular shape.

(b) In this questions, first show your understanding of the term gene mutation. Then using suitable examples outline the effect of this process in humans.

A gene mutation is a sudden irreversible change in the structure of a gene. It is also called point mutation. It results in loss or change of function of the gene in question. Gene mutation is the cause of some of the disease called genetic disease. Example is sickle cell anemia;

This is caused by a mutation in the gene responsible for synthesis of β – polypeptide chains in hemoglobin.

This results in replacement of glutamine with valine in position 6 of the chains, leading to formation of hemoglobin S.

The condition has the following effects.

- Hemoglobin S crystallizes at low oxygen tensions, making the red blood cells fragile

and to adopt a sickle shape. They can hardly pass through capillaries and the spleen sinusoids.

- The red blood cells become more easily hemolyzed in the liver and spleen. This reduces the number of red blood cells causing anaemia.
- Bilirubin, the bi-product of hemoglobin breakdown, accumulates in the body and causes yellowing of the body surface membranes especially the sclera (jaundice)

Note: other conditions that occur due to gene mutation include;

- Alkaptonuria
- Phenylketonuria
- Albinism

(c). In this question you should point out how the effect of a mutation is of importance in crop husbandry.

Mutations can induce polyploidy in plants causing hybrid vigor. This leads to;

- Increased crop yield
- Increased pest and disease resistance
- Increase size of fruits, leaves and flowers.
- Faster rates of growth.

43. Solution:

(a) Similarities between DNA and RNA

- Both contain purines adenine and guanine and the pyrimidine base cytosine
- Both contain phosphate groups.
- They both have a basic sugar- phosphate backbone in their chains
- Both contain polynucleotide chains.

Differences between DNA and RNA

DNA	RNA
• Double stranded structure. • Found only in the nucleus. • The sugar molecule is deoxyribose. • Contains a pyrimidine base thymine • Giant molecules with very high molecular weight • Has hydrogen bonds in its structure	• Single stranded structure • Found in both nucleus and cytoplasm • Found both sugar molecular is ribose • Contains a pyrimidine base uracil • Short, small with low molecular weight • Has no hydrogen bonds in its structure

•

(b) mRNA caries genetic information in form of nitrogenous bases from chromosomal DNA in the nucleus to the ribosomal RNA in the in the cytoplasm. It acts as a template for protein synthesis. It has complementary DNA base sequence to part of DNA from which it is transcribed. As a result, mRNA directs the synthesis of proteins as directed by the base sequence on the segment of DNA from it is copied, a process called translation

(c) According to molecular structure, proteins can be classified as follows in relation to function;

- Fibrous proteins from a long, tough, fibre insoluble in water. They therefore function as structural and supporting proteins and include; keratin, collagen, elastin, e.t.c.

- Globular proteins have a globular shape but lack contractile properties. They contain polypeptide chains coiled about them. They therefore act as regulatory molecules and as food storage molecules in plants. Soluble globular proteins are amphipathic and therefore act as buffers of body fluid pH.
- Conjugated proteins consist of a simple protein united with some non-protein sub-stance. Examples include; glycoproteins which form mucin of saliva that helps in softening food; chromo proteins combined with a pigment such as hemoglobin, an oxygen carrying molecule; metallo-proteins which act as enzymes.