PANCREAS, LIVER, SMALL INTESTINE AND LARGE INTESTINE

PANCREAS

Anatomy of pancreas

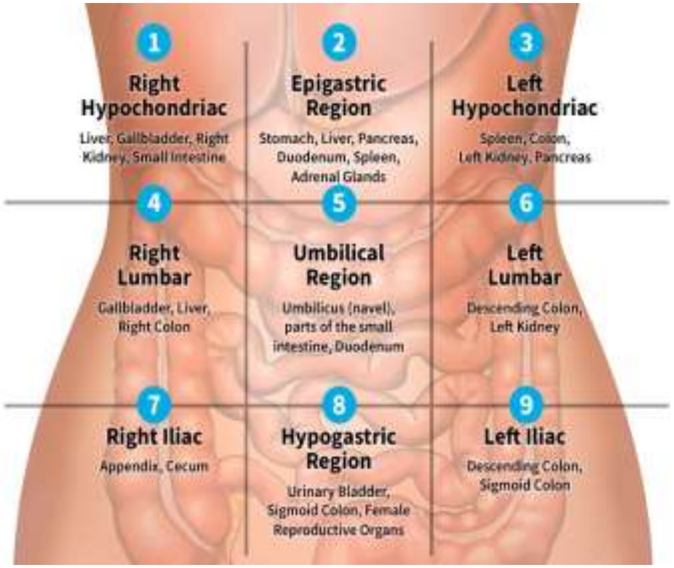
The pancreas is a pale grey gland weighing about 60 grams.

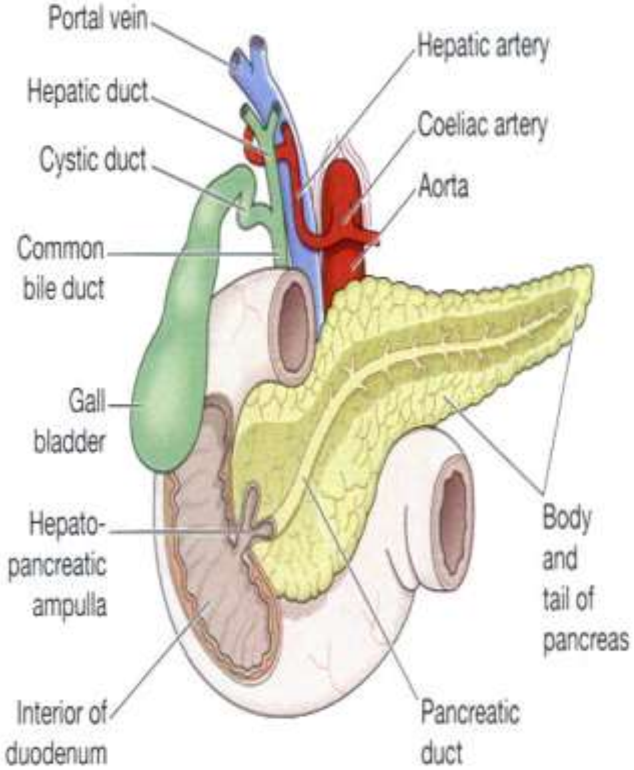
It is about 12 to 15 cm long and is situated in the epigastric and left hypochondriac regions of the abdominal cavity.

- It consists of a broad head (in the curve of the duodenum), a body (behind the stomach)and a narrow tail(lies in front of the left kidney and just reaches the spleen).
- The abdominal aorta and the inferior vena cava lie behind the gland.
- Pancreas is a dual organ having two functions, namely **endocrine function** and **exocrine function.**

-Endocrine function is concerned with the production of hormones.

-Exocrine function is concerned with the secretion of digestive juice called pancreatic juice.





The exocrine pancreas

This consists of a large number of *lobules* made up of small alveoli, the walls of which consist of secretory cells. Each lobule is drained by a tiny duct and these unite eventually to form the *pancreatic duct,* which extends the whole length of the gland and opens into the duodenum. Just before entering the duodenum the pancreatic duct joins the *common bile duct* to form the *hepatopancreatic ampulla.* The duodenal opening of the ampulla is controlled by the *hepatopancreatic sphincter* (of Oddi).

The endocrine pancreas

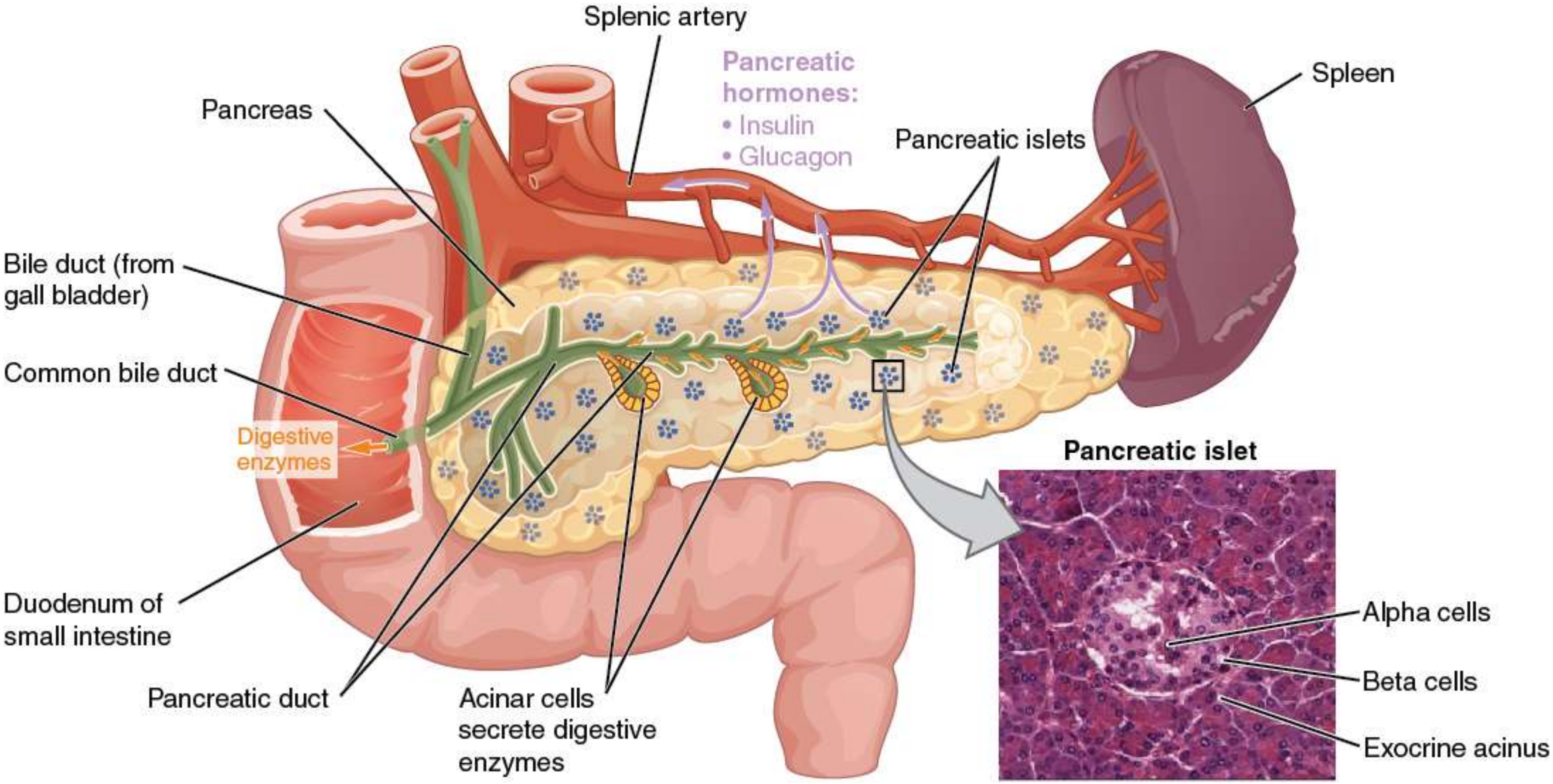
Distributed throughout the gland are groups of specialized cells called the pancreatic islets (of Langerhans). The islets have no ducts so the hormones diffuse directly into the blood. The islets have 4 types of cell, which produce different hormones. Alpha cells (glucagon), beta cells (insulin), delta cells (somatostatin) and PP cells (pancreatic polypeptide).

Blood supply

The splenic and mesenteric arteries supply arterial blood to the pancreas and the venous drainage is by the veins of the same names that join other veins to form the portal vein.

Nerve supply

As in the alimentary tract, parasympathetic stimulation increases the secretion of pancreatic juice and sympathetic stimulation depresses it.


Splenic artery
Pancreatic hormones:
• Insulin
• Glucagon
Spleen
Pancreas
Pancreatic islets
Bile duct (from gall bladder)
Common bile duct
Digestive enzymes
Pancreatic islet
Duodenum of small intestine
Alpha cells
Beta cells
Exocrine acinus
Pancreatic duct
Acinar cells secrete digestive enzymes

Functions of pancreas

- Each day the pancreas produces 1200–1500 mL (about 1.2–1.5 qt) of **pancreatic juice**, a clear, colorless liquid consisting mostly of water, some salts, sodium bicarbonate, and several enzymes.
- The sodium bicarbonate gives pancreatic juice a slightly alkaline pH (7.1–8.2) that buffers acidic gastric juice in chyme, stops the action of pepsin from the stomach, and creates the proper pH for the action of digestive enzymes in the small intestine.
- The enzymes in pancreatic juice include
  - A starch-digesting enzyme called **pancreatic amylase.**
  - Several enzymes that digest proteins into peptides called **trypsin, chymotrypsin, carboxypeptidase,** and **elastase.**
  - The principal triglyceride (fat and oil) digesting enzyme in adults, called **pancreatic lipase.**
  - And enzymes called **ribonuclease** and **deoxyribonuclease** that digest ribonucleic acid (RNA) and deoxyribonucleic acid (DNA) into nucleotides

Composition of Pancreatic juice

Pancreatic juice contains 99.5% of water and 0.5% of solids.

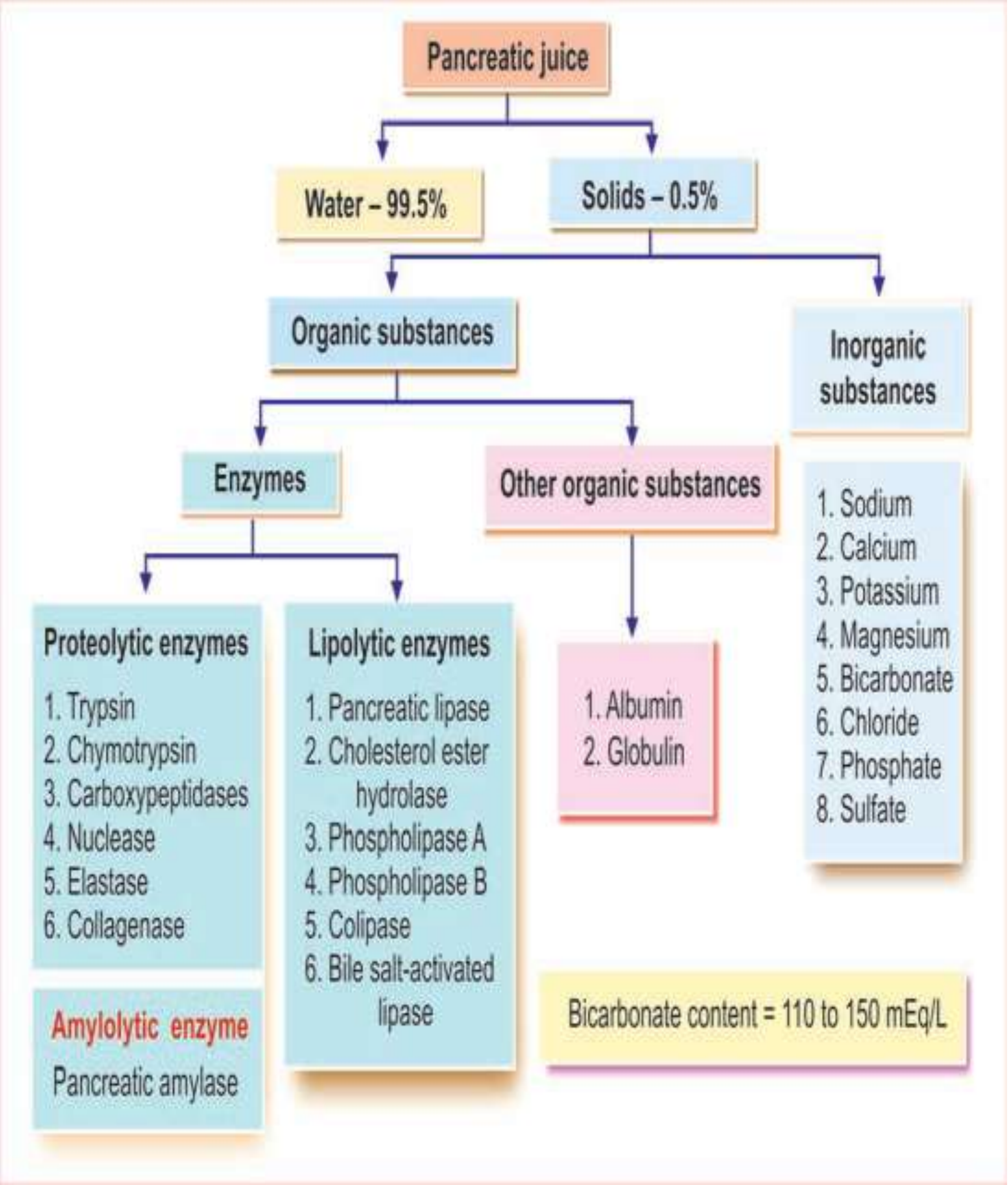
The solids are the organic and inorganic substances.

Bicarbonate content is very high in pancreatic juice.

It is about 110 to 150 mEq/ L, against the plasma level of 24 mEq/L.

High bicarbonate content makes the pancreatic juice **highly alkaline,** so that it protects the intestinal mucosa from acid chyme by neutralizing it.

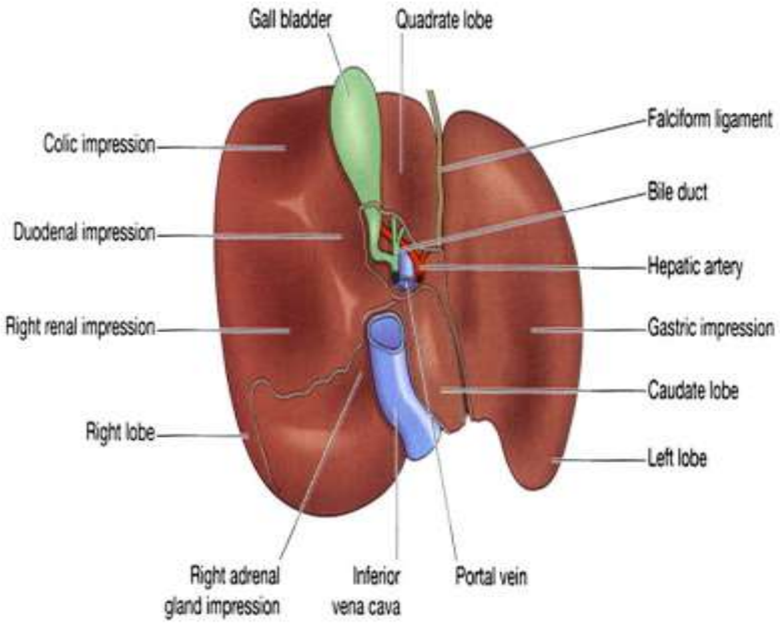
Bicarbonate ions provide the required pH (7 to 9) for the activation of pancreatic enzymes.

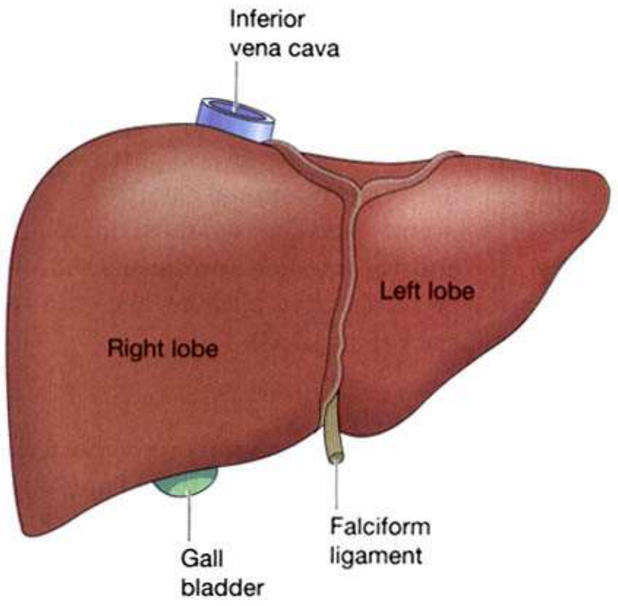


LIVER

Anatomy of liver

- The liver is the largest gland in the body, weighing between 1 and 2.3 kg. It is situated in the upper part of the abdominal cavity occupying the greater part of the right hypochondriac region, part of the epigastric region and extending into the left hypochondriac region.
- Its upper and anterior surfaces are smooth and curved to fit the under surface of the diaphragm.
- Its posterior surface is irregular in outline.
- Organs associated with the liver
    - *Superiorly and anteriorly* – diaphragm and anterior abdominal wall
    - *Inferiorly* –stomach, bile ducts, duodenum, hepatic flexure of the colon, right kidney and adrenal gland
    - *Posteriorly* –oesophagus, inferior vena cava, aorta, gall bladder, vertebral column and diaphragm
    - *Laterally* – lower ribs and diaphragm
- The liver is enclosed in a thin inelastic capsule and incompletely covered by a layer of peritoneum.





- The lobes of the liver are made up of tiny lobules just visible to the naked eye.
- These lobules are hexagonal in outline and are formed by cubical-shaped cells, the *hepatocytes,* arranged in pairs of columns radiating from a central vein. Between two pairs of columns of cells there are *sinusoids* (blood vessels with incomplete walls) containing a mixture of blood from the tiny branches of the portal vein and hepatic artery.
- This arrangement allows the arterial blood and portal venous blood (with a high concentration of nutrients) to mix and come into close contact with the liver cells.
- Amongst the cells lining the sinusoids are hepatic macrophages (Kupffer cells) whose function is to ingest and destroy any foreign particles present in the blood flowing through the liver.
- Blood drains from the sinusoids into *central* or *centrilobular veins.* These then join with veins from other lobules, forming larger veins, until eventually they become the hepatic veins which leave the liver and empty into the inferior vena cava just below the diaphragm.
- *Bile canaliculi* run between the columns of liver cells. This means that each column of hepatocytes has a blood sinusoid on one side and a bile canaliculus on the other.
- The canaliculi join up to form larger bile canals until eventually they form the *right and left hepatic ducts* which drain bile from the liver. Lymphoid tissue and a system of lymph vessels are present in each lobule.

Functions of liver

Carbohydrate metabolism:

Conversion of glucose to glycogen in the presence of insulin, and converting liver glycogen back to glucose in the presence of glucagon.

These changes are important regulators of the blood glucose level. After a meal the blood in the portal vein has a high glucose content and insulin converts some to glycogen for storage. Glucagon converts this glycogen back to glucose as required, to maintain the blood glucose level within relatively narrow limits.

Fat metabolism. *Desaturation of fat,* i.e. converts stored fat to a form in which it can be used by the tissues to provide energy.

Protein metabolism. 1.*Deamination of amino acids*

- removes the nitrogenous portion from the amino acids not required for the formation of new protein; *urea* is formed from this nitrogenous portion which is excreted in urine.
- breaks down genetic material of worn-out cells of the body to form *uric acid* which is excreted in the urine.

2.Transamination – removes the nitrogenous portion of amino acids and attaches it to other carbohydrate molecules

- forming new non-essential amino acids.
- *Synthesis of plasma proteins* and most of the *blood clotting factors* from the available amino acids occurs in the liver.

Synthesis of vitamin A from carotene:

Carotene is the provitamin found in some plants, e.g. carrots and green leaves of vegetables.

Production of heat:

The liver uses a considerable amount of energy, has a high metabolic rate and produces a great deal of heat. It is the main heat-producing organ of the body.

Secretion of bile:

The hepatocytes synthesise the constituents of bile from the mixed arterial and venous blood in the sinusoids. These include bile salts, bile pigments and cholesterol.

Storage:

It stores the substances like fat-soluble vitamins(A, D, E, K), iron, copper and some water-soluble vitamins, e.g. riboflavine, niacin, pyridoxine, folic acid and vitamin B12.

Breakdown of erythrocytes and defence against microbes:

This is carried out by phagocytic Kupffer cells (hepatic macrophages) in the sinusoids.

Detoxification of drugs and noxious substances:

These include ethanol (alcohol) and toxins produced by microbes.

Inactivation of hormones:

These include insulin, glucagon, cortisol, aldosterone, thyroid and sex hormones.

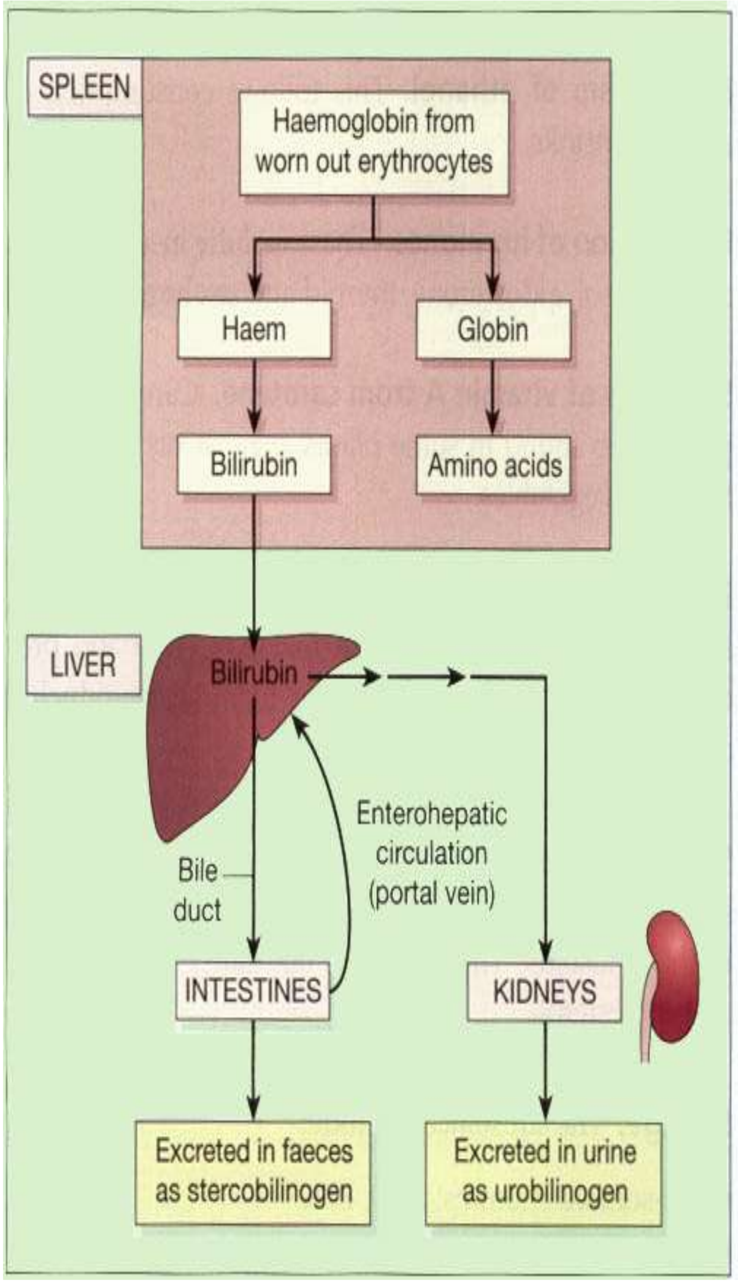
Composition of bile

About 500 ml of bile are secreted by the liver daily. Bile consists of:

- water
- mineral salts
- mucus
- bile pigments, mainly bilirubin
- bile salts, which are derived from the primary bile acids, cholic acid and chenodeoxycholic acid cholesterol.

- The bile acids, cholic and chenodeoxycholic acid, are synthesized by hepatocytes from cholesterol, conjugated (combined) with either glycine or taurine, then secreted into bile as sodium or potassium salts.
- In the small intestine they emulsify fats, aiding their digestion.
- In the terminal ileum most of the bile salts are reabsorbed and return to the liver in the portal vein.

- This *enterohepatic circulation,* or recycling of bile salts, ensures that large amounts of bile salts enter the small intestine daily from a relatively small bile acid pool.
- *Bilirubin* is one of the products of haemolysis of erythrocytes by hepatic macrophages (Kupffer cells) in the liver and by other macrophages in the spleen and bone marrow.
- In its original form bilirubin is insoluble in water and is carried in the blood bound to albumin.
- In hepatocytes it is conjugated with glucuronic acid and becomes water soluble before being excreted in bile.
- Bacteria in the intestine change the form of bilirubin and most is excreted as *stercobilinogen* in the faeces.
- A small amount is reabsorbed and excreted in urine as *urobilinogen.*



GALL BLADDER

Bile secreted from liver is stored in gallbladder. The capacity of gallbladder is approximately 50 mL. Gallbladder is not essential for life and it is removed **(cholecystectomy)** in patients suffering from gallbladder dysfunction. After cholecystectomy, patients do not suffer from any major disadvantage. In some species, gallbladder is absent.

FUNCTIONS OF GALLBLADDER

Major functions of gallbladder are the storage and concentration of bile.

1. Storage of Bile

Bile is continuously secreted from liver. But it is released into intestine only intermittently and most of the bile is stored in gallbladder till it is required.

2. Concentration of Bile

Bile is concentrated while it is stored in gallbladder. The mucosa of gallbladder rapidly reabsorbs water and electrolytes, except calcium and potassium. But the bile salts, bile pigments, cholesterol and lecithin are not reabsorbed. So, the concentration of these substances in bile increases 5 to 10 times.

3. Alteration of pH of Bile

The pH of bile decreases from 8 – 8.6 to 7 – 7.6 and it becomes less alkaline when it is stored in gallbladder.

4. Secretion of Mucin

Gallbladder secretes mucin and adds it to bile. When bile is released into the intestine, mucin acts as a lubricant for movement of chyme in the intestine.

5. Maintenance of Pressure in Biliary System

Due to the concentrating capacity, gallbladder maintains a pressure of about 7 cm H2O in biliary system. This pressure in the biliary system is essential for the release of bile into the intestine

SMALL INTESTINE

Anatomy of small intestine

Small intestine is the part of gastrointestinal (GI) tract, extending between the **pyloric sphincter** of stomach and **ileocecal valve,** which opens into large intestine. Its length is about 6 meter.

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.

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.
- 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.

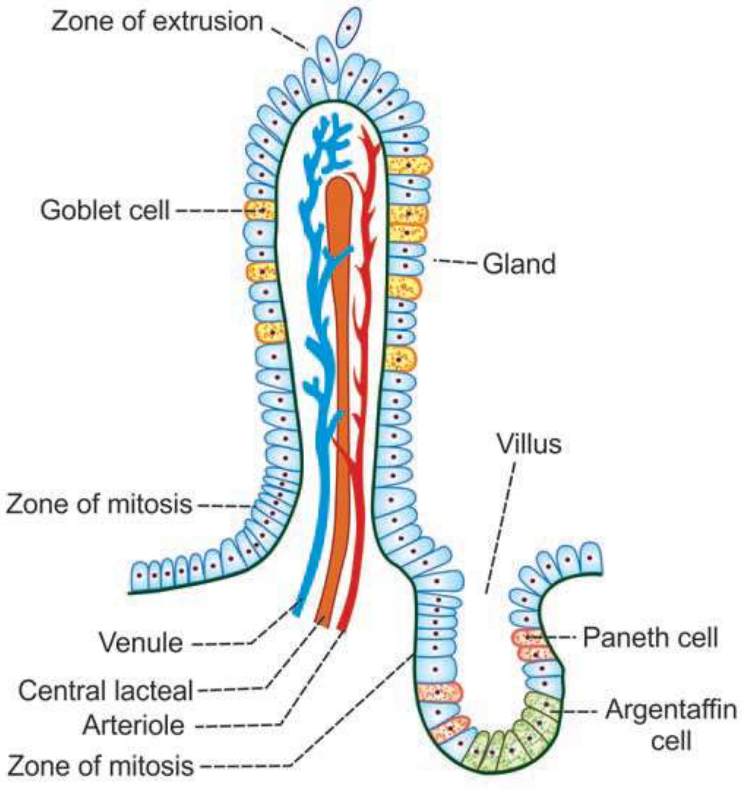
Types of cells interposed between columnar cells of intestinal glands:

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.**

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.

Secretion from small intestine is called *Succus entericus.*



Intestinal gland and villus

Functions of small intestine

- **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.

- **Secretory function**

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

- **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.

- **Hemopoietic function**

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

- **Hydrolytic process**

Intestinal juice helps in all the enzymatic reactions of digestion.

- **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. These peptidases convert peptides into amino acids.

Amylolytic Enzymes

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

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.

- **Activator function**

Enterokinase present in intestinal juice activates trypsinogen into trypsin. Trypsin, in turn activates other enzymes

- **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, car bohydrates, 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.

- **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 d enter the blood directly or through lymphatics.

LARGE INTESTINE

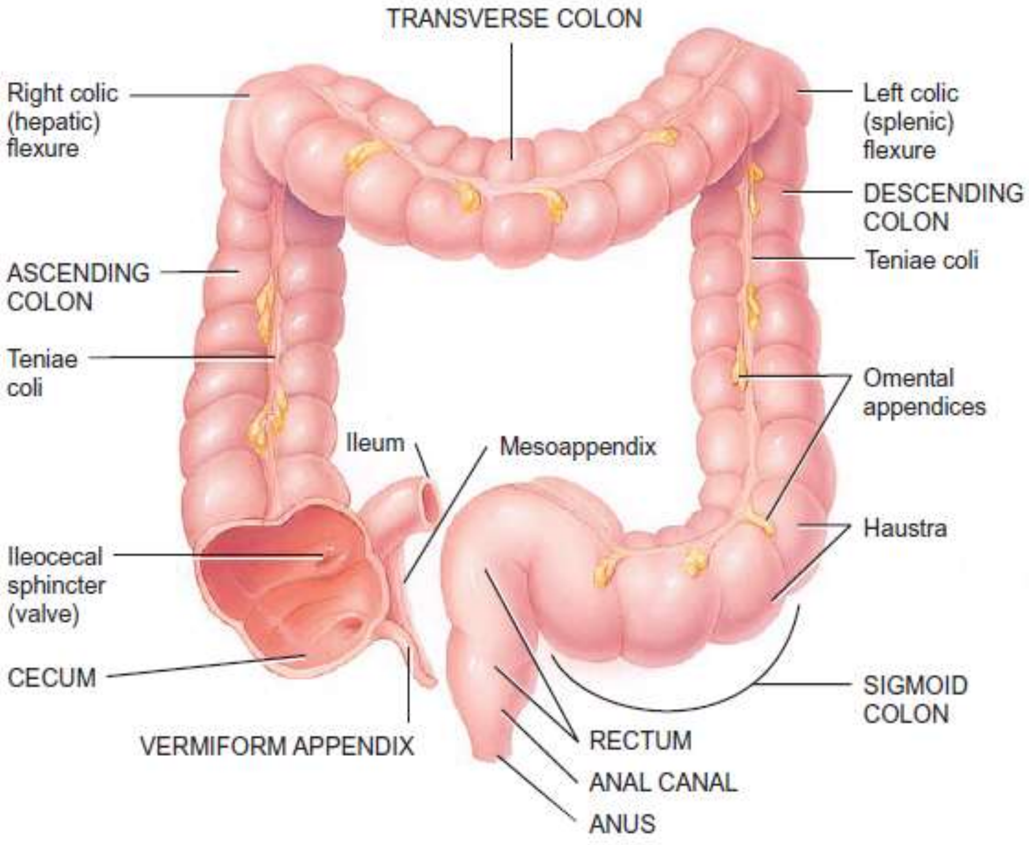
Functional anatomy of large intestine

Large intestine or colon extends from ileocecal valve up to anus.

Parts of large intestine

Large intestine is made up of the following parts:

1. Cecum with appendix
2. Ascending colon
3. Transverse colon
4. Descending colon
5. Sigmoid colon or pelvic colon
6. Rectum
7. Anal canal.



(a) Anterior view of large intestine showing major regions

Structure of wall of large intestine

Wall of large intestine is formed by four layers of structures like any other part of the gut.

1. Serous layer: It is formed by peritoneum

2. Muscular layer: Smooth muscles of large intestine are distributed in two layers, namely the outer longitudinal layer and inner circular layer.

The longitudinal muscle fibers of large intestine are arranged in the form of three long bands called **tenia coli.** The length of the tenia coli is less when compared to the length of large intestine. Because of this, the large intestine is made into series of pouches called **haustra.**

3. Submucus layer: It is not well developed in large intestine

4. Mucus layer: The crypts of Leiberkühn are present in mucosa of large intestine. But the villi, which are present in mucus membrane of small intestine, are absent in the large intestine. Only mucus-secreting glands are present in the mucosa of large intestine.

Functions of large intestine

- **Absorptive function**

Large intestine plays an important role in the absorption of various substances such as:

i. Water

ii. Electrolytes

iii. Organic substances like glucose

iv. Alcohol

v. Drugs like anesthetic agents, sedatives and steroids.

- **Formation of feces**

After the absorption of nutrients, water and other substances, the unwanted substances in the large intestine form feces. This is excreted out.

- **Excretory function**

Large intestine excretes heavy metals like mercury, lead, bismuth and arsenic through feces.

- **Secretory function**

Large intestine secretes mucin and inorganic substances like chlorides and bicarbonates.

- **Synthetic function**

Bacterial flora of large intestine synthesizes folic acid, vitamin B12 and vitamin K. By this function, large intestine contributes in **erythropoietic activity** and blood clotting mechanism.