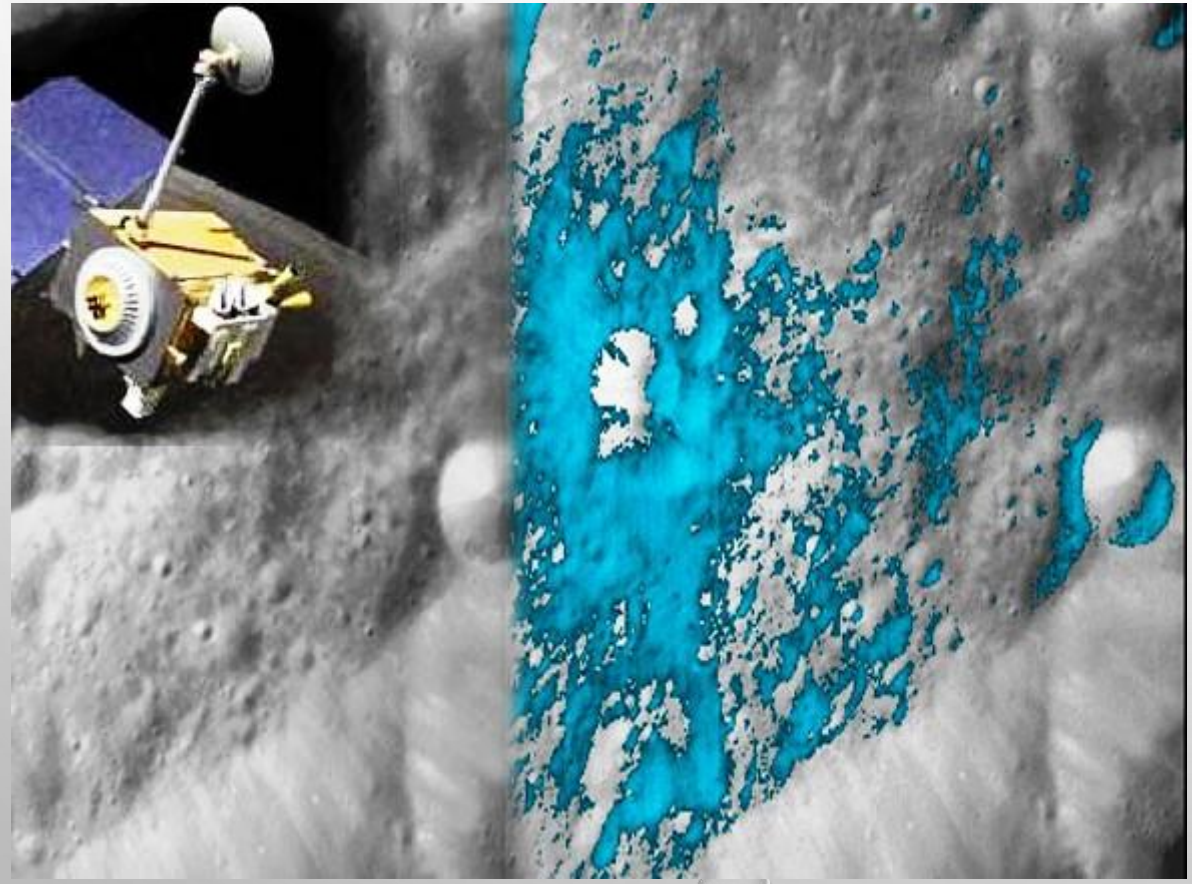
Molecules of Life

LS1101

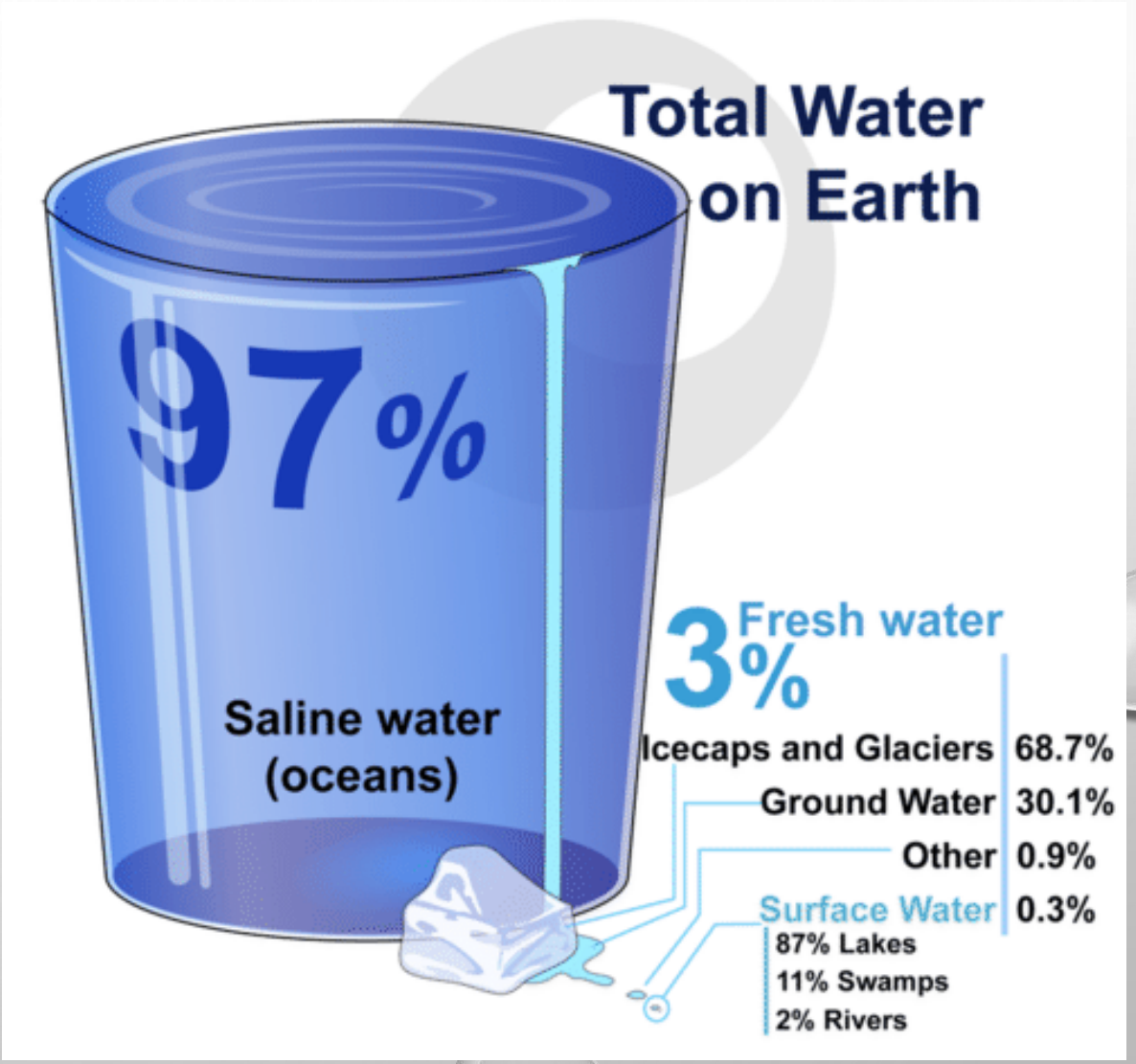
Anindita Bhadra

Autumn 2023

The Quest for Water



A Watery Planet



The Origin

4.6 billion years ago

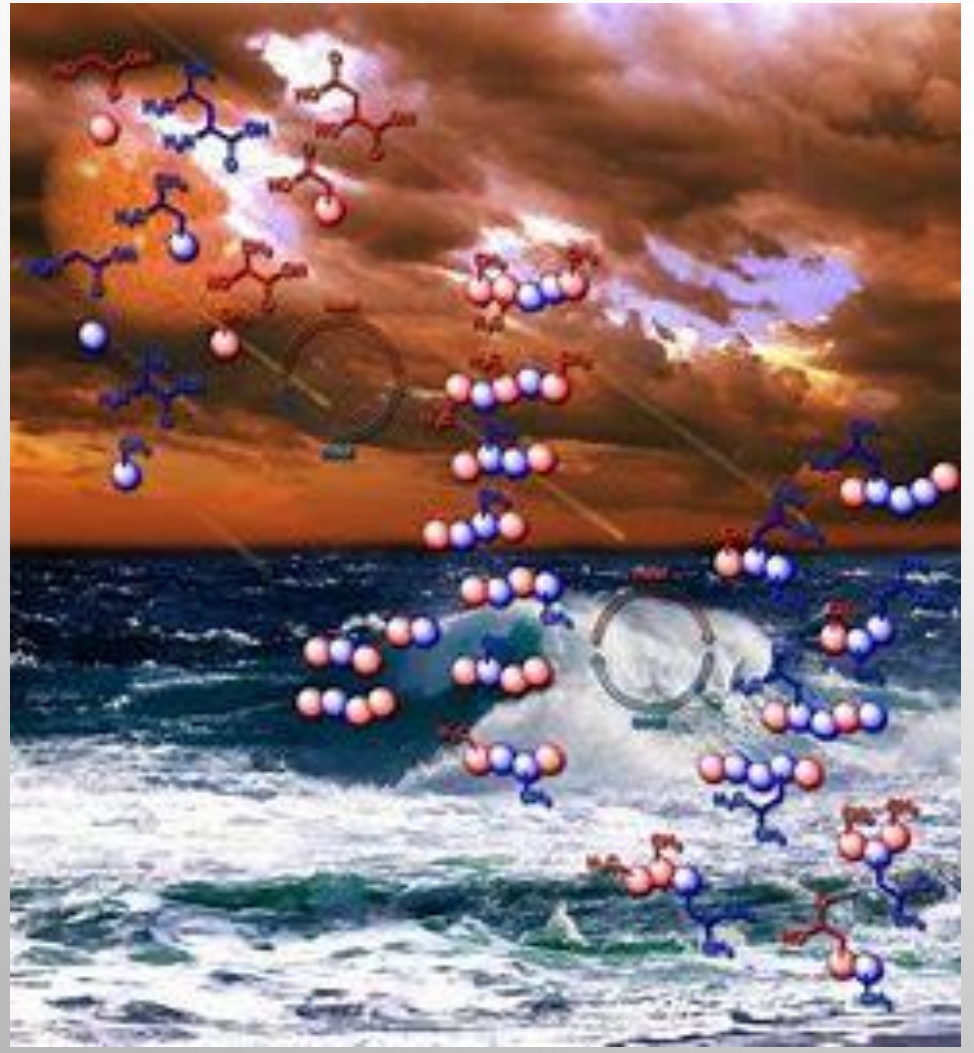
Origin of the Sun and planets

Earth was a hot ball of gases

Cooling – gases became liquids

Earliest evidence for life – 3.7 billion years ago - Greenland

The Origin



Oparin – Primordial soup theory

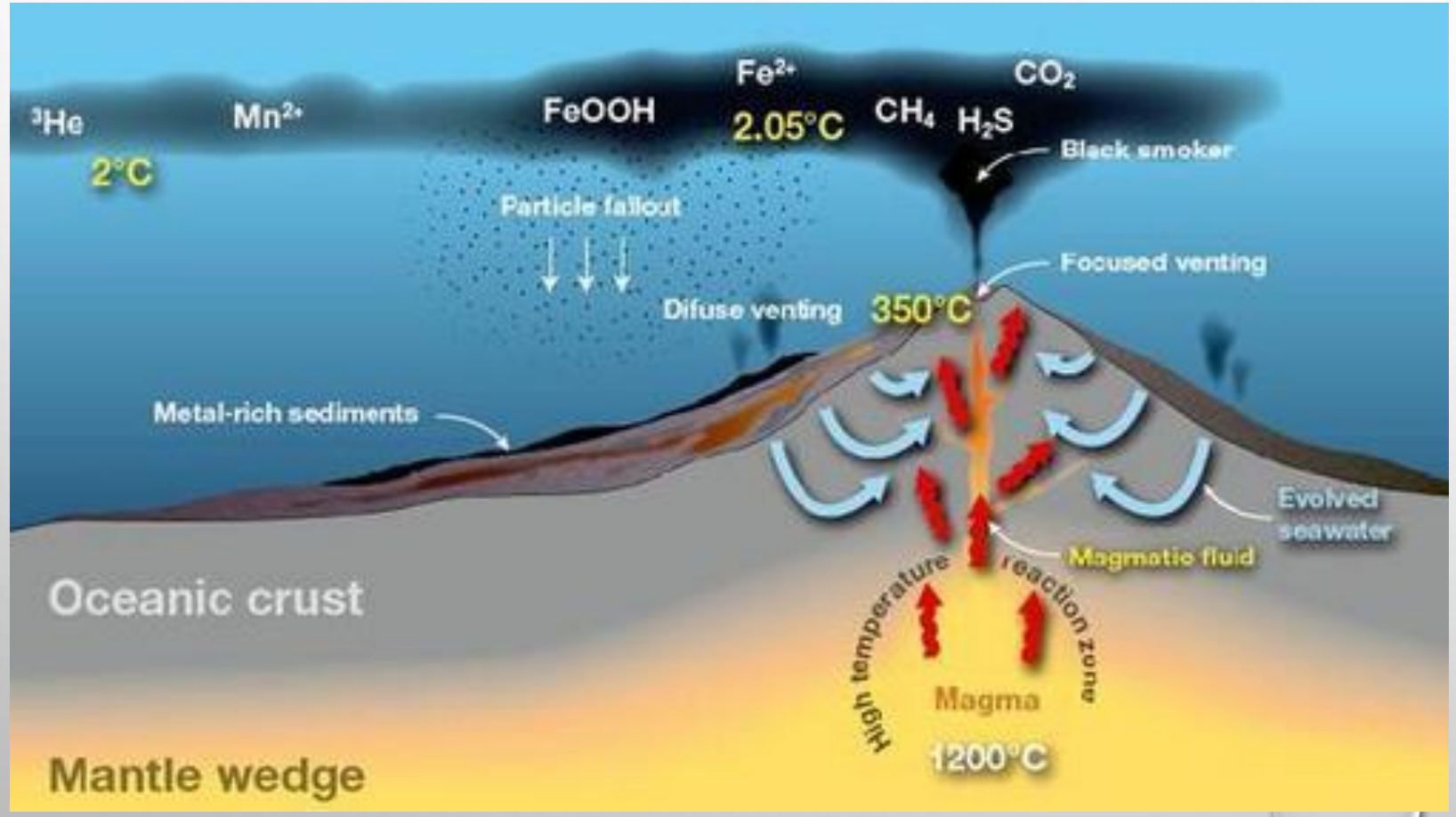
Haldane – Chemical origin of life

Urey and Miller – experiment

CO_2, H_2O, NH_3, CH_4 Gases and energy
→ Organic molecules

Several limitations

The Origin



Hydrothermal vents

High temperature

Cold seawater

Pyrites from iron and sulphur – energy

Evidence of life from 4 billion years ago

Water for Life

Water has several unique properties, which make it suitable for supporting life.

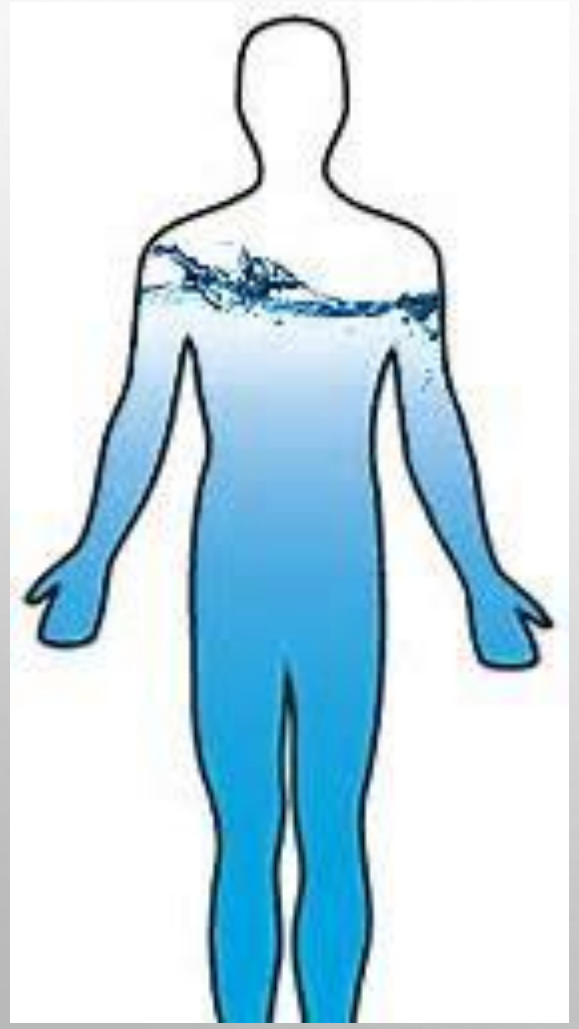
The water molecule is polar.

Water is known as the universal solvent.

Water molecules form lattices and show cohesion.

It helps in transport of gases and other molecules.

Water for Life



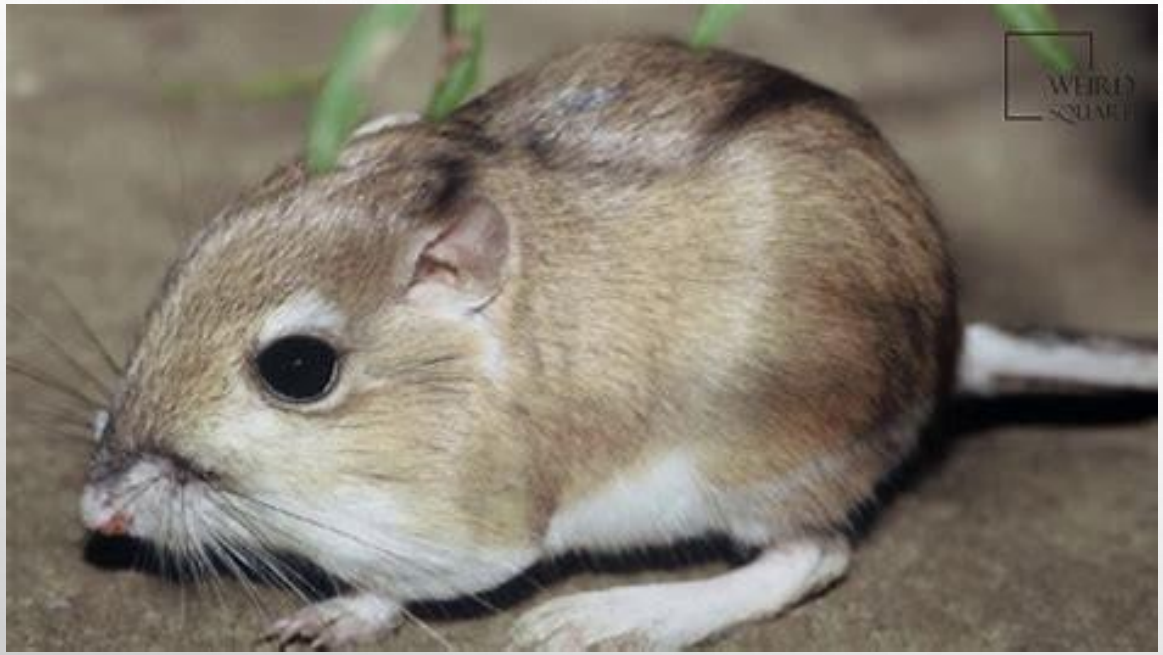
Water supports cellular structure.

Water helps to maintain the structure of the phospholipid bi-layer (polar head, non-polar tails).

Water is a good buffer.

Water helps in protein folding and helps to maintain the double helix of DNA.

Water for Life



The Kangaroo rat can survive without water?

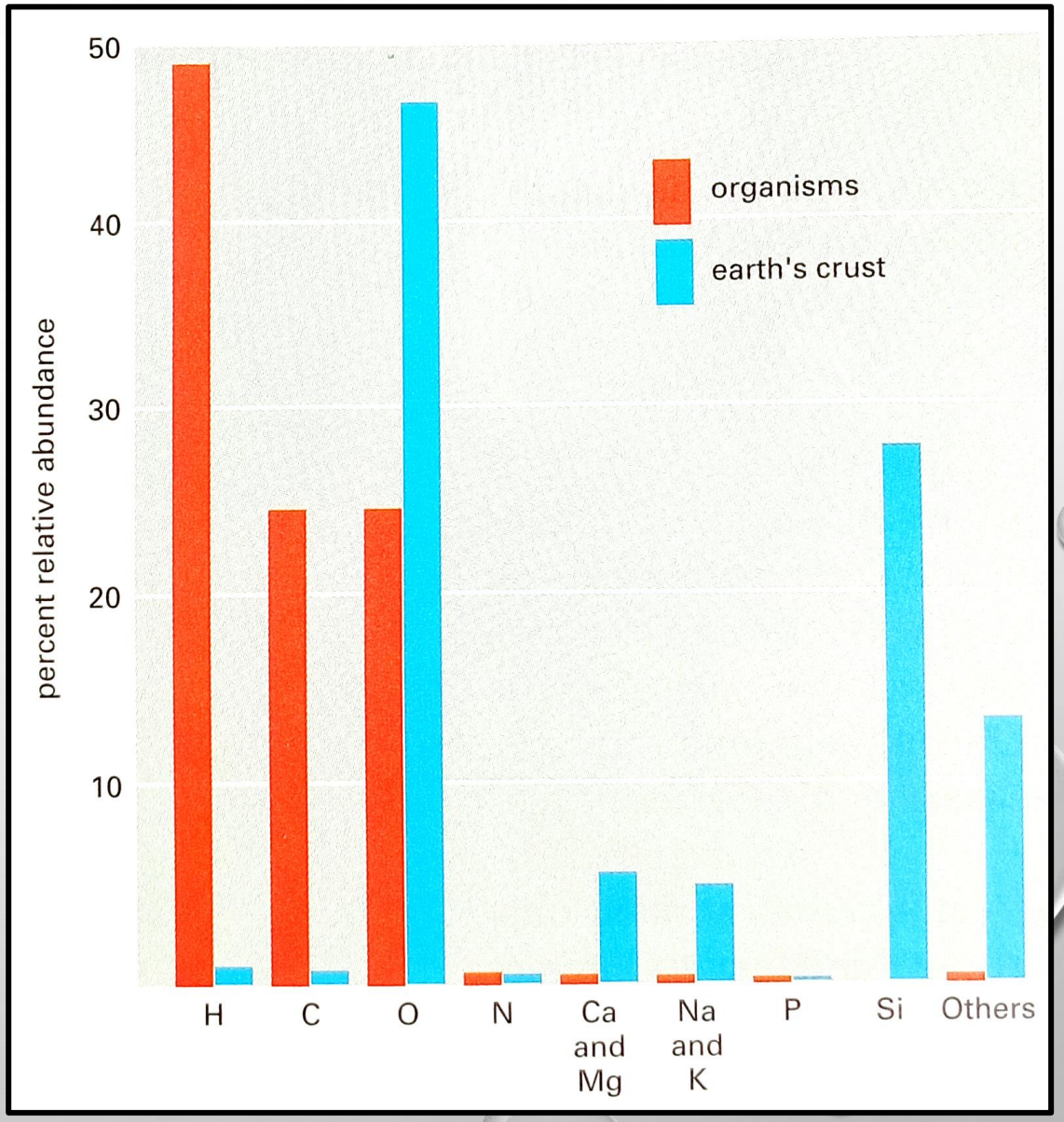
Can you think of ways in which it has adapted to a life without water?

What are Cells made of?

The relative abundance of elements is similar across organisms.

Carbon, Hydrogen, Nitrogen and Oxygent make up 96.5% of an organism's weight.

70% of a cell's weight is accounted for by Water.



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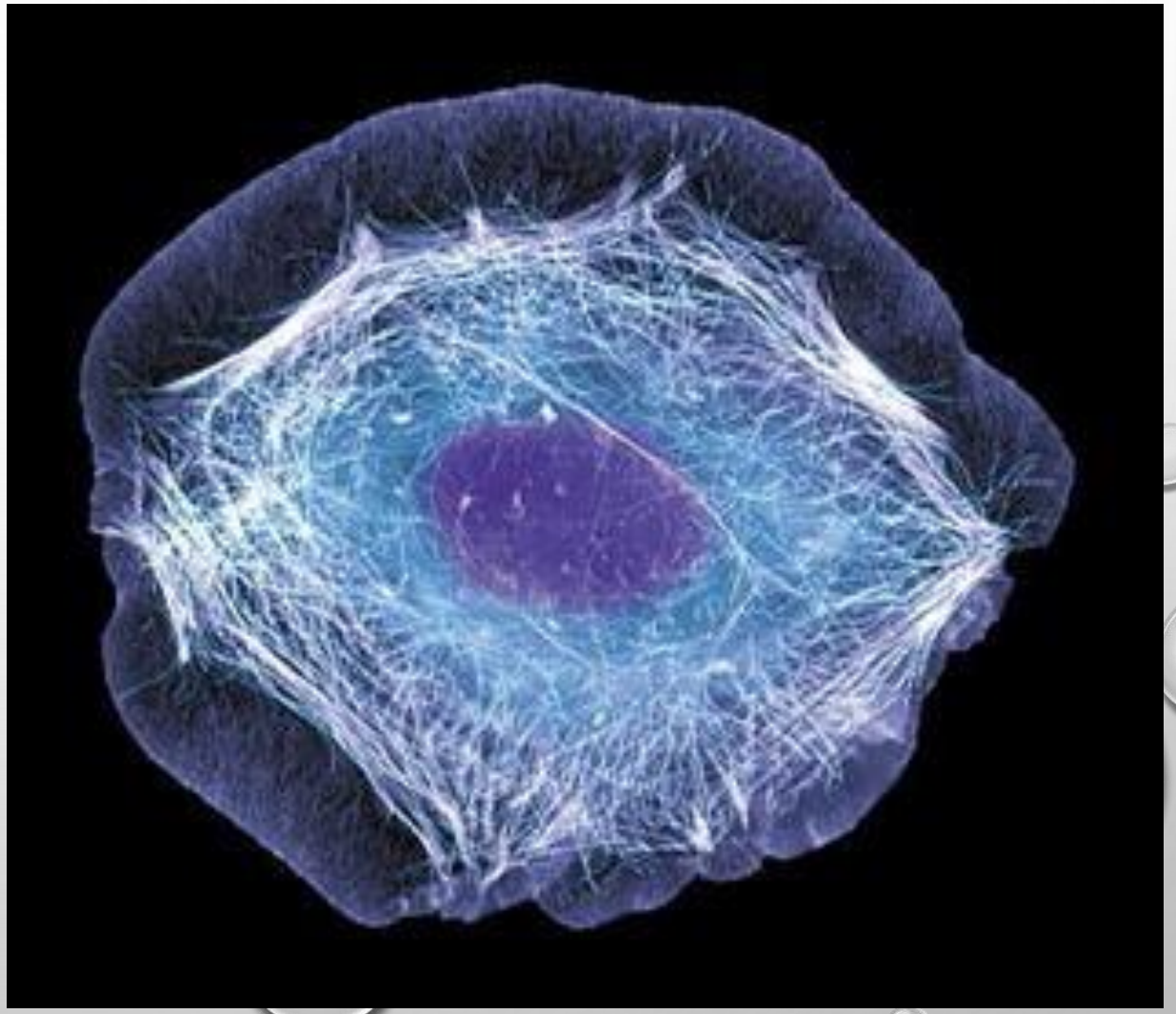


What are Cells made of?

Small organic molecules:

- molecular weight of 100 to 1000
- upto 30 C atoms
- Freely available in the cytoplasm
- Energy sources, building blocks
- Account for 1/10 of the mass of organic matter in the cell

Sugars → **Polysaccharides**

Amino acids → **Proteins**

Fatty acids → **Fats/Lipids/ Membranes**

Nucleotides → **Nucleic Acids**

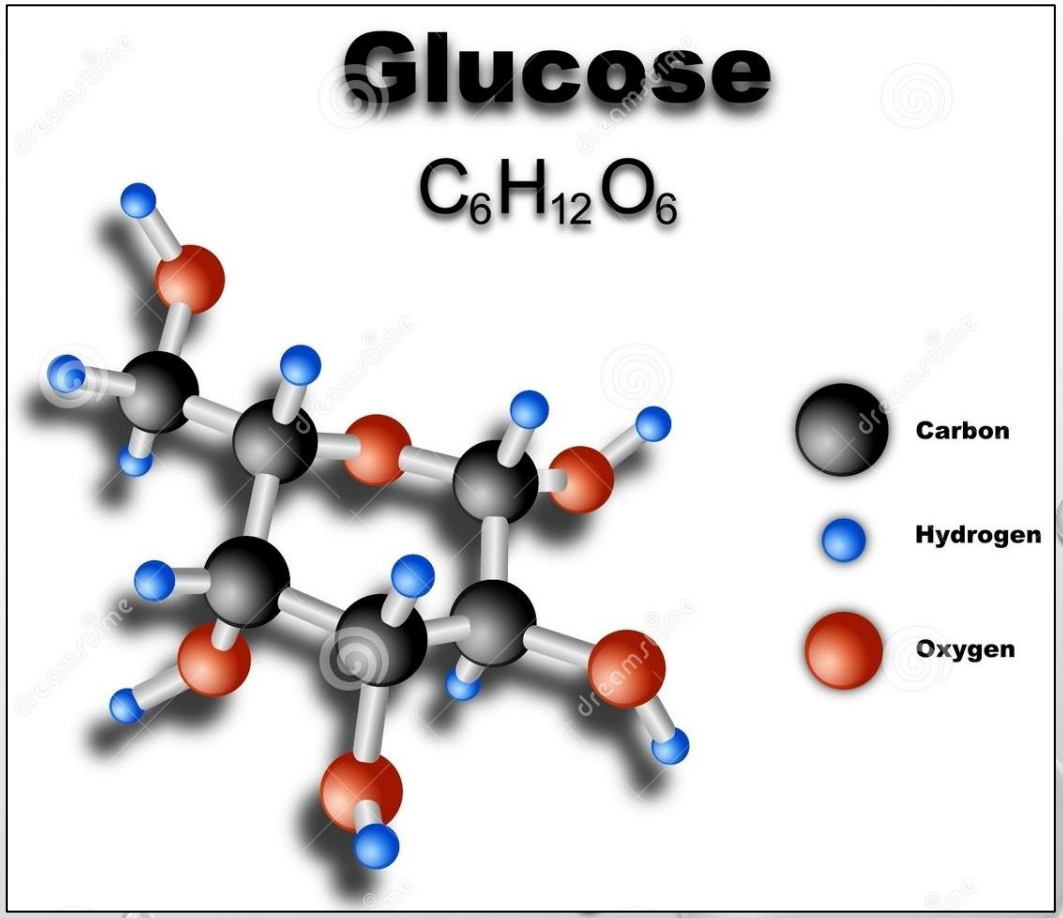
Sugars

General formula: $(CH_2O)_n$

Monosachharides combine by condensation reaction.

A large number of polysaccharides are possible.

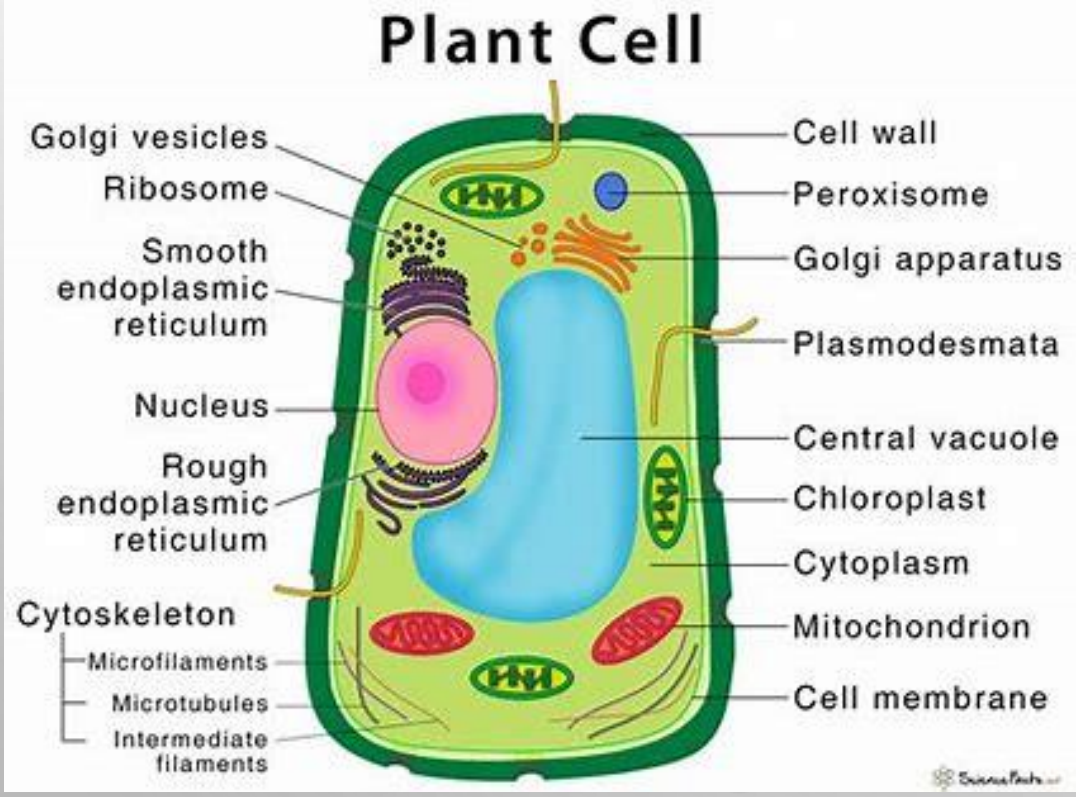
Glycogen and starch are polysaccharides composed only of glucose.



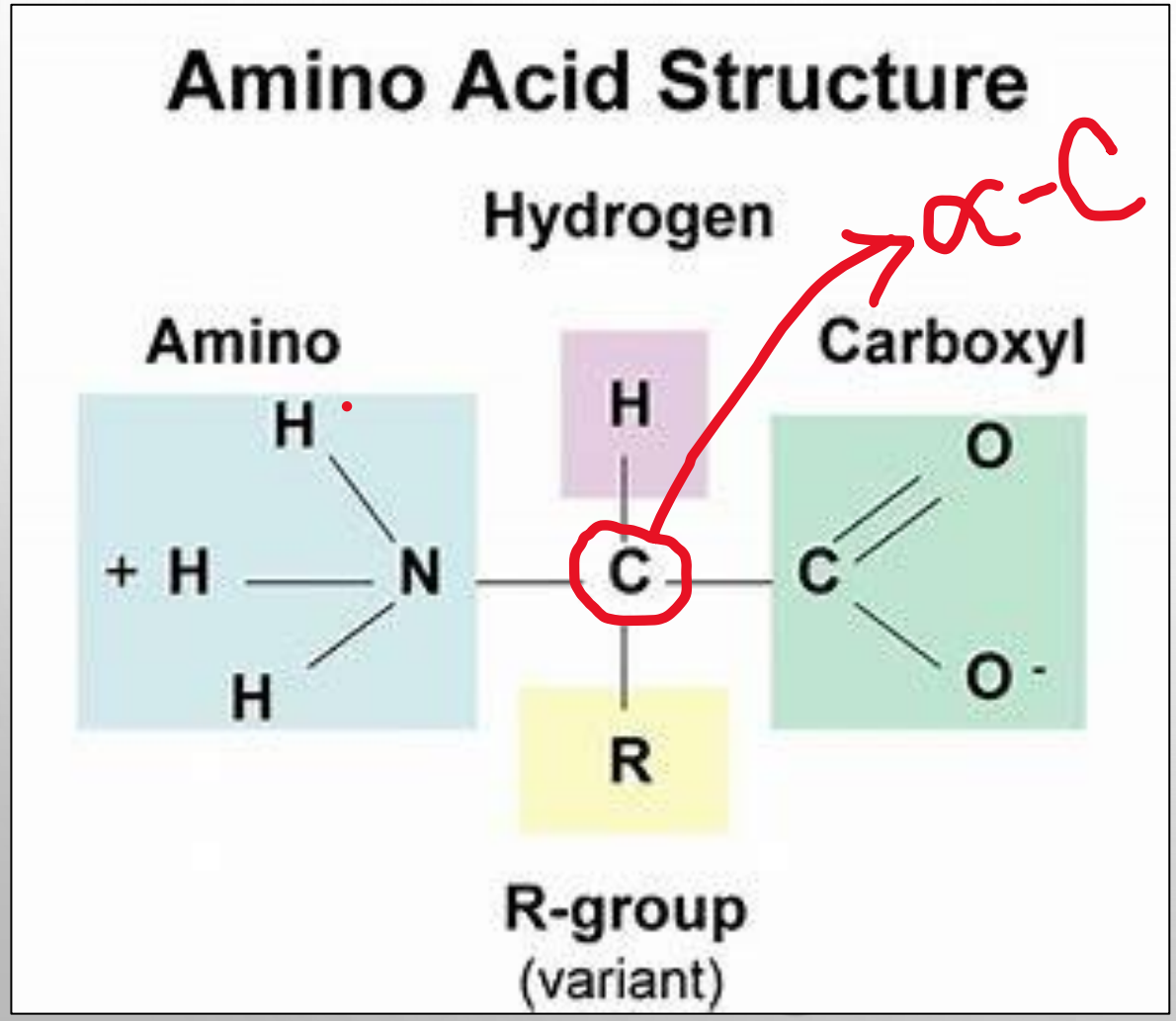
Energy source in living organisms

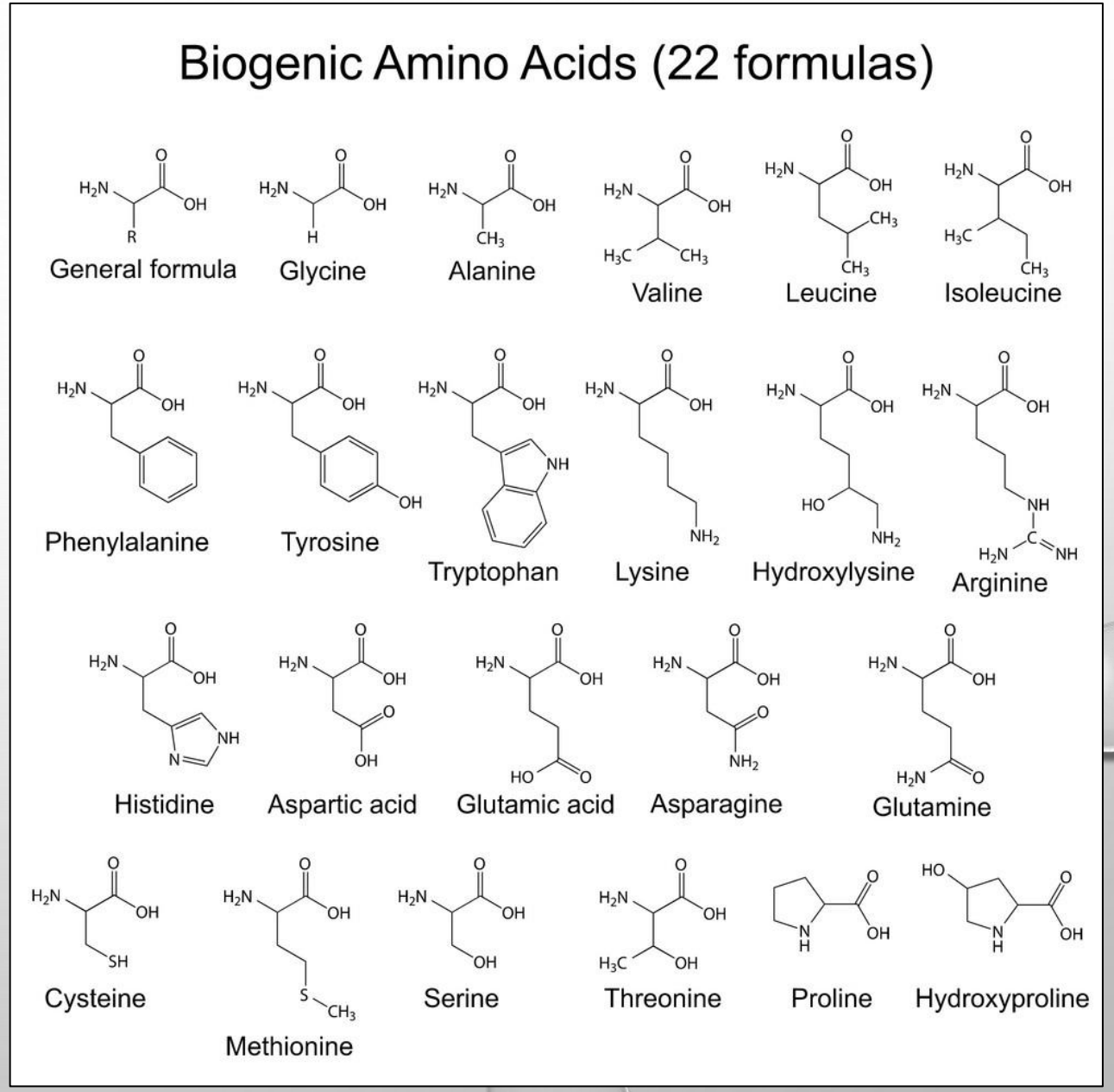
Sugars

Can you think of other functions of sugars in the living world?



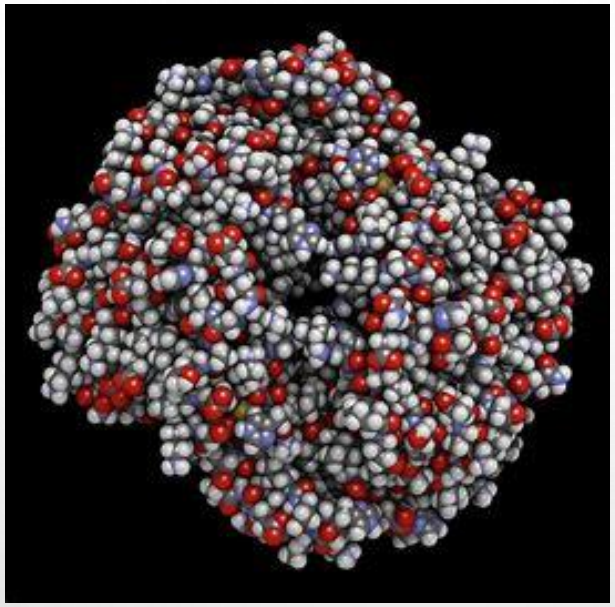
Amino Acids


Amino Acid Structure
Hydrogen
Amino
Carboxyl
H
+ H
N
H
H
C
C
O
O -
R
R-group
(variant)
α-C

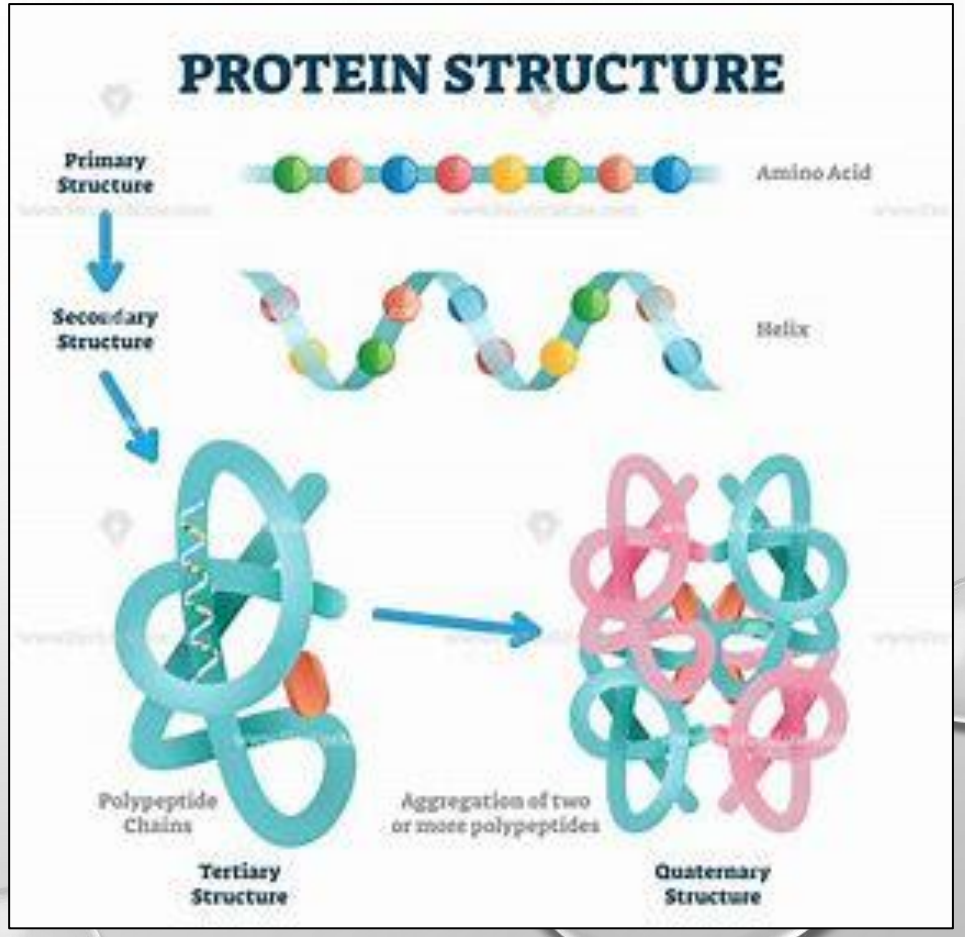

Biogenic Amino Acids (22 formulas)
General formula
Glycine
Alanine
Valine
Leucine
Isoleucine
Phenylalanine
Tyrosine
Tryptophan
Lysine
Hydroxylysine
Arginine
Histidine
Aspartic acid
Glutamic acid
Asparagine
Glutamine
Cysteine
Methionine
Serine
Threonine
Proline
Hydroxyproline

Amino Acids

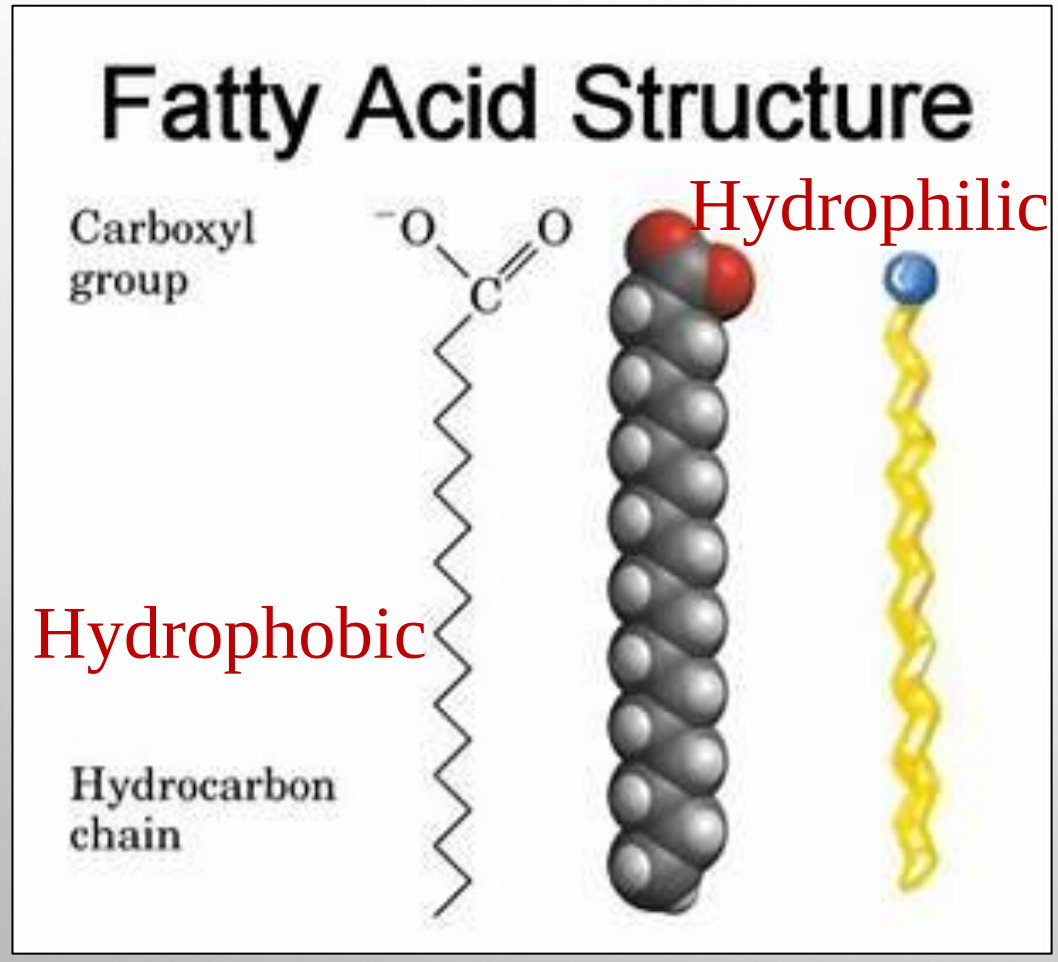
Polypeptide



Haemoglobin



Fatty Acids



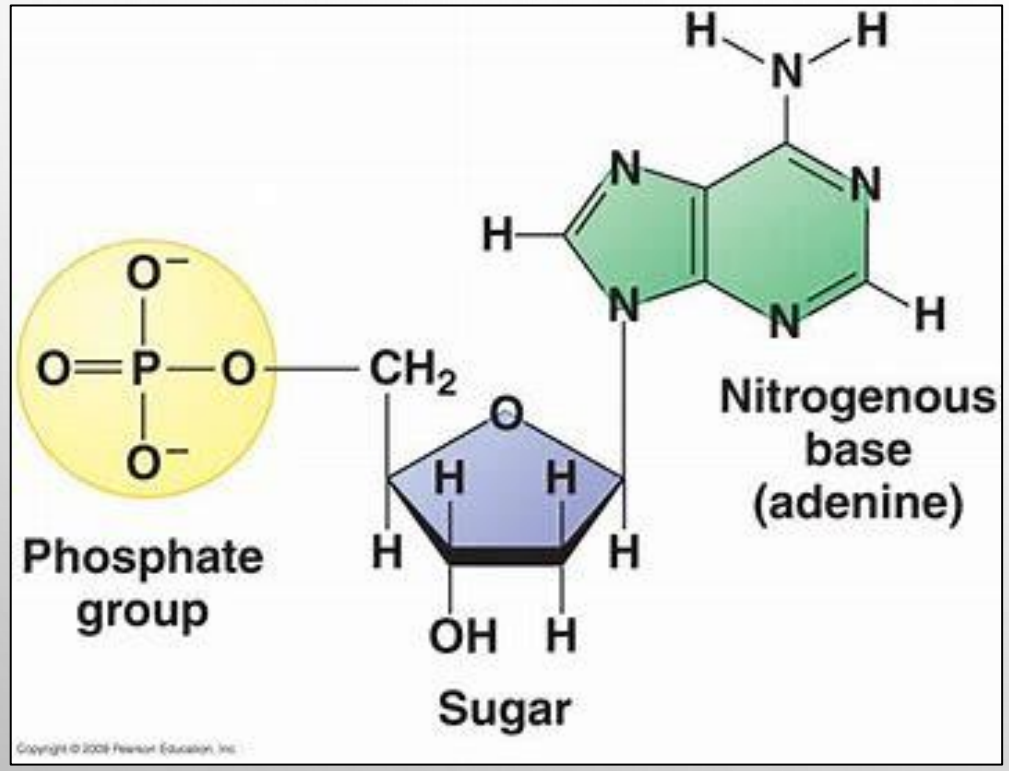
In water, they form a surface film or small micelles.

Triglycerides form large droplets of fat in the cytoplasm.

Phospholipids and glycolipids form self-sealing bilayers of all cell membranes.

Fatty acids serve as concentrated food reserves in cells.

Nucleotides



A nitrogen containing ring connected to a 5-carbon sugar.

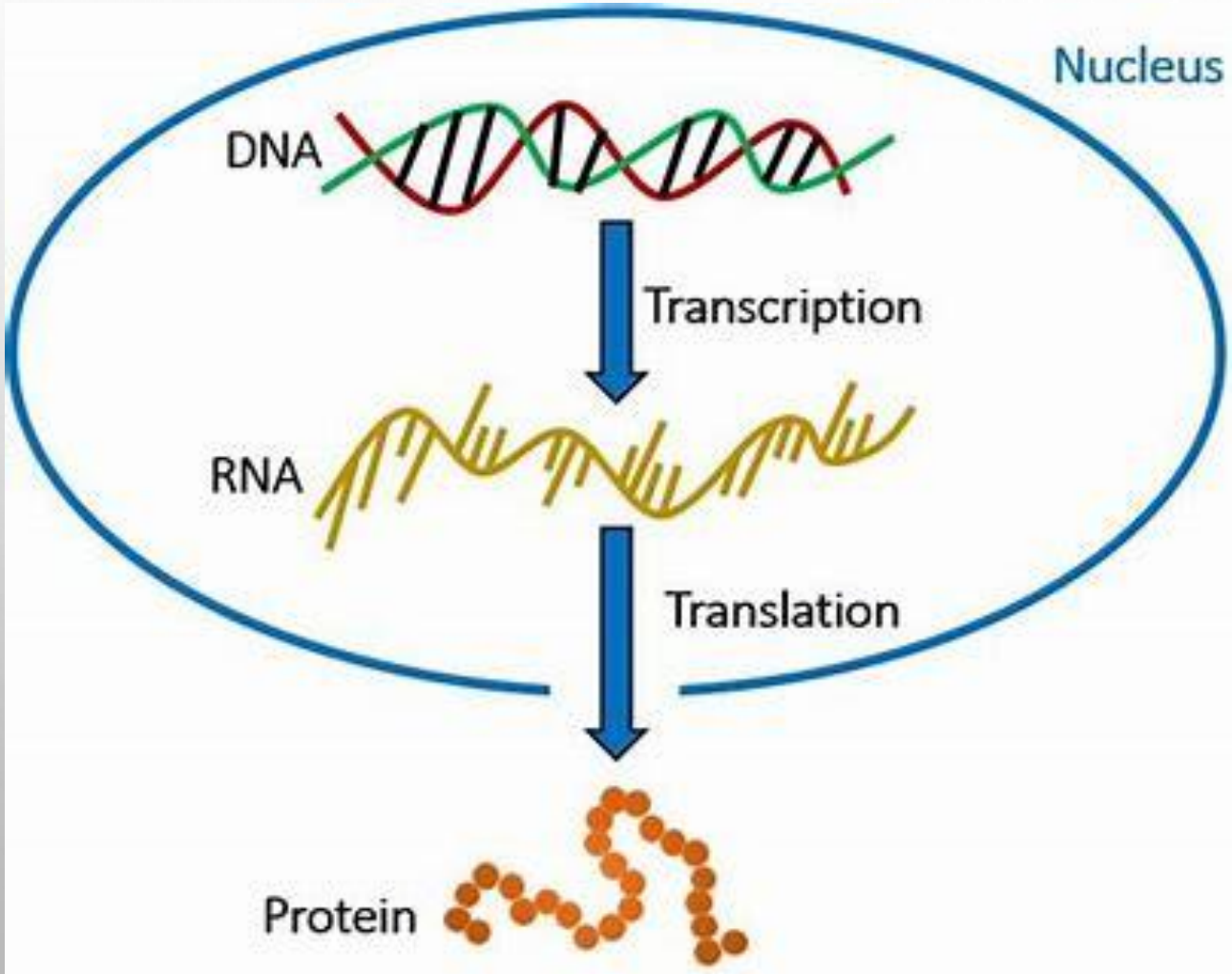
The sugar can be ribose or deoxyribose, and carries one or more phosphate groups.

The bases are Pyrimidines (Thymine, Cytosine and Uracil) and purines (Adenine and Guanine).

Nucleotides are short-term carriers of energy.

The Central Dogma of Life

The Central Dogma



DNA contains codified information.

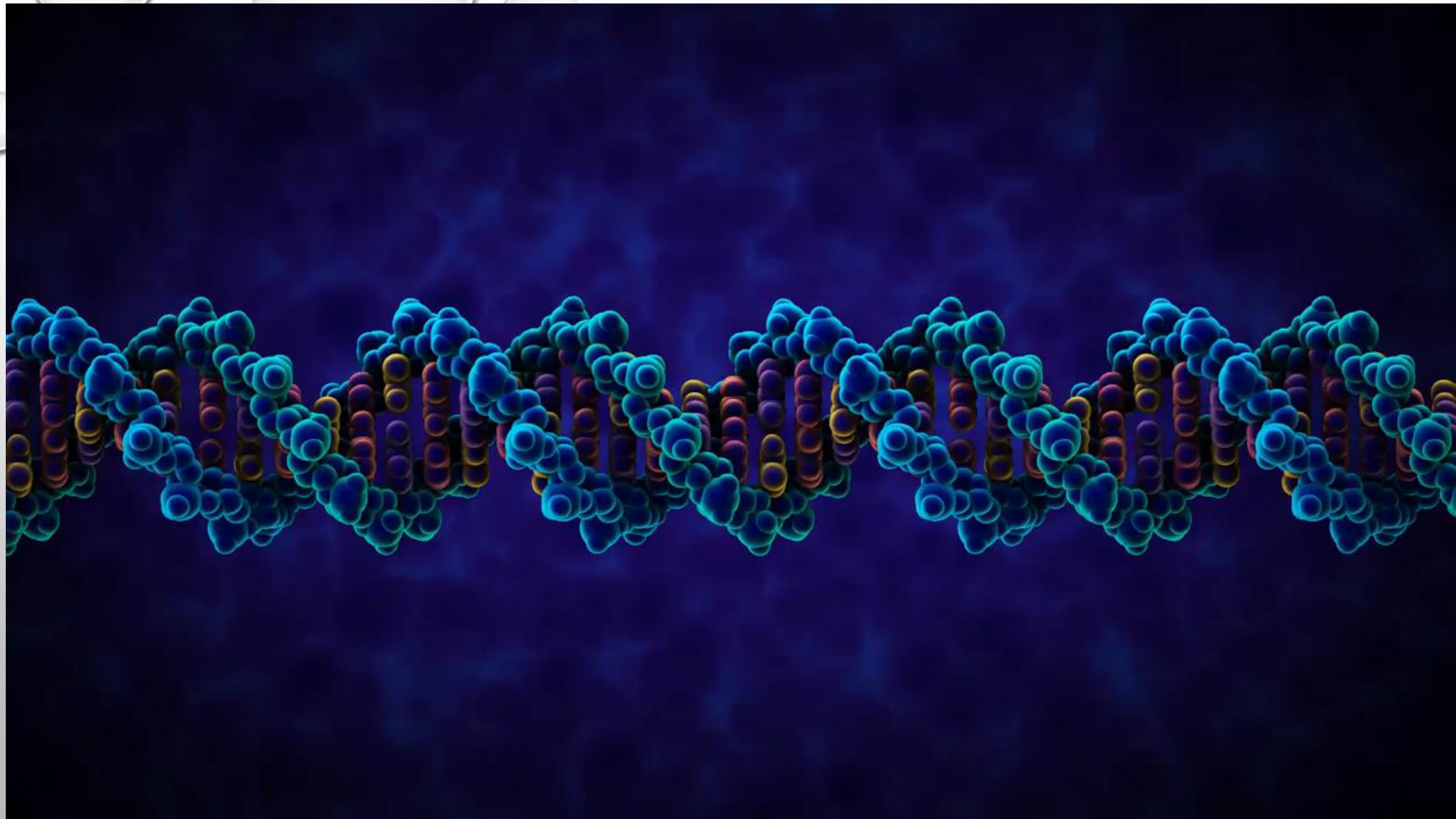
The codes are in the language of nucleotides.

DNA is always present in the cell as a double helix.

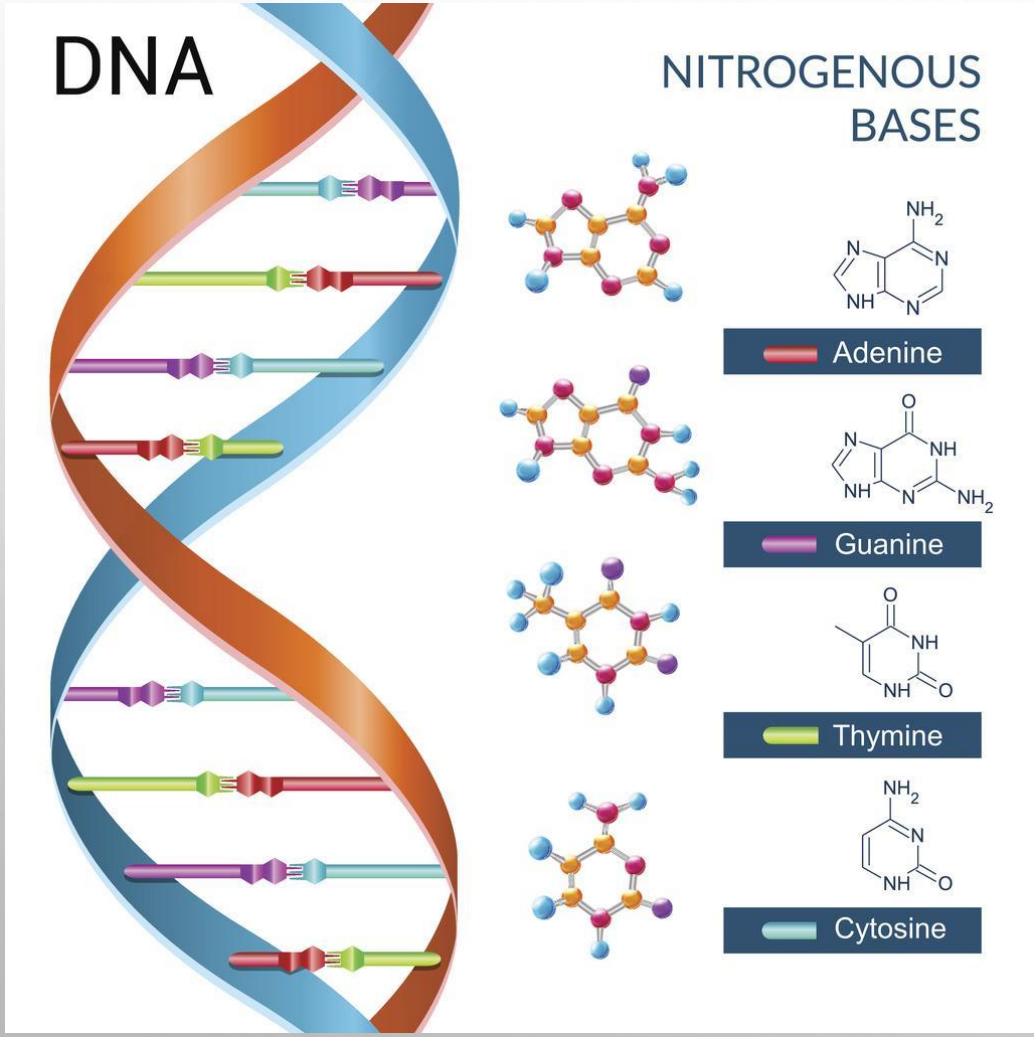
RNA is single-stranded, can fold up into multiple shapes.

RNA can perform multiple functions.

www.dnalc.org



DNA



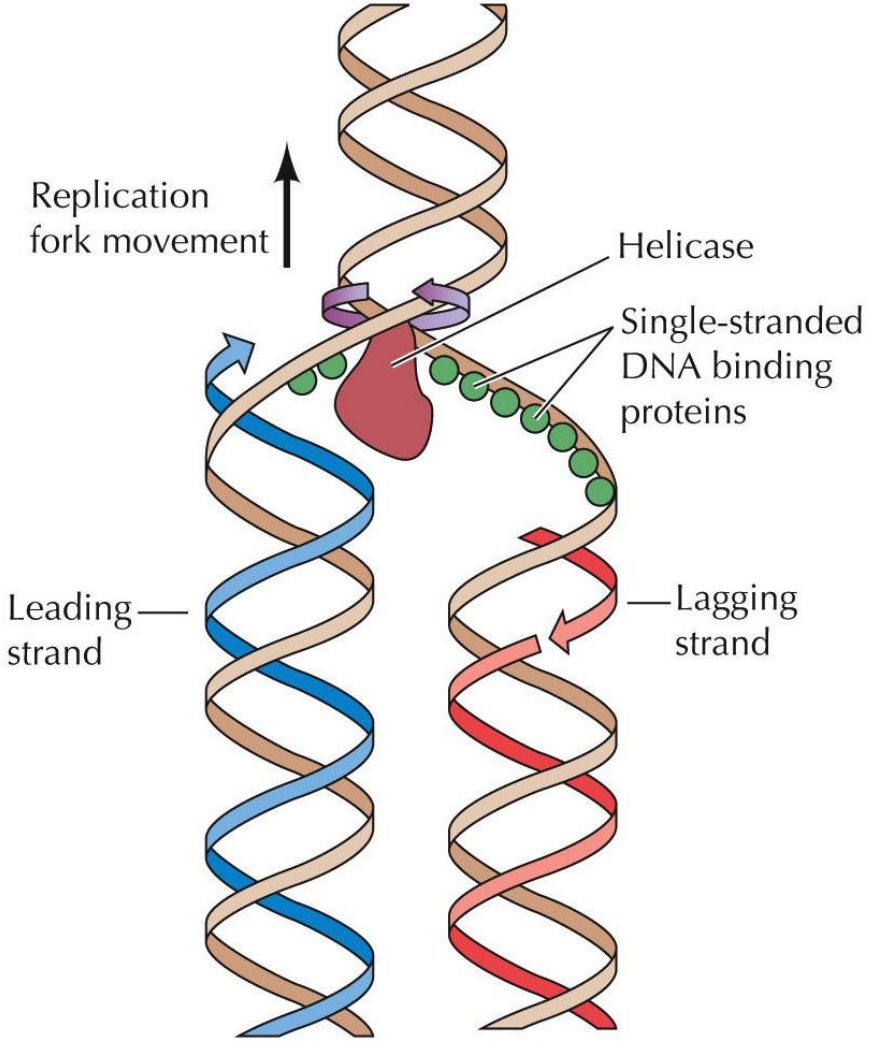
Sugar-phosphate backbone.

4 types of nucleotides linked by covalent bonds.

Two complimentary chains held by hydrogen bonds.

DNA extends at the 3’ end; the 5’-phosphate group of a neucleotide is added to the 3’ end of the chain through a phospho-diester bond.

DNA Replication



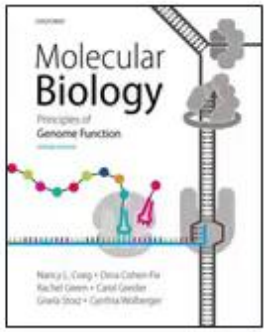
Occurs within the nucleus

Various proteins are involved in the replication process.

The replication fork is asymmetrical.

Okazaki fragments are formed on the lagging strand.

DNS polymerase is responsible for DNA chain elongation as well as proof-reading.



Molecular Biology: Principles of Genome Function

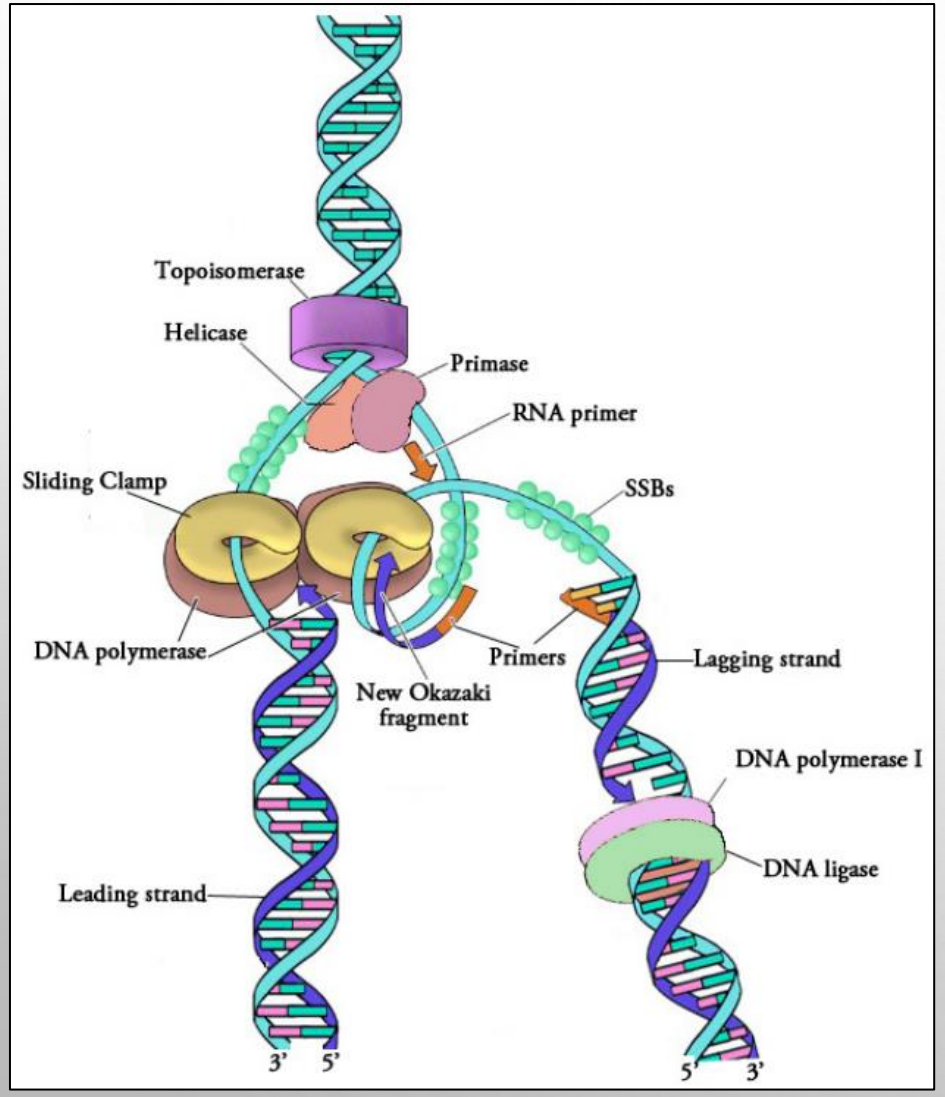
Second Edition

OXFORD
UNIVERSITY PRESS

Animation 1:
DNA replication

Animation produced by Connor Hendrich

DNA Replication - Remember



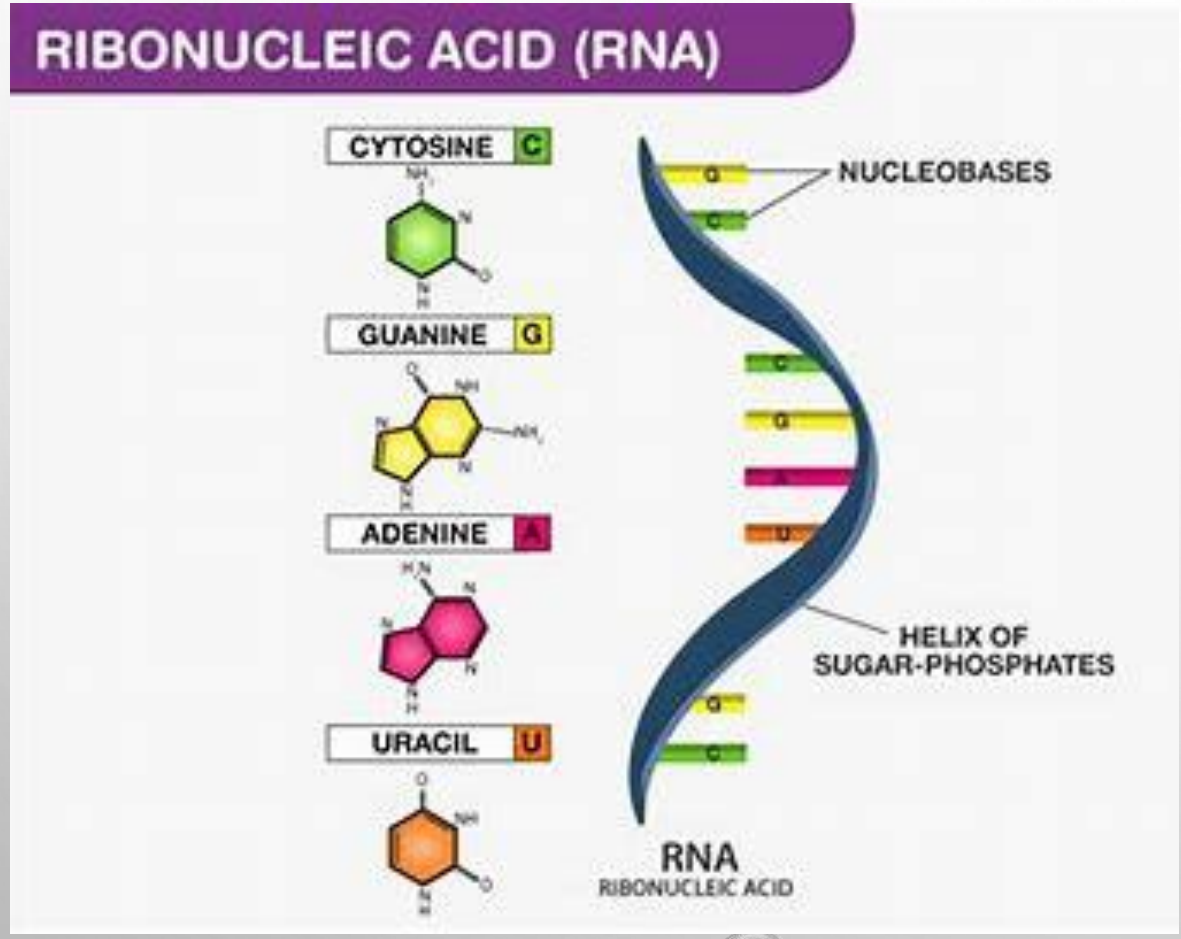
DNA Polymerase cannot start the process of replication without a primer.

It can add a nucleotide to an existing one in the 3' end.

Before moving on, it proofreads the newly added nucleotide and corrects any error.

Okazaki fragments are typically 100-200 bases long.

RNA

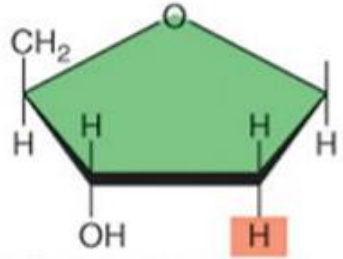


DNA vs. RNA

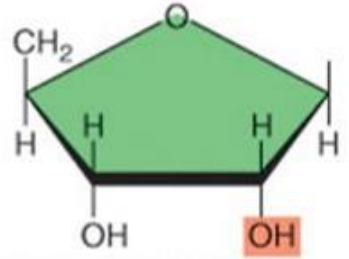
Double-stranded

Generally single-stranded

b.



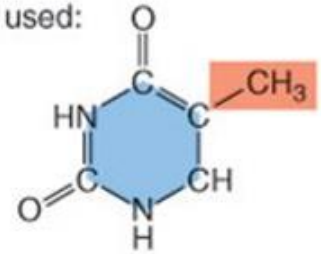
Deoxyribose as the sugar



Ribose as the sugar

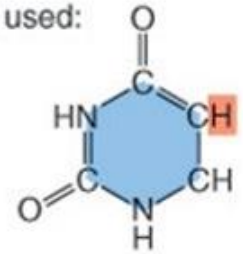
c.

Bases used:



Thymine (T)
Cytosine (C)
Adenine (A)
Guanine (G)

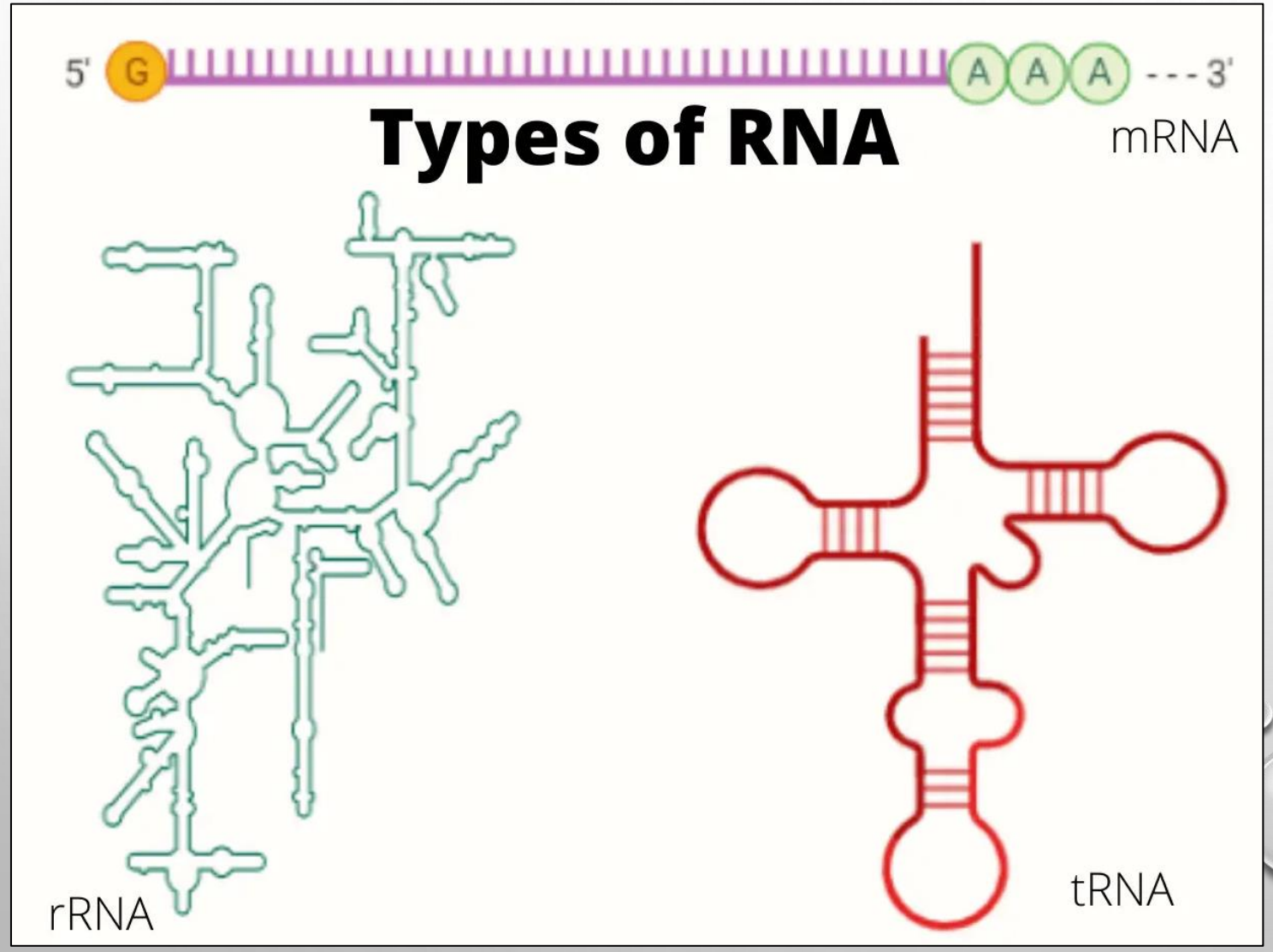
Bases used:



Uracil (U)
Cytosine (C)
Adenine (A)
Guanine (G)

d.

RNA

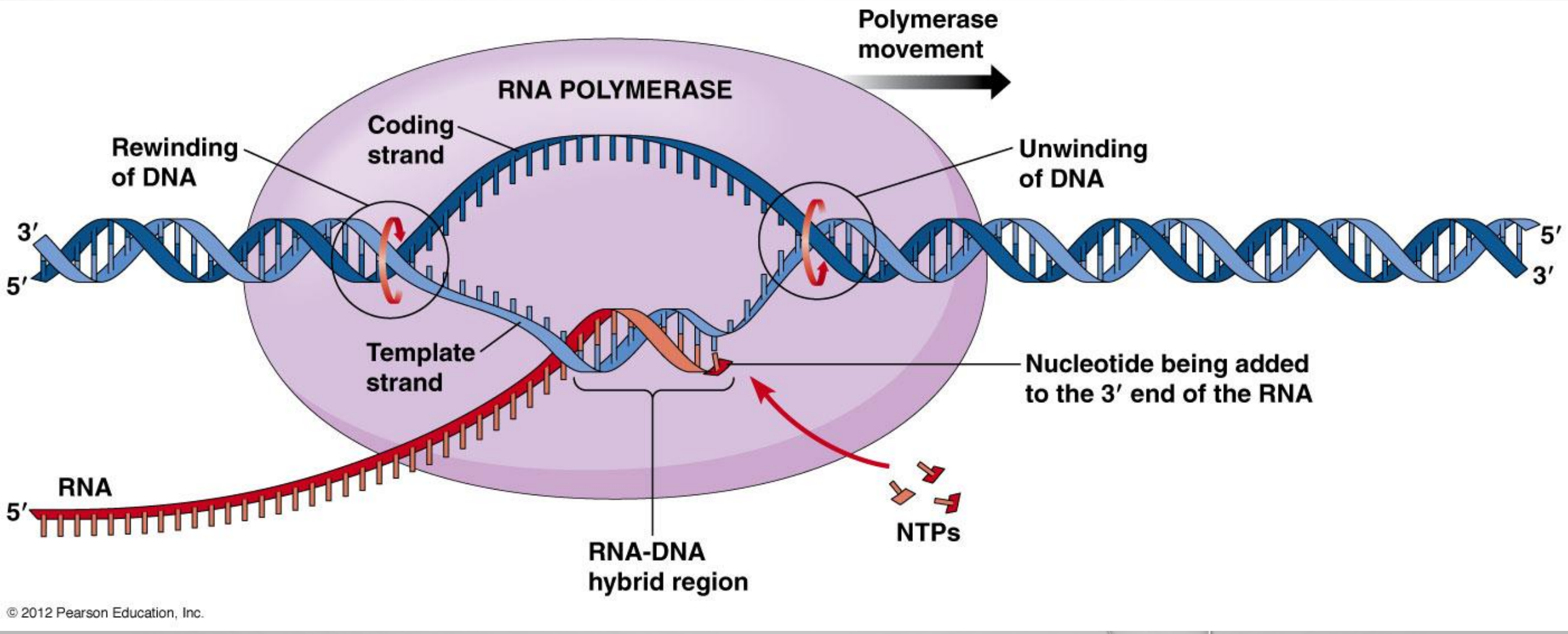


RNA is single stranded, so it can fold in various ways.

Three major types of RNA are mRNA, tRNA and rRNA.

There are other forms of RNA, like hnRNA, snRNA, miRNA, siRNA, dsRNA and ribozymes.

Transcription: DNA to mRNA



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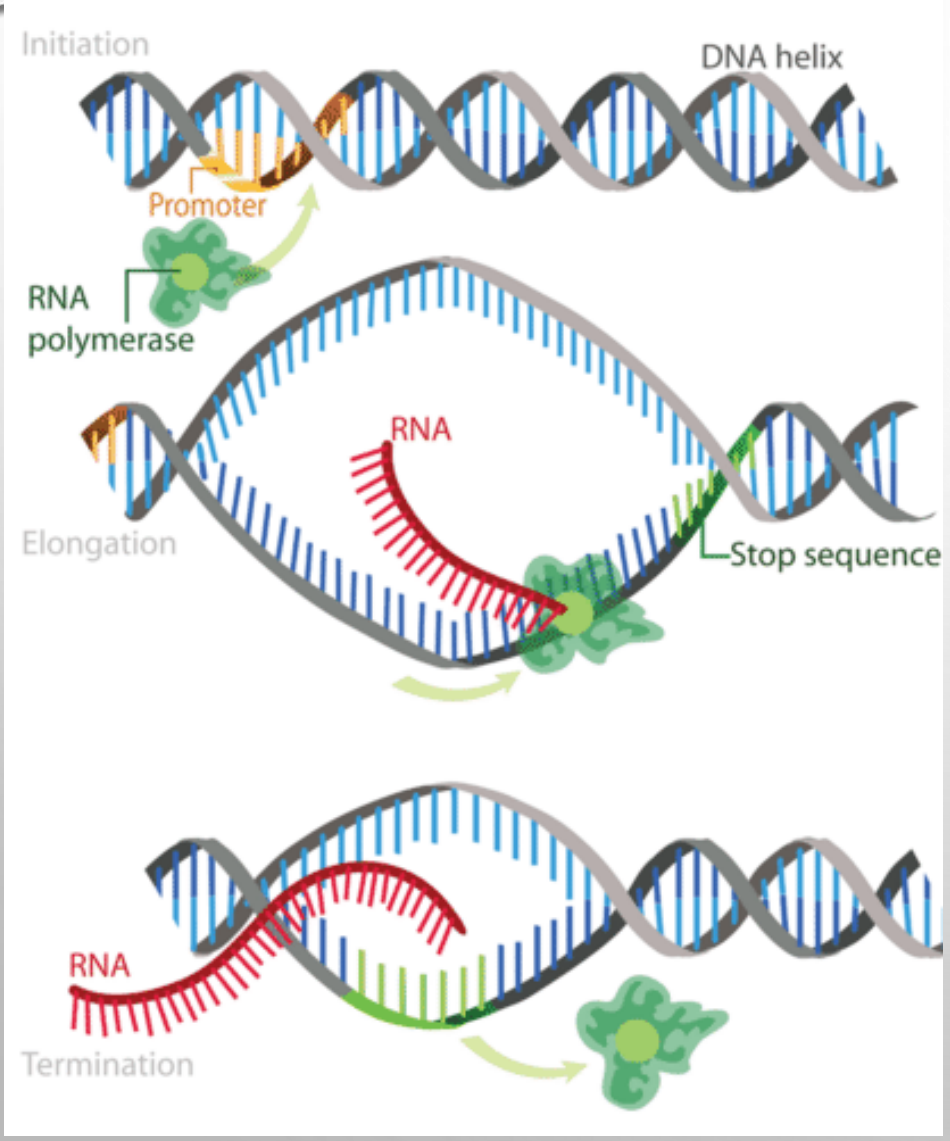


Three stages: Initiation, Elongation, Termination.

Initiation: RNA Pol binds to the promoter region of DNA → DNA unwinding starts.

Elongation: RNA Pol reads the DNA and makes mRNA. mRNA is briefly bound to the DNA strand.

Termination: RNA Pol crosses stop codon, elongation stops, mRNA detaches from DNA.

Post-transcriptional Modifications

In prokaryotes, mRNA is ready for translation immediately.

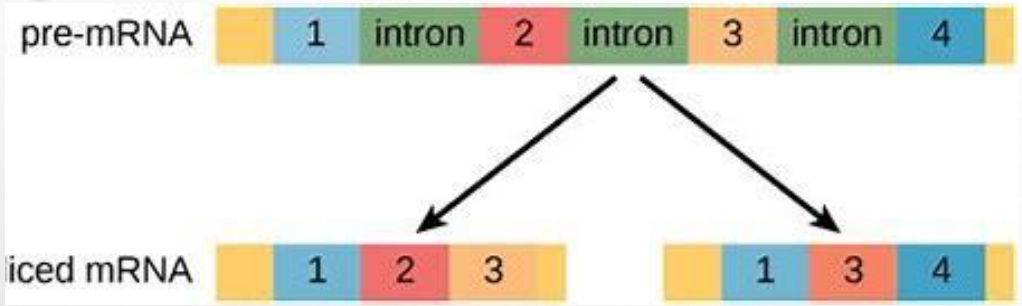
In eukaryotes, post-transcriptional modifications take place.

Splicing removes **introns** (non-coding regions) and stiches together **exons**.

Editing changes some of the nucleotides.

Polyadenylation adds a tail of adenines to the end of the mRNA. The poly-A tail is involved in the transport of mRNA from the nucleus to the cytoplasm.

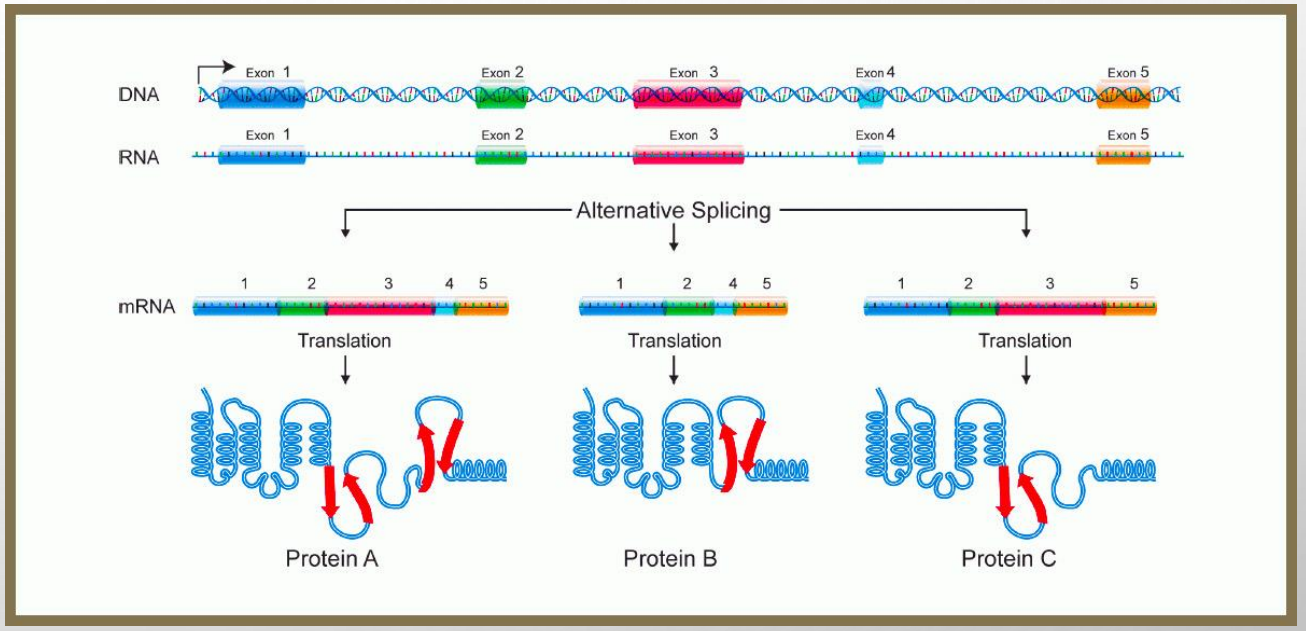
Splicing



Splicing occurs by cleavage at splice sites.

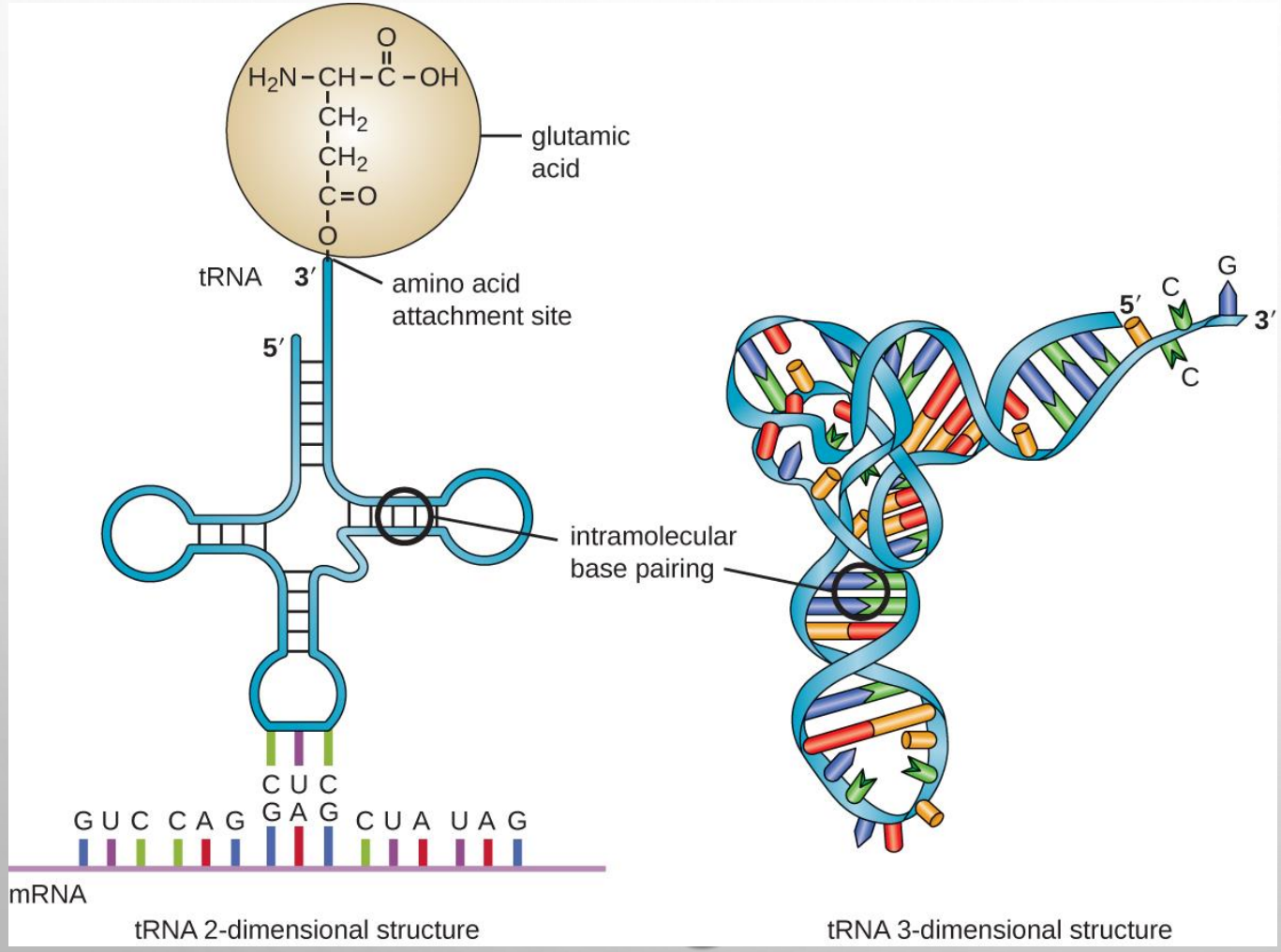
Typically, introns begin with GU at 5’ and end with AG at 3’ ends.

Splicing was first discovered in adenoviruses infecting mammalian cells.



Splicing is mediated by small nuclear ribonucleoproteins (snRNPs).

tRNA

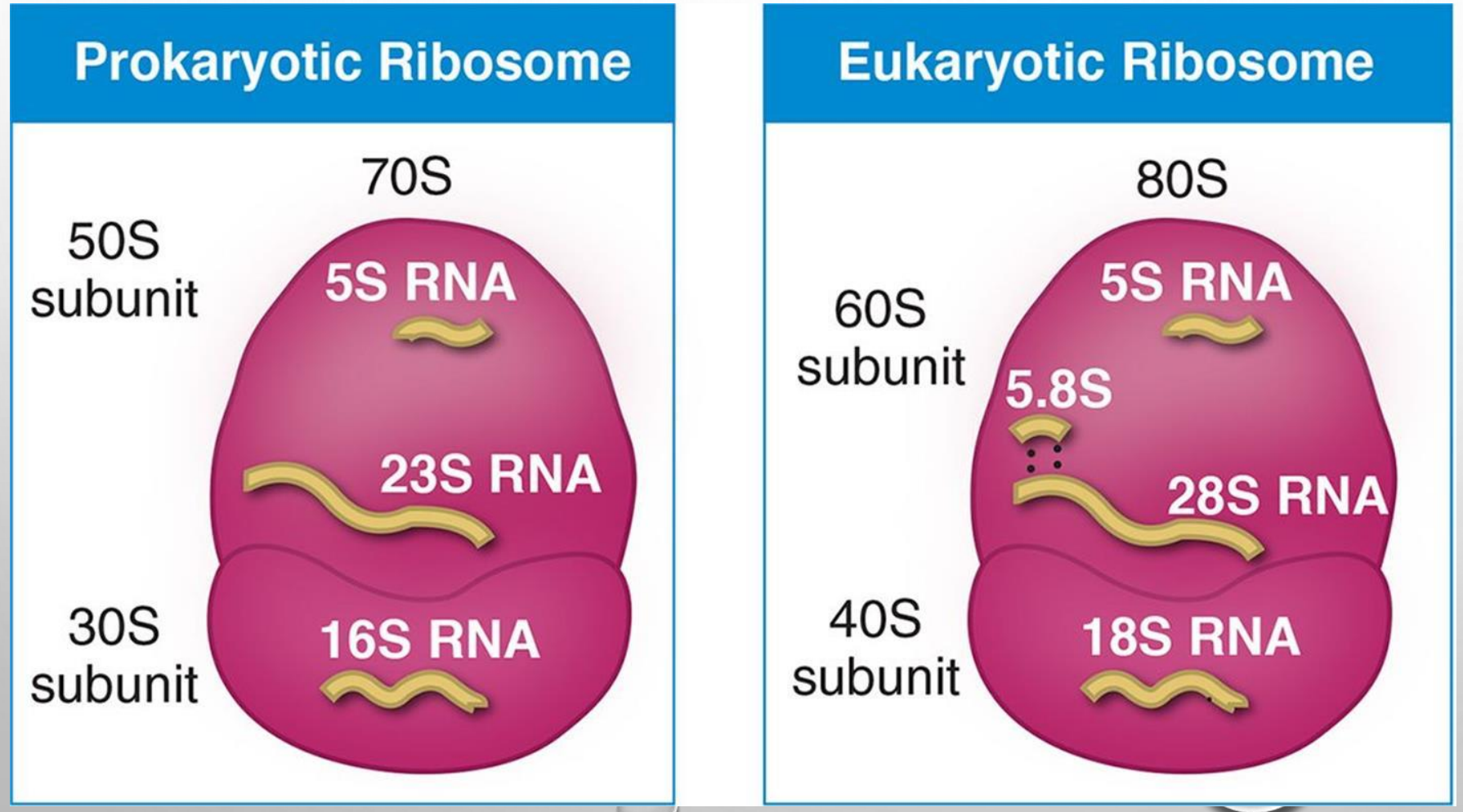


Pre tRNA is produced by transcription.

Both ends of the pre tRNA are trimmed and a CCA trinucleotide is added to the 3’ end.

tRNAs undergo nucleotide modifications and folding.

rRNA

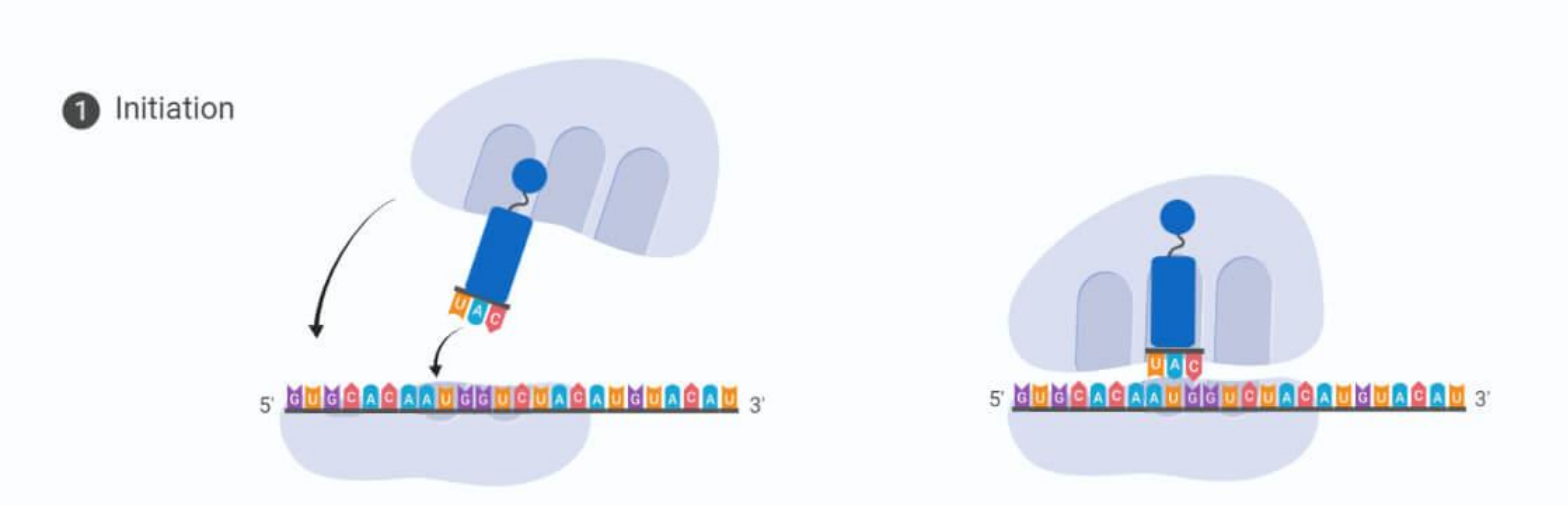


rRNA is a part of the ribosome.

It is a stable RNA.

rRNA assures proper alignment of the ribosome and mRNA.

Translation



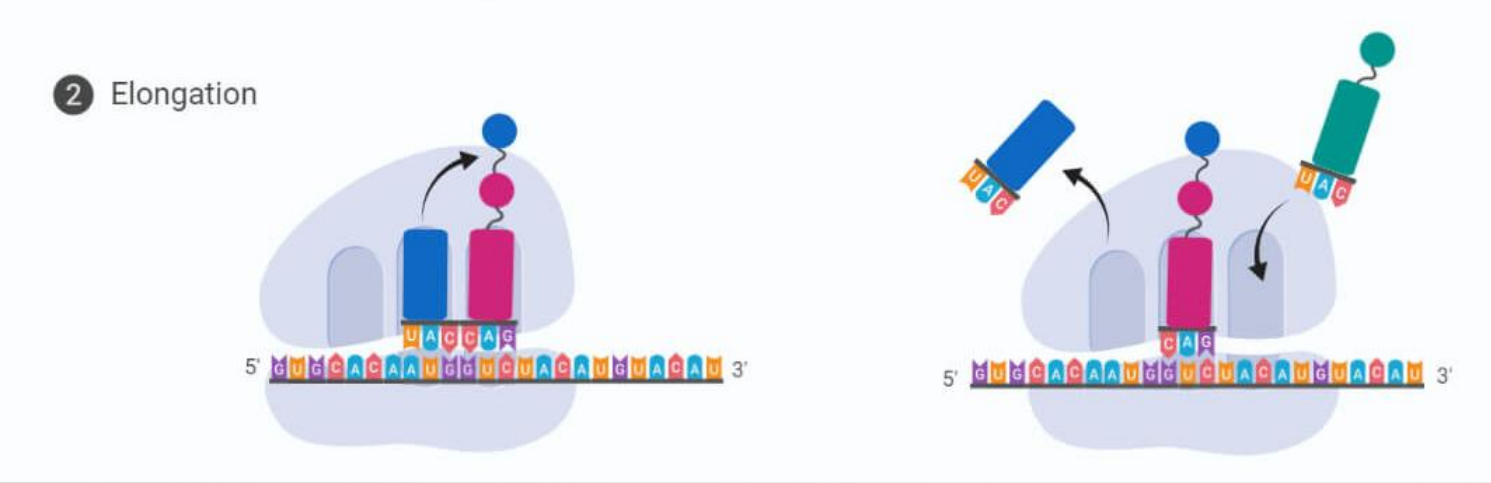
Initiation includes

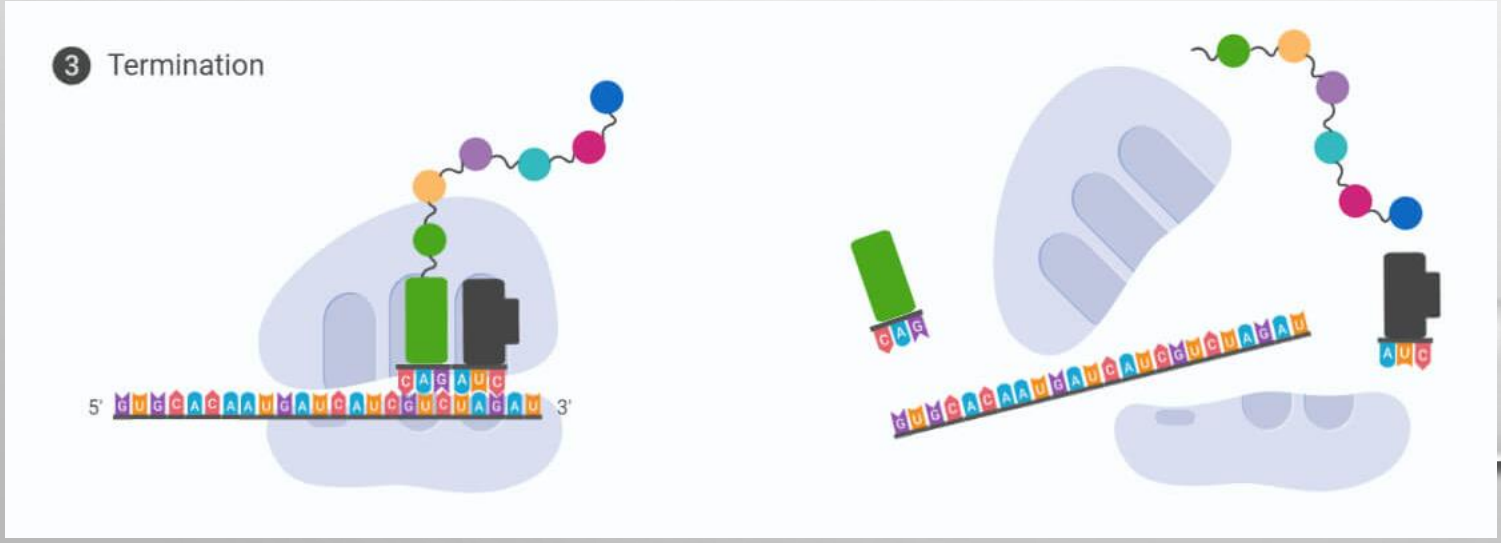
Binding of mRNA to the ribosome

Selection of the initiation codon

Binding of the acylated tRNA bearing the first amino acid.

Translation





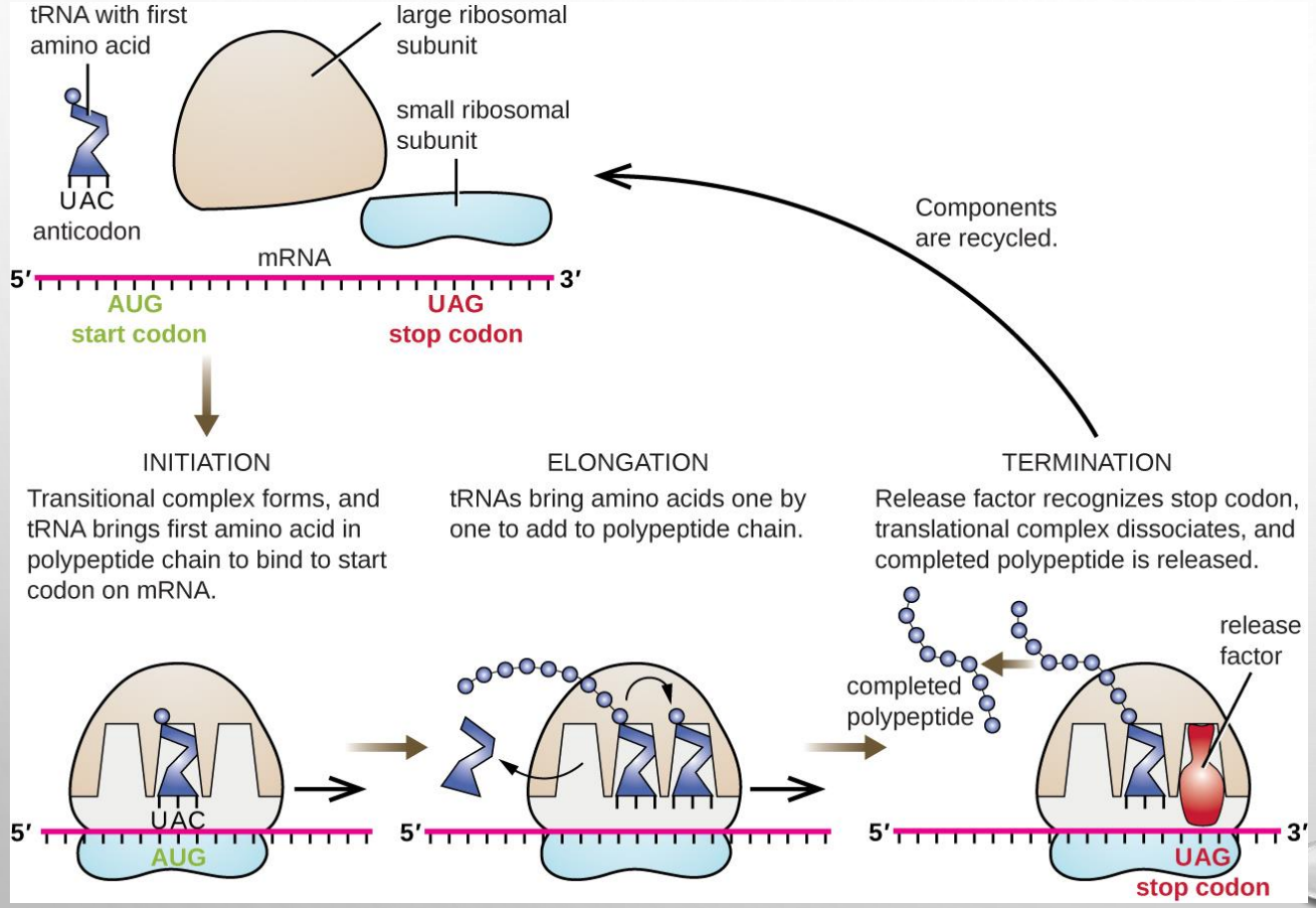
Elongation includes

Joining of two amino acids by a peptide bond

Movement of mRNA and ribosome.

Termination is release of the completed polypeptide and ribosome dissociation.

Translation



Translation starts at the **AUG start codon** and stops at the **UAG stop codon.**

The **preinitiation complex** of translation is formed by the assembly of the mRNA and the 30s subunit, followed by the joining of the 70s subunit.

A large number of proteins are involved in this process.