BHARATHIDASAN UNIVERSITY

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Programme: M.Sc., Biomedical Science

Course Code: BM35C5
Course Title: Molecular Biology

Unit-I

Structure and Properties of Nucleic Acids

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Unit I:

Structure and Properties of Nucleic acids : Nucleic acid as the genetic material (Griffith's experiment, Avery, MacLeod and McCarty‟s experiment, Hershey-Chase experiment)- Components of DNA and RNA -Watson and Crick model of DNA structure, Various forms of DNA- Physical properties of nucleic acids; Denaturation and renaturation, Cot curves – Structure and function of mRNA, rRNA, tRNA- Chromatin structure-Euchromatin, Heterochromatin- Central Dogma of Molecular Biology.

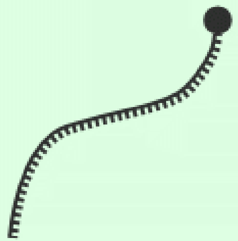
PRESENTATION: 3

RNA

- RNAs (Ribonucleic acids) are an essential component of all living cells.
- RNAs take part in the protein synthesis.
- There are three different types of RNAs present in a cell, namely- mRNA or messenger RNA, rRNA or ribosomal RNA, and tRNA or transfer RNA.
- They are named according to the function they perform. Each of the three types of RNAs performs unique functions and has different structures.
- mRNA provides a **template for gene coding** during protein synthesis,
- tRNA **carries the amino acids to the ribosomes,** which have to be added to the polypeptide chain and
- rRNA **forms ribosomes** along with proteins.

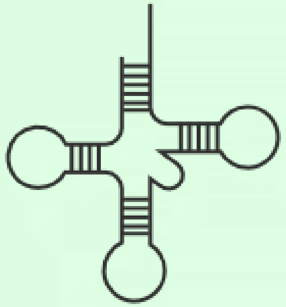
Types

mRNA



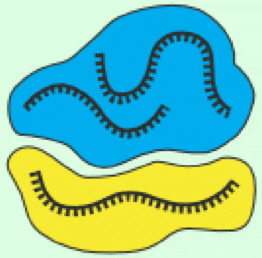
Encodes Protiens

tRNA



Act as adaptor between mRNA and amino acids

rRNA



Forms the ribosome

Messenger RNA (mRNA):

- mRNA is formed by transcription process from DNA.
- They provide a template for protein synthesis.
- RNA polymerase catalyses the transcription process.
- In eukaryotic cells, mRNA is formed in the nucleus as hnRNA (heterogenous RNA), which after processing, introns are removed and exons joined together after splicing to form mRNA and move to the cytoplasm to take part in protein synthesis.
- mRNA is modified at 5' and 3' ends for stability and to prevent hydrolysis by exonucleases. 5' end is capped by 7-methylguanosine and polyadenylation at 3' end, i.e. a poly-A tail.

Function:

- It carries the genetic message from the nucleus to the ribosomes present in the cytoplasm of a cell where amino acids are arranged according to the information in mRNA to form a specific protein molecule.

Transfer RNA (tRNA):

- tRNAs are known as **soluble RNAs**.
- As the name suggests, they are carriers of specific amino acids for coding to the growing end of the polypeptide chain during protein synthesis. Each amino acid has a specific tRNA.
- It has a folded structure, which looks like a cloverleaf. It has three hairpin loops, a small variable loop and the acceptor arm, which carries amino acids. 5’ end has a terminal phosphate group.

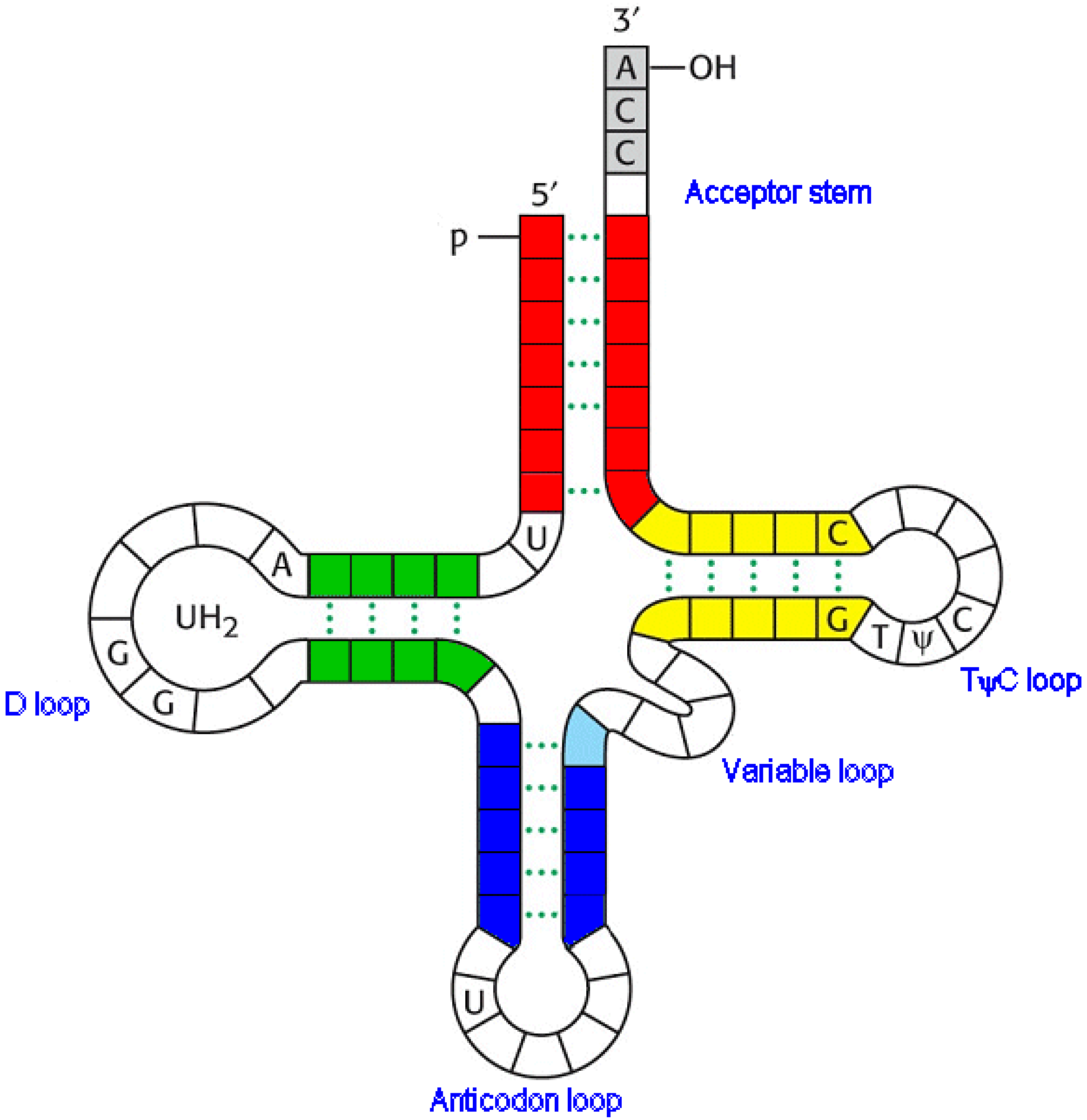
1.The acceptor arm – It is present at 3’ end and carries amino acids. It has a terminal sequence of CCA

2.The anticodon loop – It has a complementary codon for coding a particular amino acid it carries, during the translation process. And attaches to the codon on mRNA

3. TψC loop – has pseudouridine

There is a small **variable loop** present between the anticodon loop and the acceptor arm.

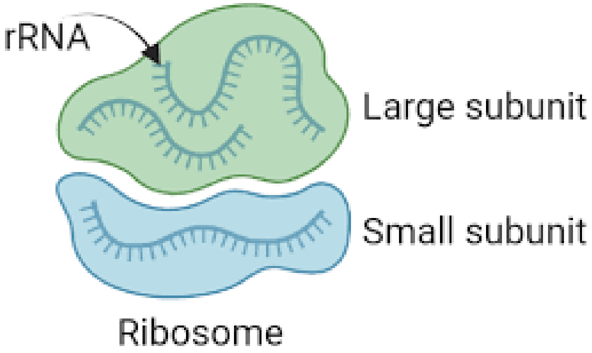
4. D loop – has dihydrouridine



Function:

- **Adaptor Molecule**: tRNA transfers specific amino acids to the growing polypeptide chain during translation.
- **Codon-Anticodon Interaction**: The anticodon of the tRNA pairs with the appropriate codon on the mRNA, ensuring the correct amino acid is added to the polypeptide chain.

Ribosomal RNA (rRNA)



- rRNA associates with certain proteins to form ribosomes. They bind to tRNA and accessory proteins and move along mRNA during translation. Large and small ribosomal subunits contain different rRNAs.

Function:

- **Structural Role**: rRNA provides the scaffold (temporary platform)for ribosome assembly and maintains the correct alignment of mRNA and tRNAs.
- **Catalytic Role**: rRNA in the large subunit catalyzes the formation of peptide bonds between amino acids.
- **Facilitating Translation**: rRNA in the small subunit is involved in decoding the mRNA by ensuring proper base-pairing between the codon and anticodon.

Difference between three types of RNAs

mRNA	tRNA	rRNA
Linear structure	Cloverleaf shape	Spherical and has a complex structure
In mammals, mRNAs are 300 to 12000 nucleotides long	76 to 90 nucleotides	Prokaryotic and eukaryotic cells contain different rRNA, e.g. 5s, 16s, 23s and 5s, 5.8s, 18s and 28s, respectively in different ribosomal subunits
Site of synthesis is the nucleus	Produced in the cytoplasm	Found in ribosomes
They provide a template or carry genetic information contained in DNA for protein synthesis	They carry specific amino acids to ribosomes for protein synthesis	They facilitate the association of ribosomes
mRNA carries codons for the translation process	They carry anticodons, specific to particular amino acid	Codons or anticodons are absent

CHROMATIN STRUCTURE

- Chromatin is the complex of DNA and proteins (mainly histones) that makes up chromosomes.

The structure of chromatin plays a important role in regulating gene expression and DNA replication.

Chromatin can exist in two main forms: euchromatin and heterochromatin.

Euchromatin

- **Euchromatin** is the **less condensed** form of chromatin, which is generally associated with actively transcribed genes. Its structure allows for easier access by transcription machinery, enabling gene expression.

Heterochromatin

- **Heterochromatin** is the **more condensed form of chromatin**, which is typically associated with regions of the genome that are transcriptionally inactive.
- **Structure**: Heterochromatin is tightly packed, making it less accessible to the transcriptional machinery. This dense packing is facilitated by specific histone modifications and the presence of certain proteins that promote chromatin compaction.
- **Function**: Heterochromatin is generally transcriptionally silent and contains repetitive DNA sequences, structural elements of chromosomes (such as centromeres and telomeres), and genes that are not required for the cell's regular functions or are permanently turned off.
- **Staining**: Heterochromatin stains darkly with DNA-specific dyes due to its highly compact structure.

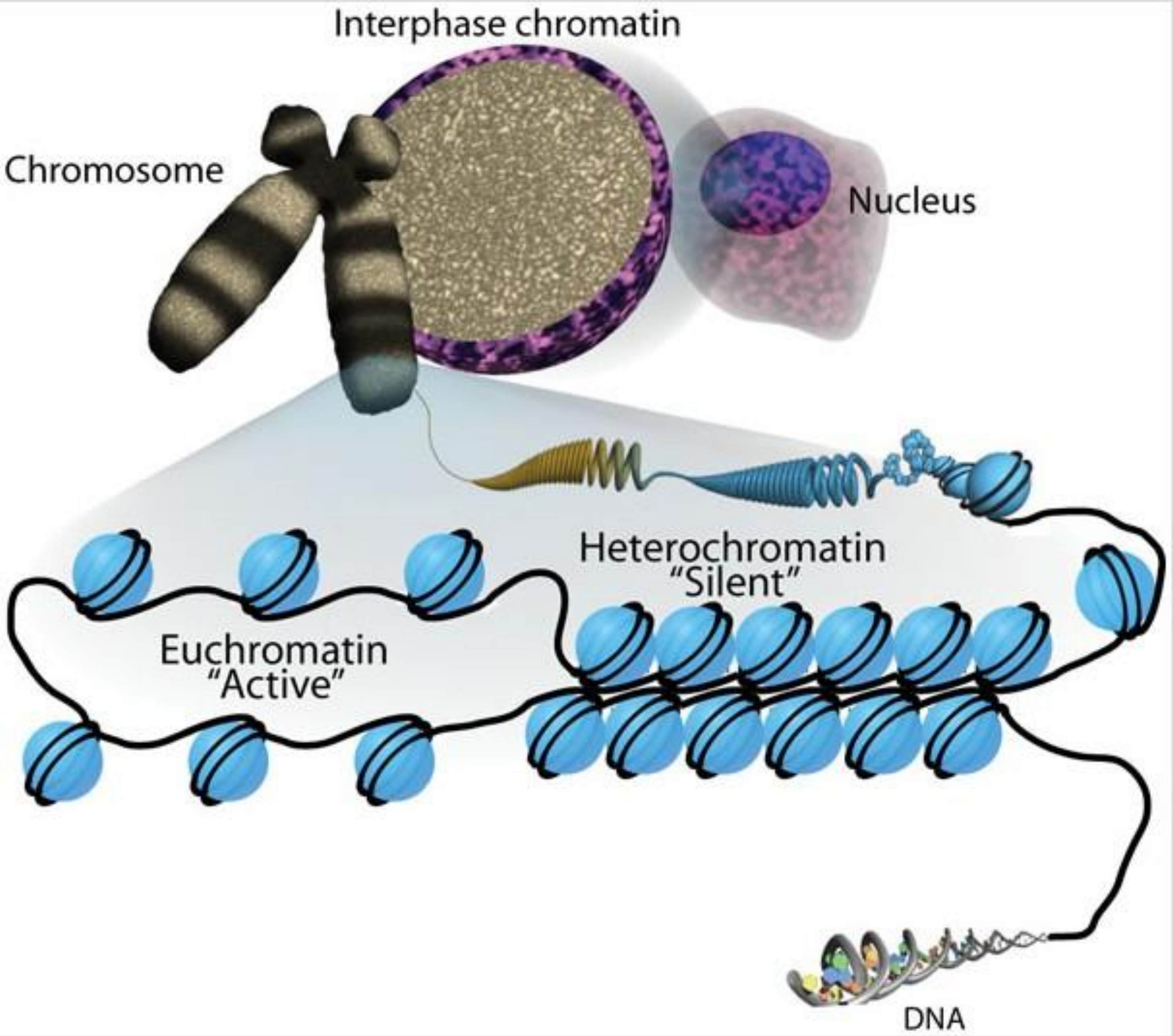
Types of Heterochromatin

1.Constitutive Heterochromatin:

1. **Definition**: Constitutive heterochromatin is permanently compacted and typically found around centromeres and telomeres. It consists of repetitive DNA sequences and is transcriptionally inactive.
2. **Function**: Provides structural support to chromosomes and plays a role in maintaining genome stability. It also helps in the segregation of chromosomes during cell division.

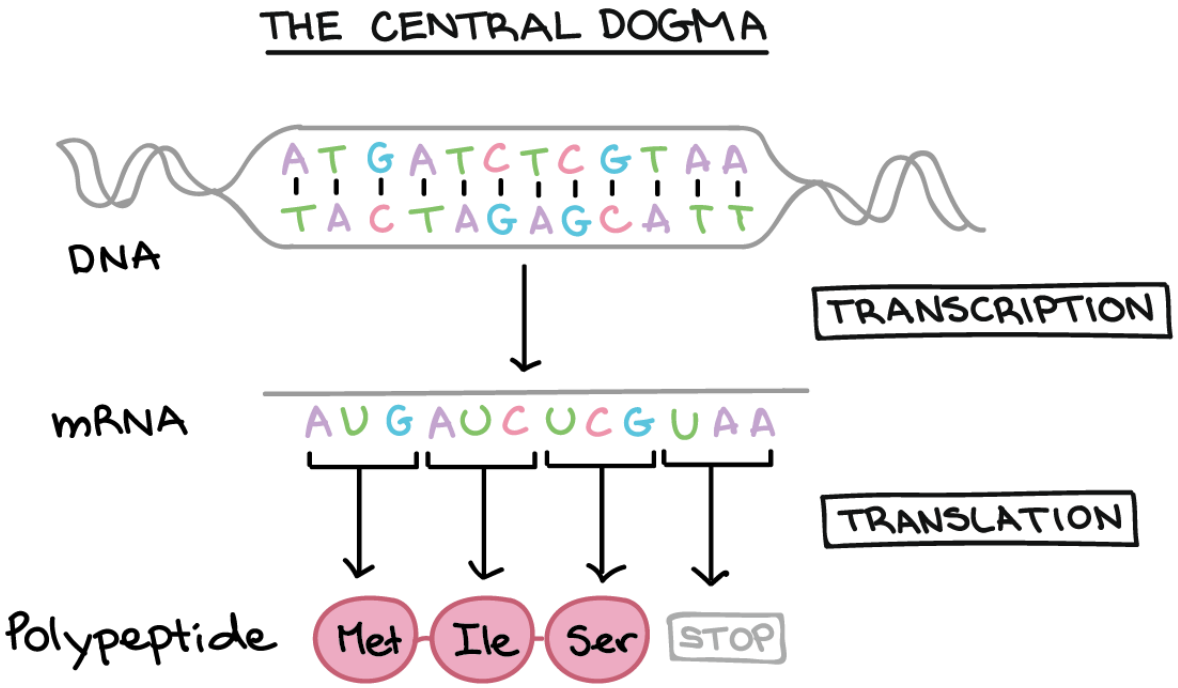
2.Facultative Heterochromatin:

1. **Definition**: Facultative heterochromatin is not permanently compacted and can transition between a condensed and relaxed state. It contains genes that can be silenced in one cell type but expressed in another, depending on the developmental stage or environmental conditions.
2. **Function**: Involved in regulating gene expression in a tissue-specific or developmental stage-specific manner. An example is the inactivation of one of the X chromosomes in female mammals (X-inactivation).


Interphase chromatin
Chromosome
Nucleus
Heterochromatin
"Silent"
Euchromatin
"Active"
DNA

CENTRAL DOGMA OF MOLECULAR BIOLOGY

- The central dogma of molecular biology describes the flow of genetic information within a biological system.
- This concept, first proposed by Francis Crick in 1958, outlines how information encoded in DNA is transcribed into RNA and then translated into proteins.



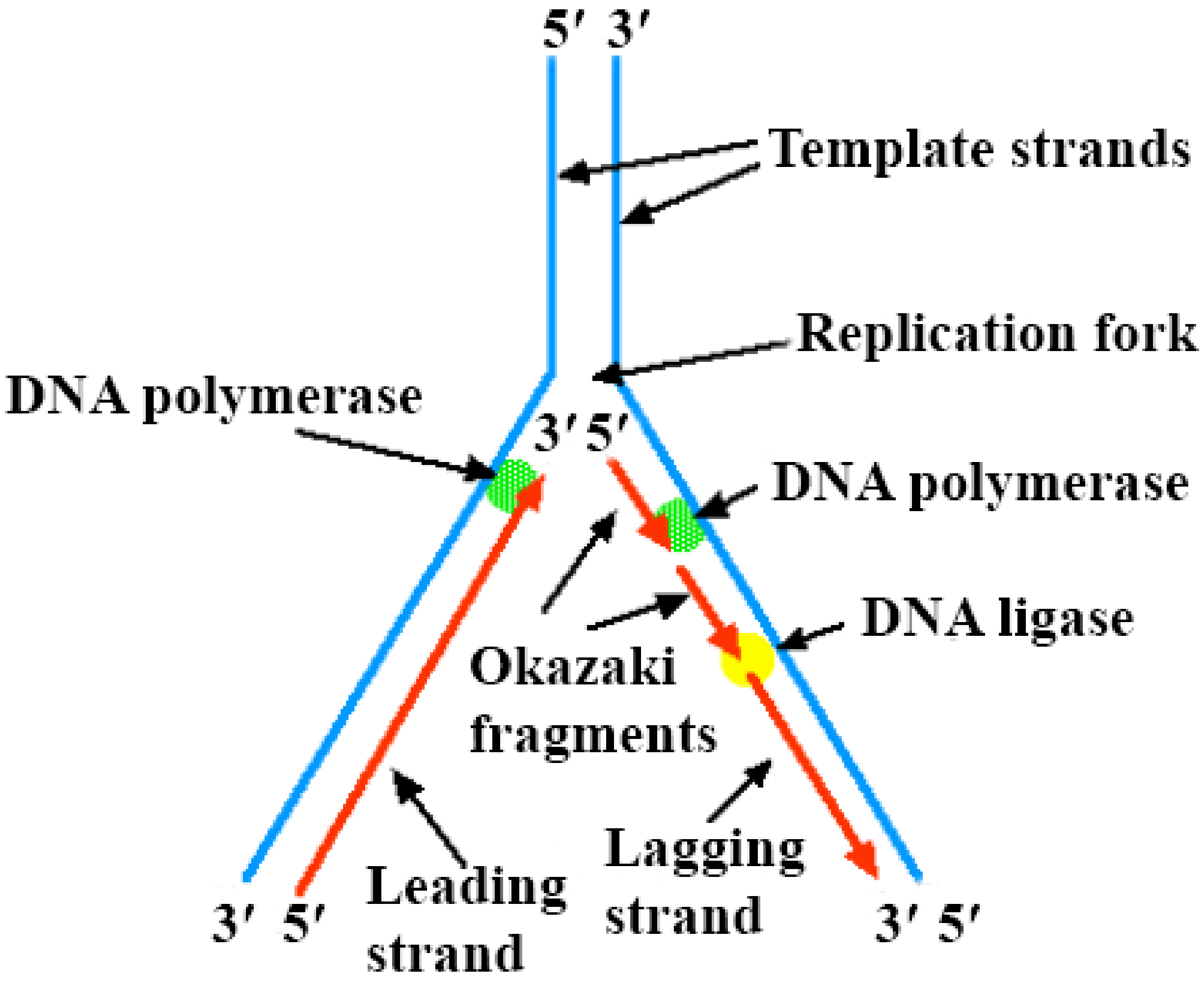
1. DNA Replication

DNA replication is the process by which a cell makes an exact copy of its DNA, ensuring that genetic information is passed on during cell division.

Process:

- **Initiation**: Replication begins at specific locations in the genome called origins of replication. Proteins called initiators bind to these sites and unwind the DNA, creating a replication fork.
- **Elongation**: DNA polymerases synthesize new strands by adding complementary nucleotides to the original strands. Leading and lagging strands are synthesized continuously and discontinuously, respectively.
- **Termination**: Replication ends when the entire DNA molecule has been copied. DNA ligase seals any nicks in the backbone, creating two identical DNA molecules.

REPLICATION FORK OR BUBBLE



2. Transcription

Transcription is the process by which genetic information from DNA is copied into a complementary RNA molecule.

- **Initiation**: RNA polymerase binds to a specific region of DNA called the promoter, which signals the start of a gene.
- **Elongation**: RNA polymerase unwinds the DNA and synthesizes a single-stranded RNA molecule by adding complementary RNA nucleotides (adenine (A) pairs with uracil (U), and cytosine (C) pairs with guanine (G)).
- **Termination**: Transcription ends when RNA polymerase reaches a terminator sequence, causing it to release the newly synthesized RNA molecule and detach from the DNA.

3. RNA Processing (in eukaryotes)

RNA processing involves modifying the primary RNA transcript to produce a mature RNA molecule that can be translated into protein.

- **Capping**: A modified guanine nucleotide is added to the 5' end of the RNA transcript, protecting it from degradation and aiding in ribosome binding.
- **Polyadenylation**: A string of adenine nucleotides (poly-A tail) is added to the 3' end, enhancing stability and export from the nucleus.
- **Splicing**: Introns (non-coding regions) are removed, and exons (coding regions) are joined together to form a continuous coding sequence.

4. Translation

Translation is the process by which the genetic information in mRNA is decoded to produce a specific protein.

- **Initiation**: The small ribosomal subunit binds to the mRNA, and a tRNA carrying the first amino acid (**methionine**) binds to the start codon (**AUG**). The large ribosomal subunit then binds to form the complete ribosome.
- **Elongation**: The ribosome moves along the mRNA, and tRNAs bring amino acids to the ribosome. Each tRNA's anticodon pairs with the complementary mRNA codon, and the ribosome catalyzes the formation of peptide bonds between amino acids, forming a polypeptide chain.
- **Termination**: Translation ends when the ribosome reaches a stop codon (UAA, UAG, or UGA). Release factors bind to the stop codon, causing the ribosome to release the completed polypeptide and disassemble.

5. Post-Translational Modifications

After translation, newly synthesized proteins often undergo additional modifications to become fully functional.

Types of Modifications:

Folding, Cleavage, Chemical Modifications, and Formation of Disulfide Bonds

Acknowledgement

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