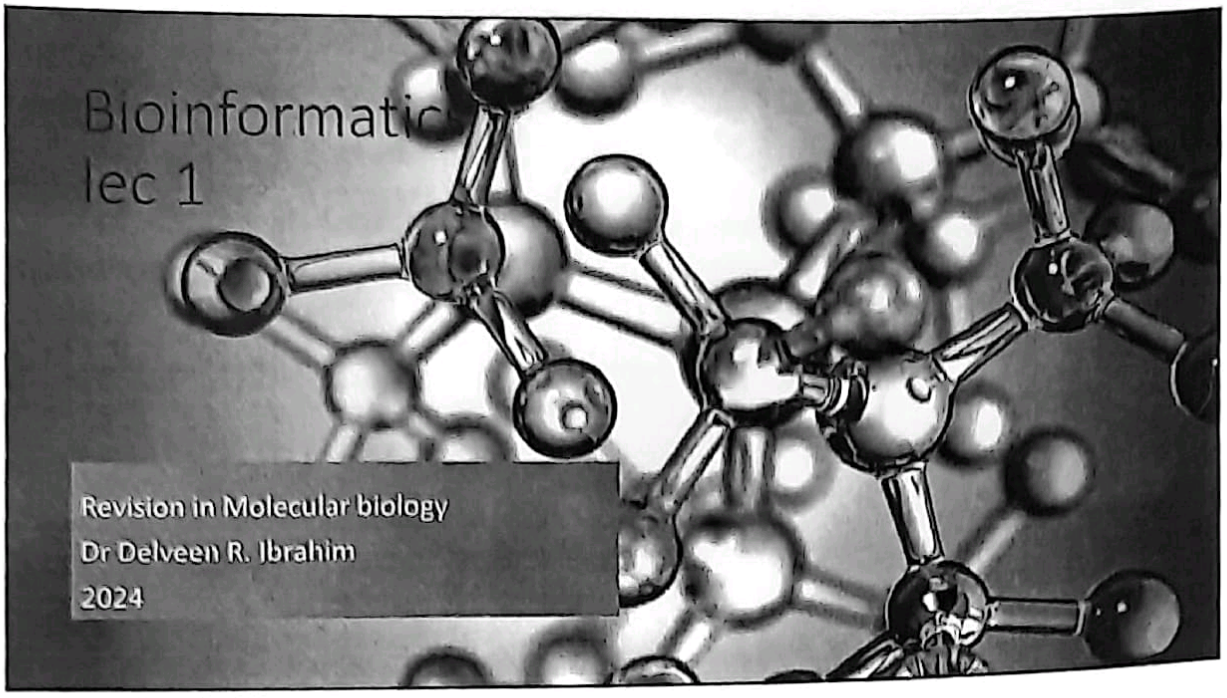
① biology
Marhalac



1

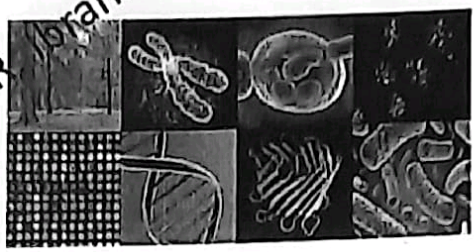
Lecture outlines:

- Terminologies
- Chromosomes in Eukaryotes, prokaryotes and viruses
- Central dogma of molecular biology
- DNA and RNA structure
- Some methods used in molecular biology

2

Basic Terminologies

- Molecular biology : is the branch of biology that studies the molecular basis of biological activity. It deals with the structure and function of the macromolecules (e.g. proteins, RNA and DNA) essential to life.



3

Basic terminology

- **Genome**

– Complete set of genes in an organism

- **Chromosomes**

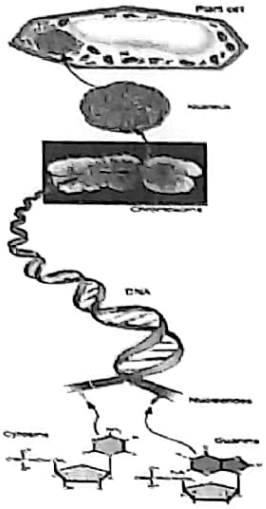
– The nucleoprotein structures that carry the genetic information

- **Gene**

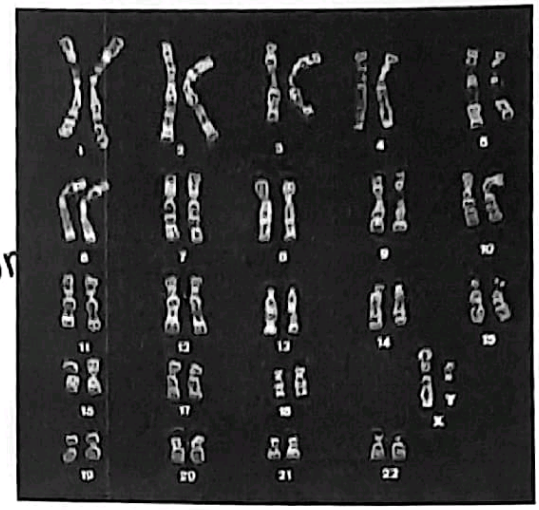
– The DNA sequence that determines the chemical structure of a specific polypeptide molecule or RNA molecule, It is the determinant of an observable trait or characteristic of an organism e.g (pigmentation)

- **Genetics** is the branch of biology that deals with heredity and variation.
- **Plasmid:** Extra-chromosomal DNA which replicates independently of the chromosome and regulates its own replication

4



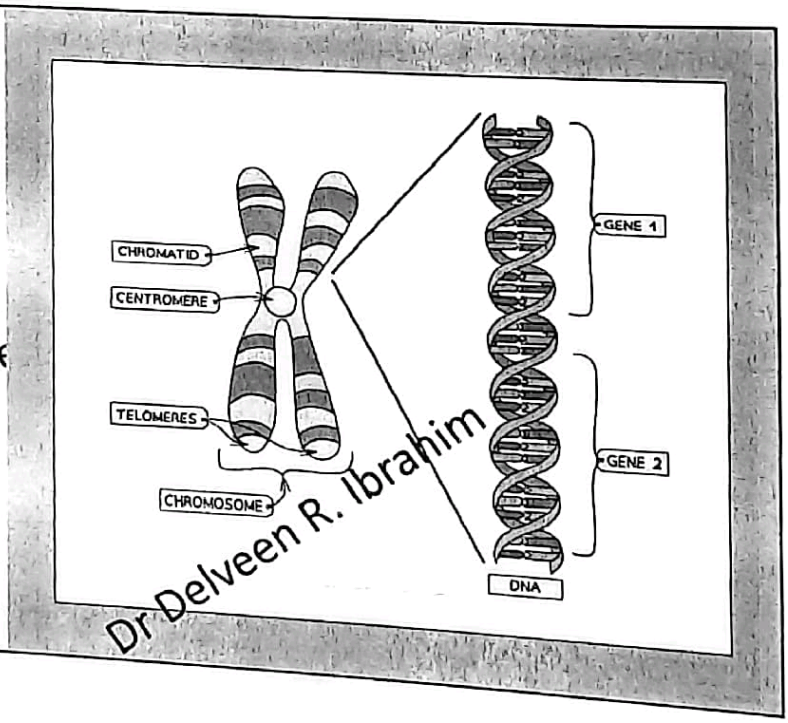
Molecular organization of a living cell.



A micrograph of the 46 chromosomes found in a cell from a human male.

5

- **A chromatid** is one-half of two identical copies of a replicated chromosome.
- During cell division, the identical copies are joined together at the region of the chromosome called the **centromere.**
- Joined chromatids are known as **sister chromatids**. Once the joined sister chromatids separate from one another in anaphase of mitosis, each is known as a **daughter chromosome**.



6

- **Histone**

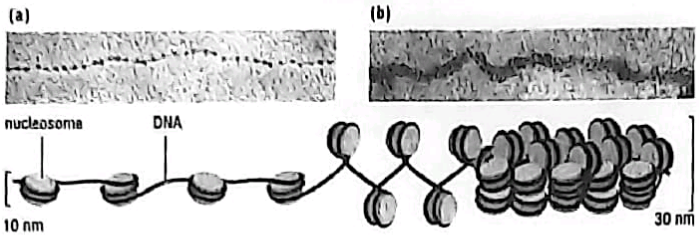
– Highly alkaline proteins , important for the proper compaction of DNA in eukaryotic cells into structural units (nucleosome).

- **Nucleosome**

– The repeating structural unit within eukaryotic chromatin is **nucleosome**—a double-stranded segment of DNA wrapped around an octamer of histone proteins.

- **Chromatin**

contains a repeating pattern in which the nucleosomes are connected by linker regions of DNA. **Chromatin** is located in the nucleus of our cells.



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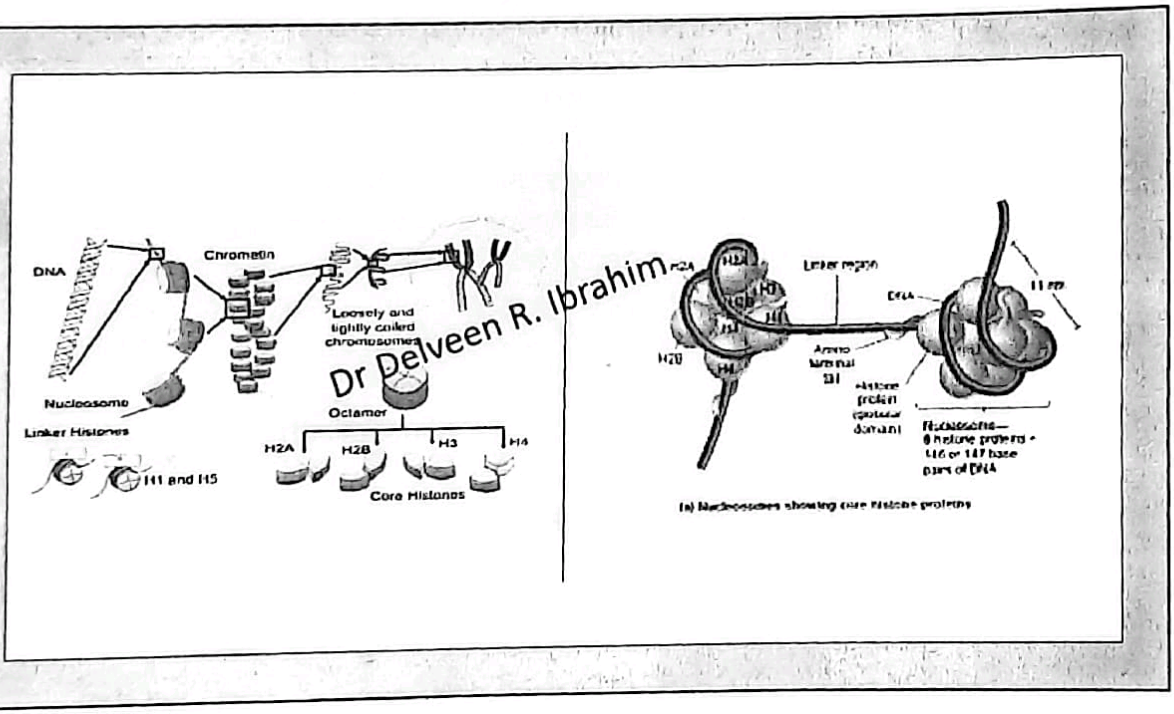

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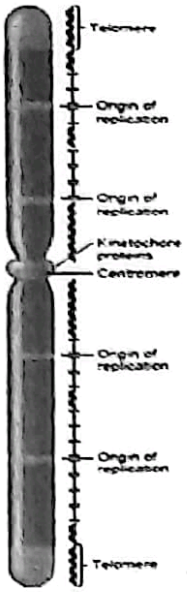


Organization of eukaryotic chromosomes.

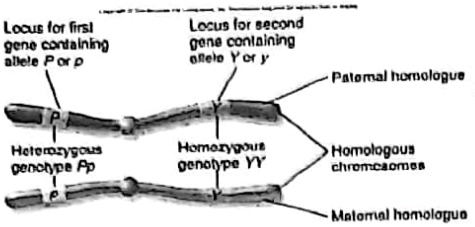
Eukaryotic chromosomes:

- are usually linear.
- A typical chromosome is tens of millions to hundreds of millions of base pairs in length.
- Eukaryotic chromosomes occur in sets. Many species are diploid, which means that somatic cells contain 2 sets of chromosomes.
- Genes are interspersed throughout the chromosome.
- Each chromosome contains many origins of replication.
- Each chromosome contains a centromere that forms a recognition site for the kinetochore proteins.
- Repetitive sequences are commonly found near centromeric and telomeric regions, but they may also be interspersed throughout the chromosome.

9

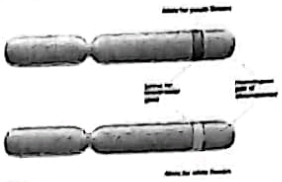
- A gene is a segment of DNA that codes for a character.
- A character is any feature of an organisms that could have multiple forms. For instance, hair color is a character. It is a feature, however, it can take multiple forms: brown, black, blond, you get it; these are traits, traits are controlled by alleles.
- So, what does this mean?
- A gene exists in the form of alleles- it's various forms.

10



Alleles

- Most genes exist in many forms called alleles.
- An allele is any of the alternative forms of a gene that may occur at a specific locus.
  - our cells have two alleles for each gene, one from each parent.



Allele : different version of a gene, such as a wild-type or a mutant version.

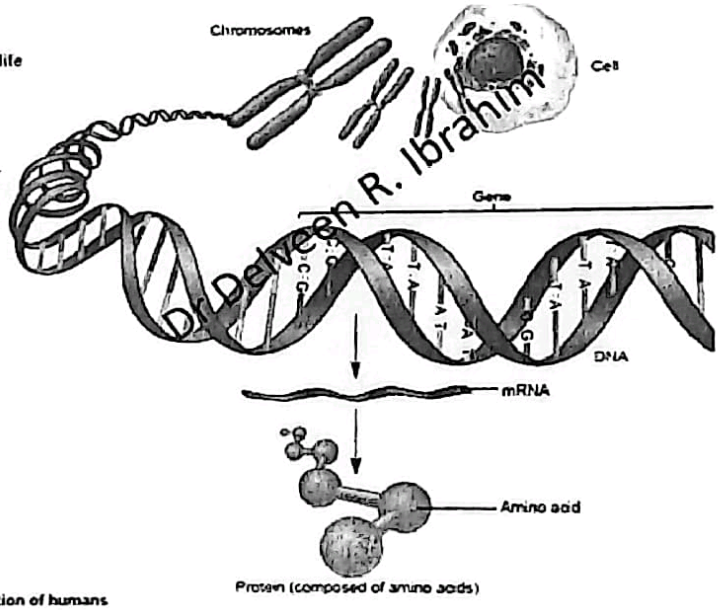
11

DNA, the molecule of life

Trillions of cells

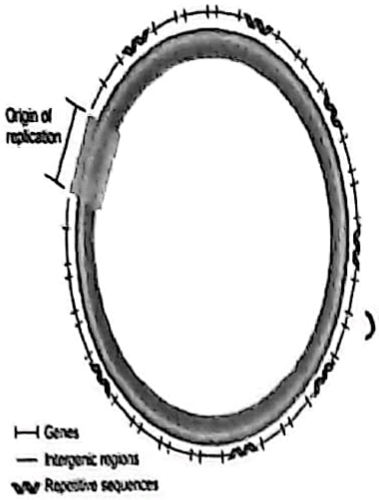
Each cell contains

- 46 human chromosomes, found in 23 pairs
- 2 meters of DNA
- Approximately 3 billion DNA base pairs per set of chromosomes, containing the bases A, T, G, and C
- Approximately 20,000 to 25,000 genes coding for proteins that perform most life functions



(a) The genetic composition of humans

12



Organization of sequences in bacterial chromosomal DNA.

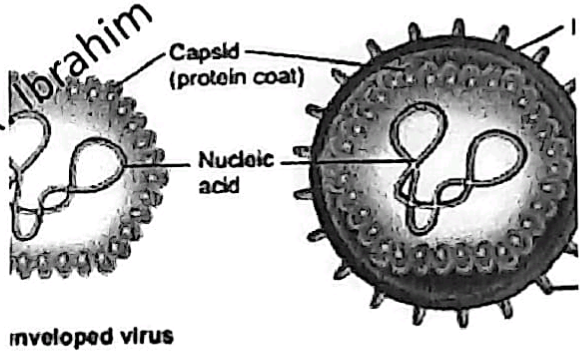
Key features of bacterial chromosome:

- Most, but not all, bacterial species contain circular chromosomal DNA.
- A typical chromosome is a few million base pairs in length.
- Most bacterial species contain a single type of chromosome, but it may be present in multiple copies.
- Several thousand different genes are interspersed throughout the chromosome. The short regions between adjacent genes are called intergenic regions.
- One origin of replication is required to initiate DNA replication.
- Repetitive sequences may be interspersed throughout the chromosome.

13

Viruses

- **Virus's genome:**
- contain nucleic acid as their genetic material, surrounded by a protein coat, or capsid
- **DNA or RNA**, but not both.
- it is **single stranded**, whereas in others, it is **double-stranded.**
- **linear or circular**



nveloped virus

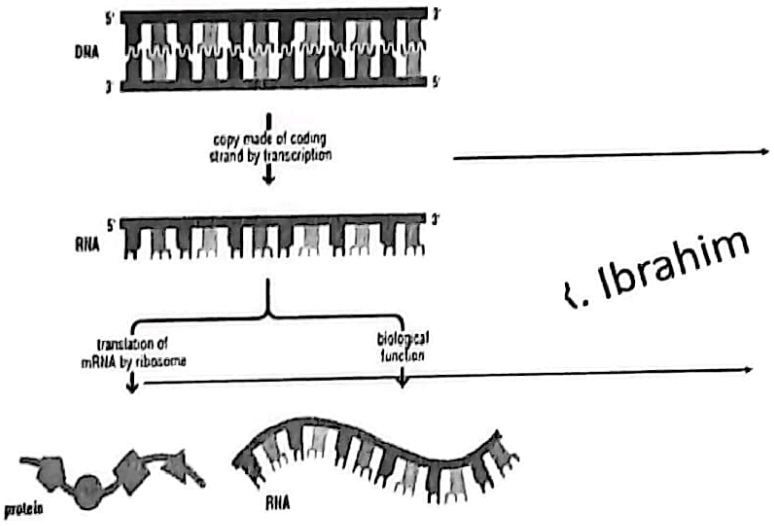
(b) Enveloped virus with

14

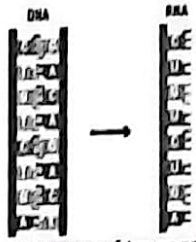
Approximate gene number and genome size for representative organisms

Approximate genome size and gene number for representative organisms		
element	gene number	genome size
Mycoplasma genitalium	~480 genes	580 000 bp
Escherichia coli	4400 genes	4 600 000 bp
Saccharomyces cerevisiae	~ 6000 genes	12 100 000 bp
Schizosaccharomyces pombe	~ 5000 genes	14 000 000 bp
worm (*Caenorhabditis elegans*)	~23 000 genes	90 000 000 bp
fruit fly (*Drosophila melanogaster*)	~27 000 genes	130 000 000 bp
dicktwood (*Arabidopsis thaliana*)	~29 000 genes	157 000 000 bp
zebrafish (*Danio rerio*)	~18 000 genes	2 000 000 000 bp
human (*Homo sapiens*)	~32 000 genes	3 200 000 000 bp
marbled lungfish (*Protopterus aethiopicus*)		130 000 000 000 bp
amoeba (*Amoeba dubia*)		670 000 000 000 bp

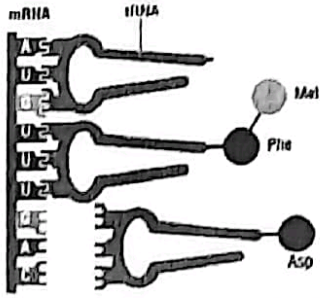
15



Central Dogma of Molecular Genetics



The process of transcription is common to all organisms



The process of translation is common to all organisms

16

Genetic Code

- How the translation occurs
- Think of this as a function
  - Input: triples of three base letters (Codons)
  - Output: amino acid
  - Example: ACC becomes threonine (T)
- Gene sequences end with:
  - TAA, TAG or TGA

17

Genetic Code

Second letter

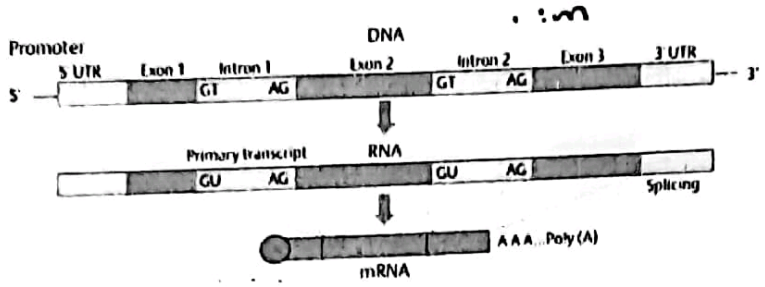
First letter	U	C	A	G	Third letter
U	UUU Phe, UUC Phe, UUA Leu, UUG Leu	UCU Ser, UCC Ser, UCA Ser, UCG Ser	UAU Tyr, UAC Tyr, UAA Stop, UAG Stop	UGU Cys, UGC Cys, UGA Stop, UGG Trp	U C A G
C	CUU Leu, CUC Leu, CUA Leu, CUG Leu	CCU Pro, CCC Pro, CCA Pro, CCG Pro	CAU His, CAC His, CAA Gln, CAG Gln	CGU Arg, CGC Arg, CGA Arg, CGG Arg	U C A G
A	AUU Ile, AUC Ile, AUA Ile, AUG Met	ACU Thr, ACC Thr, ACA Thr, ACG Thr	AAU Asn, AAC Asn, AAA Lys, AAG Lys	AGU Ser, AGC Ser, AGA Arg, AGG Arg	U C A G
G	GUU Val, GUC Val, GUA Val, GUG Val	GCU Ala, GCC Ala, GCA Ala, GCG Ala	GAU Asn, GAC Asn, GAA Glu, GAG Glu	GGU Gly, GGC Gly, GGA Gly, GGG Gly	U C A G

- A=Ala=Alanine
- C=Cys=Cysteine
- D=Asp=Aspartic acid
- E=Glu=Glutamic acid
- F=Phe=Phenylalanine
- G=Gly=Glycine
- H=His=Histidine
- (+)=Isoleucine
- K=Lys=Lysine
- L=Leu=Leucine
- M=Met=Methionine
- N=Asn=Asparagine
- P=Pro=Proline
- Q=Gln=Glutamine
- R=Arg=Arginine
- S=Ser=Serine
- T=Thr=Threonine
- V=Val=Valine
- W=Trp=Tryptophan
- Y=Tyr=Tyrosine

18

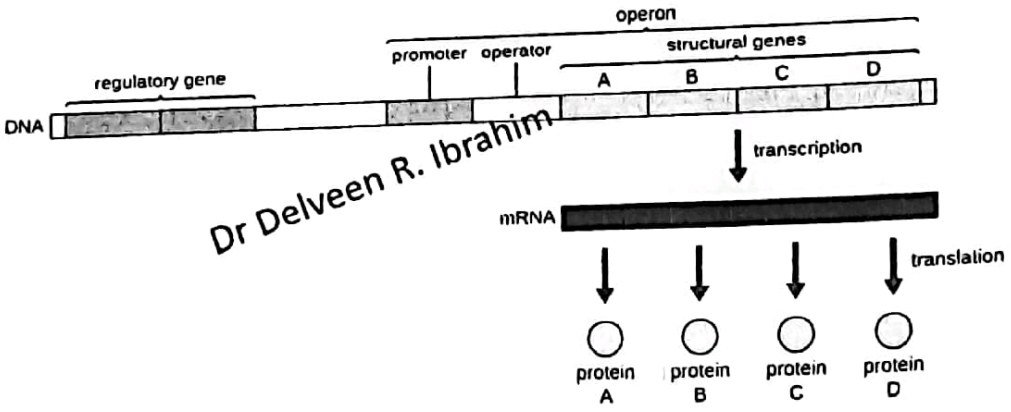
Gene structure (Eukaryotes)

- **Exon** : coding region
- **Intron** : non-coding region
- Both are transcribed into pre-mRNA, but only exons are translated



19

Gene structure in Prokaryotes

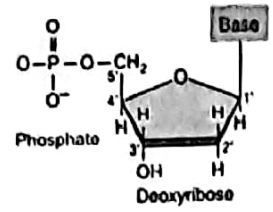


20

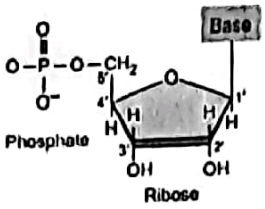
Differences between DNA and RNA

DNA

- Deoxyribonucleic acid
- 2'-deoxy-D-ribose
- Adenine
- Guanine
- Cytosine
- Thymine



(a) Repeating unit of deoxyribonucleic acid (DNA)



(b) Repeating unit of ribonucleic acid (RNA)

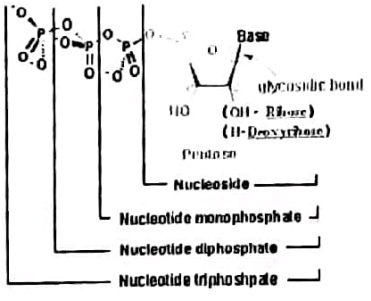
RNA

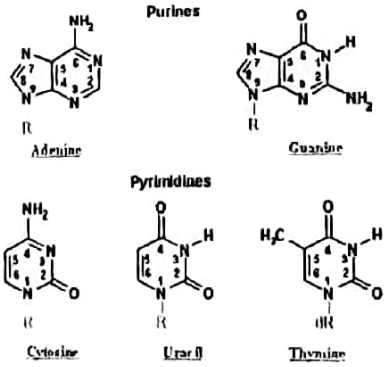
- Ribonucleic acid
- D-ribose
- Adenine
- Guanine
- Cytosine
- Uracil

21

Nucleic Acids

Made of monomer building blocks called **nucleotides.**

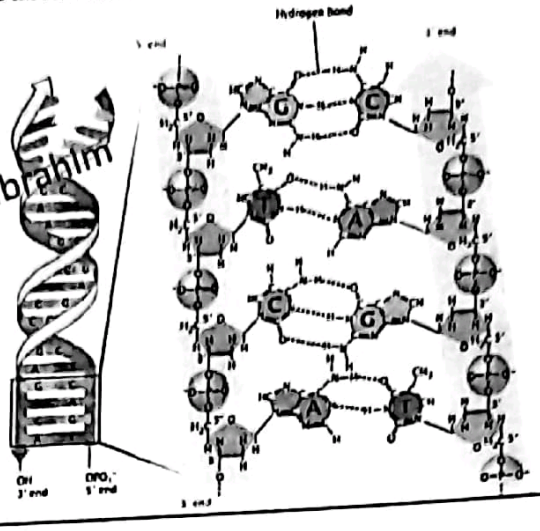




22

Key Features of the double helix structure of DNA:

- Two strands of DNA form a right-handed double helix.
- The bases in opposite strands hydrogen bond according to the AT/GC rule.
  - Purines bound to pyrimidines
  - Bound by hydrogen bonds
  - (H-bonds), which are quite weak
  - A-T (two bonds)
  - C-G (three bonds)
  - Sugars bound together by phosphodiester backbone



23

Types of DNA

➢ According to **the location in the cell**:

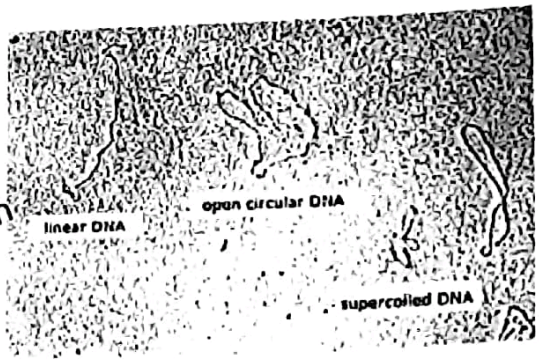
1. Nuclear (nDNA)
2. Non-nuclear
   - Mitochondrial (mtDNA)
   - Chloroplast (cpDNA)
   - Plasmid

➢ **According to the number of the strands:**

1. dsDNA
2. ssDNA

➢ **According to the shape:**

1. -Circular
   - Covalently Closed Circle (CCC Dna)
   - Open circle (OC Dna)
2. Linear



24

RNA

- Multiple roles in cells
- see the table , Remember there are many other types of RNA with different functions

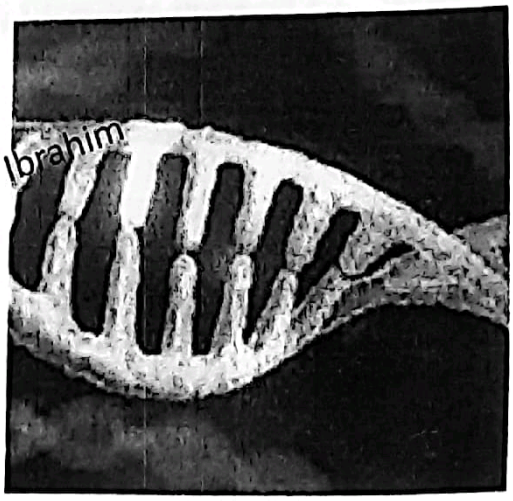
Functions of RNA Molecules

Type of RNA	Description
mRNA	Messenger RNA (mRNA) encodes the sequence of amino acids within a polypeptide. In bacteria, some mRNAs encode a single polypeptide. Other mRNAs are polycistronic—a single mRNA encodes two or more polypeptides. In most species of eukaryotes, each mRNA usually encodes a single polypeptide. However, in some species, such as *Caenorhabditis elegans* (a nematode worm), polycistronic mRNAs are relatively common.
tRNA	Transfer RNA (tRNA) is necessary for the translation of mRNA. The structure and function of transfer RNA are outlined in Chapter 13.
rRNA	Ribosomal RNA (rRNA) is necessary for the translation of mRNA. Ribosomes are composed of both rRNAs and protein subunits. The structure and function of ribosomes are examined in Chapter 13.
MicroRNA	MicroRNAs (miRNAs) are short RNA molecules that are involved in gene regulation in eukaryotes (see Chapter 15).

25

Mutation

- Mutation = change(s) in the nucleotide/base sequence of DNA; may occur due to errors in DNA replication or due to the impacts of chemicals or radiation to the DNA molecule.
- Mutation may result in coding sequences for new amino acids in proteins or not.
- New mutations are much more likely to be **harmful** rather than **beneficial** to the individual



26

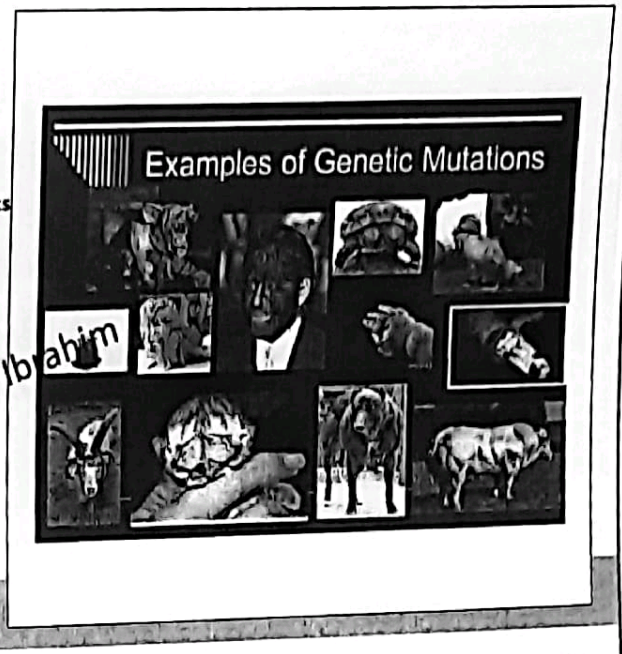
- Individuals showing these changes are known as mutants

- An individual showing an altered phenotype due to mutation are known as variant.

- Factor or agents causing mutation are known as mutagens.

- Mutation which causes changes in base sequence of a gene are known as gene mutation or point mutation

- Mutation can occur in any tissue/cell (somatic or germinal) of an organism.

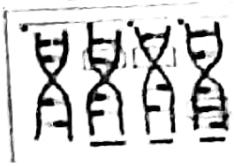


27

TYPES OF MUTATIONS

At the DNA level

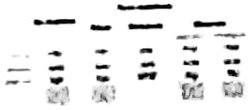
- Deletions
- Insertions
- Inversions



At Protein level

Point Mutations

- Missense mutations
- Nonsense mutations
- Frameshift deletion mutations
- Frameshift insertion mutations



In molecular genetics

- Neutral
- Non-neutral

Chromosome mutations

- Structural mutations
  - Deletions
  - Duplications
  - Inversions
  - Insertions
  - Translocations

28

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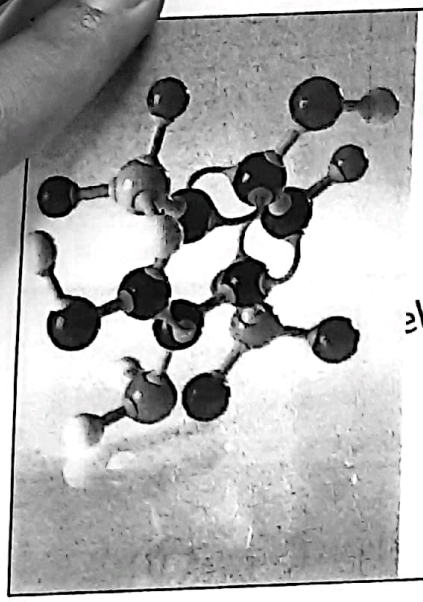


Methods in molecular biology

- **Molecular biology techniques utilize DNA, RNA, and enzymes that interact with nucleic acids to understand biology at a molecular level.**

29

Molecular biology techniques

- **This includes Many techniques, but we are going to highlight some of them:**

➢ **Hybridization and Probe**:
➢ **Nucleic acid hybridization** is the formation of a duplex between two complementary sequences while **Probe**, is a nucleic acid that can be labeled with a marker which allows identification and quantitation

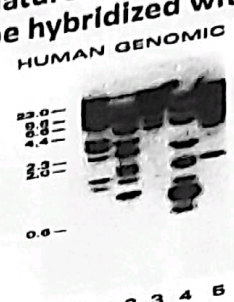
➢ This is used in **many applications** such as:
- ❑ Southern blot
- ❑ Slot (dot) blot
- ❑ Microarray
- ❑ PCR

30

(2)

Molecular biology techniques

- **Southern blotting is a procedure for transferring denatured DNA from an agarose gel to a solid support filter where it can be hybridized with a complementary nucleic acid probe**
- **The DNA is separated by size so that specific fragments can be identified**



31

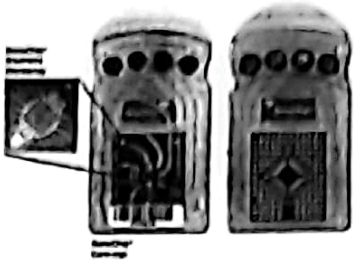
Molecular biology techniques

- **Slot (dot) blot:**
- In this technique, protein, DNA or RNA is bound directly to a solid support filter
- no size separation used, and it is Ideal for multiple samples and quantitative measurements
- Slot blotting is commonly used in the detection of specific DNA or RNA sequences and the quantification of proteins in a sample.

32

Molecular biology techniques

- **Lab-on-a-Chip technology** : is a miniaturized device that integrates into a single chip one or several analyses, which are usually done in a laboratory; analyses such as Gene expression, DNA sequencing or biochemical detection. example: **Electronic microarray**



33

Molecular biology techniques

- **PCR (polymerase chain reaction):**
- is a laboratory technique for rapidly producing (amplifying) millions to billions of copies of a specific segment of DNA, which can then be studied in greater detail.

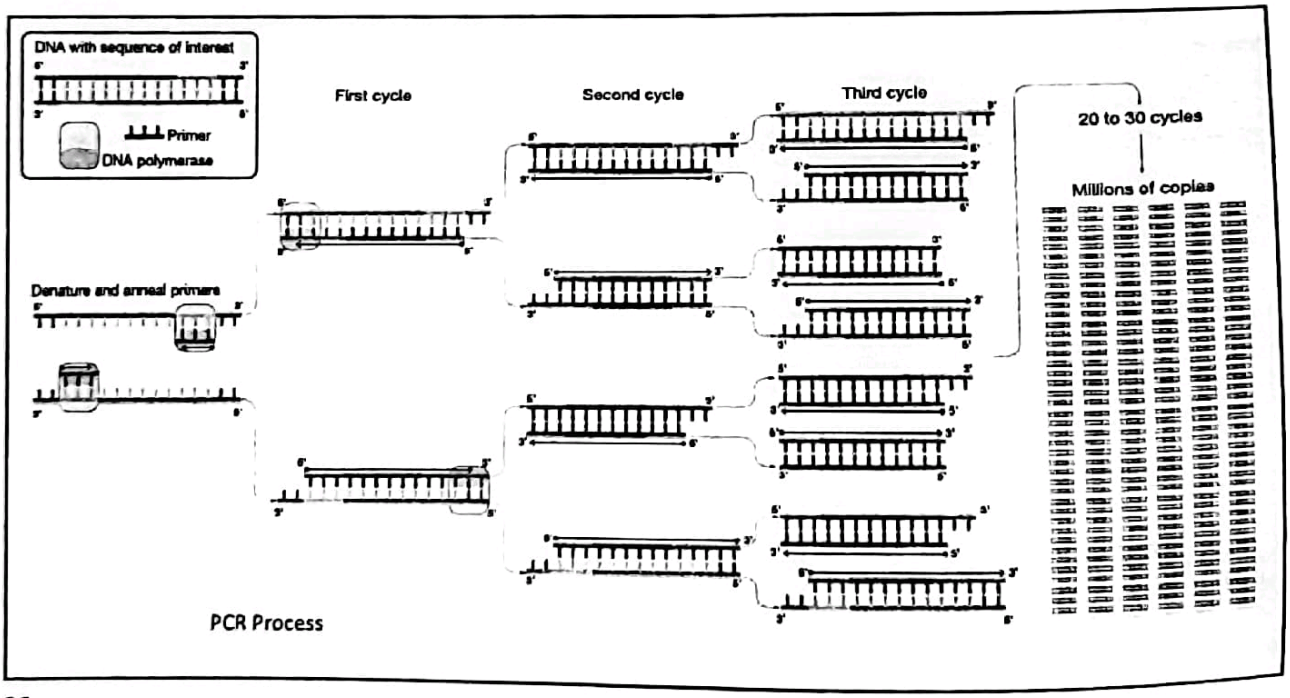
- PCR involves using short synthetic DNA fragments called **primers** to select a segment of the genome to be amplified, and then multiple rounds of DNA synthesis to amplify that segment.

34

Applications of PCR:

- **DNA Amplification:** PCR is used to amplify specific DNA sequences for various purposes, including genetic testing, cloning, and sequencing.
- **Forensic Analysis:** PCR is employed to analyze small and degraded DNA samples in forensic investigations.
- **Medical Diagnostics:** PCR is used for the detection of pathogens, genetic disorders, and the identification of specific DNA markers associated with diseases.
- **Genetic Engineering:** PCR is a crucial tool in genetic engineering for the manipulation of DNA sequences.

35



36