Regulation of Digestion

Two types of mechanisms: (neural and endocrine)

*neural control of digestion

1- Neural control of digestion is controlled largely by the parasympathetic nervous system, and local (enteric) reflexes.

2- Activation of the parasympathetic system results in secretion of digestive juices, increased motility of the stomach, and slowing down movement of food from the stomach to small intestine.

3- Stimuli: Thought, sight, taste of smell of food; distension of GI tract; chemoreceptors detecting nutrients, pH.

*Endocrine Control of Digestion

1- Gastrin: (stomach)

- produced from the stomach (G cells)

- release increased by stomach distension, peptides, amino acids, alcohol, caffeine parasympathetic innervation.

- release inhibited by highly acidic pH (< 2.0).

- functions: increases gastric (stomach) secretions (primarily HCl); increases histamine release; increases gastric motility; opens pyloric sphincter (between stomach and small intestine), relaxes ileocecal sphincter, stimulates growth of gastric mucosa.

2- Histamine: (stomach)

- Produced by enterochromaffin-like cells (ECL cells) of the stomach.

- Release is stimulated by gastrin.

- Action: increase HCl secretion from parietal cells (major factor in HCl secretion).
3- **Somatostatin**  (stomach)
- Produced by D cells of the stomach
- Secretion is stimulated by activation of the sympathetic nervous system and by acidic pH, and is inhibited by activation of the parasympathetic nervous system, continuously released, overridden by gastrin and nerves.
- Actions: inhibit gastrin and histamine secretion (decreased acid release and gastric motility); also directly inhibits acid release from parietal cells.

4- **Secretin:**  (small intestine)
- Produced by duodenum (enteroendocrine cells of the small intestine).
- stimulated by arrival of acidic chyme in duodenum
- functions: stimulates bicarbonate secretion from pancreas; inhibits gastric secretion (decreases HCl production by inhibiting gastrin release); decreases gastric motility (slowing rate of gastric digestion and delivery to the small intestine), increases hepatic bile production, increases CCK, promotes growth and maintenance of the pancreas.

5- **Cholecystokinin (CCK)**  (small intestine)
- produced by enteroendocrine cells of the duodenum.
- release stimulated by fatty acids in duodenum (also amino acids, acidic chyme).
- functions: causes gallbladder contraction (bile to small intestine); stimulates release of pancreatic enzymes; decreases gastric motility and secretion (increases somatostatin release).

6- **Gastric Inhibitory Peptide (GIP)**  (small intestine):
Secretion: Enteroendocrine cells in the small intestine mucosa.
glucose Stimulus: Chyme rich in triglycerides, fatty acids, and enter the small intestine.
Actions:
- Stimulates release of insulin by beta cells
- Inhibits gastric secretion and motility
- Stimulates lipogenesis by adipose tissue
- Stimulates glucose use by skeletal muscle cells.

7- Vasoactive Intestinal Peptide (VIP) (small intestine):
- Secretion: Enteroendocrine cells in the small intestine mucosa.
- Stimulus: Chyme entering the small intestine.
Actions:
- Stimulates buffer secretion
- Inhibits gastric secretion
- Dilates intestinal capillaries

Digestion of Carbohydrates – Sugars

Carbohydrates and food are converted into glucose and give immediate energy and glycogen, which is stored for reserve energy. Glucose and glycogen provide approximately one half of the energy nerves, muscles and other body tissues use daily. Glucose provides most if not all of the energy for brain cells.

A. Simple – the most important sugars in nutrition
1. Monosaccharides – All have the chemical formula \( \text{C}_6 \text{H}_{12} \text{O}_6 \). The basic structure is ring shaped.
   a. Glucose  b. Galactose  c. Fructose
2. Disaccharides – Made when two monosaccharides are combined through the process of condensation. Condensation is a chemical reaction in which two molecules join together to make one larger molecule.
   a. sucrose made by combining glucose and fructose
   b. maltose made by combining glucose and galactose
   c. lactose made by combining glucose and glucose

B. Complex – Made of many glucose units linked together. (Polysaccharides)
   1. Glycogen
      a. the storage form of glucose in our bodies
      b. manufactured in the liver and muscle tissue
      c. not considered as a dietary source of carbohydrates. (Not found in plants and in only limited amounts in meats.)
   2. Starch
      a. storage form of glucose in plants
      b. made of long chains of glucose units that may be straight or branched.
      c. Hydrolyzed into glucose after it is eaten
   3. Fibers
      a. polysaccharides made of linked glucose units
      b. indigestible by humans
      - humans do ’t have the enzyme to break the Beta 1~4 linkage
      - bacteria in the digestive system can break down some of the fibers so they are important for health and digestion.

**Carbohydrates in the body**

A. Digestion and absorption
   1. Purpose – breaks down large carbohydrates into glucose units. In one to four hours after eating, all the sugars and most of the starches are digested.
   2. mouth
      - salivary amalyase hydrolizes starch into shorter polysaccharide units
   3. stomach
a. salivary amalyase is destroyed by acid so its action stops
b. although acid breaks down starch to some extent, no enzymes are present in the stomach to break down carbohydrates.

4. small intestine
a. carries out most of the digestion of carbohydrates
b. major digestive enzyme is pancreatic amalyase.
c. Other enzymes specific for carbohydrates are maltase, sucrase and lactase.
d. Fibers delay the absorption of carbohydrates and fats.

5. large intestine
a. site of fiber action - include softening stools and absorption of water.
b. Digestion of fibers by bacteria produce water, gas and fatty acids. (the fatty acids are broken down and absorbed to produce energy.

6. absorption into the bloodstream
a. most is absorbed in the small intestine but a small amount can be absorbed in the mouth.
b. monosaccharides are absorbed by active transport through the walls of the small intestine.
c. Circulated in the blood and converted mainly into glucose by the liver for energy
d. Converted into glycogen and stored if energy is not needed.

**USE OF GLUCOSE**

- Energy – glucose is the primary fuel for most cells in the body.

- Sparing body protein – if glucose is scarce, the body will breakdown its own protein.

- Preventing ketosis – with no carbohydrate, fat breakdown produces ketone bodies. Can lead to ketosis.

- Storage as glycogen – liver stores are used to maintain blood sugar, while muscle stores are used to fuel activity.
**Diseases and disorders**

A. Hypoglycemia.

B. Hyperglycemia.

C. Diabetes.

**D. Lactose intolerance.**

1. Inability to digest lactose

2. Symptoms include bloating, abdominal discomfort and diarrhea occur after eating lactose.

3. 20% of prescriptions contain lactose as a filler.

**Digestion of proteins:**

- Proteins are a sequence of amino acids. Of the 20 amino acids that exist, 9 are essential amino acids, and 11 are non-essential.

- There are also 4 amino acids that can be considered conditionally essential: tyrosine, glutamine, and cysteine. arginine.

**Functions**

1- **HORMONES**

Hormones are chemical messengers that are made on one part of the body, but act on cells in other parts of the body.

2- The Immune Response is a series of steps your body takes to mount an attack against invaders. Antibodies are blood proteins that attack and inactivate bacteria and viruses.

3- **FLUID BALANCE**

Blood proteins like albumin and globulin help to regulate this balance by remaining in the capillaries and attracting fluid.

- Edema is the result of fluid imbalance.
4- ACID-BASE BALANCE

Proteins help to maintain a stable pH level in our body fluid by picking up extra hydrogen ions when conditions are acidic, and donating hydrogen ions when conditions are alkaline.

5- TRANSPORT

- Lipoproteins (chylomicrons, LDL, HDL).
- Albumin transports a variety of nutrients such as calcium, zinc, and Vitamin B6.
- Transferrin transports iron (hemoglobin – a protein, contains iron, but it transports oxygen).
- Proteins may also acts as channels or pumps across the cell membrane.

6- ENERGY SOURCE

- If the diet does not provide enough energy, the body must begin to break down its own protein
- The proteins are broken down into individual amino acids, then deaminated, and the remaining carbon, hydrogen, and oxygen compounds are used to make energy or glucose.
- If the diet contains too much protein, the excess will be converted to glucose, or stored as fat.

**DIGESTION**

- No digestion of protein takes place in the mouth, it begins in the stomach.
- Hydrochloric acid denatures protein and also converts pepsinogen to pepsin.
- Pepsin breaks the protein down into peptides of various lengths and some amino acids.
- Pepsin completes ~ 10-20% of digestion.
Pancreas makes trypsinogen and chymotrypsinogen (proenzymes) in response to protein in the small intestine.

They will be activated to trypsin and chymotrypsin.

Proteases break down polypeptides into smaller peptides (very few peptides have been broken down to amino acids at this stage).

The intestinal wall produces peptidases which continue to split the remaining polypeptides into tripeptides, dipeptides, and some amino acids.

These smaller units are transported into the enterocytes.

In the enterocyte, other peptidases immediately digest everything into single amino acids which are absorbed into the bloodstream.

**ABSORPTION**

*Most protein absorption takes place in the duodenum and jejunum*

*Most amino acids are absorbed into the bloodstream, but some remain in the enterocytes and are used to synthesize enzymes and new cells*

*99% of protein enters the bloodstream as amino acids*

Absorption of whole protein can cause a severe allergic reaction

**Digestion & absorption of lipids**

- Lipids are not water soluble.

- Triglycerides too large to be absorbed.

**Bile**

- Produced in liver, stored in gallbladder.

Alkaline solution composed of:

1- Bile salts  
2- Cholesterol  
3- Lecithin  
4- Bilirubin
Responsible for 1- fat emulsification 2- Detergent action

**Digestion of Lipid**

- Bile salts emulsify lipids Pancreatic lipase acts on triglycerides Pancreatic colipase  
- Interacts with triglyceride and pancreatic lipase.

**Emulsification**

- Produces small lipid spheres and greater surface area.

**Digestion of Lipid**

- Phospholipase A$_1$ and A$_2$ (Hydrolyzes fatty acids from phospholipids).
- Cholesterol esterase (Hydrolyzes fatty acids from cholesterol esters).

**Micelle Formation**

- Complex of lipid materials soluble in water  
- Contains: 1- bile salts 2- phospholipids 3- cholesterol  
- Combines with 2-monoglycerides, free fatty acids and fat-soluble vitamins to form (mixed micelles).

**Lipid Absorption**

- Mixed micelles move to intestinal mucosal cells (enterocytes) and release contents near cell.  
- The bile salts are re-absorbed further down the gastrointestinal tract (in the ileum), transported to the liver, and finally recycled and secreted back into the digestive tract.

**In the Enterocyte**

- Newly formed triglycerides accumulate as (lipid droplets) at the endoplasmic reticulum.
- Coated with a protein layer (Stabilizes lipids for transport in lymph and blood).

- Glycerol and short chain fatty acids directly enter mesenteric blood.

- These protein-coated lipid droplets are called **chylomicrons**.

Lipid Absorption (Chylomicrons)

- Chylomicrons absorbed from enterocytes into lacteals (lymph vessels)

- Most long chain fatty acids absorbed into lymphatic system.

- Blood lipids transported as **lipoproteins**.

![Diagram of lipid absorption](image)
Lipid Digestion in Mammals
Lipid Absorption