Chapter 41

Small Intestine

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FUNCTIONAL ANATOMY

Small intestine is the part of gastrointestinal (GI) tract, extending between the **pyloric sphincter** of stomach and **ileocecal valve**, which opens into large intestine. It is called small intestine because of its small diameter, compared to that of the large intestine. But it is longer than large intestine. Its length is about 6 meter.

Important function of small intestine is absorption. Maximum absorption of digested food products takes place in small intestine.

Small intestine consists of three portions:

1. Proximal part known as duodenum
2. Middle part known as jejunum
3. Distal part known as ileum.

Wall of the small intestine has all the four layers as in stomach (Chapter 36).

INTESTINAL VILLI AND GLANDS OF SMALL INTESTINE

INTESTINAL VILLI

Mucous membrane of small intestine is covered by minute projections called villi. The height of villi is about 1 mm and the diameter is less than 1 mm.

Villi are lined by columnar cells, which are called **enterocytes.** Each enterocyte gives rise to hair-like projections called **microvilli.** Villi and microvilli increase the surface area of mucous membrane by many folds. Within each villus, there is a central channel called lacteal, which opens into lymphatic vessels. It contains blood vessels also.

CRYPTS OF LIEBERKÜHN OR INTESTINAL GLANDS

Crypts of Lieberkühn or intestinal glands are simple tubular glands of intestine. Intestinal glands do not penetrate the muscularis mucosa of the intestinal wall, but open into the lumen of intestine between the villi. Intestinal glands are lined by columnar cells. Lining of each gland is continuous with epithelial lining of the villi (Fig. 41.1).

Epithelial cells lining the intestinal glands undergo division by mitosis at a faster rate. Newly formed cells push the older cells upward over the lining of villi. These cells which move to villi are called enterocytes. Enterocytes secrete the enzymes. Old enterocytes are continuously shed into lumen along with enzymes.

Types of cells interposed between columnar cells of intestinal glands:

1. **Argentaffin cells** or **enterochromaffin cells,** which secrete **intrinsic factor of Castle**
2. **Goblet cells,** which secrete mucus
3. **Paneth cells,** which secrete the cytokines called **defensins.**

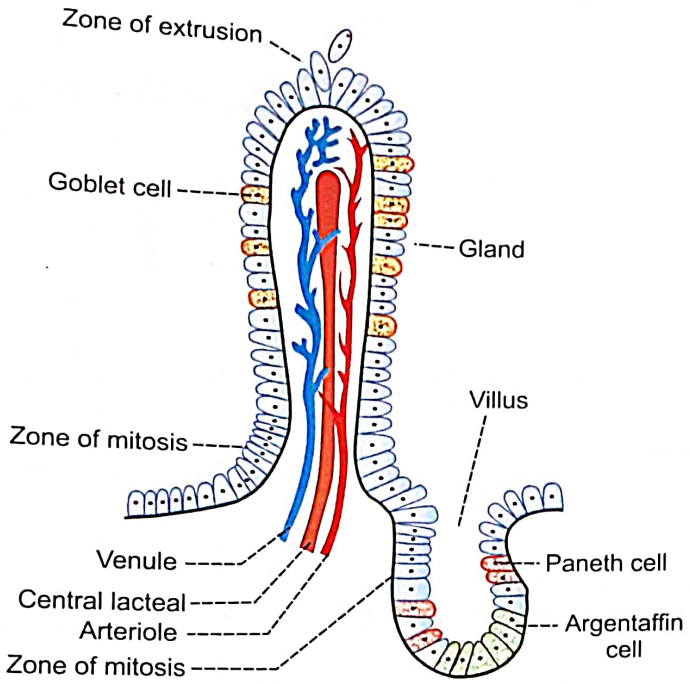

FIGURE 41.1: Intestinal gland and villus

BRUNNER GLANDS

In addition to intestinal glands, the first part of duodenum contains some mucus glands, which are called Brunner glands. These glands penetrate muscularis mucosa and extend up to the submucus coat of the intestinal wall. Brunner glands open into the lumen of intestine directly. Brunner gland secretes mucus and traces of enzymes.

PROPERTIES AND COMPOSITION OF SUCCUS ENTERICUS

Secretion from small intestine is called succus entericus.

PROPERTIES OF SUCCUS ENTERICUS

Volume : 1800 mL/day
Reaction : Alkaline
pH : 8.3

COMPOSITION OF SUCCUS ENTERICUS

Succus entericus contains water (99.5%) and solids (0.5%). Solids include organic and inorganic substances (Fig. 41.2). Bicarbonate concentration is slightly high in succus entericus.

FUNCTIONS OF SUCCUS ENTERICUS

1. DIGESTIVE FUNCTION

Enzymes of succus entericus act on the partially digested food and convert them into final digestive products. Enzymes are produced and released into succus entericus by enterocytes of the villi.

Proteolytic Enzymes

Proteolytic enzymes present in succus entericus are the peptidases, which are given in Fig. 41.2. These peptidases convert peptides into amino acids.

Amylolytic Enzymes

Amylolytic enzymes of succus entericus are listed in Fig. 41.2.

Lactase, sucrase and maltase convert the disaccharides (lactose, sucrose and maltose) into two molecules of monosaccharides (Table 41.1).

Dextrinase converts dextrin, maltose and maltriose into glucose. Trehalase or trehalose glucohydrolase causes hydrolysis of trehalose (carbohydrate present in mushrooms and yeast) and converts it into glucose.

Lipolytic Enzyme

Intestinal lipase acts on triglycerides and converts them into fatty acids.

2. PROTECTIVE FUNCTION

i. Mucus present in the succus entericus protects the intestinal wall from the acid chyme, which enters the intestine from stomach; thereby it prevents the **intestinal ulcer.**
ii. **Defensins** secreted by paneth cells of intestinal glands are the **antimicrobial peptides.**

These peptides are called natural peptide antibiotics because of their role in killing the phagocytosed bacteria.

3. ACTIVATOR FUNCTION

Enterokinase present in intestinal juice activates trypsinogen into trypsin. Trypsin, in turn activates other enzymes (Chapter 39).

4. HEMOPOIETIC FUNCTION

Intrinsic factor of Castle present in the intestine plays an important role in erythropoiesis (Chapter 10). It is necessary for the absorption of vitamin B12.

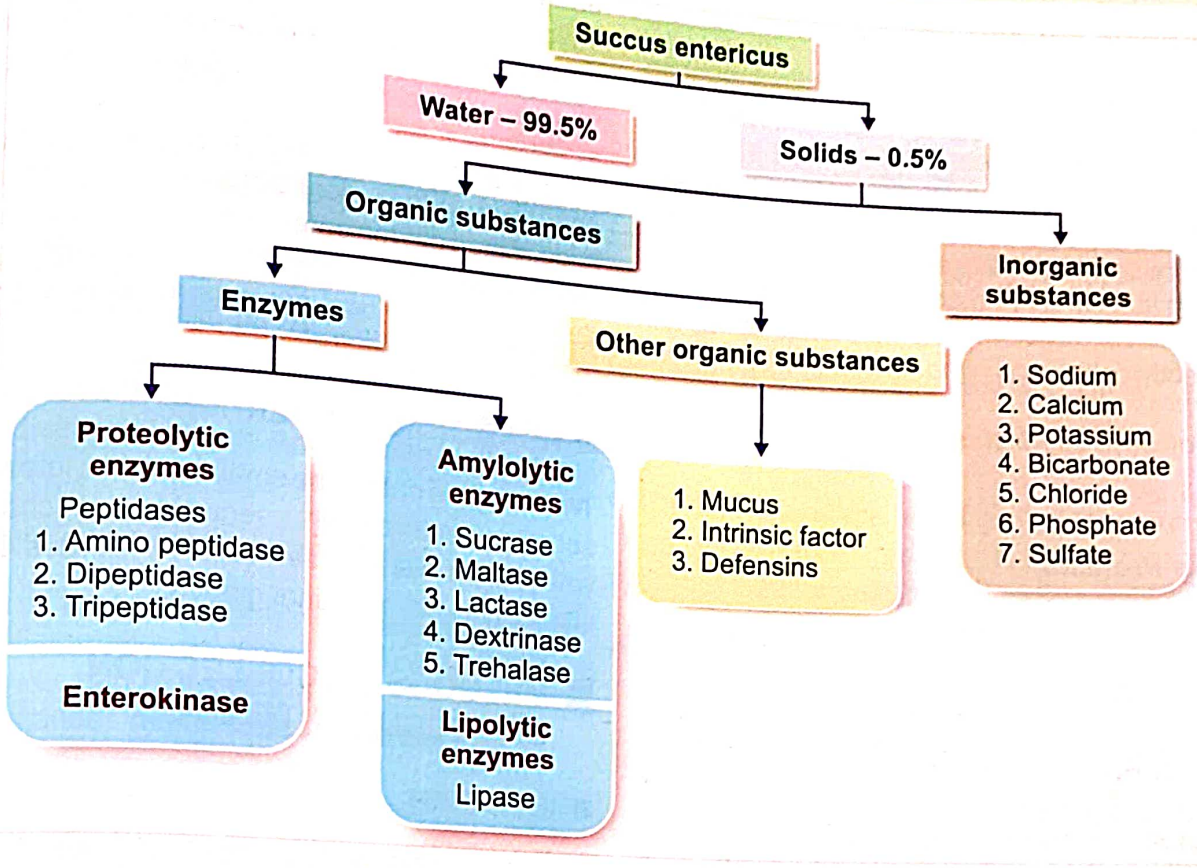

FIGURE 41.2: Composition of succus entericus

5. HYDROLYTIC PROCESS

Intestinal juice helps in all the enzymatic reactions of digestion.

FUNCTIONS OF SMALL INTESTINE

1. MECHANICAL FUNCTION

Mixing movements of small intestine help in the thorough mixing of chyme with the digestive juices like succus entericus, pancreatic juice and bile.

2. SECRETORY FUNCTION

Small intestine secretes succus entericus, enterokinase and the GI hormones.

3. HORMONAL FUNCTION

Small intestine secretes many GI hormones such as secretin, cholecystokinin, etc. These hormones regulate the movement of GI tract and secretory activities of small intestine and pancreas (Chapter 44).

4. DIGESTIVE FUNCTION

Refer functions of succus entericus.

5. ACTIVATOR FUNCTION

Refer functions of succus entericus.

6. HEMOPOIETIC FUNCTION

Refer functions of succus entericus.

7. HYDROLYTIC FUNCTION

Refer functions of succus entericus.

TABLE 41.1: Digestive enzymes of succus entericus

Enzyme	Substrate	End products
Peptidases	Peptides	Amino acids
Sucrase	Sucrose	Fructose and glucose
Maltase	Maltose and maltriose	Glucose
Lactase	Lactose	Galactose and glucose
Dextrinase	Dextrin, maltose and maltriose	Glucose
Trehalase	Trehalose	Glucose
Intestinal lipase	Triglycerides	Fatty acids

8. ABSORPTIVE FUNCTIONS

Presence of villi and microvilli in small intestinal mucosa increases the surface area of mucosa. This facilitates the absorptive function of intestine.

Digested products of foodstuffs, proteins, carbohydrates, fats and other nutritive substances such as vitamins, minerals and water are absorbed mostly in small intestine. From the lumen of intestine, these substances pass through lacteal of villi, cross the mucosa and enter the blood directly or through lymphatics.

Absorption of Carbohydrates

Refer Chapter 45.

Absorption of Proteins

Refer Chapter 46.

Absorption of Fats

Refer Chapter 47.

Absorption of Water and Minerals

i. In small intestine, sodium is absorbed actively. It is responsible for absorption of glucose, amino acids and other substances by means of sodium cotransport.
ii. Water moves in or out of the intestinal lumen until the osmotic pressure of intestinal contents becomes equal to that of plasma.
iii. In ileum, chloride ion is actively absorbed in exchange for bicarbonate. The significance of this exchange is not known.
iv. Calcium is actively absorbed mostly in upper part of small intestine.

Absorption of Vitamins

Most of the vitamins are absorbed in upper part of small intestine and vitamin B_{12} is absorbed in ileum. Absorption of water-soluble vitamins is faster than fat-soluble vitamins.

REGULATION OF SECRETION OF SUCCUS ENTERICUS

Secretion of succus entericus is regulated by both nervous and hormonal mechanisms.

NERVOUS REGULATION

Stimulation of parasympathetic nerves causes vasodilatation and increases the secretion of succus entericus. Stimulation of sympathetic nerves causes vasoconstriction and decreases the secretion of succus entericus. But, the role of these nerves in the regulation of intestinal secretion in physiological conditions is uncertain.

However, the local nervous reflexes play an important role in increasing the secretion of intestinal juice. When chyme enters the small intestine, the mucosa is stimulated by tactile stimuli or irritation. It causes the development of local nervous reflexes, which stimulate the glands of intestine.

HORMONAL REGULATION

When chyme enters the small intestine, intestinal mucosa secretes enterocrinin, secretin and cholecystokinin, which promote the secretion of succus entericus by stimulating the intestinal glands.

METHODS OF COLLECTION OF SUCCUS ENTERICUS

IN HUMAN

In human beings, the intestinal juice is collected by using multilumen tube. The multilumen tube is inserted through nose or mouth, until the tip of this tube reaches the intestine. A line is marked on the tube. Entrance of tip of the tube into small intestine is indicated when this line comes near the mouth. This tube has three lumens. To the outer two lumens, small balloons are attached. When these balloons are inflated, the intestine is enlarged. Now, the intestinal juice is collected through the middle lumen, by means of aspiration.

IN ANIMALS

Thiry Loop

A portion of intestine is separated from the gut by incising at both ends. The cut ends of the main gut are connected and the continuity is re-established. One end of isolated segment is closed and the other end is brought out through abdominal wall. It is called Thiry loop or **Thiry fistula.**

Thiry-Vella Loop

Thiry-Vella loop is the modified Thiry loop. In this, a long segment of intestine is cut and separated from the main gut. Both the ends of this segment are brought out through the abdominal wall. The cut ends of the main gut are joined.

APPLIED PHYSIOLOGY

1. MALABSORPTION

Malabsorption is the failure to absorb nutrients such as proteins, carbohydrates, fats and vitamins.

Malabsorption affects growth and development of the body. It also causes specific diseases (see below).

2. MALABSORPTION SYNDROME

Malabsorption syndrome is the condition characterized by the failure of digestion and absorption in small intestine. Malabsorption syndrome is generally caused by **Crohn's disease, tropical sprue, steatorrhea** and **celiac disease.**

3. CROHN'S DISEASE OR ENTERITIS

Enteritis is an inflammatory bowel disease (IBD), characterized by inflammation of small intestine. Usually, it affects the lower part of small intestine, the ileum. The inflammation causes malabsorption and diarrhea.

Causes

Crohn's disease develops because of abnormalities of the immune system. The immune system reacts to a virus or a bacterium, resulting in inflammation of the intestine.

Features

i. Malabsorption of vitamin
ii. Weight loss
iii. Abdominal pain
iv. Diarrhea
v. Rectal bleeding, anemia and fever
vi. Delayed or stunted growth in children.

4. TROPICAL SPRUE

Tropical sprue is a malabsorption syndrome, affecting the residents of or the visitors to tropical areas where the disease is epidemic.

Cause

The cause of this disease is not known and it may be related to infectious organisms.

Features

i. Indigestion
ii. Diarrhea
iii. Anorexia and weight loss
iv. Abdominal and muscle cramps.

5. STEATORRHEA

Steatorrhea is the condition caused by deficiency of pancreatic lipase, resulting in malabsorption of fat. Refer Chapter 39 for details.

6. CELIAC DISEASE

Celiac disease is an autoimmune disorder characterized by the damage of mucosa and atrophy of villi in small intestine, resulting in impaired digestion and absorption. It is also known as **gluten-sensitive enteropathy,** celiac sprue and non-tropical sprue.

Cause

Celiac disease is caused by gluten. It is a protein present in wheat, oats, rye, barley and other grains. **Gluten** is like a poison to individuals with celiac disease, because it damages the intestine severely.

Features

i. Diarrhea
ii. Steatorrhea
iii. Abdominal pain
iv. Weight loss
v. Irritability
vi. Depression.