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Biochemistry

Carbohydrate Metabolism ,Carbohydrate Digestion, Absorption of Carbohydrates ,Anaerobic Oxidation

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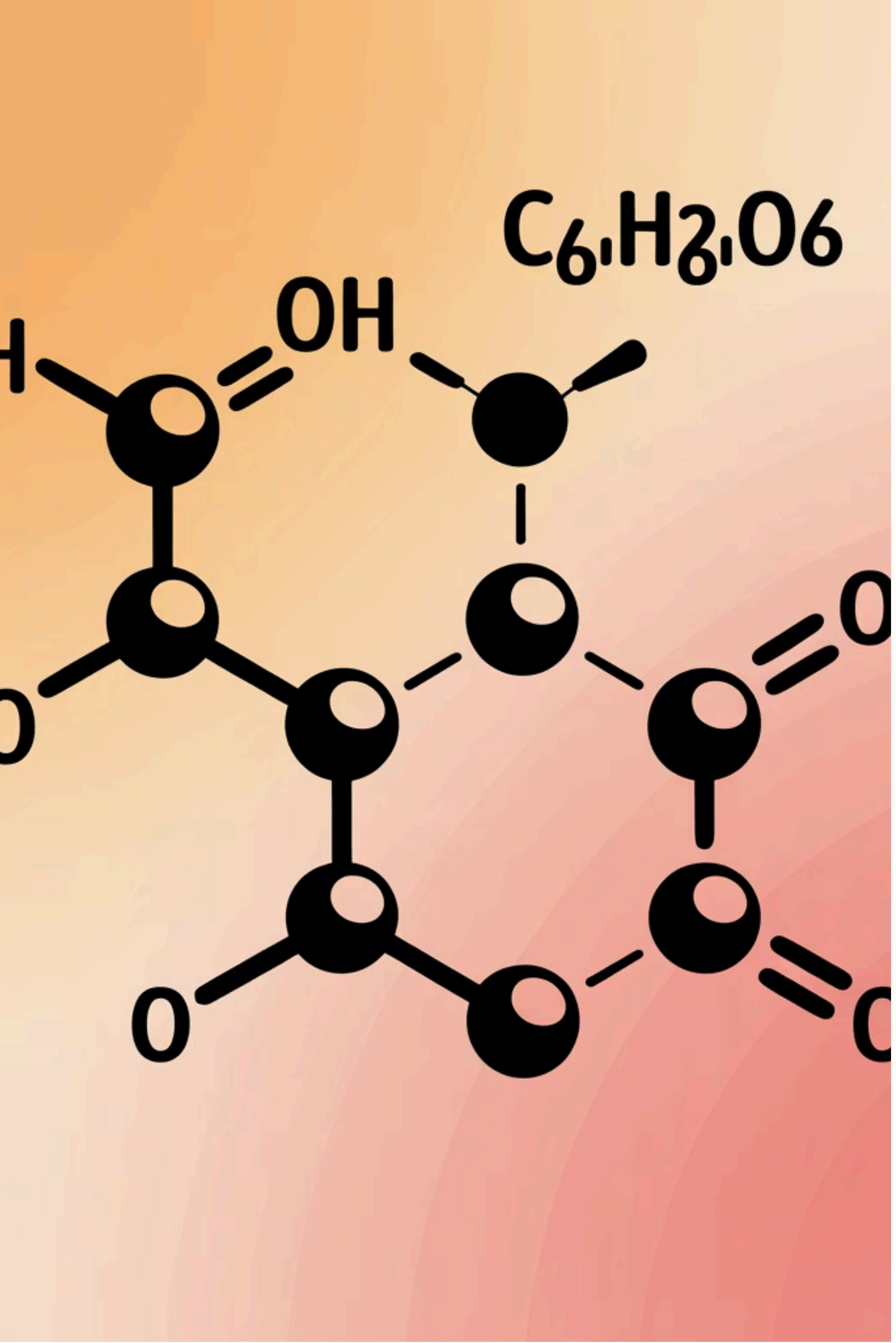
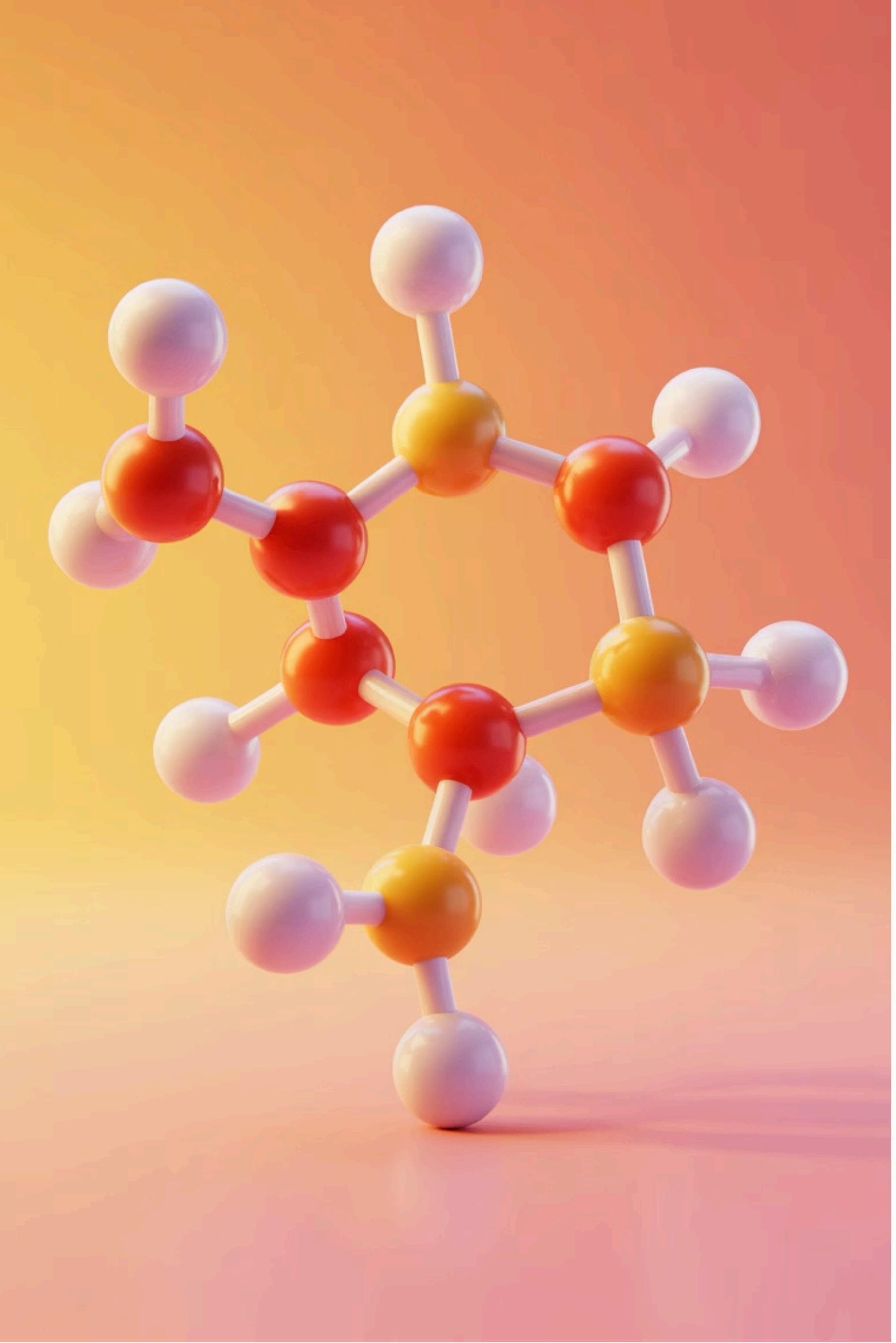


Carbohydrate Metabolism



Introduction to Carbohydrate Metabolism

Energy Importance

Carbohydrates provide approximately 4 kilocalories per gramme, making them an efficient fuel source for the body. They are particularly vital for brain function and muscle activity during physical exercise.

The brain alone consumes about 120 grammes of glucose daily, highlighting the critical role of carbohydrates in maintaining cognitive function and overall metabolic health.

Carbohydrates serve as the body's primary energy source, composed of carbon, hydrogen, and oxygen atoms in the ratio $C_n(H_2O)_n$. They are essential macronutrients that fuel cellular processes throughout the body.

Types of Carbohydrates

- **Monosaccharides:** Simple sugars including glucose, fructose, and galactose
- **Disaccharides:** Two sugar units such as sucrose, lactose, and maltose
- **Polysaccharides:** Complex chains like starch, glycogen, and cellulose

Digestion Begins in the Mouth

The digestive journey of carbohydrates commences the moment food enters the oral cavity. Salivary glands secrete the enzyme α-amylase, also known as ptyalin, which initiates the breakdown of complex starch molecules.

Enzyme Action

Salivary α-amylase cleaves α-1,4 glycosidic bonds in starch molecules, producing maltose, maltotriose, and α-limit dextrins.

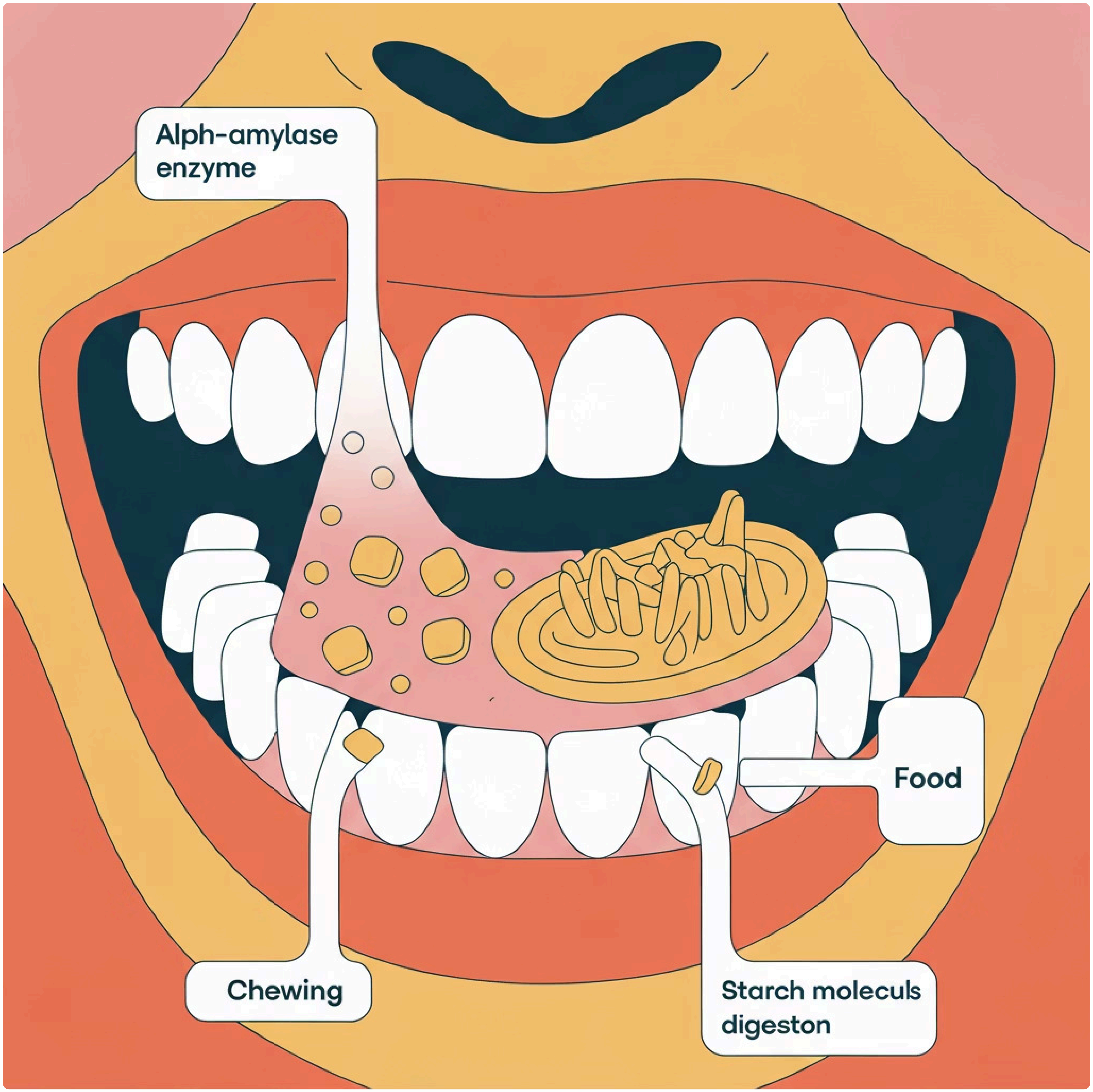
pH Requirements

The enzyme functions optimally at neutral pH (~7.0) and requires chloride ions (Cl^-) for proper activation and catalytic activity.

Mechanical Action

Mastication (chewing) thoroughly mixes food with saliva, increasing surface area and enzyme-substrate contact for efficient digestion.

The amylase enzyme specifically targets the α-1,4 bonds in the linear portions of starch, whilst α-1,6 bonds at branching points remain intact at this stage, creating limit dextrins that require further enzymatic processing.


Alph-amylase enzyme
Food
Chewing
Starch moleculs digeston

Digestion in the Stomach and Small Intestine

Brush Border Enzymes

The intestinal epithelial cells contain crucial enzymes:

- **Maltase:** Breaks maltose → glucose + glucose
- **Sucrase:** Breaks sucrose → glucose + fructose
- **Lactase:** Breaks lactose → glucose + galactose
- **Isomaltase:** Breaks α-1,6 bonds in limit dextrins

Stomach Phase

Upon reaching the stomach, the highly acidic environment (pH ~2.0) denatures and inactivates salivary α-amylase, effectively halting carbohydrate digestion. The stomach does not secrete any carbohydrate-specific enzymes, serving primarily as a storage and mixing chamber.

Small Intestine Phase

As the partially digested food (chyme) enters the duodenum, pancreatic α-amylase is secreted, resuming the breakdown of remaining starch molecules into maltose and limit dextrins.

This sequential enzymatic action ensures complete conversion of dietary carbohydrates into monosaccharides, which are the only forms that can be absorbed across the intestinal epithelium.

Absorption of Monosaccharides

Once carbohydrates are broken down into monosaccharides, they must cross the intestinal epithelial barrier to enter the bloodstream. Different monosaccharides employ distinct transport mechanisms for this crucial process.

01

Active Transport of Glucose and Galactose

These sugars are absorbed via the SGLT1 (Sodium-Glucose Linked Transporter 1) on the apical membrane. This process requires energy and couples glucose uptake with sodium ion movement, driven by the sodium-potassium pump.

02

Facilitated Diffusion of Fructose

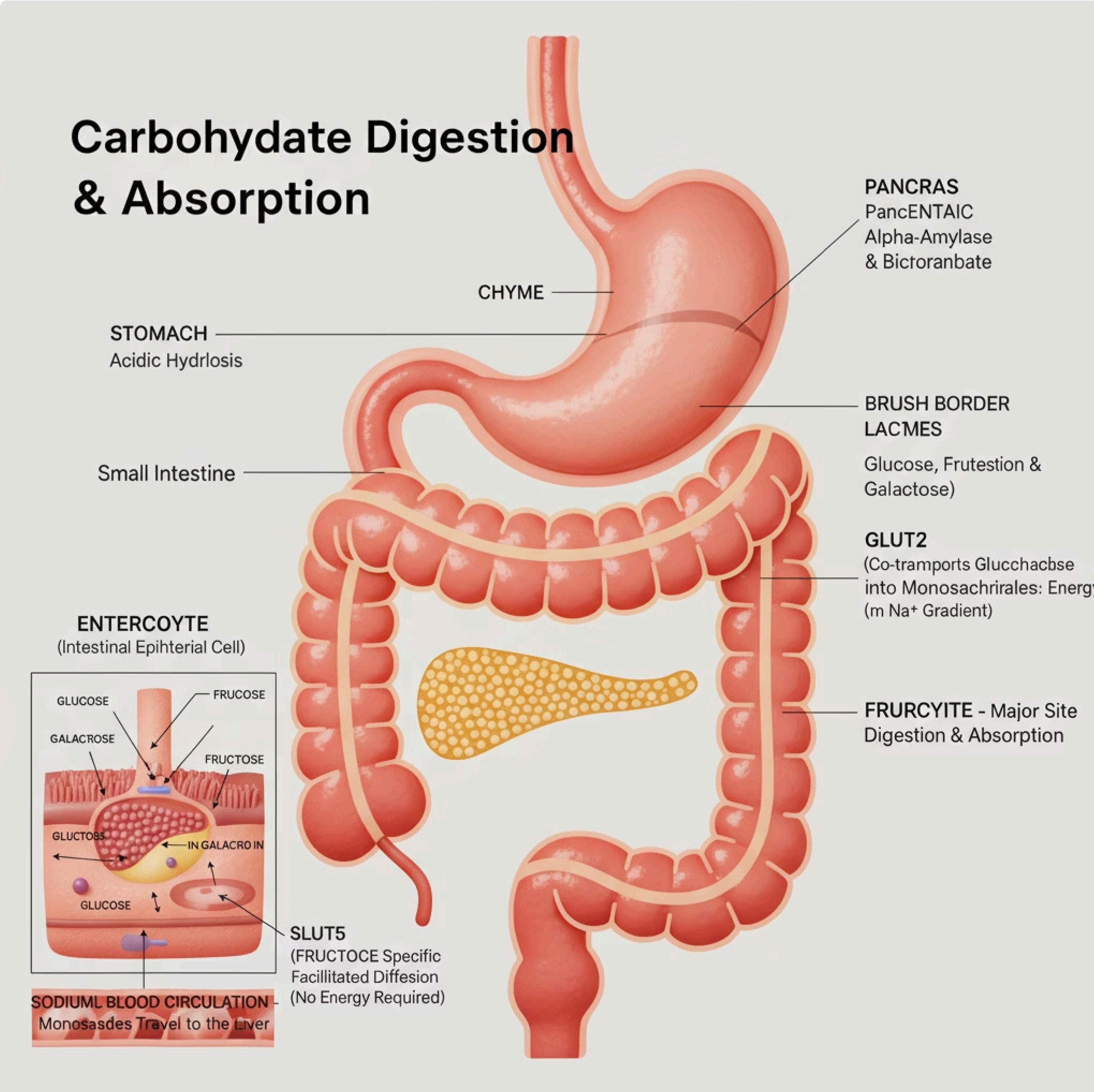
Fructose crosses the apical membrane through the GLUT5 transporter, moving down its concentration gradient without requiring direct energy input. This process is faster than active transport but less efficient at low concentrations.

03

Exit into Bloodstream

All absorbed monosaccharides exit the enterocyte via GLUT2 transporters on the basolateral membrane, entering the portal blood circulation for transport to the liver.

This sophisticated transport system ensures efficient absorption of dietary sugars whilst maintaining proper cellular function and blood glucose homeostasis.


Carbohydate Digestion
& Absorption
CHYME
PANCRAS
PancENTAIC
Alpha-Amylase
& Bictoranbate
STOMACH
Acidic Hydrlosis
BRUSH BORDER
LACMES
Glucose, Frutestion &
Galactose)
Small Intestine
GLUT2
(Co-tramports Glucchacbse
into Monosachrirales: Energy
(m Na+ Gradient)
ENTERCOYTE
(Intestinal Epihterial Cell)
FRURCYITE - Major Site
Digestion & Absorption
GLUCOSE
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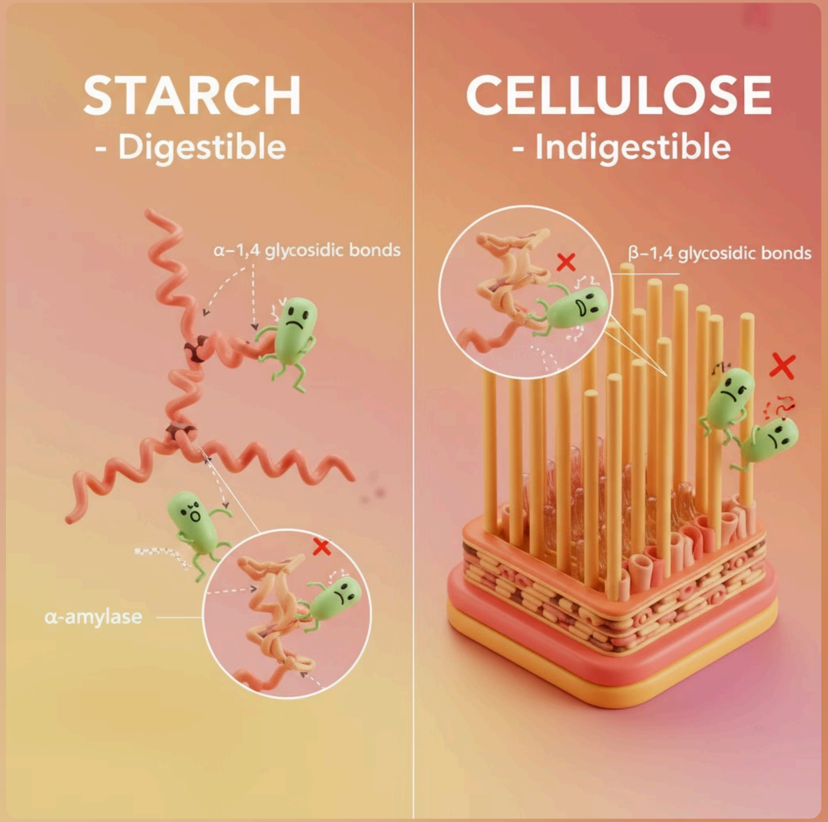
SODIUML BLOOD CIRCULATION
Monosasdes Travel to the Liver



Why Cellulose Is Not Digested

Bacterial Fermentation

Whilst humans cannot digest cellulose, beneficial gut bacteria in the colon can ferment it, producing short-chain fatty acids (SCFAs) such as acetate, propionate, and butyrate.

These SCFAs provide energy to colonocytes, reduce colonic pH, and contribute to overall gut health and immune function.

Cellulose, despite being a polysaccharide like starch, cannot be digested by human enzymes due to its unique structural configuration. The β-1,4 glycosidic bonds linking glucose units in cellulose require specific enzymes (cellulases) that humans do not produce.

Role as Dietary Fibre

- Adds bulk to intestinal contents
- Enhances intestinal motility and peristalsis
- Softens stool and prevents constipation
- Promotes healthy gut microbiome

Anaerobic Oxidation of Glucose (Glycolysis)

Glycolysis represents the metabolic pathway that converts glucose into pyruvate, occurring in the cytoplasm of cells and not requiring oxygen. This ancient metabolic process is essential for rapid energy production, particularly during intense physical activity.

1

Glucose Entry

One molecule of glucose ($C_6H_{12}O_6$) enters the glycolytic pathway

2

Energy Investment

2 ATP molecules consumed in phosphorylation steps

3

Energy Generation

4 ATP and 2 NADH molecules produced

4

Pyruvate Formation

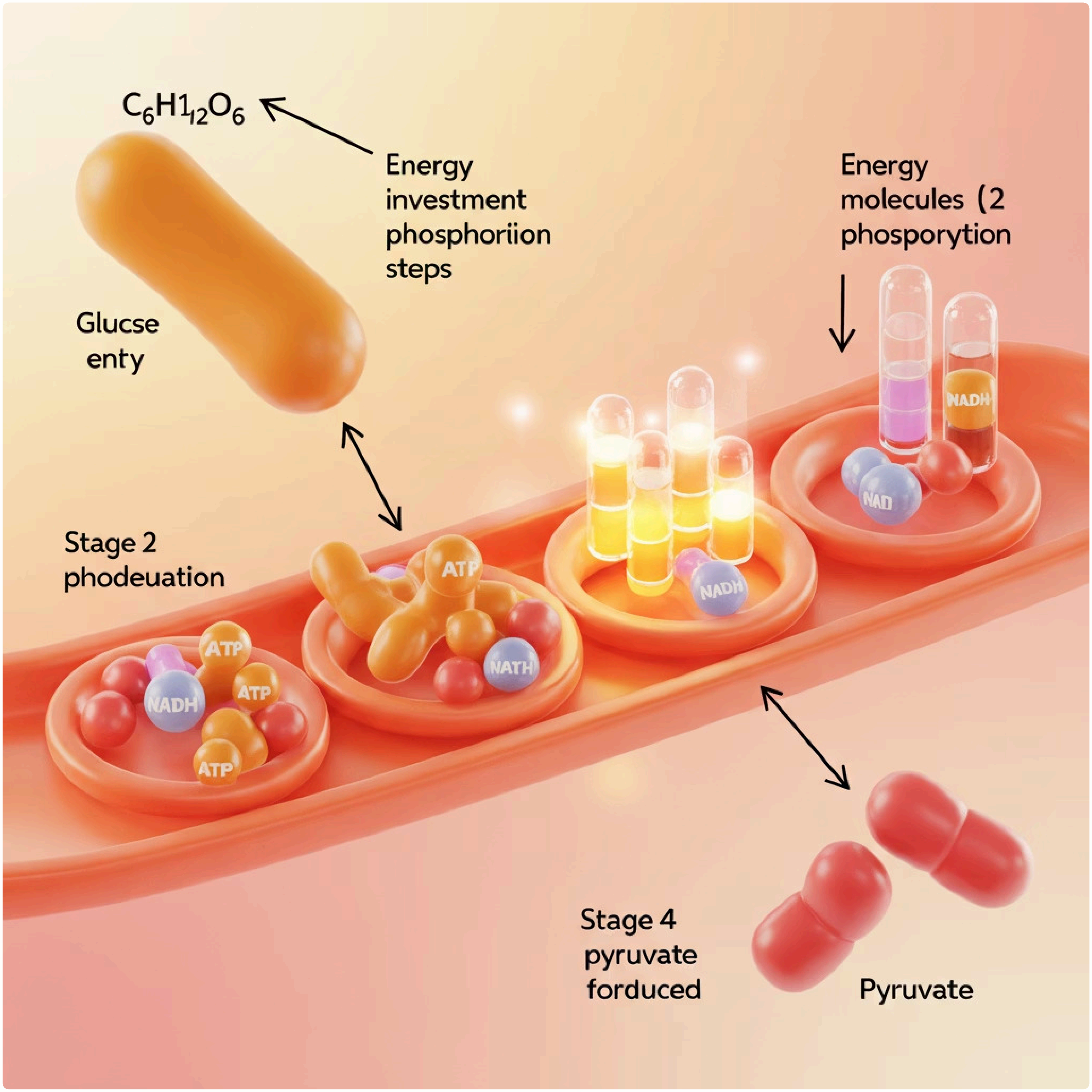
2 pyruvate molecules generated as end products

Anaerobic Conditions

When oxygen is limited or absent, pyruvate is converted to lactate by the enzyme lactate dehydrogenase. This reaction regenerates NAD^+, allowing glycolysis to continue producing ATP.

$$2H_2O + 2ATP + \text{Lactate } 2 \rightarrow {}_i2P + 2ADP + {}_6C_6H_{12}O$$

Net energy yield: 2 ATP molecules per glucose molecule under anaerobic conditions. This provides rapid but limited energy production compared to aerobic metabolism.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Energy molecules (2 phosporytion
Glucse enty
NADH
NAD
ATP
NATH
Stage 2 phodeuation
Stage 4 pyruvate forduced
Pyruvate

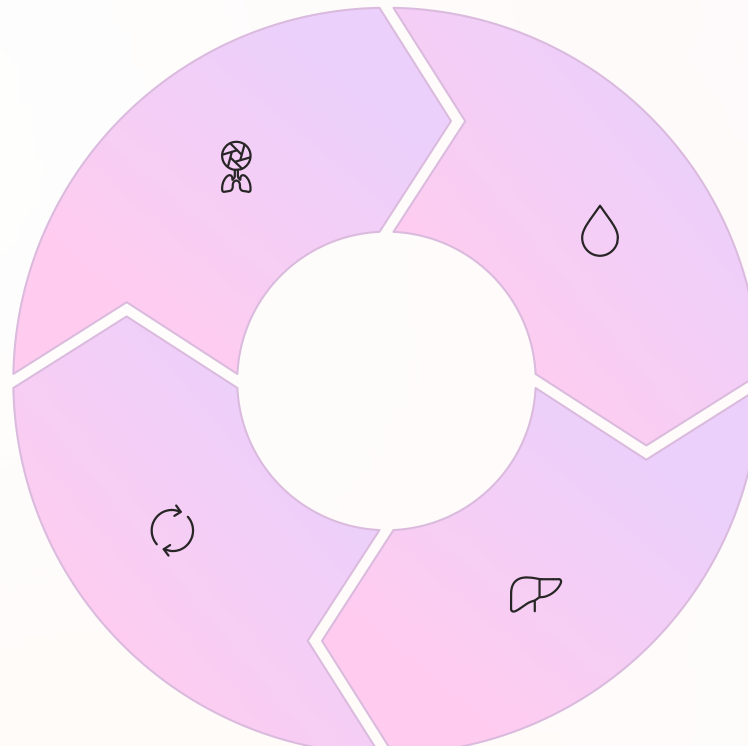
Fate of Lactate and Energy Yield

Muscle Glycolysis

Glucose converted to lactate during intense exercise

Blood Transport

Lactate released into bloodstream



Gluconeogenesis

Lactate converted back to glucose (Cori Cycle)

Liver Uptake

Hepatocytes absorb circulating lactate

Clinical Significance

During vigorous muscle contraction when oxygen supply cannot meet demand, anaerobic metabolism becomes crucial. The accumulation of lactate contributes to muscle fatigue and the "burning" sensation experienced during intense exercise.

Energy Efficiency

Anaerobic glycolysis yields only 2 ATP per glucose molecule, compared to approximately 30-32 ATP from complete aerobic oxidation. However, the anaerobic pathway is significantly faster, making it ideal for rapid energy demands.

Summary: From Digestion to Energy

Carbohydrate metabolism represents a sophisticated series of biochemical processes that transform dietary sugars into usable cellular energy, ensuring optimal function of all body systems.

1 — Oral Cavity

Salivary α-amylase initiates starch breakdown into smaller polysaccharides

2 — Small Intestine

Pancreatic enzymes and brush border enzymes complete digestion to monosaccharides

3 — Absorption

Specialised transporters move monosaccharides across intestinal epithelium

4 — Cellular Metabolism

Glucose undergoes glycolysis and further oxidation to produce ATP

Key Principles

Metabolic Flexibility

Cells can generate energy aerobically or anaerobically depending on oxygen availability and metabolic demands.

Transport Mechanisms

Multiple transport systems work in concert to absorb different monosaccharides into the bloodstream.

Enzymatic Specificity

Each carbohydrate type requires specific enzymes for breakdown, ensuring efficient digestion and absorption.

Understanding carbohydrate metabolism is fundamental to comprehending human nutrition, energy balance, and metabolic health. Proper carbohydrate intake and metabolism are essential for maintaining optimal physical performance, cognitive function, and overall wellbeing.

Thank You

« تذكر دائمًا أن الخيارات لامُتناهية، وأنك لست محدودًا بفرصةٍ واحدة أو بمستقبلٍ معين.
تذكر دائمًا أن في الحياةِ رحابة، وأن الآفاق واسعة، وأن الدنيا أكبر من أن تتمسك بشيءٍ ظنًا
منك أنه قد لا يتكرر » 😊