22.12B: Chemical Digestion of Carbohydrates, Proteins, Lipids, and Nucleic Acids

The chemical breakdown of the macromolecules contained in food is completed by various enzymes produced in the digestive system.

Learning Objectives

• Summarize chemical digestion

Key Points

• Protein digestion occurs in the stomach and the duodenum through the action of three main enzymes: pepsin, secreted by the stomach, and trypsin and chymotrypsin, secreted by the pancreas.

• During carbohydrate digestion the bonds between glucose molecules are broken by salivary and pancreatic amylase.

• The digestion of certain fats begins in the mouth, where short-chain lipids break down into diglycerides because of lingual lipase. The fat present in the small intestine stimulates the release of lipase from the pancreas, and bile from the liver enables the breakdown of fats into fatty acids.

• DNA and RNA are broken down into mononucleotides by the nucleases deoxyribonuclease and ribonuclease (DNase and RNase) that are released by the pancreas.

Key Terms

• **zymogen**: A proenzyme, or enzyme precursor, that requires a biochemical change (i.e., hydrolysis) to become an
active form of the enzyme.

- **lactose intolerance**: The inability to fully metabolize lactose.

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# Chemical Digestion

Protein digestion occurs in the stomach and the duodenum through the action of three primary enzymes:

1. Pepsin, secreted by the stomach.
2. Trypsin, secreted by the pancreas.
3. Chymotrypsin, secreted by the pancreas.

These enzymes break down food proteins into polypeptides that are then broken down by various exopeptidases and dipeptidases into amino acids. The digestive enzymes, however, are secreted mainly as their inactive precursors, the zymogens.

Thus, trypsin is secreted by the pancreas in the form of trypsinogen, which is activated in the duodenum by enterokinase to form trypsin. Trypsin then cleaves proteins into smaller polypeptides.

In humans, dietary starches are composed of glucose units arranged in long chains of polysaccharide called amylose. During digestion, the bonds between glucose molecules are broken by salivary and pancreatic amylase, and result in progressively smaller chains of glucose. This process produces the simple sugars glucose and maltose (two glucose molecules) that can be absorbed by the small intestine.

Sucrase is an enzyme that breaks down disaccharide sucrose, commonly known as table sugar, cane sugar, or beet sugar. Sucrose digestion yields the sugars fructose and glucose, which are readily absorbed by the small intestine.

Lactase is an enzyme that breaks down the disaccharide lactose into its component parts, glucose and galactose, that are absorbed by the small intestine. Approximately half the adult population produces only small amounts of lactase and are therefore unable to eat milk-based foods. This condition is commonly known as lactose intolerance.

The digestion of certain fats begins in the mouth, where lingual lipase breaks down short chain lipids into diglycerides. The presence of fat in the small intestine produces hormones that stimulate the release of pancreatic lipase from the pancreas, and bile from the liver, to enable the breakdown of fats into fatty acids. The complete digestion of one molecule of fat (a triglyceride) results in three fatty acid molecules and one glycerol molecule.

DNA and RNA are broken down into mononucleotides by the nucleases deoxyribonuclease and ribonuclease (DNase and RNase), which are released by the pancreas.
Carbohydrate digestion: A diagram of the action of the oligosaccharide-cleaving enzymes in the small intestine.

Lipid digestion: Lipid digestion involves the formation of micelles in the presence of bile salts, and the passage of micelles and fatty acids through the unstirred layer. The diagram depicts dietary fat at the top, with pancreatic lipase and bile salts forming micelles that will pass through the unstirred layer at the bottom of the diagram.