The Digestive System

Human Alimentary Canal

We eat food daily, but have you ever wondered what happens to food once it enters our body? What organs form the digestive system and how is the process of digestion carried out?

Human digestive system consists of two components: alimentary canal (that include mouth, oesophagus, stomach, small intestine and large intestine), and digestive glands (that include salivary glands, liver and pancreas).

Let us explore this in detail by studying the various organs of the digestive system and the roles they play in digestion.

The Mouth

In holozoic nutrition, food is taken inside the body through mouth. This process is known as **ingestion**. Inside the mouth, teeth, tongue and salivary glands are present. Each of them play significant role in the digestion of food.

Teeth

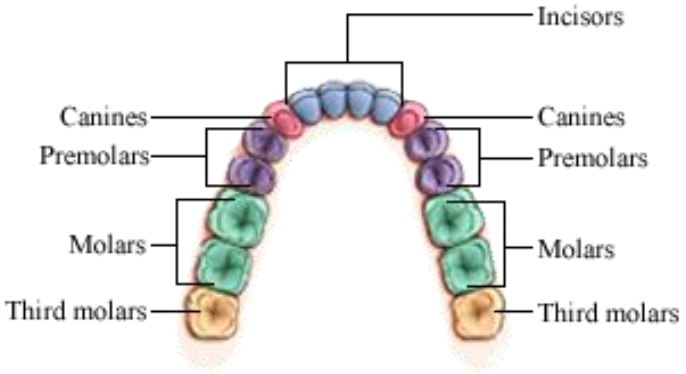
The mouth or the buccal cavity has teeth, which mechanically break down the food into smaller pieces. Teeth are rooted in separate sockets in the gums.

Do you think we have teeth from birth?

No. Babies do not have teeth. Humans grow with two sets of teeth. The first set of teeth begins to grow during infancy. This set of teeth is called **milk teeth.** These fall off between the ages of six and eight. The second set of teeth, which replaces the milk teeth, is called the **permanent teeth.** This set lasts throughout our life, unless it falls off during old age.

Look in a mirror and count your teeth. How many types of teeth do you have? Eat different food items to find out which type of teeth is being used to eat, bite, and chew these food items. Count each type. You can compare the number of teeth present in your mouth with the number of teeth others have.

If you look in a mirror, you will observe that all teeth are not similar. Have you wondered why? This dissimilarity arises from the fact that each tooth performs a different function. Let us understand the positions and functions of each type of tooth.



1. **Incisors** are the teeth present at the front portion of the mouth. There are four incisors in each jaw. They are used for biting and cutting food.

2. **Canines** are located next to the incisors. There are two canines in each jaw. They are used for tearing and piercing food.

3. **Premolars** lie next to the canines. There are four premolars in each jaw. They are used for chewing and grinding food.

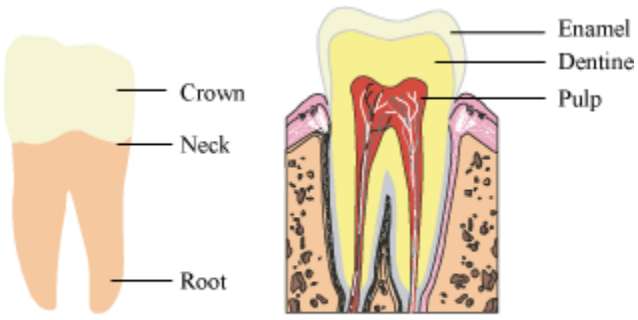
4. **Molars** lie next to the premolars at the end of the jaw. There are six molars in each jaw. They are also used for chewing and grinding food.

- In herbivores, canine teeth are absent and the incisors are sharp to cut the grass.
- In carnivores the incisors are strong and pointed while canines are enlarged.
- In omnivores, all four kinds of teeth are well developed.

Dental Formula

- **Dental formula for milk teeth** in humans is 2120/2120. It means that each half of upper jaw and lower jaw has 2 incisors, 1 canine and 2 premolars. Molars are absent in milk teeth. There are 20 teeth in the milk teeth set.
- **Dental formula for permanent teeth** in human is $\frac{2123}{2123}$. It means that each half of upper jaw and lower jaw has 2 incisors, 1 canine, 2 premolars, and 3 molars.
- **The dental formula in dogs (carnivore) is** $\frac{3142}{3143}$
- **The dental formula in rabbits (herbivore) is** $\frac{2033}{1023}$.

Structure of Tooth



Structure of the tooth

The vertical section of tooth shows the following parts

- The crown − the part lying above the gums
- The neck − it connects the crown with the root
- The root − it lies buried inside the gums and supports the tooth

The white part of the tooth is called the enamel, it consists of calcium salts.

Inner to the enamel is the dentine which is a solid tissue and contains microscopic tubules/tubes.

The dentine encloses a cavity known as the pulp cavity. This cavity supplies the tooth with nerves and blood capillaries.

At the root of the tooth is a bone like material called the cement which holds the tooth firmly to the socket.

We all love to eat sweets. However, you might have heard people saying that sweets damage our teeth. Do you know if this is true? Let us understand it further.

Tooth decay

A number of bacteria are present in our mouth, though not all of them are harmful. However, irregular and improper cleaning of teeth can lead to the growth of several harmful bacteria in our mouth. These bacteria form a yellow coloured film on the tooth-surface, called **plaque**.

Also, they break down the sugar present in leftover food particles and release acids in the mouth, which damage the teeth and form cavities (**caries**). The bacteria can enter the tooth pulp through these caries and cause infection.

This is known as **tooth decay**. This condition can lead to severe toothache. It can also result in untimely loss of teeth. **Can you name few food items that cause tooth**

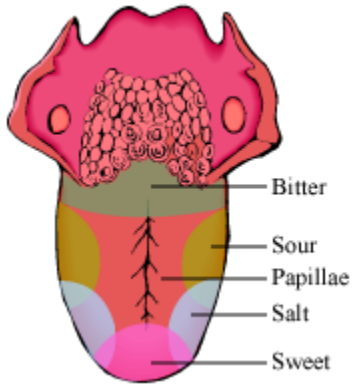
decay? Tooth decay can occur because of consuming chocolates, sweets, cold drinks, and other sugar products. **How can tooth decay be prevented?**

Tooth decay can be prevented by maintaining oral hygiene, which includes the proper cleaning of teeth. Teeth must be brushed twice a day after meals using *dantun* or dental floss.

Tongue

Tongue is a muscular organ present in the buccal cavity. **What role does it play in digestion?** The tongue mixes food with saliva during chewing. It also aids in swallowing food.

How do we taste the food we eat? We are able to taste the food we eat with the help of our **tongue**. The tongue has a large number of taste buds, which tell us the taste of different types of food items. The different regions of the tongue are shown in the given figure.



What's on my tongue?

Take a sample of sugar solution, salt solution, lemon juice, and a paste of crushed *Neem* leaves. Blindfold your classmate and ask him/her to take out his/her tongue. Now, with the help of a clean toothpick, keep different samples on different areas of the tongue. Ask your friend to identify the areas of the tongue in which he/she feels sweet, salty, sour, and bitter.

An interesting fact:

Did you know that our mouth warms or cools the food according to the need of the body!

Why do you think we can feel different types of tastes?

Salivary glands

Apart from the tongue and the teeth, the buccal cavity also has salivary glands, which secrete saliva.

What is the function of saliva? The enzymes present in saliva break down or digest the starch present in the food we eat.

Let us perform an activity to test the action of saliva.

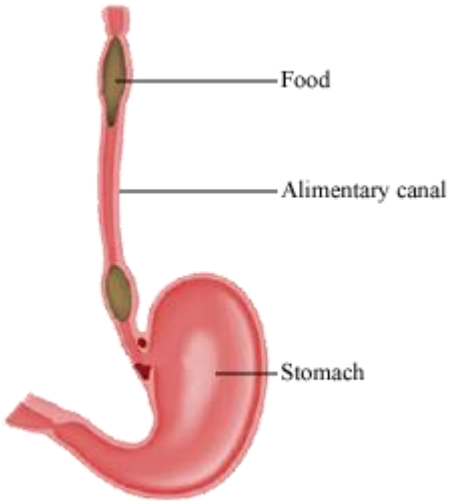
Did you know that humans produce about 1.7 litres of saliva everyday!

Pharynx

It is a common passageway for food and air. It opens into the oesophagus (which leads to the stomach) and trachea (which leads to the lungs).

The food pipe or the oesophagus

We know that the tongue helps in swallowing food. **Where does the swallowed food go from the mouth?** The swallowed food passes into the oesophagus from the mouth. The oesophagus or the food pipe runs along the neck and chest. The walls of the food pipe move to push the food down into the stomach.



Digestion in Mouth

Saliva contains enzymes salivary amylase, lysozyme, and electrolytes. Salivary amylase basically helps in starch digestion up to 30%.

$$\text{Starch} \xrightarrow[\text{pH6.8}]{\text{Salivary amylase}} \text{Maltose}$$

Two of the basic functions performed by buccal cavity are mastication of food and facilitation of swallowing.

From buccal cavity, food reaches the stomach through a process called peristalsis.

Peristalsis is the process of wave-like muscle contractions of the alimentary tract that moves food along.

What happens when food goes down the trachea instead of the oesophagus?

If food goes down the trachea or wind pipe instead of the food pipe or oesophagus, the person is not able to breathe and starts choking.

Our trachea (wind pipe) and oesophagus (food pipe) are joined near the top and separate as we go down towards the diaphragm. A thin flap of cartilage called the epiglottis usually covers the trachea while we are swallowing, so that food does not move inside the wind pipe.

However under certain conditions like swallowing too fast, talking or not chewing the food properly, some of it may enter the trachea. This may cause the airways to get partially blocked, which is called as choking. Total blockage may result in the death of the individual.

Our nervous system responds immediately to the situation by trying to eject the food. This is done by tightening the muscles between the ribs, above the oesophagus and by expanding the cavity of the throat.

Try to breathe when you are in the midst of swallowing, is it possible?

You won't be able to breathe as trachea is shut off by the epiglottis during this time.

Did you know that the human oesophagus is approximately 25 cm long?

The stomach

After the food pipe, the food enters the stomach. The stomach is a thin-walled bag. It is flattened, J- shaped, and is the widest part of the alimentary canal. It opens into the small intestine.

Digestion in Stomach

Food is stored in the stomach for about 4-5 hours. During its stay in the stomach, it is mixed with acidic gastric juices by churning movement of muscular wall and is called chyme at this stage.

Gastric juice contains hydrochloric acid. It also contains two enzymes - pepsin and rennin. The function of the acid is to convert inactivated form of pepsin into the activated form.

Small amount of protein digestion (by pepsin) occurs in the stomach.

$$\text{Proteins} \xrightarrow{\text{Pepsin}} \text{Proteases} + \text{Peptides}$$

Rennin (proteolytic enzyme) in infants helps in milk digestion.

What is the function of the stomach?

The inner lining of the stomach secretes hydrochloric acid, mucous, and digestive juices such as pepsin and rennin.

Why are they secreted? Do they have any importance? The mucous secreted by the stomach protects its inner lining.

The hydrochloric acid secreted by the stomach kills the bacteria that enter the stomach through food. It also makes the medium of the stomach acidic.

The digestive juices secreted by the stomach take part in the process of digestion by breaking down the food into smaller substances for example, pepsin breaks proteins into polypeptides, rennin changes soluble milk proteins into curd which is insoluble.

The production of chymosin in the human body begins to diminish as one grows old.

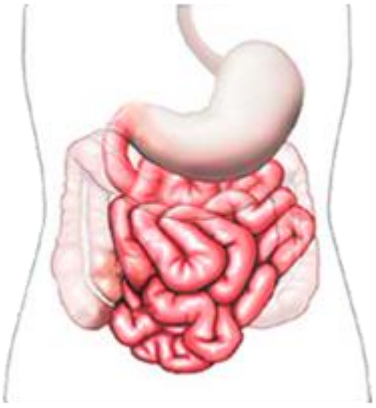
Some interesting facts:

- Did you know that the human stomach can hold up to 1.5 litres of material?
- On an average, the stomach produces 2 litres of acid everyday.
- Food stays in the stomach for 4-5 hours.

The small intestine

The stomach empties its contents into the small intestine. The small intestine is a highly coiled, tube-like structure. It is about 7.5 metres in length. It receives secretions from the liver and the pancreas in the form of bile and pancreatic juice. Apart from this, the wall of the small intestine also secretes juices.

The secretions are poured into the small intestine. Can you say why?



Small intestine

When the partly digested food reaches the small intestine, the juices secreted by the small intestine complete the process of digestion. The secreted juices in the small intestines consists of maltase, sucrase, lactase, peptidase and lipase.

Digestion in Small Intestine

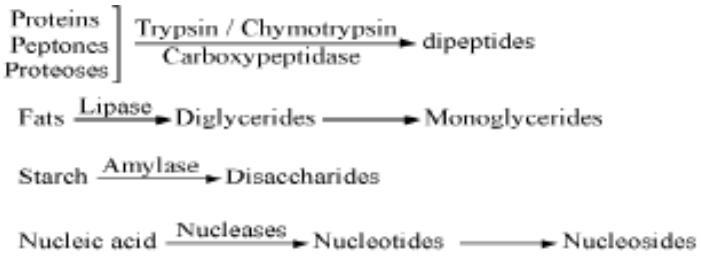
The digestion of food takes place in duodenum, which is the first part of small intestine.

The small intestine receives digestive juices from liver (bile juice) and pancreas (pancreatic juice). Small intestine itself also secretes digestive juices.

The bile juice is secreted by the liver. It does not contain any enzyme, but still is essential for digestion since it breaks the fats into smaller droplets so that the enzymes could act on them efficiently.

Three of the major enzymes present in the pancreatic juice are − trypsin, amylase and lipase.

Action of pancreatic juice results in:



After being partially digested, the food moves to the second part of small intestine where it is acted upon by enzymes such as maltase, sucrase, and lactase.

Action of intestinal juice results in:

Dipeptides $\xrightarrow{\text{Dipeptidase}}$ amino acids

Di and Monoglycerides $\xrightarrow{\text{Lipases}}$ Fatty acids + Glycerol

Maltose/Lactose/Sucrose $\xrightarrow{\text{Maltase/Lactase/Sucrase}}$ Glucose + Glucose / Galactose / Fructose

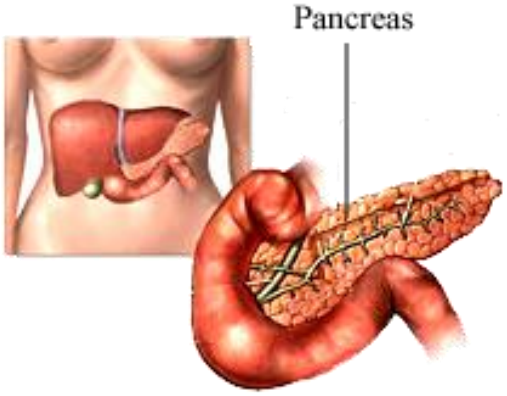
Nucleotides $\xrightarrow{\text{Nucleotidases}}$ Nucleosides $\xrightarrow{\text{Nucleosidases}}$ Sugar + Bases

What is the function of the liver in the digestive system? The liver is the largest gland of the body. It is a reddish-brown gland situated on the right side of the upper part of the abdomen. The main function of the liver is to secrete **bile juice**. Bile juice is stored in a sac-like structure called the **gall bladder**.

What is the function of bile? Bile takes part in the digestion of fats present in the ingested food.

What is the pancreas? Does it perform the same function as the liver?

The pancreas is a large cream-coloured gland. It is situated just below the stomach. It secretes **pancreatic juice,** which consists of protease, amylase and lipase enzymes. These juices take part in the digestion of carbohydrates, lipids and proteins by breaking them into simpler substances for example, amylase breaks starch into maltose, while lipase breaks complex fats into simple fats.



Hence, it is the small intestine where

- carbohydrates are broken down into simple sugar such as glucose
- fats are broken down into fatty acids and glycerol
- proteins are broken down into amino acids

What happens to the digested food? Nutrients from the digested food pass into blood vessels, which are present in the walls of the small intestine. This process is known as **absorption**.

Does the small intestine have special structures that aid in the absorption of digested food?

Let us find an answer to this.

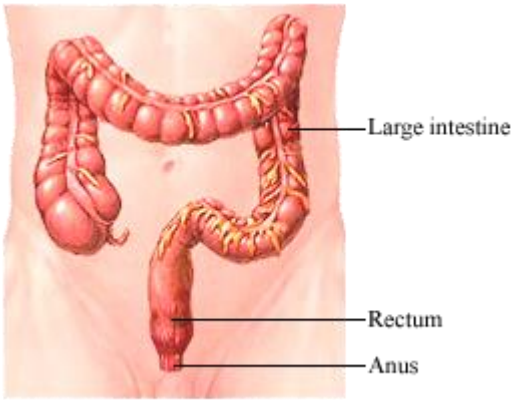
Some interesting facts:

The human liver weighs around 1.6 kg.
Do you know that the liver is the only organ of the body which has the capacity to regenerate itself?
Do you know that pancreas also regulates the level of sugar in our blood?

The large intestine

The digested food gets absorbed into the blood vessels in the small intestine and is transported to all parts of the body by these blood vessels. This process is known as **assimilation**.

What happens to the undigested and unabsorbed food material? The undigested food material from the small intestine enters the large intestine. The large intestine is wider than the small intestine, but is shorter in length. It is 1.5 metres long.



What is the function of the large intestine? The large intestine absorbs water and remaining salts from the undigested food material.

The remaining waste material then enters the **rectum.** It is stored there in the form of semi-solid faeces. The faecal material is finally removed from the body through the **anus**. This process is known as **egestion**.

The digestion of food involves several organs and processes that occur internally. How was this discovered? Who was the first person to study the process of digestion?

The discovery of the working of the stomach was an accident. In 1822, a man named Alexis St. Martin was badly injured by a gun shot. The bullet that hit him made a hole in his stomach. The doctor treating him, named William Beaumont, was able to save his life, but was unable to close the wound properly.

The doctor utilized this opportunity to study the inside of his stomach and made some wonderful observations. He found that the stomach churns the food and its walls secrete a fluid that helps in the digestion of food. He also observed that the end of the stomach opens into the intestine only after the digestion of the food inside the stomach is completed.

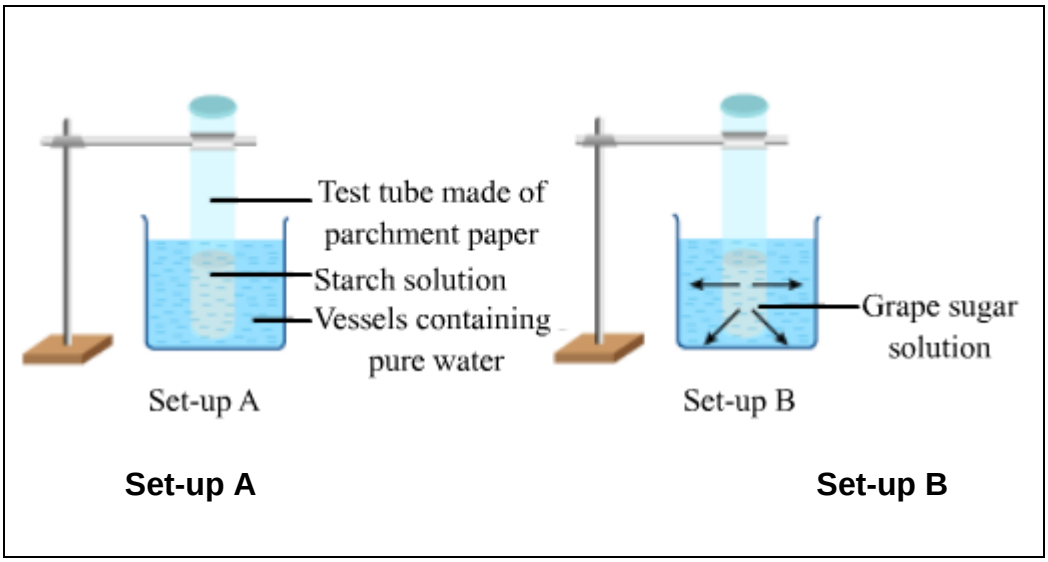
Therefore, the digestion of food starts in the mouth. The process of digestion continues in the stomach and small intestine. The absorption of nutrients occurs in the small intestine through **diffusion, active transport and facilitated transport**.

Let us understand diffusion through an activity.

Importance of diffusion

Take two tubes made of a membrane of parchment paper or bladder of a pig. Fill these tubes, one with starch paste, and the other with grape sugar solution.

Then, hang the tubes in separate vessels containing pure water (like shown below).



Experimental set-up

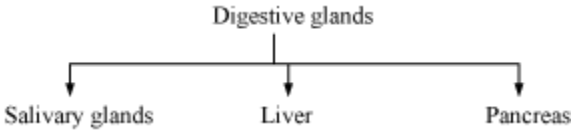
After 3 – 4 hours, taste the water of both the vessels.

You will notice that the water in the vessel containing sugar solution turns sweet, while the water of the other vessel shows no change.

Explanation of the activity: We know that starch is insoluble in water, while sugar is soluble. Therefore, sugar is able to pass through the membrane into the vessel turning the water sweet. On the other hand, starch does not pass through the membrane.

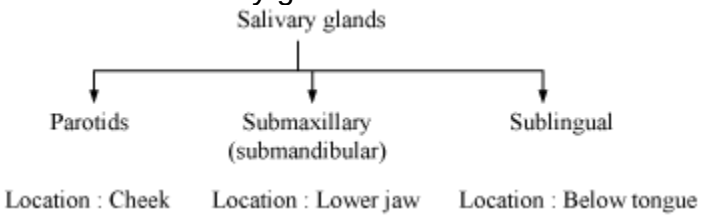
This activity proves that the food we eat is insoluble, so it must be converted into soluble form (or should be digested) to make it pass through the alimentary canal. In the above experiment, the parchment tubes represent the alimentary canal, while the surrounding water represents blood.

Digestive Glands

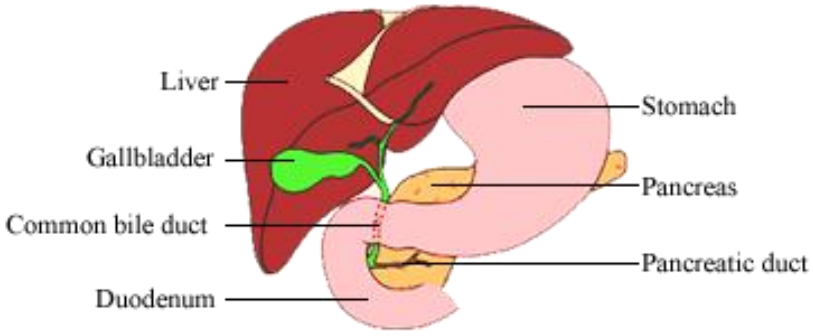


Salivary Glands

- Location − just outside buccal cavity
- Division of salivary glands:



Liver

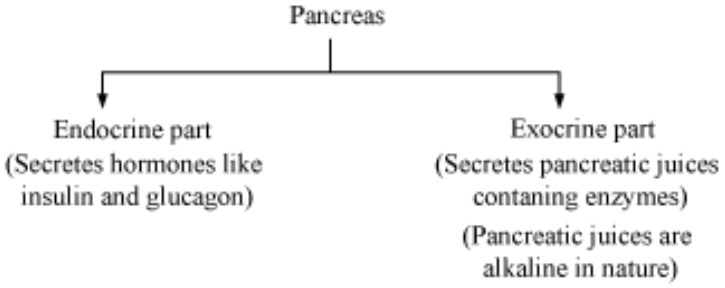


- Largest gland
- Location − Right side of abdominal cavity, just below the diaphragm
- Weight − 1. 2. to 1.5 kg in human adult
- Liver contains hepatic lobules − structural and functional unit of liver; covered by Glisson’s capsule (a sheath of connective tissue)
- Lobules contain hepatic cells that secrete bile.

- Bile passing through hepatic ducts gets stored in gall bladder (a muscular sac-like structure).
- Common Bile duct = Hepatic duct (liver duct) + Cystic duct (gall bladder duct)
- Hepato pancreatic duct = Common Bile duct + Pancreatic duct
- Hepato pancreatic duct opens into duodenum.
- Sphincter of Oddi guards the opening of hepato-pancreatic duct.

Pancreas

- Location − Between limbs of 'U'-shaped duodenum
- Compound gland having both endocrine and exocrine parts



Digestion and Absorption of Food

Process of digestion of food

- Includes both mechanical and chemical processes
- Digestion of carbohydrates − mainly in mouth and small intestine
- Digestion of fats − mainly in small intestine
- Digestion of proteins − mainly in stomach and small intestine
- Absorption − Nutrients are mainly absorbed in small intestine while the absorption of water is carried out by large intestine.

Digestion in Mouth

- Saliva contains enzymes salivary amylase, lysozyme, and electrolytes.

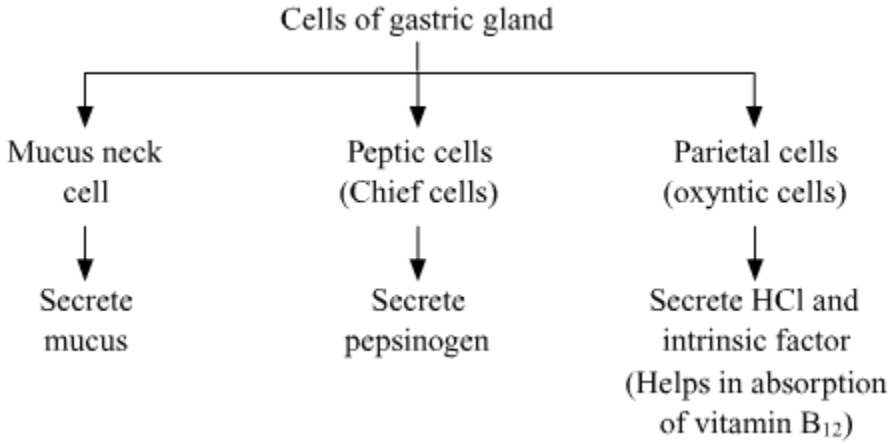
- Salivary amylase basically helps in starch digestion up to 30%.

$$\text{Starch} \xrightarrow[\text{pH6.8}]{\text{Salivary amylase}} \text{Maltose}$$

- 2 basic functions performed by buccal cavity − mastication of food and facilitation of swallowing
- Mucus in saliva lubricates and adheres food particles into *Bolus*.
- Deglutition or swallowing conveys the bolus to pharynx and then to oesophagus.
- Peristalsis conveys the bolus from oesophagus to stomach.
- Peristalsis - process of wave-like muscle contractions of the alimentary tract that moves food along
- Lysozyme present in saliva acts as an antibacterial agent.

Digestion in Stomach

- Mucosa of stomach has gastric glands containing 3 types of cells.



- Food rests in stomach for about 4-5 hours, then gets mixed with acidic gastric juices by churning movement of muscular wall and is called chyme at this stage.
- Gastric juice contains HCl, pepsinogen, rennin, and lipase.
- Proenzyme pepsinogen $\xrightarrow{\text{HCl}}$ Pepsin (active enzyme)
- Mucus and bicarbonate lubricate the gastric epithelium and protect it from action of HCl.

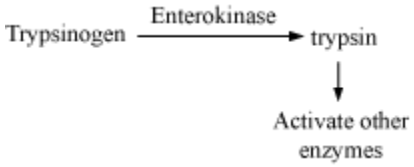
- Small amount of protein digestion (by pepsin) occurs here.

$$\text{Proteins} \xrightarrow{\text{Pepsin}} \text{Proteases} + \text{Peptides}$$

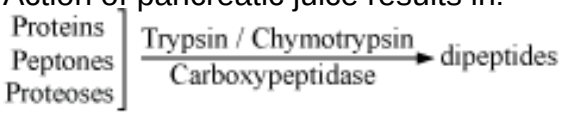
- Rennin (proteolytic enzyme) in infants helps milk digestion.

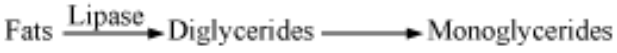
Digestion in Small Intestine

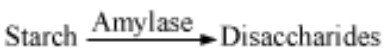
- 3 types of secretions are released into the intestine.

	Pancreatic juice **released by hepatopancreatic duct**	**Bile**	**Intestinal juice (succus entericus)**
1.	Contains inactive enzymes such as trypsinogen, chymotrypsinogen, procarboxypeptidase, amylase, lipase, nuclease, etc.	Contains bile pigments (Bilirubin and biliverdin), bile salts, cholesterol phospholipids	Contains enzymes such as maltase dipeptidase, lipase nucleosidase, etc.
2		Bile contains no enzyme.	Also contains mucus which in combination with bicarbonates released by pancreas provides alkaline medium and prevents intestinal mucosa from acid
3.		It emulsifies fats into micelles and activates lipases.	

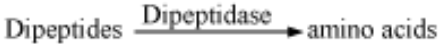
- Action of pancreatic juice results in:

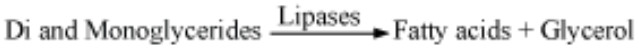


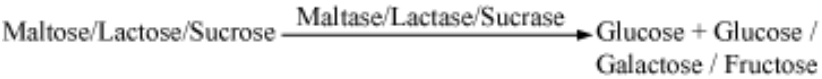


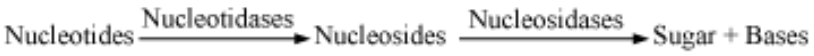


- Action of intestinal juice results in:









- Digestion occurs in − Duodenum|
  Absorption occurs in − Ileum and jejunum

Absorption of Digested Food

- Absorption of food is the process by which the end products of digestion pass through the intestinal mucosa into the blood or lymph.
- Mechanism of absorption
- **Simple diffusion** − Glucose, amino acid, electrolytes such as Cl^- follow this method; depends upon concentration gradient
- **Facilitated transport** − Fructose and some amino acids are absorbed by this method. Absorption occurs with the help of carrier ion such as Na^+.
- **Active transport** − Glucose, some amino acids, Na^+ follow this method. Absorption is against concentration gradient. Thus, it requires energy.
- Fatty acids are insoluble; hence first broken into small droplets called micelle, which further reform into small protein-coated fat globule called chylomicron (in intestinal mucosa), which are then transported into lacteals in villi, which finally release them into blood stream.

- Substances absorbed in mouth − Certain drugs are absorbed in blood capillaries, lining lower parts of tongue.
- Substances absorbed in stomach − water, simple sugars, alcohol
- Substances absorbed in small intestine − almost all nutrients

  Maximum nutrition occurs here.
- Substances absorbed in large intestine − water, minerals, drugs
- Absorbed substances finally reach tissues where they are utilized. This process is called **assimilation.**

Egestion

- Mucus secreted by large intestine adhere the undigested particles into faeces.
- Faeces enter caecum through ileo-caecal valve. Back flow of faeces is prevented by this valve.
- Faeces are stored in rectum.
- In rectum, a neural reflex is initiated causing an urge for removal of faecal matter.
- Defaecation is a voluntary process carried out by mass peristaltic movement.

Tests For Major Nutrients

Nutrients are components of food that provide energy to the body. Five major nutrients are present in the food we eat. These include carbohydrates, proteins, fats, vitamins, and minerals.

How can we find out that a particular food item is rich in which nutrient?

The presence of carbohydrates, proteins, and fats can be tested by performing simple experiments. Let us learn how these tests are carried out and what materials are required to perform them.

Dilute solutions of iodine, copper sulphate, and caustic soda are required (they can be easily prepared in the laboratory) to perform these tests.

Test for carbohydrates

Test for glucose (Benedict's solution)

- Take a small amount of glucose and dissolve it in water in a clean test tube.
- To this solution add 5-6 drops of Benedict's solution (mixture of copper sulphate, sodium hydroxide and tartaric acid) and heat for about two minutes.
- If a brick-red precipitate is observed, it confirms the presence of glucose.

Test for starch

• To prepare a **dilute solution of iodine**, a few drops of tincture iodine are added to a test tube half-filled with water.

When the dilute solution of iodine is added to food items containing starch e.g., raw potato, the colour of the food item changes to blue, indicating the presence of starch.

Let us perform a test to find the presence of starch in a food item.

Take a raw potato and cut it into two halves. Put one half of the potato on a plate and use a dropper to put 2-3 drops of iodine solution on it.

You will observe that the colour of the potato slice changes to blue-black.

The presence of this blue-black colour indicates that potatoes contain starch.

Other food items containing starch are rice, sugarcane, maize, mango, sweet potato, etc.

Test for proteins (Biuret test)

• To prepare a **copper sulphate solution**, 2 g copper sulphate is dissolved in 100 mL of water.

• To prepare a **solution of caustic soda**, 10 g of caustic soda is dissolved in 100 mL of water.

These two solutions are used to test the presence of proteins in food items.

A food item containing proteins turns violet when two drops of copper sulphate and ten drops of caustic soda are added to it.

Let us perform an activity to test the presence of proteins.

Test for fats

In order to test the presence of fats, the food item containing fats is crushed on a piece of paper. This paper is then dried and viewed against light.

You will observe that the crushed food leaves an oily patch on the paper, making it translucent i.e., light is faintly visible through it.

This confirms the presence of fats in the food item.

Let us perform a test to find the presence of fats in a food item.

Take a few groundnuts and wrap them in a piece of paper. Crush them in such a way that the paper is not torn. Let the paper dry and then hold the paper against light.

What do you observe?

An oily patch is formed on the portion of the paper where the nuts were crushed.

You will observe that light can faintly pass through this oily patch, confirming the presence of fats.

An interesting fact:

- Did you know that milk, apart from being a perfect human food, is also a perfect nutrient medium for the growth of bacteria? Hence, milk must be properly handled as it can become unwholesome.