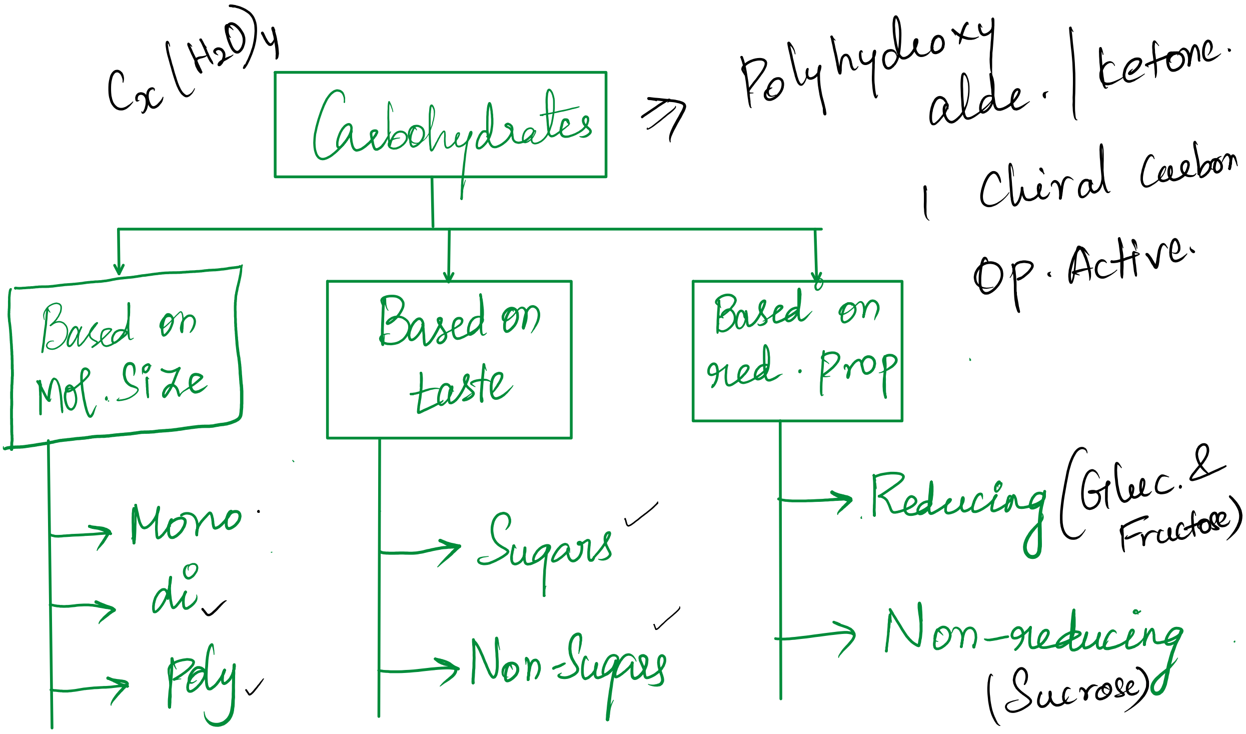
Biomolecules



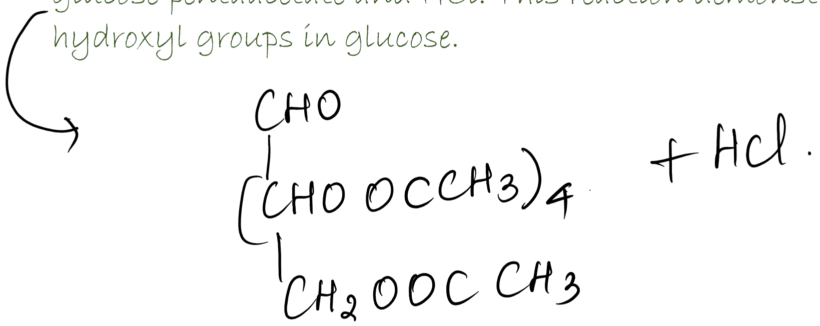
MONOSACCHARIDES

Chemical Reactions of Glucose:

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{H^+} \underset{C_6H_{12}O_6}{\text{Glucose}} + \underset{C_6H_{12}O_6}{\text{Fructose}}$$

1. Reaction with acetyl chloride (CH_3COCl):

When glucose reacts with acetyl chloride in the presence of $ZnCl_2$, it forms glucose pentaacetate and HCl. This reaction demonstrates the presence of hydroxyl groups in glucose.



Treatment with PCl_5:

Glucose reacts with phosphorus pentachloride to form pentachloroglucose $(CHCl)_4$ along with $POCl_3$ and HCl. This further confirms the presence of hydroxyl groups.

(CHO)

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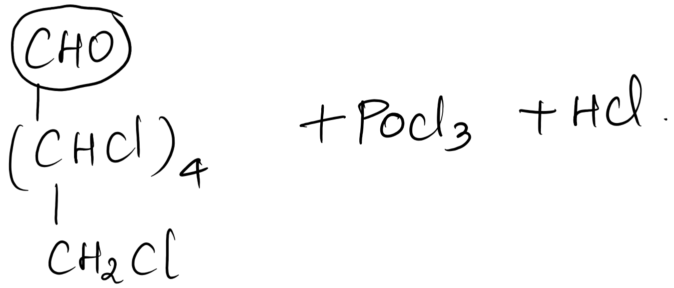
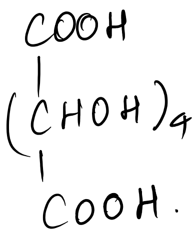


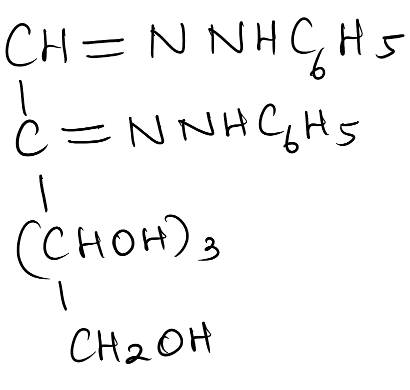
Reduction reaction: When glucose is treated with sodium amalgam and water ($Na\text{-}Hg/H_2O$), it forms sorbitol ($CH_2OH(CHOH)_4CH_2OH$). This reaction shows that glucose can be reduced at its aldehyde group.

Oxidation reactions: $CH_2OH(CHOH)_4COOH$

- With bromine water: Forms gluconic acid
- With nitric acid: Produces saccharic acid with additional oxidation
- The formation of these acids proves the presence of both aldehyde and primary alcohol groups

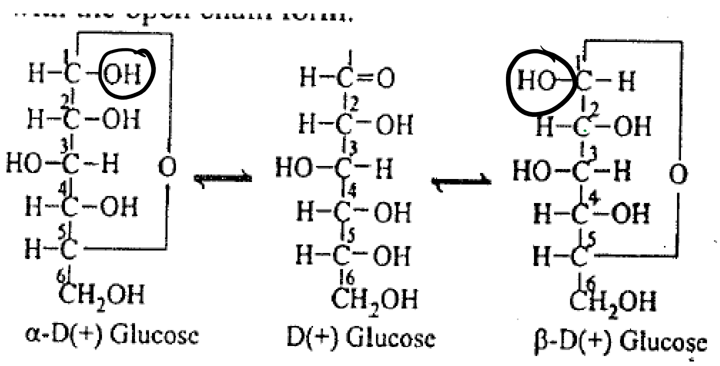


Formation of glucosazone: Glucose reacts with excess phenylhydrazine ($C_6H_5NHNH_2$) to form glucosazone, which has characteristic yellow needle-shaped crystals. This is a crucial identification test.



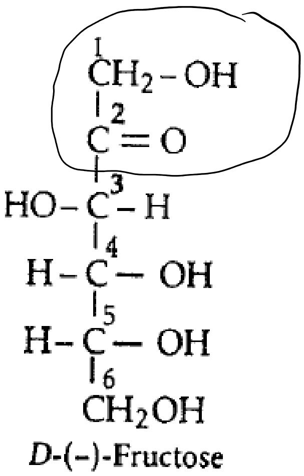
Structural Insights: The straight-chain structure of glucose explains most properties but fails to explain three important observations:

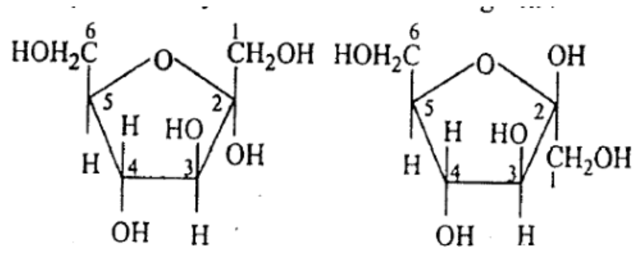
- No reaction with 2,4-DNP and $NaHSO_3$
- No reaction of its pentaacetate with NH_2OH
- Existence of α and β forms



These observations are better explained by glucose's cyclic structure, which exists in equilibrium with the open chain form. The cyclic structure can take two forms:

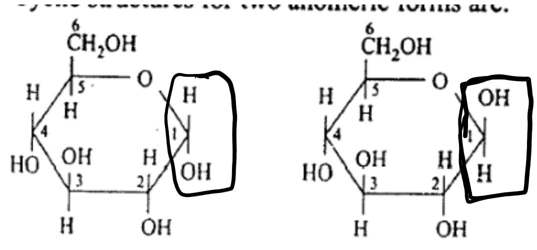
- Furanose form: Five-membered ring containing oxygen





α-D-(–)-Fructofuranose β-D-(–)-Fructofuranose

- Pyranose form: Six-membered ring containing oxygen



α-D(+) Glucose or α-D(+) Glucopyranose

β-D(+) Glucose or β-D(+) Glucopyranose

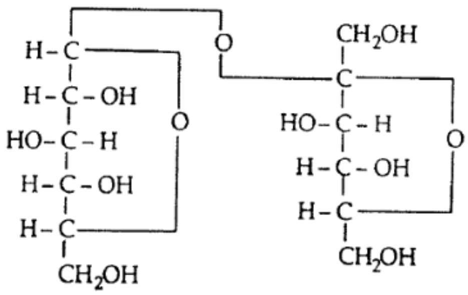
Mutarotation: A particularly important phenomenon is mutarotation, where α-D-(+)-glucose converts to β-D-(+)-glucose in aqueous solution, reaching an equilibrium. The specific rotation changes from +112° to +19° at equilibrium (+ 52.7°).

Anomers:

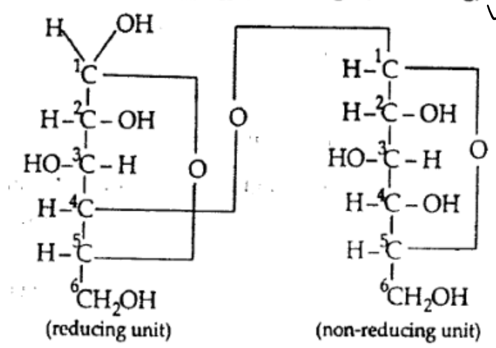
stereoisomers that differ in configuration only around C-1 (the anomeric or glycosidic carbon). This explains the existence of α and β forms of glucose

Disaccharides :

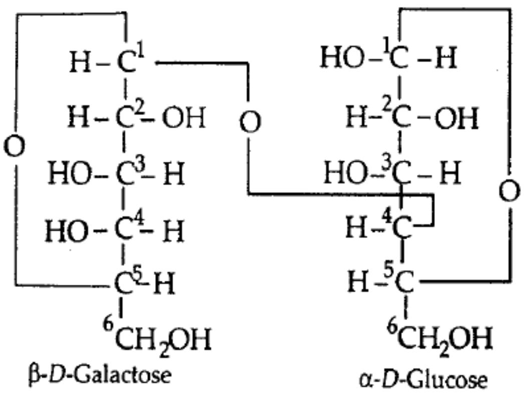
- **Sucrose, $C_{12}H_{22}O_{11}$ (Cane sugar, non-reducing) :**



- **Maltose, $C_{12}H_{22}O_{11}$ (Malt sugar, reducing) :**



- **Lactose ($C_{12}H_{22}O_{11}$) (Milk sugar, reducing) :**



Polysaccharides:

Starch is one of the most significant polysaccharides, serving as the primary energy source for humans.

key characteristics and behaviour:
The structure of starch consists of two main components:
amylose and amylopectin.

Amylose forms a straight chain with α-1,4-glycosidic bonds between glucose units. **Amylopectin**, however, is more complex, having both α-1,4-glycosidic bonds in the main chain and α-1,6-glycosidic bonds at branching points. When we eat starchy foods, our body begins breaking them down immediately.

In our saliva, the enzyme amylase initiates this process:

Starch →	Dextrin →	Maltose →	Glucose

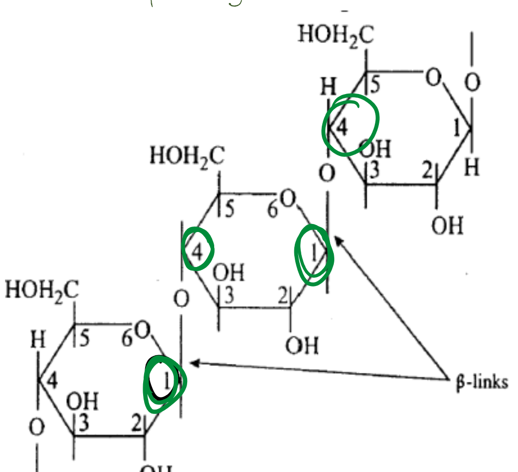
$(C_6H_{10}O_5)_n \rightarrow (C_6H_{10}O_5)_x \rightarrow C_{12}H_{22}O_{11} \rightarrow C_6H_{12}O_6$

A distinctive property of starch is its reaction with iodine, producing a characteristic blue color. This serves as a key identification test. Importantly, starch doesn't reduce Fehling's or Tollens' reagents because its reducing groups are involved in glycosidic bonds.

Cellulose:

Another crucial polysaccharide, differs significantly from starch. It forms the structural framework of plant cell walls and is remarkably abundant - making up 90-95% of cotton and 45-50% of wood.

Its structure involves β-D-glucose units connected by β-1,4-glycosidic linkages between C-1 of one glucose unit and C-4 of the next.



Cellulose

1,4-glycosidic

Glycogen, often called "animal starch," serves as the storage form of glucose in animals. It's primarily found in the liver, muscles, and brain, with a structure similar to amylopectin but more extensively branched.

Proteins and Amino Acids:

Proteins are complex biomolecules composed of amino acids linked through **peptide** bonds (-CONH-).

COOH H$_2$N COHN

Understanding amino acids is crucial for comprehending protein structure and function:

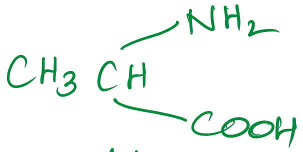
Amino acids share a common structure but differ in their side chains. They can be classified into several categories:

Except glycine

1. **Non-polar side chains:**
   - Simple ones like glycine (no side chain) and alanine (methyl group)

$HOOC-CH_2-NH_2$

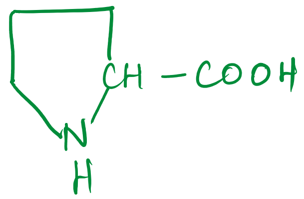
Glycine.



Alanine

- Branched ones like valine, leucine, and isoleucine (all essential)

- Special cases like proline, which forms a unique ring structure



2) Polar but neutral side chains:
- Hydroxyl-containing (serine, threonine)
- Sulfur-containing (cysteine, methionine)
- Aromatic (tryptophan, tyrosine)
- Amide-containing (asparagine, glutamine)

Amino acids with charged side chains:
- Basic (lysine, arginine, histidine)
- Acidic (aspartic acid, glutamic acid)

Amphoterism:

A fascinating property of amino acids is their amphoteric nature - they can act as both acids and bases. This leads to the formation of **zwitterions,** where the amino acid carries both positive and negative charges. At a specific pH called the isoelectric point, the amino acid exists as a neutral zwitterion, showing minimum solubility.

Proteins can be classified based on their shape and structure:
1. **Fibrous proteins:** These have parallel polypeptide chains held together by hydrogen and disulfide bonds, making them insoluble in water. Examples include keratin and myosin.
2. **Globular proteins:** These form three-dimensional spherical structures and are typically soluble in water. Insulin and albumins are prime examples.

Protein Structure and Its Levels:

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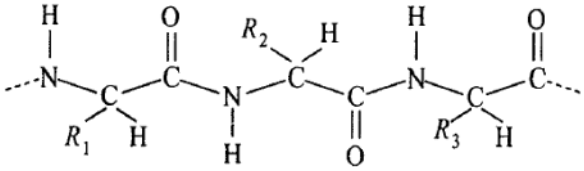
Protein Structure and Its Levels:

The structure of proteins can be understood through four hierarchical levels, each building upon the previous one:

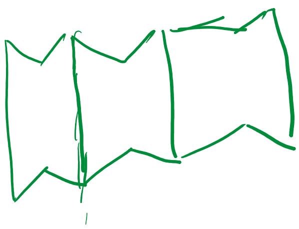
Primary Structure: This is the most basic level - imagine it as the raw sequence of amino acids linked together by peptide bonds. Each peptide bond forms between the carboxyl group (-COOH) of one amino acid and the amino group ($-NH_2$) of another, creating a backbone with side chains (R_1, R_2, R_3, etc.) hanging off like branches from a tree.



Secondary Structure: This level shows how the protein chain begins to fold into regular patterns:

1. α-Helix: Picture a spiral staircase, where the protein chain coils around itself like a spring. Hydrogen bonds between every fourth amino acid stabilize this structure, making proteins like keratin in hair incredibly strong yet flexible.

1. β-Pleated Sheet: Imagine a folded paper fan - the protein chain folds back and forth upon itself, creating a flat sheet structure. These sheets are particularly common in silk proteins, giving them their unique strength.



Intermolecular H-bonds.

Tertiary Structure: Think of this as the final 3D shape of a single protein chain. Various forces come into play here - hydrophobic interactions push some parts inward, while polar regions stay on the surface. This level gives proteins like hemoglobin their specific functional shape.

Quaternary Structure: This is like a protein team - multiple folded protein chains (called subunits) come together to form one functional unit. Hemoglobin, with its four subunits, is a classic example.

Enzymes and Their Properties:

Enzymes are nature's catalysts, and their behavior follows several key principles:

1. **Mechanism of Action**:

   The process follows a clear sequence:

"ase"

- Enzyme (E) meets substrate (S) → Forms ES complex
- ES complex transforms → EI (intermediate) complex ✓
- EI complex changes → EP (product) complex
- Finally, EP breaks apart → Free enzyme + Product

2. **Key Properties:**

- High Efficiency: They can catalyze millions of reactions per second
- Specificity: Like a lock and key, each enzyme works with specific substrates
- Temperature Sensitive: Most work best around body temperature (37°C)
- pH Dependent: Each has an optimal pH range (often around 7)

- **Vitamins**

  These are organic compounds which cannot be produced by the body and must be supplied in small amounts in diet for normal health, growth and maintenance of body. Multiple deficiencies caused by lack of more than one vitamin are common in human beings. This condition of vitamin deficiency is known as avitaminosis.

  * The vitamins which are soluble in water are called water soluble vitamins. e.g. vit. B, vit. C, etc. ⇒ Water Soluble BC

  * The vitamins which are soluble in fats are called fat soluble vitamins. e.g. vit. A, D, E, K. fat soluble.

Nucleic acids are polynucleotides present in the nuclei of all living cells in the form of nucleoproteins. They are the fundamental molecules of heredity and contain genetic information essential for all living organisms.

Basic Components (High Priority Topic)

Each nucleotide consists of three essential components:

- Pentose Sugar (5-carbon sugar)
- Nitrogenous Base
- Phosphate Group (H_3PO_4)

Types of Pentose Sugar (Important for JEE)

- D-ribose ($C_5H_{10}O_5$): Present in RNA

  Contains an OH group at 2' position

- 2-Deoxy-D-ribose ($C_5H_{10}O_4$): Present in DNA

  Lacks oxygen at 2' position

Nitrogenous Bases (Critical for Both JEE & NEET)

Purines (Double-ring structures)

- Adenine (A)

  Structure: $C_5H_5N_5$

  Contains two nitrogen-containing rings

- Guanine (G) AG

  Structure: $C_5H_5N_5O$

  Forms three hydrogen bonds with cytosine

Pyrimidines (Single-ring structures)

- Cytosine (C)

  Structure: $C_4H_5N_3O$

- Thymine (T) - Only in DNA CUT

  Structure: $C_5H_6N_2O_2$

- Uracil (U) - Only in RNA

  Structure: $C_4H_4N_2O_2$

Nucleoside = Pentose Sugar + a nitrogenous base

Nuclotide = Nucleoside + Phosphoric acid. + N.B

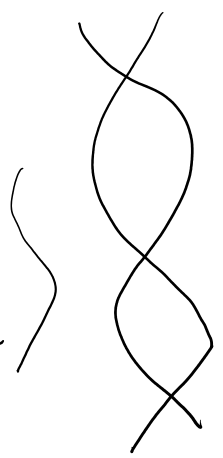
Nucleoside vs Nucleotide (Important Distinction for JEE)

Nucleoside = Pentose sugar + Nitrogenous base

Nucleotide = Nucleoside + Phosphoric acid (at 5' carbon)

DNA vs RNA Comparison (Critical Table for Both Exams)

Feature	DNA	RNA
Sugar	2-deoxy-D-ribose	D-ribose
Pyrimidine bases	Cytosine, Thymine	Uracil, Cytosine
Purine bases	Adenine, Guanine	Adenine, Guanine
Structure	Double-stranded helix	Single-stranded
Location	Nucleus (mainly)	Nucleus + Cytoplasm
Replication	Self-replicating	Non-self-replicating
Size	Larger	Smaller
Stability	More stable	Less stable



Chargaff's Rules (Important for Both Exams)

First Rule: A = T, G = C (in DNA)
Second Rule: Purine = Pyrimidine
Base Pairing:

A=T (2 H-bonds) ✓
G≡C (3 H-bonds) ✓
In RNA: A=U

Biological Functions (Essential for NEET)

Replication

- Semiconservative process
- Produces identical DNA copies
- Enzyme-catalyzed

Protein Synthesis

- Transcription: DNA → RNA
- Translation: RNA → Protein
- Genetic code: Triplet codon system

Mutations (Important for NEET)

- Definition: Changes in nitrogenous base sequence
- Effects:

- Altered amino acid sequence
- Modified protein structure
- Possible genetic disorders

Important Practice Problems

JEE-Level Problem:

3. Calculate the number of hydrogen bonds in a DNA segment containing 30% adenine. Total number of nucleotides = 100.

A = T = 30%
G = C = 20%

No. of H-bonds = (A-T pairs × 2) + (G-C pair × 3)
= (30 × 2) + 20×3
= 120.

NEET-Level Problem:

1. If a DNA segment has 20% cytosine, predict the percentage of other bases.

C = G = 20%
A = T = 30%

= 100%

Hormones:

These chemical messengers can be classified into three main types:

1. Steroid Hormones:
   - Examples: testosterone, estrogen, cortisone
   - Fat-soluble molecules that easily cross cell membranes
   - Control development and metabolism
2. Peptide Hormones:
   - Examples: insulin, oxytocin
   - Water-soluble proteins that work through cell surface receptors
   - Control various metabolic processes
3. Amine Hormones:
   - Examples: thyroxine, epinephrine
   - Derived from amino acids
   - Control metabolism and stress responses

JEE Main 2023: Q:

A polypeptide has 8 amino acids. Calculate the total number of peptide bonds present.

" No. of Peptide bonds is always one less than AA."

8 - 1 = 7 Peptide bond.

NEET 2022: Q: Which of the following statements about enzymes is incorrect? a) They are highly specific b) They possess both active and allosteric sites c) They are predominantly proteins d) ✗ They can be used indefinitely

- JEE Advanced 2023:

Q: Match the following:

	Column A	Column B	
A	Insulin p.	Peptide hormone	A
B	Thyroxine	q. Steroid hormone	C
C	Estrogen	r. Amine hormone	B

NEET 2023: Q: Which statement about nucleic acids is correct?

a) RNA contains thymine ⇒ Uracid.

b) DNA is single-stranded ⇒ double stranded.

c) In DNA, adenine pairs with thymine through two hydrogen bonds

d) RNA contains uracil and ribose sugar ✓

JEE Main 2022: Q: Calculate the pH of isoelectric point of glycine if $pKa_1 = 2.34$ and $pKa_2 = 9.60$

$$pI = \frac{(pKa_1 + pKa_2)}{2}$$

$$= \frac{2.34 + 9.60}{2} = \frac{11.94}{2} = 5.97.$$