Digestion and Absorption of Carbohydrates, Proteins, and Fats

Introduction

Digestion is the process by which complex food substances are broken down into simple absorbable forms by the action of enzymes secreted along the alimentary canal.

Absorption is the process by which these digested molecules pass through the intestinal mucosa into the blood or lymph for use by the body's cells.

The entire process occurs mainly in the small intestine, with the help of secretions from the salivary glands, stomach, pancreas, liver, and intestinal glands.

Digestion and Absorption of Carbohydrates

Forms of Carbohydrates in the Diet

- Polysaccharides: Starch, glycogen, cellulose (plant fiber – not digestible)
- Disaccharides: Sucrose (cane sugar), lactose (milk sugar), maltose (from starch)
- Monosaccharides: Glucose, fructose, galactose

Digestion of Carbohydrates

In the Mouth

Enzyme: Salivary amylase (ptyalin) secreted by parotid glands.

Action: Hydrolyzes starch to maltose, maltotriose, and α-limit dextrins.

Optimum pH: Around 6.7–7.0 (slightly alkaline).

Digestion continues until food reaches the acidic stomach, where amylase is inactivated.

In the Stomach

No carbohydrate-digesting enzymes.

Acidic pH (1.5–3.5) stops salivary amylase activity.

Food is converted into chyme and passed into the duodenum.

In the Small Intestine

Pancreatic Amylase: Secreted by the pancreas into the duodenum.

Breaks remaining starch and dextrins into maltose, maltotriose, and small oligosaccharides.

Brush Border Enzymes (in intestinal mucosa):

Maltase: Maltose to two glucose molecules

Sucrase: Sucrose to glucose and fructose

Lactase: Lactose to glucose and galactose

Isomaltase (α-dextrinase): Breaks α-limit dextrins to glucose

Absorption of Carbohydrates

Site: Mainly jejunum and upper ileum.

Absorbed form: Monosaccharides only.

Mechanisms:

Glucose and Galactose: Active transport via SGLT-1 (sodium-dependent glucose transporter).
Fructose: Facilitated diffusion via GLUT-5 transporter.
All monosaccharides enter bloodstream through GLUT-2 transporters to the portal vein and then to the liver.

Digestion and Absorption of Proteins

Forms of Proteins in the Diet

Animal and plant proteins (complex polypeptides).
Small amounts of amino acids and peptides already present in some foods.

Digestion of Proteins

In the Stomach

Enzyme: Pepsin (secreted as inactive pepsinogen by chief cells).
Activator: Hydrochloric acid (HCl) converts pepsinogen to pepsin.
Action: Breaks proteins into proteoses, peptones, and small polypeptides.
pH optimum: 1.5–3.5.

In the Small Intestine

Pancreatic Enzymes:

•Trypsin (from trypsinogen by enterokinase)
•Chymotrypsin (from chymotrypsinogen by trypsin)
•Elastase (breaks elastic fibers)
•Carboxypeptidase A and B (cleave terminal amino acids from peptide ends)

These enzymes hydrolyze large polypeptides into smaller peptides and amino acids.
Brush Border Enzymes (from intestinal mucosa):
Aminopeptidase, Dipeptidase, and Tripeptidase complete digestion into free amino acids.

Absorption of Proteins

Site: Mainly jejunum and ileum.
Absorbed form: Amino acids, dipeptides, tripeptides.
Mechanisms:
Amino acids: Active transport with sodium-dependent carriers.
Dipeptides and Tripeptides: Absorbed by special hydrogen-linked carriers, then hydrolyzed inside enterocytes to amino acids.
Amino acids enter the portal circulation to the liver for metabolism and protein synthesis.

Digestion and Absorption of Fats (Lipids)

Forms of Lipids in Diet

•Triglycerides (fats and oils)
•Phospholipids

•Cholesterol and cholesterol esters
•Fat-soluble vitamins (A, D, E, K)
Digestion of Fats
In the Mouth and Stomach
Lingual lipase (from tongue) and gastric lipase (from stomach) begin partial digestion into diglycerides and free fatty acids.
Important mainly in infants for milk fat digestion.
In the Small Intestine
Bile salts (from liver): Emulsify large fat globules into tiny droplets, increasing surface area for enzymes.
Pancreatic lipase: Acts on emulsified fats to produce monoglycerides and free fatty acids.
Colipase: Helps lipase bind to lipid-water interface.
Micelle Formation:
Monoglycerides, free fatty acids, and bile salts form micelles that transport fats to the brush border of intestinal mucosa.
Absorption of Fats
Inside enterocyte
Fatty acids and monoglycerides are re-esterified into triglycerides.
These combine with cholesterol and proteins to form chylomicrons.
Chylomicrons enter lymphatic capillaries (lacteals), then pass into the thoracic duct and finally into the bloodstream.
Short-chain fatty acids are absorbed directly into the portal blood without forming chylomicrons.
Clinical Correlations
Lactose Intolerance: Deficiency of lactase leads to undigested lactose causing diarrhea and bloating.
Pancreatic Insufficiency: Lack of lipase leads to fat malabsorption causing steatorrhea (fatty stool).
Celiac Disease: Damage to intestinal villi leads to poor nutrient absorption.
Bile Duct Obstruction: Prevents emulsification of fats and impairs fat digestion.
Conclusion
The digestion and absorption of carbohydrates, proteins, and fats are essential processes that convert complex food molecules into simpler forms usable by the body.
Each macronutrient requires specific enzymes, pH conditions, and transport mechanisms.
Efficient function of digestive glands, intestinal mucosa, bile secretion, and peristalsis ensures proper nourishment and energy supply for all body functions.

References

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