COURSE GUIDE

NSC 222
HUMAN PHYSIOLOGY II

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Printed 2022

ISBN: 978-058-660-X

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COURSE GUIDE

GENERAL INTRODUCTION

Welcome to the second year course in Human Physiology, NSC 222 – Human Physiology II. In the first level course, we learn that Physiology is about how the body does the work of helping us to attain a state of health. We also learnt that the nurse must be adequately grounded in Physiology to help her/him in determining the functionality of the various organs that also work within the systemic framework. The knowledge of normal function is also the basis of diagnosing disturbances of physiological processes.

COURSE OBJECTIVES

At the completion of this course, you will be able to:

Apply the knowledge of respiratory and gastrointestinal physiology in analyzing health and nursing care needs and planning care of patients.

WORKING THROUGH THIS COURSE

The course will be delivered adopting the blended learning mode, 70% of online but interactive sessions and 30% of face-to-face during laboratory sessions. You are expected to register for this course online before you can have access to all the materials and have access to the class sessions online. You will have hard and soft copies of course materials, you will also have online interactive sessions, face-to-face sessions with instructors during practical sessions in the laboratory. The interactive online activities will be available to you on the course link on the Website of NOUN. There are activities and assignments online for every unit every week. You must visit the course sites weekly and do all assignments to meet deadlines and to contribute to the topical issues that would be raised for everyone's contribution.

You will be expected to read every module along with all assigned readings to prepare you to have meaningful contributions to all sessions and to complete all activities. You must attempt all the Self Assessment Questions (SAQ) at the end of every unit to help your understanding of the contents and to help you prepare for the in-course tests and the final examination. You will also be expected to keep a portfolio where you keep all your completed assignments.

COURSE MATERIALS

Course Guide

Course Text in Study Units

Textbooks (Hard and electronic) and Book of Laboratory Practical

Assignment File/Portfolio

STUDY UNITS

This course is made up of 5 modules comprising 13 units as listed below:

Module 1 Gastrointestinal Physiology

Unit 1 Organization and Secretions of the Gastrointestinal Tract
Unit 2 Gastrointestinal Motility
Unit 3 Gastrointestinal Hormones, Digestion and Absorption

Module 2 Nervous System

Unit 1 Overview of the Nervous System
Unit 2 Integration of Central Nervous System with Other Systems

Module 3 Endocrine System And Reproductive System

Unit 1 The Endocrine System
Unit 2 The Reproductive System

Module 4 Urinary System

Unit 1 Introduction to Urinary System
Unit 2 The Structure of the Kidney

Module 5 The Special Senses

Unit 1 The Tongue and the Sense of Taste
Unit 2 The Nose and the Sense of Smell
Unit 3 The Ear and the Sense of Hearing
Unit 4 The Eyes and the Sense of Vision

REFERENCE TEXTBOOKS

Berne, R.M., B. M., & Stanton, B. A. (2010). Berne & Levy physiology (6th Edt.). Philadelphia, PA: Mosby/Elsevier.

Fox SI. (2012). Human Physiology. 12th edition, Mc Graw Hill, New York.

Ganong WF. (2010). Review of Medical Physiology. 23rd edition, Mc Graw Hill, New York.

Guyton AC, Hall JE. (2001). Textbook of Medical Physiology. Harcourt International Edition, 10th edition, W.B. Saunders, Philadelphia.

Oyebola DO. (2002). Essential Physiology, Vol 1, Nihort Press.

COURSE REQUIREMENTS AND EXPECTATIONS OF YOU

Attendance of 95% of all interactive sessions, submission of all assignments to meet deadlines; participation in all CMA, attendance of all laboratory sessions with evidence as provided in the log book, submission of reports from all laboratory practical sessions and attendance of the final course examination. You are also expected to:

1. Be versatile in basic computer skills.
2. Participate in all laboratory practical up to 90% of the time.
3. Submit personal reports from laboratory practical sessions on schedule.
4. Log in to the class online discussion board at least once a week and contribute to ongoing discussions.
5. Contribute actively to group seminar presentations.

EQUIPMENT AND SOFTWARE NEEDED TO ACCESS COURSE

You will be expected to have the following tools:

1. A computer (laptop or desktop or a tablet)
2. Internet access, preferably broadband rather than dial-up access
3. MS Office software – Word PROCESSOR, Powerpoint, Spreadsheet
4. nBrowser – Preferably Internet Explorer, Moxilla Firefox
5. Adobe Acrobat Reader

NUMBER AND PLACES OF MEETING (ONLINE, FACE-TO-FACE, LABORATORY PRACTICALS)

The details of these will be provided to you at the time of commencement of this course

DISCUSSION FORUM

There will be an online discussion forum and topics for discussion will be available for your contributions. It is mandatory that you participate in every discussion every week. Your participation links you, your face, your ideas and views to that of every member of the class and earns you some mark.

COURSE EVALUATION

There are two forms of evaluation of the progress you are making in this course. The first are the series of activities, assignments and end of unit, computer or tutor-marked assignments, and laboratory practical sessions and the report. These constitute the continuous assessment that all carry 30% of the total mark. The second is a written examination with multiple choice, short answers and essay questions that take 70% of the total mark that you will do on completion of the course.

Students' evaluation: The students will be assessed and evaluated based on the following criteria:

In-Course Examination: In line with the university's regulation, in-course examination will come up in the middle of the semester These would come in form of Computer Marked Assignment. This will be in addition to 1compulsory Tutor Marked Assignment (TMA's) and three Computer marked Assignment that comes after every module….. o Laboratory practical: Attendance, the record of participation and other assignments will be graded and added to the other scores form other forms of examinations.

Final Examination: The final written examination will come up at the end of the semester comprising essay and objective questions covering all the contents covered in the course. The final examination will amount to 60% of the total grade for the course.

Learner-Facilitator evaluation of the course

This will be done through group review, written assessment of learning (theory and laboratory practical) by you and the facilitators.

GRADING CRITERIA

Grades will be based on the following Percentages

Tutor Marked Individual Assignments	10%	
Computer marked Assignment	10%	
Group assignment	5%	30%
Discussion Topic participation	5%	
Laboratory practical	10%	
End of Course examination	70%	

GRADING SCALE

A = 70-100

B = 60 - 69

C = 50 - 59

F = < 49

SCHEDULE OF ASSIGNMENTS WITH DATES

To be provided for each module by the facilitator in addition to the ones already spelt out in the course materials.

SPECIFIC READING ASSIGNMENTS

To be provided by each module

COURSE OVERVIEW NSC 222 - Human Physiology (II)

This course is in continuation of NSC 221, Human Physiology (I) where we covered the functional cell, cardio-vascular/cardio-pulmonary physiology. In this course we would cover respiratory and gastrointestinal physiology. Respiration is the commonly acknowledged sign of life.

HOW TO GET THE MOST FROM THIS COURSE

1. Read and understand the context of this course by reading through this course guide paying attention to details. You must know the requirements before you will do well.
2. Develop a study plan for yourself.
3. Follow instructions about registration and master expectations in terms of reading, participation in discussion forum, end of unit and module assignments, laboratory practical and other directives given by the course coordinator, facilitators and tutors.

4. Read your course texts and other reference textbooks.
5. Listen to audio files, watch the video clips and consult websites when given.
6. Participate actively in online discussion forum and make sure you are in touch with your study group and your course coordinator.
7. Submit your assignments as at when due.
8. Work ahead of the interactive sessions.
9. Work through your assignments when returned to you and do not wait until when examination is approaching before resolving any challenge you have with any unit or any topic.
10. Keep in touch with your study centre, the NOUN, School of Health Sciences websites as information will be provided continuously on these sites.
11. Be optimistic about doing well.

MAIN COURSE

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MODULE 1 GASTROINTESTINAL PHYSIOLOGY

UNIT 1 ORGANIZATION AND SECRETIONS OF THE GASTROINTESTINAL TRACT

CONTENT

1.0 INTRODUCTION

Beyond air exchange, the body depends on nutrients that should be taken, digested and absorbed to supply energy and other micronutrients needed. This module covers the organization of the gastrointestinal system, the secretions, the hormones and the processes of digestion and absorption.

Digestion is defined as the process by which food is broken down into simple chemical substances that can be absorbed and used as nutrients by the body. Most of the substances in the diet cannot be utilized as such. These substances must be broken into smaller particles so that they can be absorbed into the blood and distributed to various parts of the body for utilization. Digestive system is responsible for these functions. The gastrointestinal system performs digestive functions that provide the nutrients needed for energy and other organic functions. The GIT system is organized with different organs that also allow for the control release of contents through sphincters. In this unit, you will learn about the organization and the functions of some of the organs in the GIT.

2.0 OBJECTIVE

By the end of this unit, you will be able to:

- explain the Organization of the gastrointestinal tract GIT
- describe the sphincters in the GIT
- describe the salivary glands and the secretions.
- describe other secretions (pancreatic, intestinal, gall bladder) of the GIT and their functions.

3.0 MAIN CONTENT

3.1 Organization of the gastrointestinal tract

The gastrointestinal system includes alimentary canal, extending from pharynx to anus and accessory organs like salivary gland, liver and pancreas. Figure 1 shows the entire alimentary tract.

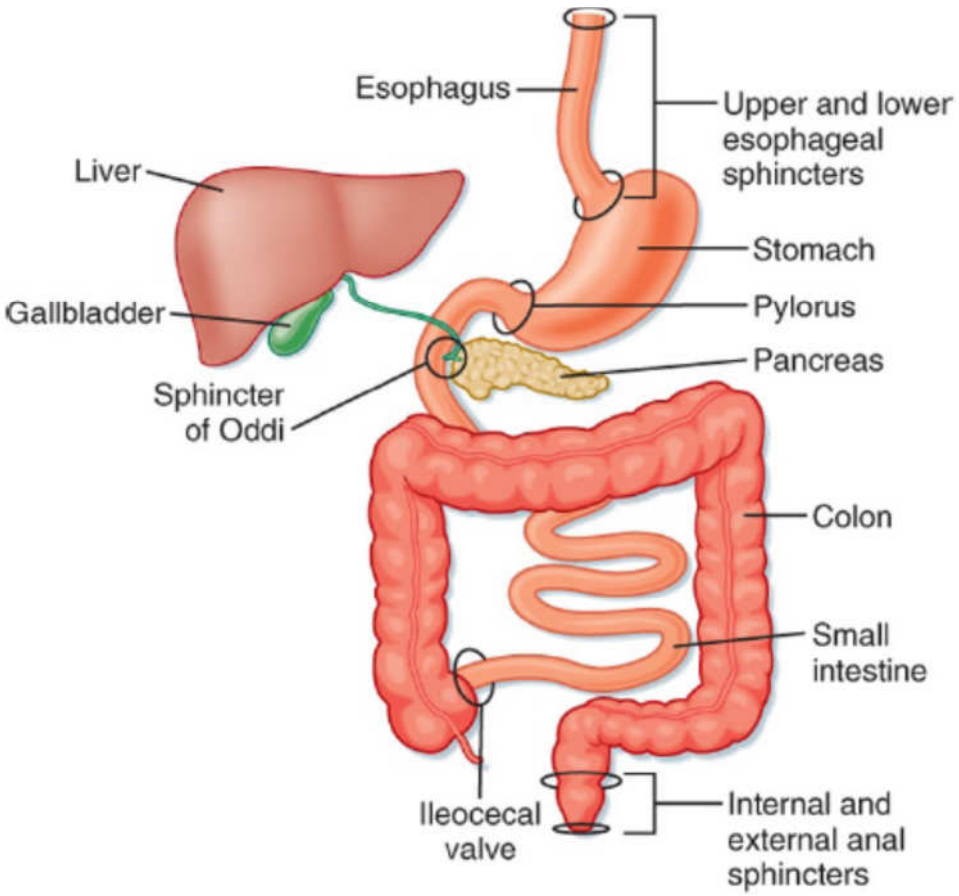

Figure 1: The Alimentary tract

Organizational structure

The digestive tract includes the mouth, pharynx, esophagus, stomach, small intestine, large intestine, rectum and anus. The histology is similar in all parts except the esophagus and the anus where serous attachment is not present.

Figure 2 shows a typical cross-section of the intestinal wall. The basic structures include: (i) serous coat (ii) muscular layer – longitudinal and circular layer (iii) sub-mucosa (iv) Mucosa

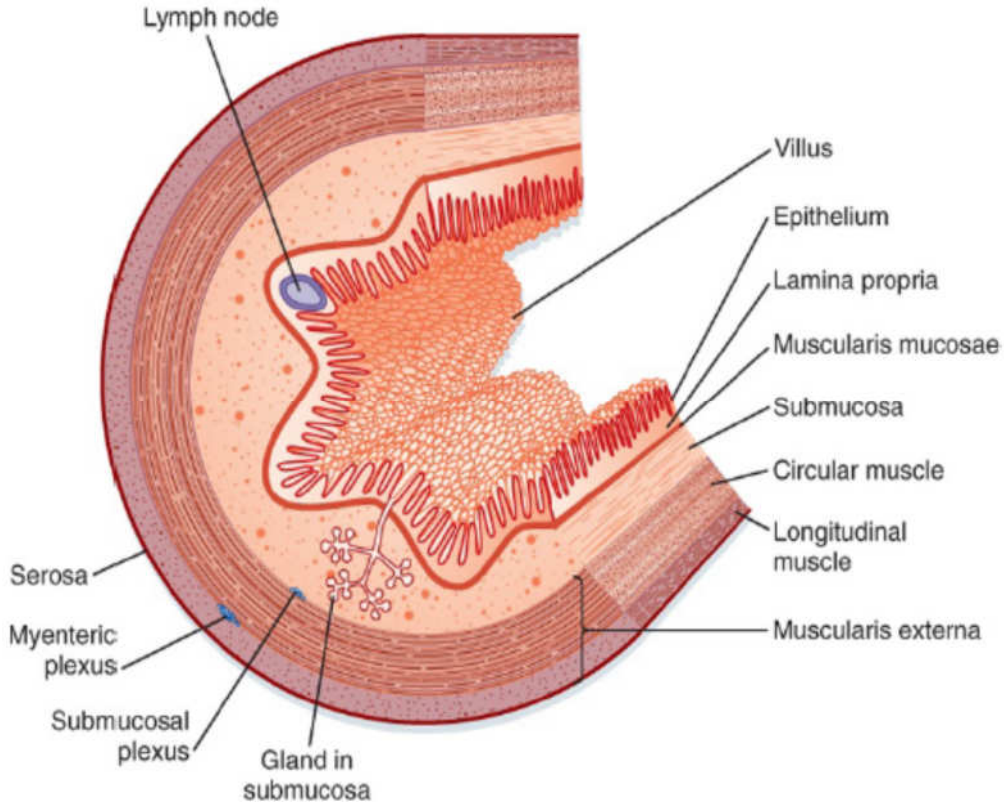

Figure 2: Typical cross section of the gut

Innervation

The wall of gastrointestinal tract (GIT) has intrinsic nervous system (enteric nervous system) beginning from the esophagus extending down the anus. It is composed mainly of two plexus.

1. The outer one lies between the longitudinal and circular layer and is called Auerbach's or Myenteric plexus.
2. submucosa plexus or Meissner's plexus lies in the submucosa layer.

The myenteric plexus control GIT movement. It is sensitive to stretch while the submucosal or meissner's control secretion and local blood flow. It is sensitive to osmolar changes, pH changes and chemical composition of food. The enteric nervous system can function on its own,

independently of the extrinsic nerves supply to the gut. The extrinsic innervation can modify the activity of the enteric nervous system. The extrinsic supply comes from the autonomic nerves. The sympathetic fibres gives relaxation of smooth muscle and vasocontraction of smooth muscle, vasodilation and secretion of the digestive juice.

3.2 The sphincters

The alimentary tract is divided into functional compartment by sphincter. They include:

i. Upper esophageal sphincter
ii. Lower esophageal sphincter
iii. Pyloric
iv. Sphincter of Oddi
v. Ileocecal sphincter
vi. Internal sphincter (smooth muscle/involuntary)
vii. Outer sphincter (skeletal muscle/voluntary)

Characteristics of sphincters

i. They have high tension/pressure area. The tensions within the sphincter are very high.
ii. The resting tone is greater than the other two adjacent segments which result in intraluminal high pressure zone that separate the two lumen to compartments.
iii. It relaxes in response to appropriate stimulus, so that flow may occur from one compartment to the next.
iv. It regulates or maintains aurocaudal (mouth to anus) flow of GIT contents

Functions of sphincters

i. The upper esophageal sphincter prevent air into the esophagus during respiration.
ii. The lower esophageal sphincter prevents irritant gastric from refluxing into the esophagus
iii. The pyloric sphincter separates the acidic environment of the stomach from the alkaline environment of the duodenum.
iv. The ileocecal sphincter separates ileum from the cecum, disallowing the faeces in the cecum from refluxing back into the ileum.
v. The sphincter of Oddi allows intermittent flow of pancreatic secretion and bile.
vi. The internal sphincter has smooth muscle and it shows involuntary movement of defecation, while the outer anal sphincter has skeletal muscle and shows voluntary movement.

3.3 Salivary glands and Secretions

The digestive secretion in the mouth comes from salivary gland. There are three major salivary glands.

i. Parotid (behind the tongue)

ii. Submaxillary (Submandibular)

iii. Sublingual

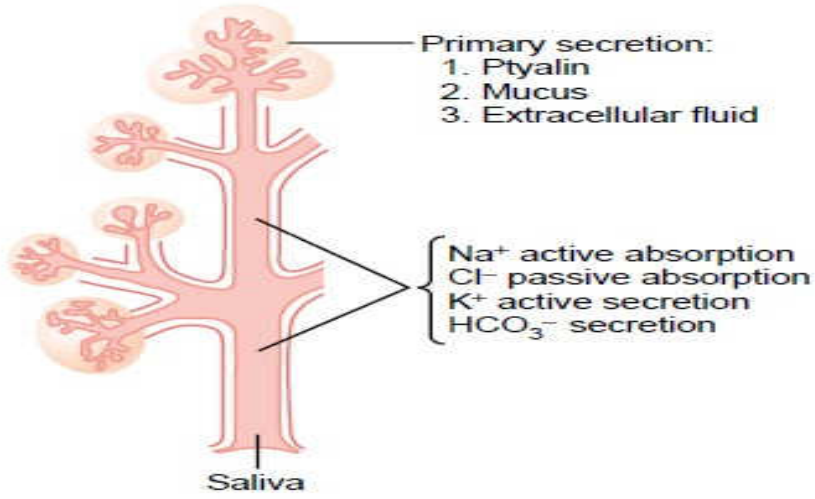

Figure 3: Formation and secretion of saliva by a submandibular salivary gland

They are exocrine glands. Each has acini and duct cells. In the acini, two types of secreting cells have being found:

i. Serous secretion containing an alpha-amylase; this is the enzyme for the digestion of starches.

ii. A mucous secretion, containing mucin, which is important for lubrication purposes There is also lingual lipase, secreted by the Ebner's glands. The parotid glands produce entirely the serous type of secretion; the submandibular glands secrete both the serous and mucous types and the sublingual produce only the mucous type of secretion.

The submaxillary produces 10% secretion, sublingual produced 5% secretion and parotid produced 25%.

Innervation

The salivary glands are supplied by both sympathetic and parasympathetic nerves. The sympathetic action gives vasoconstriction which causes secretion to be viscous and scanty.

The parasympathetic effect causes vasodilation and causes copious secretion. The parasympathetic fiber of cranial nerve-7 supplies some submaxillary and sublingual and cranial nerve-9 supplies the parotid gland.

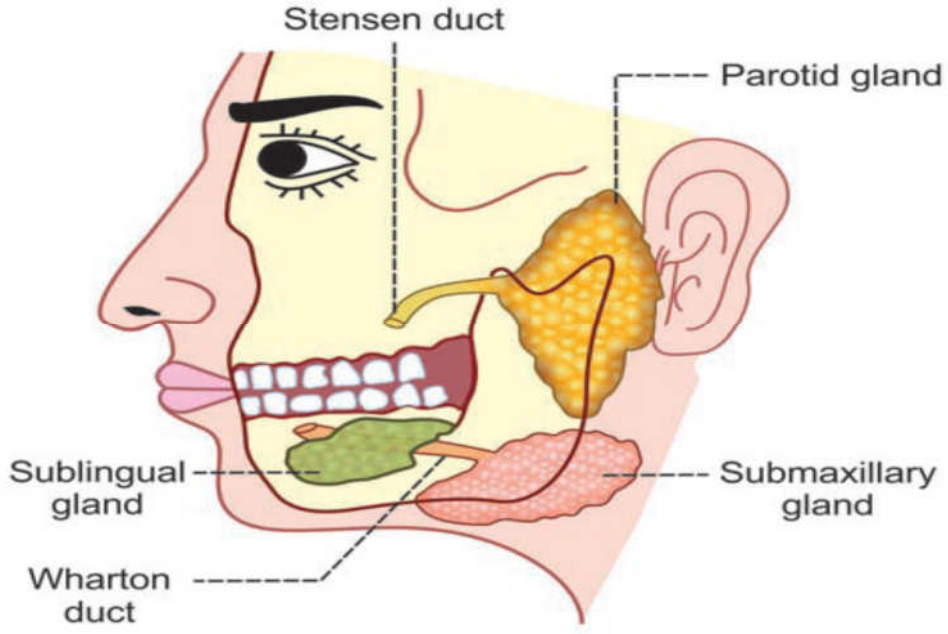

Figure 4: Major salivary glands

The parasympathetic is mediated via the release of acetylcholine that can be blocked by atropine.

Composition of saliva

i. The secretion of saliva per day ranges from 1000 ml- 1500ml.
ii. It has a pH of 6.8 which ranges from 6.7- 7.
iii. It contains 99.5% water and 0.5% solid

The solid consists of organic and organic substances. The major inorganic constituent are: Na^+, K^+, Cl^-, HCO_3^-, Ca^{++} and Mg^{2+}.

The organic substances include the enzyme- α- amylase, mucin, lysozymes, IgA, blood group antigens, urea, uric acid, etc.

Duct cells function

The saliva in the duct is isotonic while the saliva in the mouth is hypotonic. This is due to the change that takes place in the lumen of the ducts. The duct-epithelial cell shows active reabsorption of sodium ion in exchange for potassium ion. There is also reabsorption of Cl^- in exchange for HCO_3^- since the duct cells are impermeable to water, the removal of sodium and chloride ions makes the saliva to be hypotonic.

Aldosterone which is a mineralocorticoid acts on salivary duct to cause sodium ion reabsorption in exchange for potassium ion.

The concentration of Na+ and K+ in saliva depends on flow rate. At high flow rate, less time is allowed for transfer of ions and hence Na+ is more than K+ but the saliva remains isotonic at a high flow rate.

Regulation of secretion

Salivary secretion is regulated mainly by neural mechanisms. It shows both conditional and unconditional reflexes.

Conditional reflex is established by learning, and the secretion can be seen from sight, smell and thought of food. Unconditional reflex comes from presence of food in the mouth.

The secretion of saliva in both sides of reflexes is caused by activity of parasympathetic nerves (VII) and (IX) supplying the glands.

Secretion is almost abolished (reduced) during sleep. There is a decrease in resting flow rate when there is dehydration, anxiety, fear and severe mental effort.

Functions of the saliva

i. The enzyme α- amylase acts on boiled starch and convert it to maltose. The beginning of carbohydrate digestion occurs in the mouth.
ii. The mucin present in the saliva lubricate the food which helps in mastication
iii. Saliva is necessary for swallowing
iv. Helps in taste perception of food materials by dissolving them
v. It facilitates speech. Speech is difficult in dry mouth
vi. Lysozymes and IgA present in the saliva gives birth to bactericidal and immunity functions respectively.
vii. It neutralizes the gastric acid that refluxes into the esophagus and release heart burn.

3.4 Gastric secretion

Gastric juice is secreted by gastric glands present in the gastric mucosa of fundus and body of the stomach. There are 3 types of cells namely:

i. Neck and surface epithelial cell that secrete mucous
ii. The chief cell that secretes enzyme
iii. Parietal or Oxyntic cells that secrete Hydrochloric acid (HCl) and intrinsic factors.

Composition of gastric secretion

The volume of secretion per day is about 2 liters and the pH varies between 1.8 – 2.0.

The inorganic constituents include Na+, Cl-, PO4-, K+ and SO4-. The organic substances present in the secretion are digestive enzyme (pepsinogen, renin, lipase), mucin and intrinsic factors.

Function of HCl (Hydrochloric acid)

The concentrated Hcl in the gastric juice is necessary to activate pepsinogen to pepsin, the extreme acidity is bactericidal. The acid pH in the upper part of duodenum facilitates ion absorption.

Function of gastric juice

The beginning of protein digestion takes place in the stomach. Pepsin acts on protein and convert it to peptone. The enzyme is secreted by chief cell as active pepsinogen.

Gastric renin: Is a milk curdling enzyme which is absent in human but present in cows.

Gastric lipase: Is a weak fat-splitting enzyme.

Intrinsic factor: Is secreted by the parietal cell of the fundus. It is required for the absorption of vitamin B12 (cyanocobalamin or extrinsic factor). The absorption of vitamin B12 occurs in the terminal ileum.

Mucus: Is secreted by surface epithelial cell and neck cell of the gland. The surface epithelial cell also secrete bicarbonates, the mucus and the bicarbonate form gel in the lining of the gastric mucosa. This gel protects the mucosa from the action of the acid. There is a pH gradient from the lumen to the mucosal wall of the stomach. The pH in the mucosal is 7 and that of the lumen is 2. The presence of HCO3- and mucus form the acid mucosa barrier.

Certain condition like chronic stress, alcohol and aspirin tends to arose the acid mucosa barrier.

Hydrochloric acid secretion

Hydrochloric acid (HCl) is the gastric juice secreted from the parietal cells. The secretion of Hcl is an active process and it is transported against the electrochemical gradient.

The concentration of Hcl in gastric juice is 150 mEq/L whereas it is 00004 mEq/L in plasma. The source of H+ is from the dissociation of H2CO3. The H2CO3 is formed from hydration of CO2 in the presence of carbonic anhydrase enzyme. Carbonic acid dissociates to H+ and HCO3-. The

hydrogen ion formed is exchanged with potassium ion and the transport carrier is H+- K+ ATPase. The energy released from the breakdown of ATP is utilized for the active transport of H+. Chloride ion is also actively transported from the cell into the lumen and coupled with H+ to form Hcl. The active transport of Hcl is followed by the passive transport of water into the lumen. The secretion of H+ leaves bicarbonate ion within the cell. The HCO3- combines with Na+ and enters the blood as NaHCO3. It is known during digestion, alkaline level in the blood and urine rise and it is called Postprandial alkaline tide.

Agents causing secretion of Hydrochloric acid

i. Gastrin is released from pyloric antrum
ii. Acetylcholine is secreted from the vagal ending iii. Histamine comes from enterochromaffin cell lining the mucosa When vagus is activated it releases acetylcholine. This stimulates the release of GRP (Gastric Releasing Peptide) followed by secretion of gastrin.

Vagal stimulation also causes the release of histamine. All these cause release of Hcl.

When there is peptic ulcer, treatment could be induced by inhibiting acid secretion, and this could be achieved from the following

i. Inhibiting H2 receptors by cimetidine
ii. Blocking hydrogen ion – potassium ion ATPase by omeprazole.

Regulation of gastric secretion

Gastric juice secretion is regulated by both neural and hormonal mechanisms. Neural regulation is mediated via the vagus. Acetylcholine is released by vagal ending. The acetylcholine activates phospholipase C which in turn raises intracellular Ca2+. The intracellular Ca2+ promotes the secretion of gastric juice. Hormonal regulation is by gastrin which is secreted from the pyloric antrum.

3.4.1 Phases of gastric secretion

There are 3 phases of gastric secretion: (1) Cephalic phase (2) Gastric phase (3) Intestinal phase

Cephalic phase

Conditional reflexes like sight, smell and thought of food causes secretion of gastric juice. The presence of food in the mouth also causes secretion in the stomach. The cephalic phase occurs by the activity of the vagus. Shaming-feeding experiments in animals like a dog gives an example of cephalic secretion. The quantity of juice secreted is small. The cephalic

phase accounts for about 10% of the total secretion associated with a meal.

Gastric phase

The gastric phase accounts for about 80% of the total secretion of gastric juice. This phase is initiated by the presence of food in the stomach. The food stretches the stomach wall and this distension stimulates the gastric glands via both the extrinsic (vagal) and intrinsic (nerve plexuses) reflex pathways to produce gastric juice. Distension of the pyloric antrum also results in the release of gastrin into the blood by an intrinsic reflex. In addition, some substances in the food, known as secretagogues, elicit release of gastrin by the intrinsic reflex. Such substances include meat extracts, protein digestion products, alcohol, bile acids and caffeine. During this phase, maximum secretion occurs.

Intestinal phase

The arrival of food and the product of digestion in the intestine also stimulates gastric secretion. The quantity produced is very small. However, the presence of food in the duodenum inhibits secretion of gastric juice. This inhibition is mediated through enterogastric reflex. The presence of acid and fat in the duodenum causes the release of secretin and cholecystokinin. Also, there is the release of VIP, GIP- all of which are enterogastrones. i.e. they cause inhibition of gastric secretion.

3.3 Pancreatic secretion

The pancreas has both exocrine and endocrine functions. The digestive enzymes are secreted from exocrine pancreas. The exocrine pancreas consists of acini and ducts.

Composition

About 1500 ml of pancreatic juice are secreted daily. Pancreatic juice is a watery alkaline fluid; isotonic with plasma and rich in digestive enzymes. The alkalinity is due to HCO3- secreted from the duct epithelial cells. Other inorganic substances are Na+, K+, Cl- and SO4-. The organic constituents includes: peptidase, amylase, lipase, nuclease.

Regulation of pancreatic secretion

The regulation is mainly from hormones. The 2 types of hormone regulating 2 types of secretion.

i. Secretin is produced by the duodenal mucosa. Presence of acid chyme in the duodenum is the main stimulus resulting in secretion of watery fluid which in bicarbonate that helps to neutralize the acid pH.

ii. Cholecystokinin (CCK) causes secretion of the pancreatic juice which in digestive enzymes. It also acts on the gut bladder. Stimulus is product of food digestion entering the duodenum.

3.5 Bile

Bile is secreted by the liver cells (liver lobules) and stored in the gallbladder. Secretion of bile The volume secreted per day is 500-700 ml, and secretion occurs when chyme enters the duodenum. PH is 7.6-7.8. \

Composition of bile

Bile released from the gall bladder into the duodenum has the following composition. Water - 92%

Bile Salts - 6%

Bilirubin - 0.3%

Cholesterol – 0.3%

Fatty acids - 0.3%

Lecithin – 0.3%

Other lipids – 0.2%

Na+ - 130mEq/L

K+ - 12mEq/L

Ca2+ - 23mEq/L

Cl- - 25mEq/L

HCO3- - 10mEq/L

BILE SALTS

They are secretory products of the liver. They are formed from cholesterol which gives rise to primary bile acid which becomes conjugated into Na+ and K+ to form taurocholate and glucocholate.

Formation of bile salts

Bile salts are formed from bile acids. There are two primary bile acids in human, namely cholic acid and chenodeoxycholic acid, which are formed in liver and enter the intestine through bile. Due to the bacterial action in the intestine, the primary bile acids are converted into secondary bile acids:

Cholic acid → deoxycholic acid

Chenodeoxycholic acid → lithocholic acid

Secondary bile acids from intestine are transported back to liver through enterohepatic circulation. In liver, the secondary bile acids are conjugated with glycine (amino acid) or taurin (derivative of an amino acid) and form conjugated bile acids, namely glycocholic acid and taurocholic acids. These bile acids combine with sodium or potassium ions to form the salts, sodium or potassium glycocholate and sodium or potassium taurocholate

Functions of bile salts

Bile salts are required for digestion and absorption of fats in the intestine. The functions of bile salts are:

1. Emulsification of Fats
2. Absorption of Fats
3. Cholagogue Action
4. Choleretic Action
5. Laxative Action
6. revention of Gallstone Formation

Bile pigments

Bile pigments are the excretory products in bile. Bilirubin and biliverdin are the two bile pigments and bilirubin is the major bile pigment in human beings. Formation of bile salts Bile pigments are formed during the breakdown of hemoglobin, which is released from the destroyed RBCs in the reticuloendothelial system.The breakdown of haemoglobin gives rise to bilirubin and biliverdin which are bile pigment. They are excretory products of the liver. The golden yellow of the bile is due to the presence of the pigment.

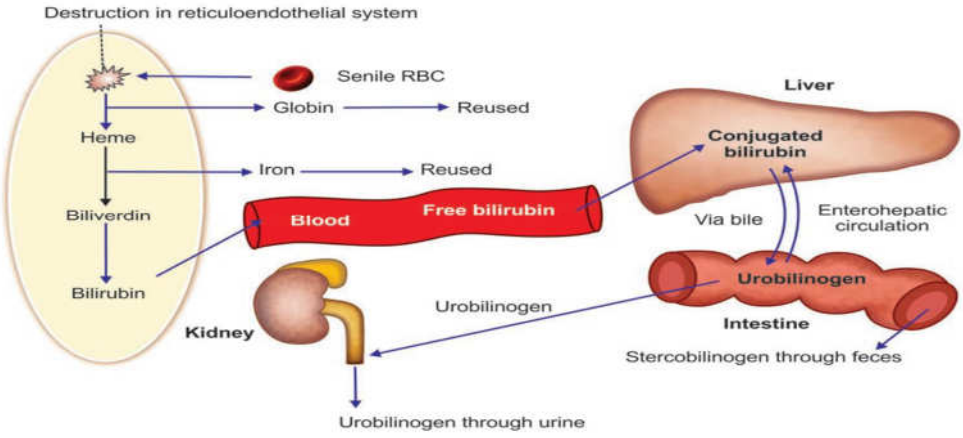

Figure 5: Formation and circulation of bile pigments

Phospholipids

Lecithin is the chief phospholipids present in the bile. It is insoluble in water. It becomes solubilized in micelles.

Cholesterol

Cholesterol in bile is solubilized in micelles. The presence of bile salt keeps cholesterol in solution and prevents its precipitation to form stones.

Functions of the bile

Digestion and absorption of fats and fat soluble vitamins (ADEK) depends on presence of bile.

The fat is lipid soluble while the digestive enzyme lipase is enzyme soluble.

To facilitate the action of lipase on lipids, bile shows the following effects:

i. The bile produces emulsification of fat. By this, large molecules are broken down into smaller ones.
ii. They show hydrotropic effects. This action of bile enables lipase enzyme to digest the fat. iii. Bile reduces surface tension. This effect facilitates the lipase enzyme action.

i. The micelles that is formed after digestion promotes absorption. The micelles consist of digested glycerides combined with bile.

FUNCTIONS OF BILE

Most of the functions of bile are due to the bile salts.

1. digestive function
2. absorptive functions
3. excretory functions
4. laxative action
5. antiseptic action
6. choleretic action
7. maintenance of ph in
8. prevention of gallstone formation
9. lubrication function
10. cholagogue action

ENTEROHEPATIC CIRCULATION

The bile salts that are secreted into the duodenum are reabsorbed and recirculated. About 90% of the bile salt that enter the small intestine are absorbed from the terminal ileum, and enter the liver through the portal

circulation. From the liver, it is recirculated into the duodenum; this forms enterohepatic circulation.

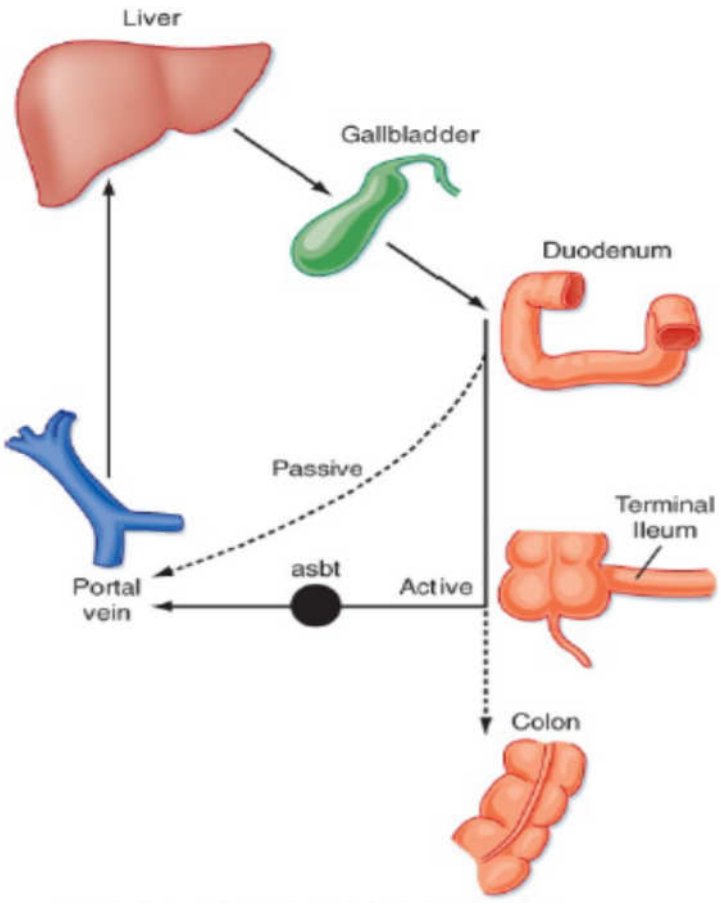

Figure 6. Enterohepatic circulation of bile acids

The bile salts in circulating pool are only 3-6gm but the quantity required for digestion is 4—8 gram. Normal digestion and absorption of fat can take place by recirculation. The total circulating pool circulate twice during digestion of each meal.

The rate of synthesis depends on the rate of returns to the liver. About 0.2 gm/day of bile is lost in faeces.

Any condition that affects enterohepatic circulation and decrease bile pool and causes mal absorption of bile and fat soluble vitamins may result in steatorrhea.

Regulation of bile

Bile secretion is regulated by hormones. There are 2 mechanisms:

i. Hormone secretin produced from duodenum when acid chyme enters acts on the biliary duct cells to increase secretion of water and electrolytes which helps to neutralize the acid chyme, and this action is known as hydrocholeretic effects.

   a. The bile salt in the bile causes stimulation of the liver to secrete more bile. This action is called choleretic effect.

ii. Hormone cholecystokinin (CCK) also acts on gall bladder smooth muscle causing contraction and expulsion of bile. This action of CCK on gall bladder is called chologugue effect.

Gall bladder

Gall bladder stores, releases and makes the bile into concentration by active reabsorption of Na+ and HCO3-, passively by the reabsorption of water.

Gall stones

There are 2 types of gall stone- cholesterol stone and pigment stone.

Normally, cholesterol and lecithin are found in solution by the formation of micelles. When there is alteration in concentration, cholesterol crystallizes to form stones. Cholesterol stones are radiolucent.

Pigment stones are formed due to infection or obstruction of the biliary tree. The conjugation of bilirubin makes it insoluble resulting in precipitation. Pigment stones are radiopaque.

Intestinal secretion

The small intestine consists of duodenum, jejunum, and ileum. The small intestinal secretion is mainly water, mucus and electrolytes. It is alkaline in nature and ranges between 10001500ml/day. Digestive enzymes are not secreted into the lumen, they are present in the apical surface of the villi. At the base of the villi are glands called Crypts of Lieberkuhn which contains cells that secrete mucus. The intestinal gland of the duodenum are called Brunner's gland which also secrete mucus. The mucus secreted by the Brunner's gland provides protection to the mucosa lining against mechanical damage and also lubricate the mucosa lining.

Regulation of intestinal secretion

Regulation is neural and hormonal. Vagal stimulation during digestion causes secretion of intestinal hormones. Vasoactive intestinal peptide (VIP) hormones increase secretion of intestinal glands. The most important is the local enteric nervous system.

4.0 CONCLUSION

The gastrointestinal system performs digestive functions that provide the nutrients needed for energy and other organic functions. The GIT system is organized with different organs that also allow for control release of contents through sphincters.

5.0 SUMMARY

In this unit, you have learnt about the organization of the gastrointestinal tract and the various sphincters with different characteristics and functions. You have also learnt that the salivary glands of different types produce secretions that also perform digestive functions. Gastric, pancreatic, gall bladder secretions also perform different functions.

6.0 TUTOR-MARKED ASSIGNMENT

Activity: - See Laboratory manual and the experiments on gastrointestinal system.

Please answer the following questions:

1. Describe the organization of the gastrointestinal tract
2. Describe the sphincters in the GIT
3. Explain what gastric secretion is and list its major composition
4. Describe the three phases of gastric secretion
5. Discuss the pancreatic secretion and its major composition
6. Describe the composition and functions of the bile.

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UNIT 2 GASTROINTESTINAL MOTILITY

CONTENT

1.0 INTRODUCTION

The physical activity of processing the food items from the point of entry to the point of eliminating the waist takes a course in gastrointestinal motility. This unit traces these actions from the mouth to the anus.

2.0 OBJECTIVE

By the end of this unit, you will be able to:

- explain the term, Gastrointestinal motility
- describe the act and use of Mastication (Chewing)
- describe the process of Swallowing (Deglutition)
- list the functions of the stomach
- describe the act of Gastro-intestinal motility
- describe the process of Defeacation.

3.0 MAIN CONTENT

3.1 Gastrointestinal motility

The main function of the alimentary tract is to ingest, digest and absorb food materials. For this to be carried out, appropriate mixing must be provided. The mixing/propulsion are different at each compartmental stage of the tract. It requires both neural and hormonal mechanisms.

i. Mastication (Chewing)
ii. Swallowing (Deglutition)
iii. Gastric motility
iv. Motility of the small intestine
v. Motility of the colon

vi. Defeacation (passage of faeces)

3.2 Chewing

Chewing is the process by which food brought into the mouth is broken down into smaller pieces by the teeth. In the process, the food is mixed with saliva. Chewing makes it easier to swallow the food and contributes to its enjoyment by homogenizing and mixing the food with saliva, thus releasing taste-producing substances. Chewing can be carried out voluntarily, but is more frequently a reflex activity. By subdividing the food into smaller particles, chewing makes it possible for the food to mix more readily with digestive secretions of the stomach and duodenum. The tongue and the cheek muscles are used to keep the food mass between the teeth during mastication.

3.3 Deglutition (Swallowing)

It refers to the act of swallowing. It consists of oral, pharyngeal and esophageal stages. The 1st stage is voluntary, the 2nd and 3rd stages are involuntary and reflex in nature.

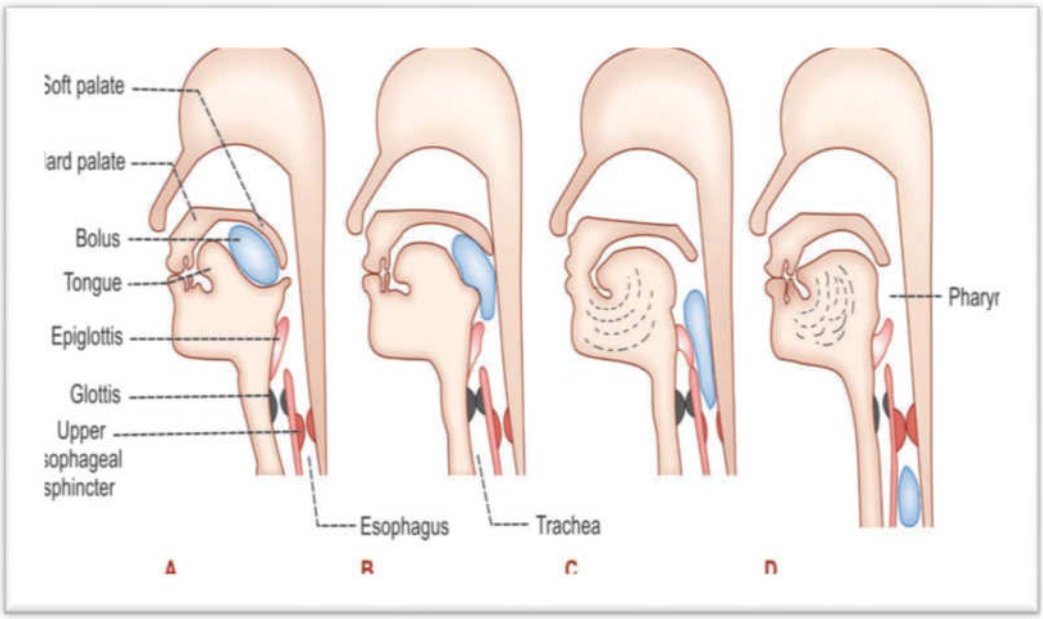

Figure 1: Stages of deglutition. A. Preparatory stage; B. Oral stage; C. Pharyngeal stage; D. Esophageal stage

Oral stage

It is voluntary. The food is masticated by mixing with saliva. The solid food is converted to a soft bolus and positioned in the dorsum of the tongue. In this stage, the bolus passes through the oral cavity toward the pharynx assisted by the tongue pressing against the hard palate.

Pharyngeal stage

The presence of food at the entry of the pharynx stimulates receptors in the tonsil and epiglottis which initiate the reflex. This stage is involuntary: the efferent and afferent impulses are carried by cranial nerves V, IX, X and XII.

The center is the swallowing center located in the medulla and the lower pons. This reflex allows the bolus to enter the esophagus and not the trachea. The entry of the bolus into the nasopharynx is prevented by:

i. The soft palate raises and presses against the posterior pharyngeal wall.
ii. There is an upward and forward movement of the larynx which causes the glottis approximately with the epiglottis and seal with the larynx. The vocal cord also approximately inhibiting speech.
iii. There is ceasation of respiration at this stage. The bolus is therefore directed at the esophagus. Esophageal stage

The bolus enters the esophagus from the pharynx through the upper esophageal sphincter and enters the stomach through the lower esophageal sphincter.

Entry of food bolus causes distension and relaxation of upper esophageal sphincter. This is as a result of inhibition of the vagus nerve. This distension initiate a wave of peristalsis which spread along the length of esophagus pushing the bolus forward. These are: primary peristalsis wave travelling at 3-4cm/sec (frequency). The force of gravity helps the wave of movement. Liquid travels faster than solid to reach the stomach. When the bolus reaches the lower esophageal sphincter, it relaxes and allows the bolus to enter the stomach, after which it closes to prevent regurgitation into the esophagus; this action is regulated by the myenteric plexus which secretes VIP or NO (nitric oxide). If the primary peristalsis does not completely empty the esophagus, one or more secondary peristalsis arises from distal part of esophagus.

Disorders of swallowing

1. Dysphagia - difficulty in swallowing
2. Achalasia – difficulty in emptying the food from the esophagus to stomach due to absence of peristalsis in the lower 3rd or failure of cardiac sphincter to relax.

3.4 Gastric motility Functions of the stomach

i. Storage organ: stomach can store large quantity of food, as it shows receptive relaxation.

ii. Beginning of protein digestion by pepsin occurs in the stomach.
iii. It makes food into chyme by propulsive, mixing and retropulsive movement.
iv. The acid in the stomach has bactericidal effect. The gastric secretion has intrinsic factor which is necessary for absorption of vitamin B12.
v. The acid in the stomach convert cane sugar to fructose and glucose. The acid in chyme in the duodenum facilitates iron absorption.

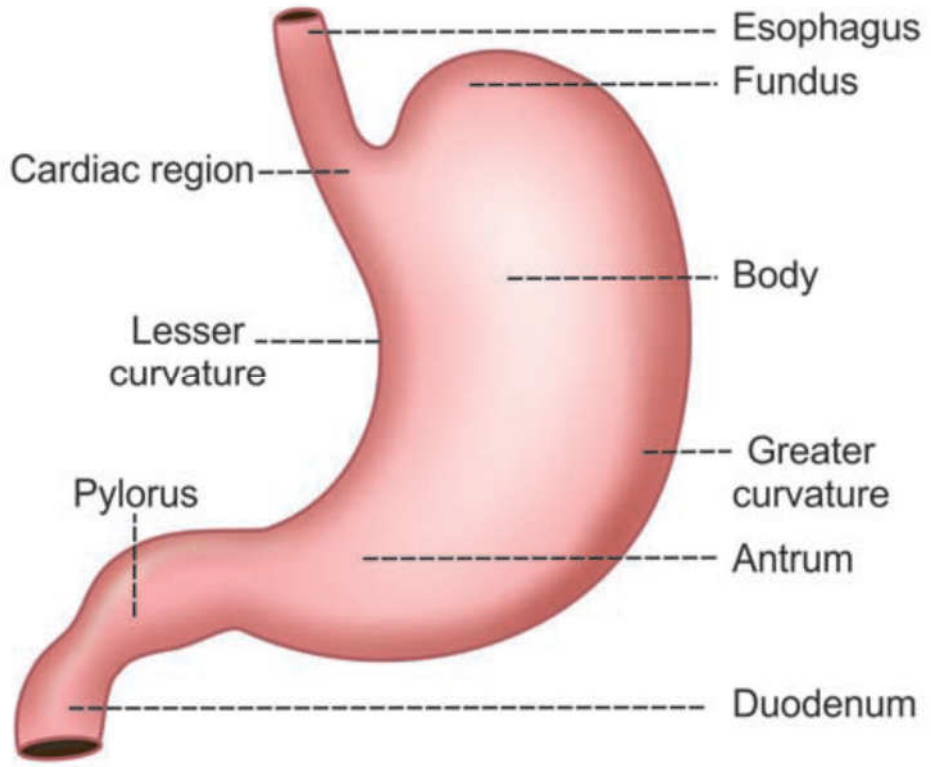

Figure 2: Physiologic anatomy of the stomach

Movement in the stomach Receptive relaxation

The stomach shows receptive relaxation, accommodating large volume of food. The receptors for this are present in the wall of pharynx and the stomach. The food is stored in the fundus and the body. The afferent and efferent are the vagus. It causes the plexus to secrete VIP. Vagotomy does not completely abolish reflective relaxation, it only decreases it.

Digestive peristalsis (Mixing of food)

The distal part of the stomach shows peristalsis. The distension of the wall of the distal part (antrum) stimulates intrinsic plexus. The smooth muscle first shows slow waves which is not propagatory, and it's called basal electrical rhythm (BER). The membrane potential reaches the threshold level of pharynx. The entry of Na+ and Ca2+ causes depolarization, resulting in spike potential (action potential) which is

propagatory and forms peristalsis. Peristalsis consists of wave of contraction followed by relaxation frequency of which is 3/min.

When the food reaches the pyloric sphincter, it retropul back to the antrum because the pyloric sphincter is closed. The propulsion, mixing and retropulsion in the pyloric breaks down the food to chyme and helps through mixing by the gastric juice. Each time the peristalsis arises at the sphincter, only 2-3 ml is empty to the duodenum.

Gastric emptying

Gastric emptying occurs mainly due to gastroduodenal plexus cycle caused by digestive peristalsis of the stomach. The transit time for the gastric empty of the food is 3-4 hrs.

As peristalsis reaches the sphincter, the chyme is retropuls allowing only small quantity (2-3 ml) to emptied into the duodenum and closes back.

Factors influencing emptying

Liquid leaves the stomach earlier than solid. Carbohydrate empty faster than protein and fat is emptied last. Increase in acid pH inhibit emptying. Isotonic leaves earlier than hypo or hypertonic fluids.

Enterogastric reflex

Presence of fats, acid or hyper osmolar solution in the duodenum inhibit gastric emptying. Other duodenal factors include:

i. The degree of distension of duodenum
ii. Presence of any degree of irritant in the duodenal mucosa
iii. Degree of acidity in the duodenal chyme
iv. Degree of osmolarity of the chyme

The inhibition is mediated by neural and hormonal mechanisms. The neural involves the inhibition of the vagus while hormonal mechanism includes release of secretin, VIP, CCK and GIP; these hormones inhibit gastric motility.

3.5 Motility of the small intestine

The movement that are seen in small intestine are as follows:

1. Segmental contraction
2. Peristalsis contraction
3. Pendular contraction
4. Villi movement

Segmental contraction

The frequently occurring movement in the small intestine is the segmental contraction. Slow waves develop in the circular smooth muscle of the wall due to stimulation of the plexus. When the slow wave reaches threshold, segmental contraction that is propagatory develops. The frequency of the slow wave is highest in the duodenum (12/min) and lowest in the ileum (8/min). This facilitates the bolus to be propelled aborally. The segmental contraction involves ring-like regular constriction along the length of the segment of the intestine. The constricted part latter relaxes and the relaxed part constrict. This process is repeated over and over again resulting in the bolus moving back and forth within the lumen.

Functions of segmental peristalsis are as follows:

i. Bolus mixes well with digestive enzymes and facilitate completion of digestion
ii. The segmental contraction causes exposure of digested food to the villi surface for absorption
iii. The occurrence of segmental contraction in the proximal segment and inhibition in the distal segment facilitate propulsion of bolus toward the segment colon.

Peristalsis contraction

Sometimes the longitudinal muscle contraction gives pendular contraction which facilitates mixing of bolus with digestive enzymes.

Villi movement

There is contraction of the smooth muscle of the villi that results into forward and backward movement. The hormone- villi kinin stimulates the movement which facilitates absorption of digested food.

Gastroileal reflex

Distension of the stomach by food causes relaxation of ileocecal sphincter and allows emptying of the ileal content into the caecum. Distension of the ileum will also cause the relaxation of the sphincter and emptying. On the other hand, the distension of the caecum will result in contraction of the caeca and prevent reflux of the caecal content into the ileum. This is facilitated by the ileocecal valve. The activity of the ileocecal sphincter is controlled by the myenteric plexus.

Functions of the small intestine

i. It contains pancreatic bile and intestinal secretion

ii. Completion of digestion and absorption of digested food occurs in the small intestine
iii. Presence of villi facilitates absorption of digested food iv. The duodenal mucosa secretes gastrointestinal hormones like secretin, CCK, VIP, motilin, etc.
v. Payer's patches in the ileum are lymphoid organs which help in immunity.

Migrating motor complex

It is an interdigesting peristalsis occurring in the stomach and small intestine. It occurs in between meal at every 70-90 mins interval. Each peristalsis last 10mins. It is developed due to activity of intrinsic myenteric system. It helps in sweeping the content of the stomach and small intestine towards colon toward interdigestive period. Motilin is the hormone responsible.

The large intestine

It includes the caecum, ascending colon, transverse colon and descending or sigmoid colon, rectum and anus.

The mucosa secretes mucus but there are no villi, hence no absorption of food, no digestive enzymes.

However, it has important functions:

i. Absorption of water and electrolytes
ii. Formation of faeces
iii. Secretion of mucus to lubricate the faeces
iv. The bacteria fluoride synthesis vit B and vit K.

Motility of the large intestine

i. The large intestine shows haustral shutting (segmental contraction)
ii. Mass peristalsis (contraction)
iii. Peristalsis

Haustral shutting

It is similar to segmental contraction of the small intestine. In the large intestine, the longitudinal muscle forming 3 bands taenia coli. The enteric plexus below this is greater and the region adjacent has a thin wall. It gives rise to sac-like pouches along the length of segment of the colon that are called haustrau.

The back and forth movement causes the chyme to be exposed for absorption of water and electrolytes. Out of 1,500ml of the mixed chyme

that enters the colon per day, all will be absorbed leaving 50-100ml in the faeces.

The haustral shutting also facilitate propulsive movement of the faeces to the distal colon. Transit time in the colon is very slow (5-10cm/hr).

Mass peristalsis

It occurs in a large segment of the colon, the contraction is powerful enough to cause the colon to be in contracted state for a long period. It is stimulated by myenteric plexus. The main function is to sweep the faeces along the segment of the colon.

The mass contraction occurs 3-5 times per day and usually lead to defeacation.

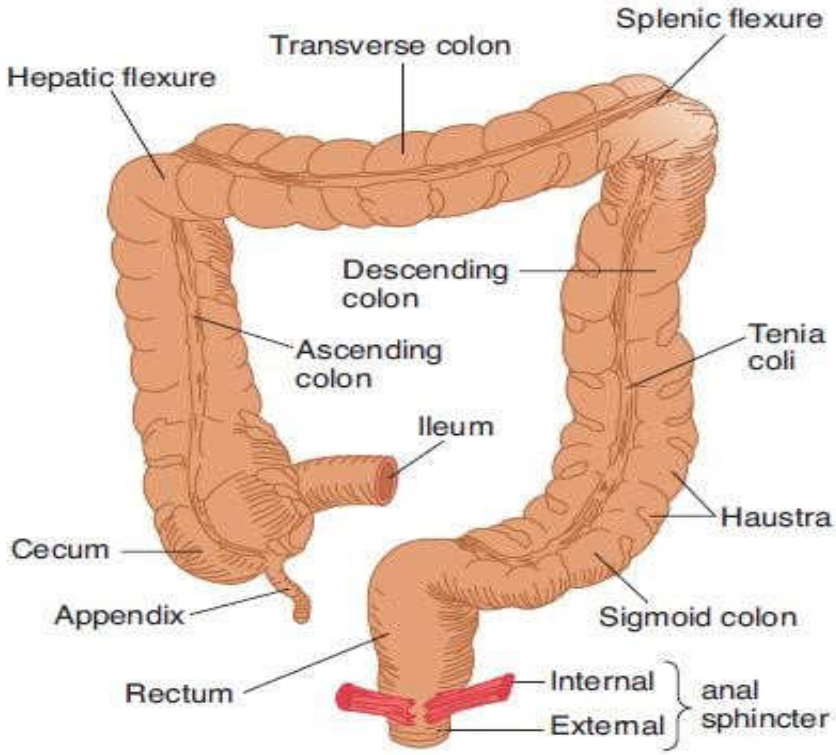

Figure 3: The human colon

3.6 Defeacation

Defeacation is the act of passing faeces. It is a complex behavior involving both reflex and voluntary actions. The rectum is normally empty. When faeces are pushed into the rectum by mass movements, the urge to defeacate is felt. The anal sphincters however prevent escape of faeces unless the individual is prepared for defeacation. There are two anal sphincters, the internal and the external sphincters. The internal sphincters consist of a circular smooth muscle that is in the anal wall, while the external sphincter consists of striated voluntary muscle that

surrounds the internal sphincter and also extends distal to it. The internal sphincter is supplied by parasympathetic nerves and the external sphincter, which is under voluntary control, is supplied by somatic nerves.

Act of defecation

Act of defecation is preceded by voluntary efforts like assuming an appropriate posture, voluntary relaxation of external sphincter and the compression of abdominal contents by voluntary contraction of abdominal muscles. Usually, the rectum is empty. During the development of mass movement, the feces is pushed into rectum and the defecation reflex is initiated. The process of defecation involves the contraction of rectum and relaxation of internal and external anal sphincters. Internal anal sphincter is made up of smooth muscle and it is innervated by parasympathetic nerve fibers via pelvic nerve. External anal sphincter is composed of skeletal muscle and it is controlled by somatic nerve fibers, which pass through pudendal nerve. Pudendal nerve always keeps the external sphincter constricted and the sphincter can relax only when the pudendal nerve is inhibited.

The process of defeacation can be subdivided into main components:

i. The part under the defeacation reflexes
ii. The part under voluntary control

The defeacation reflexes

There are two types of defeacation reflexes

i. The intrinsic defeacation reflex

ii. The parasympathetic defeacation reflex

The intrinsic defeacation reflex is mediated via the myenteric plexuses. When faeces enter the rectum, distension of the rectal wall initiate peristaltic waves via a local reflex circuit and these peristaltic waves spread to the descending colon, sigmoid colon and rectum forcing faeces towards the anus. As the peristaltic waves approach the anus, the internal and external relaxes. If the external sphincter is also relaxed, defeacation will occur. The peristaltic waves produced by the intrinsic defeacation reflex is usually weak and may not be effective in causing defeacation. This weak contraction is often reinforced by contractions mediated by the parasympathetic defeacation reflex, which involves parasympathetic nerves in the sacral segment of the spinal cord. These parasympathetic impulses augment the ineffectual weak movements produced by the intrinsic defeacation reflex so that they become powerful and effective in emptying the bowel.

In spite of the two reflexes above, defeacation can only occur if the circumstance is socially acceptable for the act. The ability not to defeacate in some circumstances is due to the fact that the conscious mind takes over voluntary control of the external sphincter. Relaxation of the internal sphincter and forward movement of the faeces towards the anus normally cause an instantaneous contraction of the external sphincter. Impulses from the cerebral cortex which pass through the somatic nerves to the external sphincter will either inhibit the sphincter to allow defeacation to occur or further contract it if the circumstance is not conducive to defeacation.

When the circumstances are right for defeacation to occur, the defeacation reflex is followed by relaxation of the external anal sphincter. Intra-abdominal pressure is elevated to aid in the expulsion of faeces. Evacuation is normally preceded by a deep breath, so that the diaphragm descends towards the abdominal cavity. The glottis is closed and contraction of the respiratory muscles on full lungs raises both the intrathoracic and intra-abdominal pressure. Contraction of the muscles of the wall of the abdomen causes a further increase in intra-abdominal pressure. The additional pressure generated by this bearing down effort as well as the strong contractions of the defeacation reflex helps to force faeces out of the anus through the relaxed sphincters.

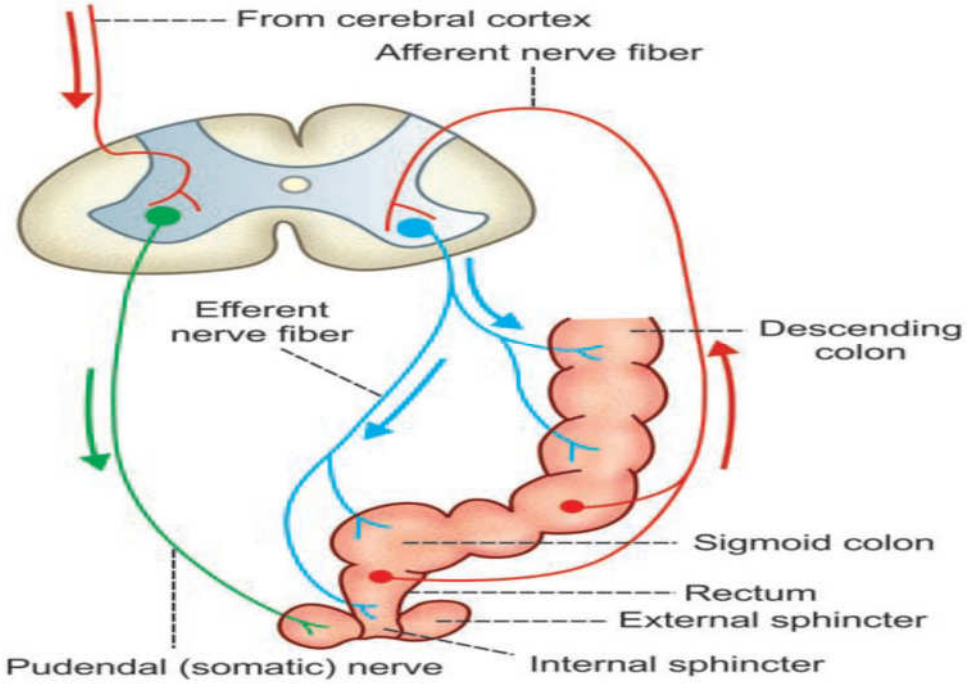

Figure 4: **Afferent and efferent pathways of the parasympathetic mechanism for enhancing the defeacation reflex**

4.0 CONCLUSION

The main function of the alimentary tract is to ingest, digest and absorb food materials. For this to be carried out, appropriate mixing must be provided. The mixing/propulsion are different at each compartmental stage of the tract. It requires both neural and hormonal mechanisms.

5.0 SUMMARY

In this unit, you have learnt about gastrointestinal motility, the acts of mastication, swallowing and movement of the bulk through the tract.

6.0 TUTOR-MARKED ASSIGNMENT

Activity: See the Laboratory manual and directives from the Facilitator

Please answer the following questions:

- Describe the act and use of Mastication (Chewing)
- Describe the process of Swallowing (Deglutition)
- List the functions of the stomach
- Describe the act of Gastro-intestinal motility
- Describe the process of Defeacation.

7.0 REFERENCES/FURTHER READING

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UNIT 3 GASTROINTESTINAL HORMONES, DIGESTION AND ABSORPTION

CONTENT

1.0 INTRODUCTION

Gastrointestinal hormones are chemical agents secreted by the endocrine glands released into general circulation and acts on the alimentary tract. Gastrointestinal (GI) hormones are the hormones secreted in GI tract. These hormones are polypeptides in nature and belong to the family of local hormones. Major function of these hormones is to regulate the secretory activities and motility of the GI tract. They include the following: (a) gastrin (b) secretin (c) cholecystokinin- pancreozymin (CCK-P2) (d) gastric-inhibitory peptide (GIP) (e) vasoactive intestinal peptide (VIP) (f) motilin (g) gastric releasing peptide (GRP). Importantly, hormones help with digestion. The food which the body needs can be classified into carbohydrate, proteins and fats. This cannot be absorbed in their natural forms through the gastrointestinal tract. Before they can be made available for body use, they must be broken down into smaller molecules which can be absorbed. This process of breaking down is known as digestion. It is the end product of digestion that is now absorbed. The basic process in the digestion of all food types is called hydrolysis. This unit will improve your knowledge on gastric hormones, digestion and absrbtion.

2.0 OBJECTIVE

By the end of this unit, you will be able to:

- describe the gastric hormones
- explain the process of digestion in human
- discuss the process of digestion of proteins and fats
- discuss the absorption processes of carbohydrate, fat, proteins and vitamins.

3.0 Main Content

3.1 Gastric Hormones

3.1.1 Gastrin

Gastrin is a peptide with 34 amino acid residues. It is secreted mainly by the G cells of pyloric glands of stomach. It is also secreted by TG cells in stomach, duodenum and jejunum. In fetus, the islets of Langerhans also secrete this hormone There are three forms of gastrin which are being isolated. We have

G-17-17 amino acid residue

G-34-34 amino acid residue

G-14-14 amino acid residue

G-17 is the most biological active form, the half-life between G-14 and G-17 is 2-3mins in circulation while G-34 has 15mins as its half-life.

Action of gastrin

i. It stimulates gastric acid and pepsin secretion (more than 1000 times more potent than histamine)
ii. It stimulates growth of gastric mucosa
iii. It stimulates insulin and glucagon secretion after a protein meal but not after carbohydrate
iv. It stimulates the contraction of cardiac sphincter
v. It stimulates gastric motility

Regulation of gastrin

i. Distension of the stomach.
ii. Presence of protein and product of protein breakdown.
iii. Stimulation of parasympathetic supply, pyloric action and acetylcholine secretion.
iv. Blood borne factor like Ca2+ and epinephrine.
v. Presence of acid in the stomach has a negative feedback control which inhibits gastrin secretion.
vi. Substances like secretin, GIP, VIP, glucagon, and calcitonin inhibits gastrin secretion.

3.1.2 CCK – P2 (cholecystokinin – pancreozymin)

Cholecystokinin is made up of 39 amino acid residues. Previously it was thought that there were two separate hormones, namely pancreozymin and cholecystokinin. It was thought that pancreozymin stimulated the secretion of pancreatic juice with large amount of enzymes and the cholecystokinin stimulated the contraction of gallbladder. But now it is

established that the same hormone has actions on both pancreas and gallbladder. So, it is named as cholecystokinin-pancreozymin (CCK-PZ) or cholecystokinin (CCK). Cholecystokinin is secreted by I cells in mucosa of duodenum and jejunum. A small quantity of the hormone is secreted in the ileum also. It is found in the nerves in many parts of the body, including distal ileum, colon, and brain. It is secreted in the mucosa of the upper intestine (duodenum). Porcine CCK exists in various form, e.g. 58, 39, 33, 12, 8 and 4. Half –life is 5 mins.

Action of CCK- P2

i. It stimulates secretion of pancreatic juice, rich in enzyme or rich in digestive juice. ii. It augment action of secretin in producing secretion of an alkaline pancreatic juice
iii. It inhibits gastric emptying
iv. It exerts a trophic effect on the pancreas stimulating the growth of the exocrine cells
v. It increases the secretion of interleukins
vi. It enhances motility of small intestine and colon
vii. It stimulates the contraction of the gall bladder and the relaxation of the sphincter of Oddi
viii. Along with secretin, it augments contraction of pyloric sphincter thus preventing the reflux of duodenal content into the stomach
ix. It stimulates the glucagon secretion

3.1.3 Secretin

Secretin is a peptide hormone with 27 amino acid residues. Historical importance of secretin is that, it was the first ever hormone discovered. It was discovered in 1902 by Bayliss and Starling. It is secreted by the S cells of duodenum, jejunum and ileum. Secretin is first produced in an inactive form called prosecretin. It is converted into secretin by the acidity of chyme. Secretin is stimulated by the entry of the product of food digestion into the duodenum, e.g. amino acid, protein and fat. There is a positive feedback regulation of secretin by presence of food.

Action of Secretin

i. It increases the secretion of HCO_3^- by pancreatic duct and biliary tract
ii. It promotes the secretion of watery alkali pancreatic juice
iii. It augment the action of CCK in producing pancreatic juice rich in digestive enzymes
iv. It decreases gastric acid secretion
v. It causes contraction of the pyloric sphincter
vi. It increases insulin secretion
Regulation of secretin

i. Secretion of secretin is stimulated by acid chyme bathing the duodenum
ii. Alkali secretion helps to neutralized the acidity
iii. Products of protein digestion is also a stimulus.

3.1.4 Gastric inhibitory peptide

i. Gastric inhibitory peptides is produced in the K-cell in the mucosal of duodenum and jejunum. It consists of 43 amino acids. In large doses, it causes inhibition of gastric secretion and motility. In smaller doses, it does not show this action.
ii. It stimulates insulin secretion and forms one of the important B-cells stimulating hormones.

Regulation of gastric inhibitory peptide

1. Secretion of GIP is caused by present of glucose and fats in the duodenum.

3.1.5 Vasoactive intestinal peptide (VIP)

Vasoactive intestinal polypeptide (VIP) contains 28 amino acid residues. This polypeptide is secreted in the stomach and small intestine. A small amount of this hormone is also secreted in large intestine

Action of vasoactive intestinal peptide

i. It stimulates intestinal secretion of electrolytes and water
ii. It relaxes intestinal smooth muscles including the sphincter
iii. It causes dilatation of peripheral blood vessels
iv. It inhibits gastric acid secretion
v. It potentiate action of acetylcholine of salivary gland.

Enterogastrones: They are hormones which causes inhibition of gastric secretion and motility. They are secreted in the duodenum in response to the presence of acid chyme in the lumen. They include secretin, GIP and VIP.

3.1.6 Motilin

Motilin is built by 22 amino acid residues. It is secreted by Mo cells, which are present in stomach and intestine. It is also believed to be secreted by enterochromoffin cells of intestine. Motilin is secreted when the chyme from stomach enters the duodenum. The concentration in the blood undergoes cyclic fluctuation during fasting. The peak blood level corresponds to the beginning of the activity of myoelectric motor complex (mmc).

Action of motilin

i. It stimulates gastric acid secretion
ii. It causes contraction of the gall bladder to increase bile concentration.
iii. It prepares the intestine for the next meal.

Other hormones include somatostatin, glucagon, gastric releasing peptide (GRP), neurotensin and substance P.

3.2 Digestion Digestion of carbohydrate

Almost all carbohydrate of the diet are large polysaccharide or disaccharide, which are combinations of monosaccharides bound together by the process of condensation. Hydrogen ion (H+) has been removed from one of the monosaccharide while a hydroxyl ion (OH-) has been removed from the next one.

The two monosaccharides combines with each other at this site of removal and the H+ and OH- combine to form water (H2O). The dietary carbohydrate is mainly; Amylopectin, which consists of chains of glucose molecules joined by 1,4 - α linkages, with some branches linked by 1,6 – α linkages. For digestion of carbohydrate to take place the specific ion returns the H and OH ions to the polysaccharide and thereby separate the monosaccharides from each other and this process is called hydrolysis.

R1 R11 + H2O R1H + R11OH

Three major sources of carbohydrate exists in the normal human diet and these are : sucrose; the disaccharide known as cane sugar, lactose; the disaccharide in milk and starches, large polysaccharides present in almost all non-animals foods, particularly grains and tubers.

When food is chewed, it is mixed with saliva, which contains the enzymes ptyalin and this is an α-amylase from the parotid gland. This enzyme hydrolyzes starch into the disaccharide maltose and isomaltose. An isomaltose is small polymers of glucose containing 3 to 9 glucose molecules. Because the food remains in the mouth for only a short time, about 3 to 5% of all the starches eaten becomes hydrolyzed. Even though the food does not remain in the mouth long enough for ptyalin to complete the breakdown of starches into maltose, its actions can continue as long as an hour after the food has entered the stomach i.e. until the content of the fundus mix with the stomach secretions. Then, the activities of the α-amylase is blocked by the acid of gastric secretions. Before food properly mix with this gastric secretions, about 30-40% of the starches would have been hydrolyzed into maltose.

Pancreatic secretions contain a large quantity of α-amylase and immediately after the chyme empties from the stomach into the duodenum and mixes with pancreatic juice, starches that have not already been split and digested amyloses are converted before they pass the jejunum.

The epithelial cells contain four enzymes: lactase, sucrase, maltase, and isomaltose, which are capable of splitting disaccharides: lactose, sucrose, maltose and isomaltose into their constituents monosaccharides. The enzymes are located in the brush border of the cells lining the lumen of the intestine.

Lactose splits into a molecule of glucose and a molecule of galactose. Sucrose splits into a molecule of glucose and fructose. Maltose splits into 2 molecules of glucose and isomaltose into several molecules of glucose.

Since the ordinary diet contains far more starches than sucrose and lactose. Glucose represents about 80% of the final product of carbohydrate, while galactose and fructose represent about 10% each.

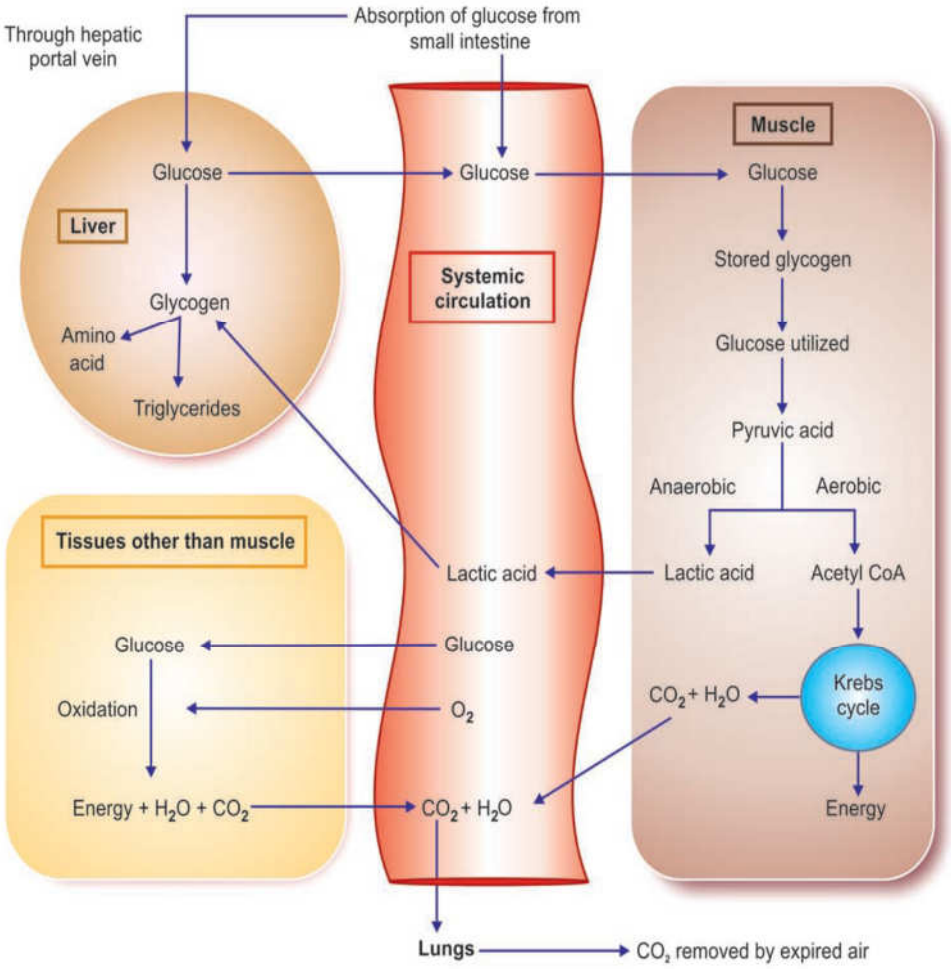

Figure 5. The digestion of carbohydrates

Digestion of fat

Lipid digestion begins in the stomach. Gastric lipase is released in large quantities from gastric chief cells; it adsorbs to the surface of fat droplets dispersed in the gastric contents and hydrolyzes component triglycerides to diglycerides and free fatty acids. However, little lipid assimilation can take place in the stomach because of the acidic pH of the lumen, which results in protonation of the free fatty acids released by gastric lipase. Lipolysis is also incomplete in the stomach because gastric lipase, despite its optimum catalytic activity at acidic pH, is not capable of hydrolyzing the second position of the triglyceride ester, which means that the molecule cannot be fully broken down into components that can be absorbed into the body. There is also little if any breakdown of cholesterol esters or the esters of fat-soluble vitamins. Indeed, gastric lipolysis is dispensable in healthy individuals because of the marked excess of pancreatic enzymes. The majority of lipolysis takes place in the small intestine in health. Pancreatic juice contains three important lipolytic enzymes that are optimized for activity at neutral pH. The first of these is pancreatic lipase. This enzyme differs from the stomach enzyme in that it is capable of hydrolyzing both the 1 and 2 positions of triglyceride to yield a large quantity of free fatty acids and monoglycerides. At neutral pH, the head groups of the free fatty acids are charged, and thus these molecules migrate to the surface of the oil droplets. Lipase also displays an apparent paradox in that it is inhibited by bile acids, which also form part of the small intestinal contents. Bile acids adsorb to the surface of the oil droplets and would thereby cause lipase to dissociate. However, lipase activity is sustained by an important cofactor, colipase, which is also supplied in pancreatic juice. Colipase is a bridging molecule that binds both to bile acids and to lipase; it anchors lipase to the oil droplet even in the presence of bile acids. Pancreatic juice also contains two additional enzymes that are important in fat digestion. The first of these is phospholipase A2, which hydrolyzes phospholipids such as those present in cell membranes. Predictably, this enzyme would be quite toxic in the absence of dietary substrates, and thus it is secreted as an inactive pro-form that is activated only when it reaches the small intestine. Furthermore, pancreatic juice contains a relatively nonspecific, so-called cholesterol esterase that can break down not only esters of cholesterol, as its name implies, but also esters of fat-soluble vitamins and even triglycerides. Interestingly, this enzyme requires bile acids for activity (contrast with lipase, discussed earlier), and it is related to an enzyme produced in breast milk that plays an important role in lipolysis in neonates.

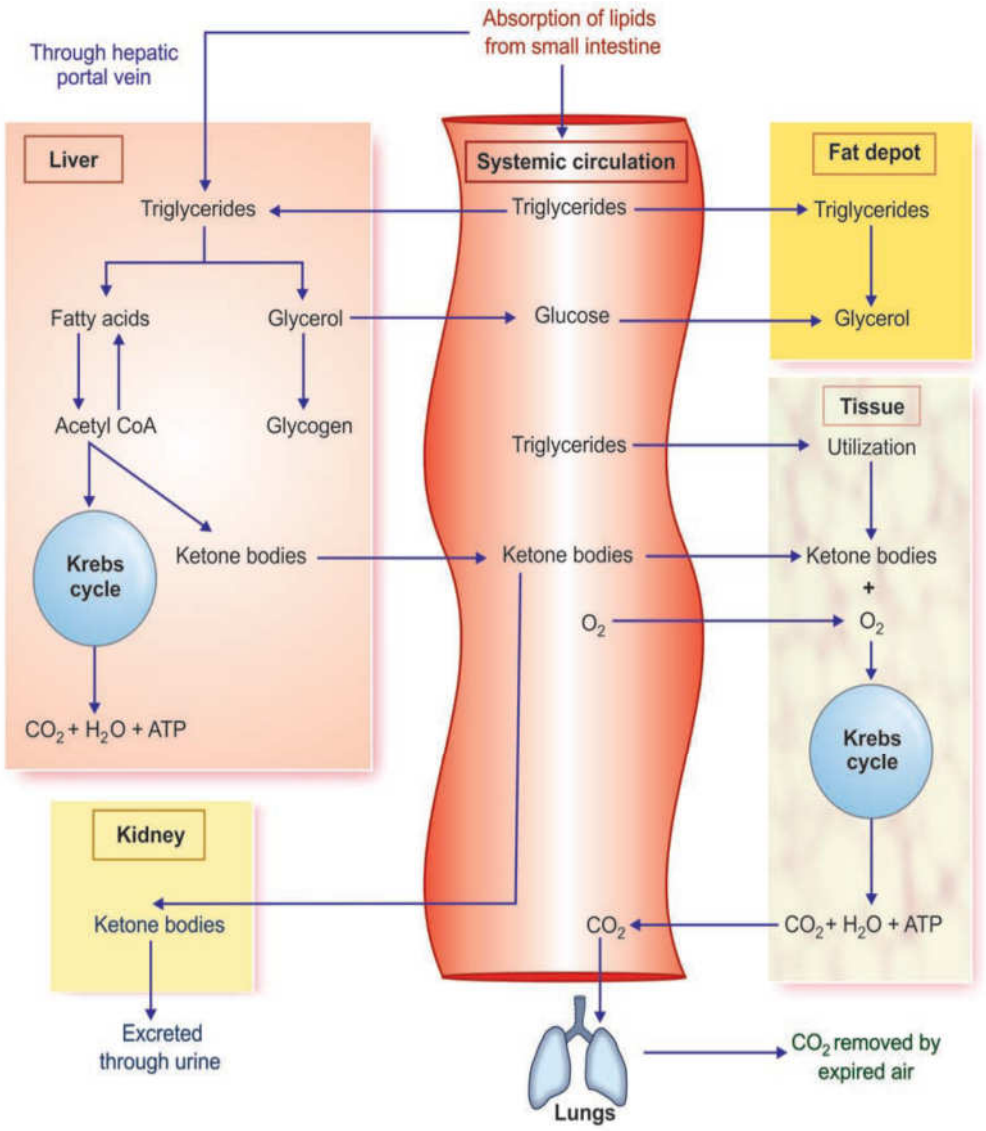

Figure 6: Schematic diagram of lipid metabolism

As lipolysis proceeds, the products are abstracted from the lipid droplet, first into a lamellar, or membrane, phase and subsequently into mixed micelles composed of lipolytic products, as well as bile acids. The amphipathic (meaning that they have both a hydrophobic and hydrophilic face) bile acids serve to shield the hydrophobic regions of lipolytic products from water while presenting their own hydrophilic faces to the aqueous environment (Fig. 29-15). Micelles are truly in solution and thus markedly increase the solubility of lipid in the intestinal contents. This increases the rate at which molecules such as fatty acids can diffuse to the absorptive epithelial surface. Nevertheless, given the very large surface area of the small intestine and the appreciable solubility of the products of triglyceride hydrolysis, micelles are not essential for the absorption of triglyceride. Thus, patients who have insufficient output of bile acids (caused, for example, by a gallstone that obstructs bile output) do not normally show fat malabsorption. On the other hand, cholesterol and the fat-soluble vitamins are almost totally insoluble in water and accordingly

require micelles to be absorbed even after they have been digested. Thus, if luminal bile acid concentrations fall below the critical micellar concentration, patients can become deficient in fat-soluble vitamins.

Digestion of proteins

Dietary proteins are derived entirely from meat and vegetables. Proteins are formed from long chains of amino acids bind together by peptide linkages. Digestion of proteins, unlike carbohydrate start in the stomach.

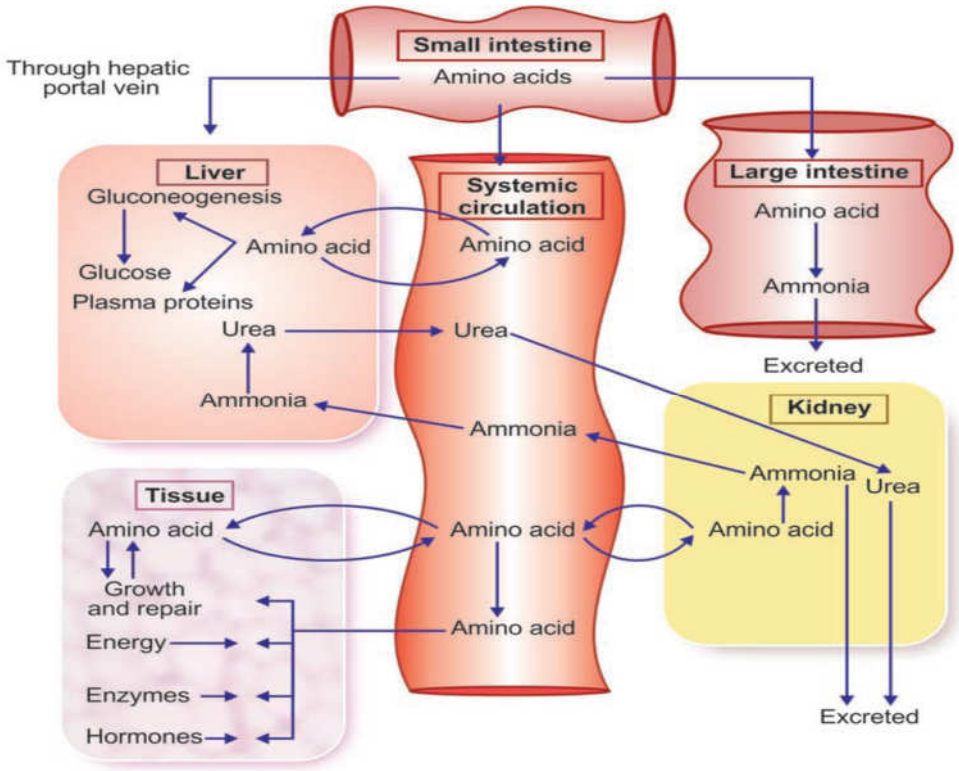

Figure 7: **Schematic diagram of protein metabolism**

Pepsin is capable of digesting essentially all the different types of proteins in diet. One of its important feature is to digest collagen and albuminoid that is affected little by other digestive enzyme. Collagen is a major constituent of intercellular connective tissue of meat. Pepsin, however only begins the process of protein digestion by providing as much as 10-30% of the total protein digestion. Most protein digestion occurs in the small intestine under the influence of a proteolytic enzymes of the pancreatic secretion. When protein leaves the stomach, they are in form of proteases, peptones and large polypeptides. On entering the small intestine, they are trapped by the pancreatic enzymes, trypsin, chymotrypsin and carboxypolypeptidase. Both trypsin and chymotrypsin transmit protein molecules into small polypeptides. Carboxypolypeptidase then cleaves individual amino acids from the carboxyl ends of the polypeptides. The brush border of small intestine

contains several enzymes for hydrolyzing the final linkages of remaining dipeptides and other small polypeptides. These enzymes are; aminopolypeptidase and dipeptidase.

3.2 Absorption

The end product of the digestion of different types of food ingested or secreted electrolytes, vitamins and large quantity of water secreted in various digestive juices must be moved from the lumen of the gut across the epithelium to the interstitial fluid. The process of transport from gut lumen into body's interstitial fluid is called absorption. The main absorptive portion of the gut is the small intestine with a large surface area. The surface area is achieved by the following:

i. The mucosal infolding, called the valvulae corniventis.
ii. Billions of small villi projecting about 1mm from the surface of the mucosa
iii. A brush border consisting of about 600 villi per cell

The combination of the three above increase the absorptive area of the mucosal about 600 folds. The total area of small intestine is 250m2. Absorption occurs basically by active transport and diffusion.

Absorption of carbohydrate

Glucose, other hexoses and pentoses are rapidly absorbed across the wall of small intestine. These sugars are absorbed before the content of the small intestine reach the terminal part of the ileum. The transport is an active process, and this can be demonstrated by several important experimental observation and they are:

i. Transport can be blocked by metabolic inhibitors such as IAA, cyanite and phlorhizin
ii. Transport is selective, the order of preferences for transporting difference monosaccharides and their relative rate of transport in comparison with glucose are; galcatose-1.1, glucose-1.0, fructose-0.4, mannose-1.2, xylose-0.15, arabinose-0.1.
iii. There is competition between certain sugars for the respective carrier system

Glucose and galactose in small intestine enter the cells by secondary active transport with sodium ion. Transport of other hexoses are affected by the amount of Na ion in interstitial lumen. Glucose and Na share the same co-transporter or symport called Na-dependent glucose transporter (SGLT). There are two members of this family; SGLT 1 and SGLT 2.

Since the intracellular concentration of Na ions is low in interstitial cell, Na diffuses into the cell along its concentration gradient. Glucose moves

with the Na and is released in the cell. The Na ion is transported into the lateral intracellular spaces and the glucose from the inside of the cell by another transporter; the SGLT 2 into the interstitium and finally into the capillaries.

Absorption of glucose is called a secondary active transport because the energy for transport is provided indirectly by the active transport of Na out of the cell.

Fructose, however, utilizes a different mechanism its absorption is independent of Na ions or transport of glucose and galactose. It is transported by facilitated diffusion from the intestinal lumen into the cells of the intestine by a transporter GLUT 5 and out of the cell into the interstitium by another transporter GLUT 2. Some fructose is converted to glucose in the mucosal cells. Pentoses are absorbed by simple diffusion. All monosaccharides are absorbed into the portal blood draining the small intestine.

Absorption of lipids (fats)

The digestive end product of fat dissolve in the lipid portion of bile acid micelles. These micelles are soluble in the chyme. In this form, the monoglycerides and fatty acids are transported to the surfaces of the brush border microvilli penetrating the recesses of the moving agitating microvilli. Here, the monoglycerides and the fatty acids diffuse through the epithelial membrane, because they are soluble in the membrane.

The bile acid micelles is now left to diffuse back into the chyme, absorbing more monoglycerides and fatty acids. Undigested triglycerides and diglycerides are both highly soluble in the lipid membrane of epithelial cells. However, only small quantity of these are normally absorbed, because the bile micelles will not ferry them to the epithelial membrane. On entering the epithelial cells, fatty acids and monoglycerides are taken up by the small endoplasmic reticulum and are recombined to form new triglycerides. Once form the triglycerides aggregate within the endoplasmic reticulum into globules along with absorbed cholesterol and phospholipids globules are called chylomicrons. These globules diffuses to the side of the epithelial cells and is extrude by process of cellular exocytosis into the space between the cells. From the site of the epithelial cells, chylomicrons find their ways into the central lactus of the villi, and from here they are propelled along with the lymph by the lymphatic pump upward through the thoracic duct to be emptied into the great vein of the neck. Between 80 and 90% of all fat absorbed from the gut get into the interstitium in this manner.

Absorption of proteins

Amino acids (and some small peptides) are absorbed mainly in the duodenum and upper jejunum into the portal blood. D- amino acids are absorbed passively, whereas L-amino acids are absorbed actively by a Na-linked carrier mechanism. There are at least four specific mechanisms by which amino acids are absorbed: one for neutral amino acids, one for basic amino acids, one for acidic amino acids and one for the imino acids (proline, sarcosine).

Dipeptides and tripeptides may be absorbed from the lumen and are later hydrolyzed within the epithelial cells. In neonates, antibodies and other proteins contained in colostrum may be absorbed in their intact form by pinocytosis.

Absorption of Water

Only a small amount of water move across the gastric mucosa but water moves in both directions across the mucosa of the small and large intestines in response to osmotic gradient.

Absorption of ions/electrolytes

Na+ is actively absorbed throughout the small and large intestines. Active transport of Na+ is important in the secondary transport of glucose and some amino acid.

Chloride ions are rapidly absorbed mainly by passive diffusion in the upper part of the small intestines. They move along with the absorbed Na+ to balance the electrical gradient caused by Na+ ion absorption. K+ ions are absorbed across the gastrointestinal mucosa by diffusion.

Absorption of Vitamins

Water soluble vitamins are rapidly absorbed while the absorption of fat soluble vitamins is dependent of fat absorption. Most vitamins are absorbed in the upper small intestine but vitamin B12 is absorbed in the ileum.

4.0 CONCLUSION

Six different hormones secreted in different parts of the gastrointestinal tract are discussed with information on different functions performed to prepare the different organs to support digestion and absorption in different parts of the tract.

5.0 SUMMARY

In this unit, you have learnt about the following hormones, Gastrin, Ccholecystokinin – pancreozymin (CCK – P2), Secretin, Gastric inhibitory peptide, Vasoactive intestinal peptide (VIP) and Motilin. You have also learnt about digestion of the various smaller molecules in different areas of the gastro-intestinal tract. Absorption through active, passive transport and diffusion in different areas of the gastro-intestinal tract.

6.0 TUTOR-MARKED ASSIGNMENT

1. Describe the forms and actions of the following hormones:

    a) Gastrin
    b) CCK – P2 (cholecystokinin – pancreozymin)
    c) Secretin
    d) Gastric inhibitory peptide
    e) Vasoactive intestinal peptide (VIP)
    f) Motilin

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MODULE 2 NERVOUS SYSTEM

Unit 1 Overview of the Nervous System
Unit 2 Integration of Central Nervous System with other Systems

UNIT 1 OVERVIEW OF THE NERVOUS SYSTEM

CONTENTS

1.0 INTRODUCTION

The nervous system consists of the brain, spinal cord, sensory organs, and all of the nerves that connect these organs with the rest of the body. Together, these organs are responsible for the control of the body and communication among its parts. The brain and spinal cord form the control Centre known as the central nervous system (CNS), where information is evaluated and decisions made. The sensory nerves and sense organs of the peripheral nervous system (PNS) monitor when you sit, stand, or walk by controlling muscular activities. Your body temperature remains stable on a cold winter day or in a warm kitchen Because your rate of heat generation and heat loss are closely regulated.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- explain the activities of the nervous system
- describe a general overview of the nervous system
- describe the anatomical divisions of the nervous system and their functions
- describe the structure of the brain.

3.0 MAIN CONTENT

The nervous system, which accounts for a mere 3 percent of the total Body weight, is the most complex organ system. It is vital not only to life but also to our appreciation of life. This unit details with the Structure and function of neural tissue and introduces principles of neurophysiology that are vital to an understanding of the nervous system's capabilities and limitations.

3.1 Division of the Nervous System

Central Nervous System

The brain and spinal cord together form the central nervous system, or CNS. The CNS acts as the control center of the body by providing its processing, memory, and regulation systems. The CNS takes in all of the conscious and subconscious sensory information from the body's sensory receptors to stay aware of the body's internal and external conditions. Using this sensory information, it makes decisions about both conscious and subconscious actions to take to maintain the body's homeostasis and ensure its survival. The CNS is also responsible for the higher functions of the nervous system such as language, creativity, expression, emotions, and personality. The brain is the seat of consciousness and determines who we are as individuals.

Peripheral Nervous System

The peripheral nervous system (PNS) includes all of the parts of the nervous system outside of the brain and spinal cord. These parts include all of the cranial and spinal nerves, ganglia, and sensory receptors.

Somatic Nervous System

The somatic nervous system (SNS) is a division of the PNS that includes all of the voluntary efferent neurons. The SNS is the only consciously controlled part of the PNS and is responsible for stimulating skeletal muscles in the body.

Autonomic Nervous System

The autonomic nervous system (ANS) is a division of the PNS that includes all of the involuntary efferent neurons. The ANS controls subconscious effectors such as visceral muscle tissue, cardiac muscle tissue, and glandular tissue. There are 2 divisions of the autonomic nervous system in the body: the sympathetic and parasympathetic divisions.

Sympathetic. The sympathetic division forms the body's "fight or flight" response to stress, danger, excitement, exercise, emotions, and embarrassment. The sympathetic division increases respiration and heart rate, releases adrenaline and other stress hormones, and decreases digestion to cope with these situations.

Parasympathetic. The parasympathetic division forms the body's "rest and digest" response when the body is relaxed, resting, or feeding. The parasympathetic works to undo the work of the sympathetic division after a stressful situation. Among other functions, the parasympathetic division works to decrease respiration and heart rate, increase digestion, and permit the elimination of wastes.

Enteric Nervous System

The enteric nervous system (ENS) is the division of the ANS that is responsible for regulating digestion and the function of the digestive organs. The ENS receives signals from the central nervous system through both the sympathetic and parasympathetic divisions of the autonomic nervous system to help regulate its functions. However, the ENS mostly works independently of the CNS and continues to function without any outside input. For this reason, the ENS is often called the "brain of the gut" or the body's "second brain." The ENS is an immense system—almost as many neurons exist in the ENS as in the spinal cord.

Action Potentials

Neurons function through the generation and propagation of electrochemical signals known as action potentials (APs). An AP is created by the movement of sodium and potassium ions through the membrane of neurons. *Resting Potential:* At rest, neurons maintain a concentration of sodium ions outside of the cell and potassium ions inside of the cell. This concentration is maintained by the sodium-potassium pump of the cell membrane which pumps 3 sodium ions out of the cell for every 2 potassium ions that are pumped into the cell. The ion concentration results in a resting electrical potential of - 70 millivolts (mV), which means that the inside of the cell has a negative charge compared to its surroundings.

Threshold Potential: If a stimulus permits enough positive ions to enter a region of the cell to cause it to reach -55 mV, that region of the cell will open its voltage-gated sodium channels and allow sodium ions to diffuse into the cell. -55 mV is the threshold potential for neurons as this is the "trigger" voltage that they must reach to cross the threshold into forming an action potential.

Depolarization*:* Sodium carries a positive charge that causes the cell to become depolarized (positively charged) compared to its normal negative charge. The voltage for depolarization of all neurons is +30 mV. The depolarization of the cell is the AP that is transmitted by the neuron as a nerve signal. The positive ions spread into neighbouring regions of the cell, initiating a new AP in those regions as they reach -55 mV. The AP continues to spread down the cell membrane of the neuron until it reaches the end of an axon.

Repolarization: After the depolarization voltage of +30 mV is reached, voltage-gated potassium ion channels open, allowing positive potassium ions to diffuse out of the cell. The loss of potassium along with the pumping of sodium ions back out of the cell through the sodium-potassium pump restores the cell to the -55 mV resting potential. At this point the neuron is ready to start a new action potential.

Synapses

A synapse is the junction between a neuron and another cell. Synapses may form between 2 neurons or between a neuron and an effector cell. There are two types of synapses found in the body: chemical synapses and electrical synapses.

Chemical synapses: At the end of a neuron's axon is an enlarged region of the axon known as the axon terminal. The axon terminal is separated from the next cell by a small gap known a the synaptic cleft. When an AP reaches the axon terminal, it Opens voltage-gated calcium ion channels. Calcium ions cause vesicles containing chemicals known as neurotransmitters (NT) to release their contents by exocytosis into the synaptic cleft. The NT molecules cross the synaptic cleft and bind to receptor molecules on the cell, forming a synapse with the neuron. These receptor molecules open ion channels that may either stimulate the receptor cell to form a new action potential or may inhibit the cell from forming an action potential when stimulated by another neuron.

Electrical synapses: Electrical synapses are formed when 2 neurons are connected be small holes called gap junctions. The gap junctions allow electric current to pass from one neuron to the other, so that an AP in one cell is passed directly on to the other cell through the synapse.

3.3 Anatomy of the Nervous Tissue

The majority of the nervous system is tissue made up of two classes of cells: neurons and neuroglia.

Neurons. Neurons, also known as nerve cells, communicate within the body by transmitting electrochemical signals. Neurons are different from other cells in the body due to the many long cellular processes that extend from their cell body. The cell body is the roughly round part of a neuron that contains the nucleus, mitochondria, and most of the cellular organelles. Small tree-like structures called dendrites extend from the cell body to pick up stimuli from the environment, other neurons, or sensory receptor cells. Long transmitting processes called axons extend from the cell body to send signals to other neurons or effector cells in the body.

There are 3 basic classes of neurons: afferent neurons, efferent neurons, and interneurons.

1. Afferent neurons
2. Efferent neurons
3. Interneurons

Neuroglia

Neuroglia, also known as glial cells, act as the "helper" cells of the nervous system. Each neuron in the body is surrounded by 6 to 60 neuroglia cells that protect, feed, and insulate the neuron. Because neurons are extremely specialized cells that are essential to body function and almost never reproduce, neuroglia are vital to maintaining a functional nervous system.

3.3.1 Functions of the Nervous System

The nervous system has 3 main functions: sensory, integration, and motor.

1. Sensory:
2. Integration:
3. Motor:

4.0 CONCLUSION

The nervous system is unique in the vast complexity of thought processes and control of actions that it can perform. It receives each minute literally millions of bits of information from the different sensory nerves and sensory organs and then integrates all of these to determine the responses that are to be made by the body.

5.0 SUMMARY

The study in this unit included an overview of the nervous system, divisions of the nervous system, the anatomy of the nervous system and the functions of the nervous system.

6.0 TUTOR-MARKEDASSIGNMENT

1. Discuss in details the divisions of the nervous system.
2. List and discuss the functions of the nervous system.

7.0 REFERENCES/FURTHER READING

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UNIT 2 INTEGRATION OF CENTRAL NERVOUS SYSTEM WITH OTHER SYSTEMS

CONTENTS

1.0 INTRODUCTION

Central nervous system (CNS) consists of brain and spinal cord. The brain plays a central role in the control of most bodily functions such as awareness, movements, thoughts, speech, learning and memory. The spinal cord plays an important role in some movements via some reflex pathways without the participation of brain structures. The spinal cord is the extension of brain that descend from foramen magnum to the first lumber vertebra. It is called central because it combines information from the entire body and coordinates activity across the whole body.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- describe the embryonic origin of Central nervous system.
- describe the divisions of central nervous system
- identify the structures and function of the brain regions
- look at the types cells involved, different regions in the brain and spinal circuit.
- explain how CNS can be affected by diseases and injury.

3.0 MAIN CONTENT

3.1 Origin of Central Nervous System

In the developing embryo, the Nervous system develops from ectoderm the form neural plate, the neural plate differentiates and give rise neural tube and neural crest. The neural tube differentiated into central nervous system (i.e., the brain and spinal cord). The brain developed at the cranial end of the embryonic neural tube. By the end of fourth week of development the prosencephalon (forebrain), mesencephalon (midbrain) and rhombencephalon (hindbrain) as primary vesicles are formed. A week later, the prosencephalon gives rise to telencephalon and diencephalon and hindbrain gives rise to metencephalon and myelencephalon resulting in a total of five secondary vesicles.

In adults, the telencephalon develops into cerebral hemispheres, diencephalon gives rise to thalamus, hypothalamus and other structures. Mesencephalon continues as midbrain, metencephalon developed into pons and cerebellum while myelencephalon becomes medulla oblongata. The medulla oblongata, pons, and the midbrain formed the adult brainstem.

3.2 The meaning of Central Nervous System

The CNS is the formed of nervous system that includes brain and spinal cord. It is formed by nerve cells and supporting cells called glia cell. The brain is protected by the cranial structure (skull) and the spinal cord extend from the back of the brain down to the center of the spine, stopping at the lumbar region of vertebral canal. Both Brian and spinal cord are Shielded within a protective triple-layered membrane called the meninges. The CNS has been thoroughly studied by a scientist, but it still holds many secrets in controlling our emotions, movements, thoughts, and desires. It also controls our heart rate, respiration, hormonal system, and homeostasis. However, the retina, optic nerve, olfactory nerves and olfactory epithelium considered to be part of the CNS alongside the brain and the spinal cord. This is due to their connection directly to the brain tissue without intermediate nerve fibers connection.

3. 3 Scopes of Central Nervous System

The central nervous system consists of brain and spinal cord. Brain is the most complex organ that controls thought, memory, emotions, touch, motor skills, vision, breathing, hunger, temperature and all processes that regulates the human body; the cerebral cortex (the outermost part of the brain and the largest part by volume) contains about 15–33 billion neurons, each of which are connected to thousands of other neurons. In total, about 100 billion neurons and 1,000 billion supporting cells make up the human brain. brain uses about 20% of total body’s energy. The

brain is divided into three different regions: The forebrain, the midbrain and the hindbrain. The brain is the central control module of the body and coordinates activity. However, many higher functions like reasoning, problem-solving and creativity involve different areas working together in a Networks.

Part of the brain. Basically, there are three part of brain which include cerebrum, brainstem and cerebellum.

3.4 Cerebrum

The cerebrum is the structure of the telencephalon, it is the largest portion of the brain of about 80% of its mass and it is the brain region primarily responsible for the intellectual functions. Other areas of the cerebrum enable speech, judgment, thinking, as well as reasoning, problem-solving, emotions and learning. Some functions are related to vision, hearing and other senses. The cerebrum consists of five paired lobes that contains gray mater in its cortex, and white matter in its center and in the deeper cerebral nuclei within the right and left hemispheres which are connected Internally by a large fiber tract called corpus callosum. These lobes are frontal, parietal, temporal and occipital, which are visible from the surface and the deep insula, which is covered by parts of the frontal, parietal, and temporal lobes.

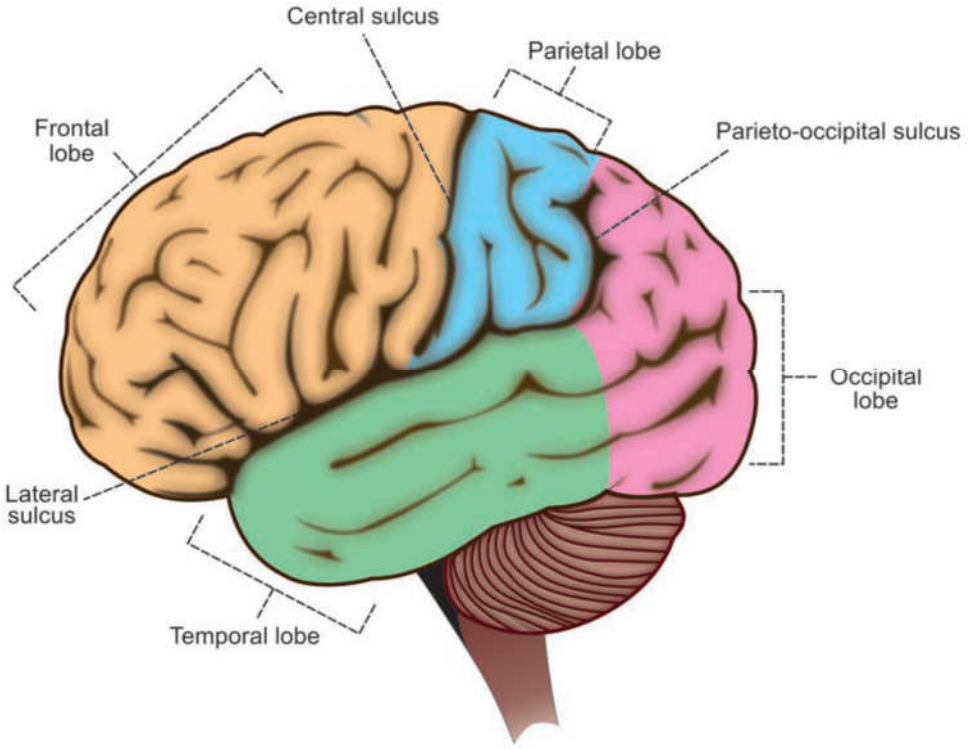

Figure 1: Lobes of cerebral cortex

Temporal lobe (green): Contains auditory centers that receive sensory information for processing sensory input and assigning it emotional meaning. The lobe also involved in laying down long-term memories, interpretation, association of auditory and visual information and in some aspects of language perception are also housed here.

Occipital lobe (purple): visual processing region of the brain that housing the visual cortex. It is responsible for vision and coordination of eye movements.

Parietal lobe (yellow): the parietal lobe integrates sensory information including interpretation of textures and shapes, spatial awareness, and navigation. Touch stimulation from the skin is ultimately sent to the parietal lobe. It also plays a part in understanding speech and formulating words to express thoughts and emotions.

Frontal lobe (pink): positioned at the anterior portion of each cerebral hemispheres, the frontal lobe contains the majority of dopamine-sensitive neurons and is involved in attention, reward, short-term memory, motivation, and planning.

Insula lobe: This lobe is responsible for the encoding of memory and in the integration of sensory Informa with visual responses. It receives information from olfactory, gustatory, auditory and somatosensory areas and helps in control of autonomic responses to the visceral and cardiovascular system.

3.5 Brainstem

The brainstem which is the middle of the brain connects the cerebrum with the spinal cord. The brainstem includes the midbrain, the pons and the medulla oblongata.

Midbrain (mesencephalon): Is a highly complex structure with a range of different nuclei and colliculi (neuron clusters), neural pathways and other structures such as substantia nigra and basal ganglia. These structures performed various functions, from hearing and movement to calculating responses and environmental changes. It is also an area affected by Parkinson's disease that is rich in dopamine neurons, also part of movement and coordination.

Pons: Pons is the bridge that connect between midbrain and medulla. The four (CN V, VI, VII and VIII) out of the 12 cranial nerves originated from pons, which enable a range of activities such as tear production, chewing, blinking, focusing vision, balance, hearing and mood changing. Damage to the central pons can cause a condition called locked-in syndrome.

Medulla: Below the pons is the medulla where the brainstem meets the spinal cord. The medulla is important for survival. Medulla regulates many body activities including heart rhythm, maintaining a correct blood pressure, breathing, oxygen and carbon dioxide levels. The medulla also produces reflex activities such as sneezing, vomiting, coughing and swallowing.

3.6 Cerebellum

The cerebellum is the second largest structure of the rain located at the back of the head, below the temporal and occipital lobes above the brainstem. Like cerebral cortex, it contains outer gray and inner white mater as well as the two hemispheres. The function of cerebellum is to coordinate voluntary muscles movements, motor learning and for coordinating the movement of different joins during movements. and to maintain posture, balance and equilibrium

Deeper structures within the Brain

Moreover, we will look at some specific deep structures of the brain in a little more detail:

1. Pituitary gland: The pituitary gland sometimes called master gland. It is a pea-sized structure found deep in the brain behind the bridges of the nose on Sella turcica. The pituitary glands control the function of other glands in the body, regulates the flow of hormones from thyroid, adrenals, ovaries and testicles. The glands receive the chemical signals from hypothalamus through its stalk and blood supply.
2. Hypothalamus: It is located above the pituitary glands and sends it chemical messages that control its function. Hypothalamus helps to regulates body temperature, secretes numbers of neurohormones, synchronizes sleep patterns, controls hunger and thirst and also plays a role in some aspects of memory and emotion.
3. Amygdala: This is two almond-shaped strictures of nuclei, an amygdala is located under each half (hemisphere) deep within the temporal lobe of the brain. Included in the limbic system, the amygdalae regulate emotion and memory and are associated with the brain's reward system, stress, and the "fight or flight" response when someone perceives a threat.
4. Hippocampus: A curved seahorse-shaped organ on the undersurface of each temporal lobe, the hippocampus is part of substantial structure called the hippocampal formation. Its major functions are to supports memory, learning, navigation and perception of space. It also receives information from the cerebral cortex and may play an important role in Alzheimer's disease.

5. Pineal Gland: This is a melanin secreting gland located deep in the brain and attached by a stalk to the top of the third ventricle. The pineal gland responds to light and dark, which regulates circadian rhythms and the sleep-wake cycle.
6. Ventricles and Cerebrospinal Fluid: Deep within the brain are four open areas with passageways between them. They also open into the central spinal canal and the area below arachnoid layer of the meninges. The ventricles produce cerebrospinal fluid, or CSF, a watery fluid that circulates in and around the ventricles and the spinal cord, and between the meninges. CSF functions is to surrounds and cushions the spinal cord and brain, washes out waste and impurities, and delivers nutrients.
7. Basal ganglia: this is a region of the base of the brain that consist of three clusters of neurons (caudate nucleus, putamen and Globus pallidus) that involved in the control of voluntary motor movements, procedural learning, and decisions about which motor activities to carry out. Diseases associated with this area include Parkinson's disease and Huntington's disease.
8. Broca's area: this is a small area on the left side of the brain (sometimes on the right in left-handed individuals) that is important in language processing. When this area damaged, an individual finds it difficult to speak but can still understand speech. Stuttering is sometimes associated with an underactive of this area.
9. Corpus callosum: It is a large white matter structure within the brain with a broad band of nerve fibers that join the left and right hemispheres. It allows the two hemispheres to communicate. Dyslexic children have smaller corpus callosums while, left-handed people, ambidextrous people, and musicians typically have larger ones.
10. Thalamus: This is structure positioned in the center of the brain, the thalamus receives sensory and motor input and relays it to the rest of the cerebral cortex. Its functions involved in the regulation of consciousness, sleep, awareness, and alertness.
11. Brain Coverings (Meninges): Meninges are three layers of protective covering that surround the brain and the spinal cord. The outermost layer, called the dura mater, is thick and tough. It includes two layers: The periosteal layer which lines the inner dome of the skull (cranium) and the meningeal layer is below that. Spaces between the layers allow for the passage of veins and arteries that supply blood flow to the brain. The arachnoid mater (middle layer) is a thin, web like layer of connective tissue that does not contain nerves or blood vessels. Below the arachnoid mater is the cerebrospinal fluid, or CSF. The innermost layer called pia mater, is a thin membrane that hugs the surface of the brain and follows its contours. The pia mater is rich with veins and arteries.

3.7 Spinal Cord

The spinal cord, lies loosely in the full length of the back, carries information between the brain and body, but also carries out other tasks. From the brainstem, where the spinal cord meets the brain, 31 spinal nerves enter the cord. Along its length, it connects with the nerves of the peripheral nervous system (PNS) that run in from the skin, muscles, and joints. Motor commands from the brain travel from the spine to the muscles and sensory information travels from the sensory tissues toward the spinal cord and finally up to the brain.

The spinal cord contains circuits that control certain reflexive responses, such as the involuntary movement your arm might make if your finger was to touch a flame. The circuits within the spine can also generate more complex movements such as walking. Even without input from the brain, the spinal nerves can coordinate all of the muscles necessary to walk. For instance, if the brain of a cat is separated from its spine so that its brain has no contact with its body, it will start spontaneously walking when placed on a treadmill. The brain is only required to stop and start the process, or make changes if, for instance, an object appears in your path.

White and gray matter

The CNS can be roughly divided into white and gray matter. As a very general rule, the brain consists of an outer cortex of gray matter and inner housing tracts of white matter. While the gray matter of the Spinal cord is located centrally surrounded by a white matter. Both types of tissue contain glial cells, which protect and support neurons. White matter mostly consists nerve projections called axons and oligodendrocytes (a type of glial cell) whereas gray matter consists predominantly of neurons.

Central glial cells

Also called neuroglia, glial cells are often called supporting cells for neurons. Neuroglia cells are non-excitable and cannot transmit impulses. Without glial cells, developing nerves often lose their way and struggle to form functioning synapses. Glial cells are found in both the CNS and PNS but each system has different types.

The following are brief descriptions of the neuroglia cells found in CNS.

Astrocytes: these cells are star-shaped like that have numerous projections and anchor neurons to their blood supply. They induce formation of Blood Brain Barrier (BBB), and also regulate the local environment by removing excess ions and recycling neurotransmitters.

Oligodendrocytes: Also called oligodendroglia, responsible for creating the myelin sheath. Also provide support to the CNS neurons by forming semi-stiff connective tissues between the neurons.

Microglia: Are the smallest glia cells derives from monocytes. Functions are to engulf and destroys the microorganism and cellular debris by phagocytosis. Also act as miniature macrophages.

Ependymal cells: lining the internal cavity of spinal cord and the brain's ventricles (fluid-filled spaces), these create and secrete cerebrospinal fluid (CSF) and keep it circulating using their whip-like cilia.

Radial glia: act as scaffolding for new nerve cells during the embryonic development nervous system.

3.8 Cranial Nerves (Cn)

The cranial nerves are 12 pairs of nerves that arise directly from the brain and pass through foramens in the skull rather than traveling along the spinal cord. These nerves collect and send information between the brain and parts of the body (mostly the neck and head). The olfactory and the optic nerves (out of 12 pairs) arise from the forebrain and are considered part of the central nervous system: The 12 parks of cranial nerve are: Olfactory nerves (CN I), Optic nerves (CN II), Oculomotor nerves (CN III), Trochlear nerves (CN IV), Trigeminal nerves (CN V), Abducent nerves (CN VI), Fascial nerves (CN VII), Vestibulocochlear nerves (VIII), Glossopharyngeal nerves (CN IX), Vagus nerves (CN X), Spinal accessory nerves (CN XI) and Hypoglossal nerves (CN XII).

3.9 Central Nervous System Diseases

The major causes of disorders that affect the CNS are:

- Trauma
- Infections

Degeneration: Example is Parkinson's disease which involves the gradual degeneration of dopamine-producing cells in the basal ganglia.

Structural defects: the most common examples are birth defects; including anencephaly, where parts of the skull, brain, and scalp are missing at birth.

Tumors: both cancerous and noncancerous tumors can impact parts of the central nervous system. Both types can cause damage and yield an array of symptoms depending on where they develop. Autoimmune disorders: in some cases, an individual's immune system can mount an attack on healthy cells. For instance, acute disseminated encephalomyelitis is characterized by an immune response against the brain and spinal cord, attacking myelin (the nerves' insulation) and, therefore, destroying white matter.

Stroke: a stroke is an interruption of blood supply to the brain; the resulting lack of oxygen causes tissue to die in the affected area.

4.0 CONCLUSION

The central nervous system or, shortly, the CNS, is the key part of the nervous system built by neurons concentrated in the nerve centers and located in the spinal canal and the cranial cavity (skull). It extends along the longitudinal axis of the body. In humans, this system consists of brain, located in the cranial cavity and the spinal cord, located in the spinal canal. The brain is the control tower of the body and the Spinal cord is the body's main message carrier. The parts of the human CNS are Spinal cord, and the brain (medulla oblongata, pons, cerebellum, diencephalon, telencephalon, and mesencephalon).

5.0 SUMMARY

The central nervous system (CNS) controls most functions of the body and mind. It consists of two parts: the brain and the spinal cord or medulla caudalis. The brain is the most complex organ in the body and it is the center of our thoughts, the interpreter of our external environment, and the origin of control over body movement. Like a central computer, it interprets information from our eyes (sight), ears (sound), nose (smell), tongue (taste), and skin (touch), as well as from internal organs such as the stomach. The spinal cord is the highway for communication that carries signals back and forth between the body and the brain. When the spinal cord is injured, the exchange of information between the brain and other parts of the body is disrupted.

6.0 TUTOR-MARKED ASSIGNMENT

1. Nervous System consists of:
   A. Brain
   B. Spinal Cord
   C. Nerves
   D. All the above

2. Which of the following statement is correct about Cerebellum?
   A. It regulates the muscular movement for locomotion.
   B. It is a part of brain.
   C. Both A and B
   D. Neither A nor B
3. Which nerves are attached to the brain and emerge from the skull?
   A. Cranial Nerves
   B. Spinal Nerves
   C. Thoracic Nerves
   D. Sacral Nerves

4. Name the system that controls every activity that you do?
   A. Nervous System
   B. Exocrine System
   C. Endocrine System
   D. Respiratory System

5. What is the unit of Nervous system?
   A. Brain
   B. Spinal Cord
   C. Neuron
   D. Nerves

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MODULE 3 ENDOCRINE SYSTEM AND REPRODUCTIVE SYSTEM

UNIT 1 THE ENDOCRINE SYSTEM

CONTENTS

1.0 INTRODUCTION

This unit introduces the components and functions of the endocrine system and explores the interactions between the nervous and endocrine systems. We shall consider specific endocrine organs, hormones and functions.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- describe the endocrine system
- identify the components of the endocrine system
- describe the three categories of hormones
- explain the integration between the endocrine system and the nervous system.

3.0 MAIN CONTENT

3.1 An Overview of the Endocrine System

The ability of cells to communicate with each other represents an underpinning of human biology. cell-to-cell communication exists at various levels of complexity and distance. Endocrine signaling involves

(1) The regulated secretion of an extracellular signaling molecule, called a hormone, into the extracellular fluid;
(2) Diffusion of the hormone into the vasculature and its circulation throughout the body; and
(3) Diffusion of the hormone out of the vascular compartment into the extracellular space and binding to a specific receptor within cells of a target organ. Because of the spread of hormones throughout the body, one hormone often regulates the activity of several target organs. Conversely, cells frequently express receptors for multiple hormones. The endocrine system is a collection of glands whose function is to regulate multiple organs within the body to

(1) Meet the growth and reproductive needs of the organism and
(2) Respond to fluctuations within the internal environment, including various types of stress. The endocrine system comprises the following major glands:

Endocrine pancreas
Parathyroid glands
Pituitary gland (in association with hypothalamic nuclei)
Thyroid gland
Adrenal glands
Gonads (testes or ovaries)

These endocrine glands synthesize and secrete bioactive hormones and, with the exception of gonads, which perform both endocrine and gametogenic functions, are dedicated to hormone production. A transitory organ, the placenta, also performs a major endocrine function. In addition to dedicated endocrine glands, there are endocrine cells within organs whose primary function is not endocrine. These include cells within the heart that produce atrial natriuretic peptide, liver cells that produce insulin-like growth factor type I (IGF-I), cells within the kidney that produce erythropoietin, and numerous cell types within the gastrointestinal tract that produce gastrointestinal hormones. There also exist collections of cell bodies (called nuclei) within the hypothalamus that secrete peptides, called neurohormones, into capillaries associated with the pituitary gland. A third arm of the endocrine system is represented by numerous cell types that express intracellular enzymes, ectoenzymes, or secreted enzymes that modify inactive precursors or less active hormones into highly active hormones. An example is the generation of angiotensin II from the inactive polypeptide angiotensinogen by two subsequent proteolytic cleavages. Another example is activation of vitamin D by two subsequent hydroxylation reactions in the liver and kidney to produce the highly bioactive hormone 1,25-di hydroxyvitamin D (vitamin D).

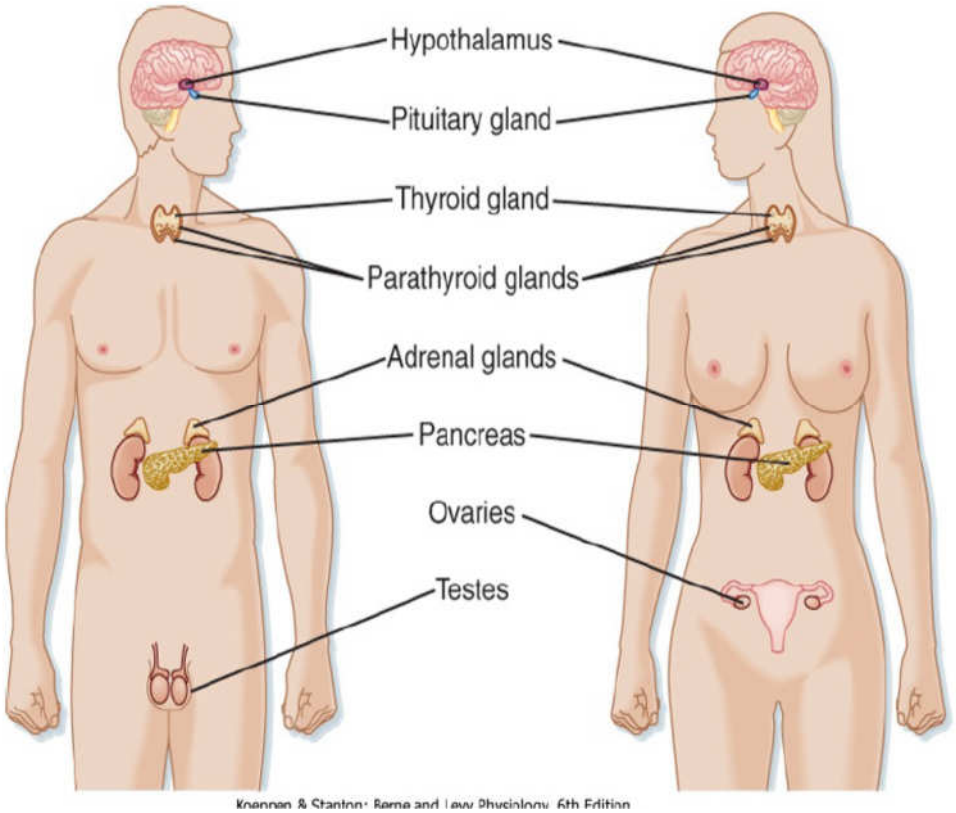

Figure 2: **Glands of the endocrine system.**

CONFIGURATION OF FEEDBACK LOOPS WITHIN THE ENDOCRINE SYSTEM

The predominant mode of a closed feedback loop among endocrine glands is negative feedback**.** In a negative feedback loop, "hormone A" acts on one or more target organs to induce a change (either a decrease or increase) in circulating levels of "component B," and the change in component B then inhibits secretion of hormone A. Negative-feedback loops confer stability by keeping a physiological parameter (e.g., blood glucose) within a normal range. There are also a few examples of positive feedback in endocrine regulation. A positive closed feedback loop, in which hormone X increases levels of component Y and component Y stimulates secretion of hormone X, confers instability. Under the control of positive-feedback loops, something has "got to give." For example, positive-feedback loops control processes that lead to rupture of a follicle through the ovarian wall or expulsion of a fetus
from the uterus.

SELF- ASSESSMENT EXERCISE

i. What are endocrine cells?
ii. List the four endocrine organs that you know.

3.3 Hormones

Hormones are chemical messengers that are released in one tissue and Transported in the bloodstream to reach specific cells in other tissues.

Types of Hormones

Hormones are classified biochemically as proteins/peptides, catecholamines, iodothyronines, or steroid hormones. The chemical nature of a hormone determines (1) how it is synthesized, stored, and released; (2) how it is transported in blood; (3) its biological half-life and mode of clearance; and (4) its cellular mechanism of action.

Proteins/Peptides Protein and peptide hormones can be grouped into structurally related molecules that are encoded by gene families. Protein/peptide hormones gain their specificity from their primary amino acid sequence and from posttranslational modifications, especially glycosylation. Because protein/peptide hormones are destined for secretion outside the cell, they are synthesized and processed differently from proteins destined to remain within the cell or to be continuously added to the membrane (Fig. 37-5). These hormones are synthesized on the polyribosome as larger preprohormones or prehormones. The nascent peptides have at their N-terminal a group of 15 to 30 amino acids called the signal peptide. The signal peptide interacts with a ribonucleoprotein particle, which ultimately directs the growing peptide chain through a pore in the membrane of the endoplasmic reticulum located on the cisternal (i.e., inner) surface of the endoplasmic reticular membrane. Removal of the signal peptide by a signal peptidase generates a hormone or prohormone, which is then transported from the cisternae of the endoplasmic reticulum to the Golgi apparatus, where it ispackaged into a membrane-bound secretory vesicle that is subsequently released into the cytoplasm. The carbohydrate moiety of glycoproteins is added in the Golgi apparatus.

Functions of Hormones

1. Help regulate:
    - Chemical composition and volume of internal environment (interstitial fluid)
    - Metabolism and energy balance
    - Contraction of smooth and cardiac muscle fibers
    - Glandular secretions
    - Some immune system activities
2. Control growth and development.
3. Regulate operation of reproductive systems.

4. Help establish circadian rhythms.

SELF - ASSESSMENT EXERCISE

Hormones can be classified into 3 groups: ----------, ---------- and ----------

4.0 CONCLUSION

You should have seen that the endocrine system includes all the endocrine cells and tissues of the body. They have glandular secretory cells that release their secretions into the extracellular fluid. The main function of the endocrine system is to preserve homeostasis by coordinating and regulating the activities of other cells, tissues, organs, and systems. The endocrine system consists of cells, tissues, and organs that secrete hormones critical to homeostasis. The body coordinates its functions through two major types of communication: neural and endocrine. Neural communication includes both electrical and chemical signaling between neurons and target cells. Endocrine communication involves chemical signaling via the release of hormones into the extracellular fluid. From there, hormones diffuse into the bloodstream and may travel to distant body regions, where they elicit a response in target cells. Endocrine glands are ductless glands that secrete hormones. Many organs of the body with other primary functions—such as the heart, stomach, and kidneys—also have hormone-secreting cells. Hormones are derived from amino acids or lipids. Amine hormones originate from the amino acids tryptophan or tyrosine. Larger amino acid hormones include peptides and protein hormones. Steroid hormones are derived from cholesterol.

5.0 SUMMARY

In this unit we have considered the fact that endocrine cells are different from exocrine cells; the latter secrete their products onto epithelia's surfaces generally by way of ducts. Also, there are several similarities as well as distinctions between the endocrine system and the nervous system.

6.0 TUTOR-MARKEDASSIGNMENT

Discuss the synergistic relationship of the endocrine and nervous systems.

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UNIT 2 THE REPRODUCTIVE SYSTEM

CONTENTS

1.0 INTRODUCTION

The reproductive system is the only system that is not essential to the life of the individual, although its activities do impact other systems. The system ensures the continuous existence of the human race. Sexually mature males and females produce individual reproductive cells that come together and produce new being.

2.0 OBJECTIVES

By the end of this unit, you will be able to: Explain reproduction

- describe the mail reproductive organs
- describe the female reproductive organs
- describe the hormones involved in reproduction.

3.0 MAIN CONTENT

3.1 Male reproductive organs

A) Testes: The structures include epididymis, straight tubules, ciliated rete testes, lobules and seminiforous tubules (2-3 per lobule) which consists of the following:

- Leydig cells
- Sertoli cells
- Spermatogonia

Other reproductive structures include:
Vas deferens - muscular walls, propels spermatozoa towards urethra
Seminal vesicle - contributes 60% seminal volume.

Prostate gland - contributes 25% of seminal volume
Cowper's gland – produces mucus
Hormones of the male reproductive system include:
Gonadotropin releasing hormone (GnRH) - triggers FSH & LH release from anterior pituitary.
Follicle stimulating hormone (FSH) - triggers spermatogenesis, inhibin.
Lutenizing hormone (LH) - stimulates testosterone secretion
Testosterone - induces secondary male characteristics, stimulates late spermatogenesis steps.
Androgen binding protein (ABP) - binds testosterone, concentrates it in seminal tubules

SELF-ASSESSMENT EXERCISE

i. Highlight the importance of the reproductive system.
ii. What are the components of the testes?

3.2 Female reproductive organs

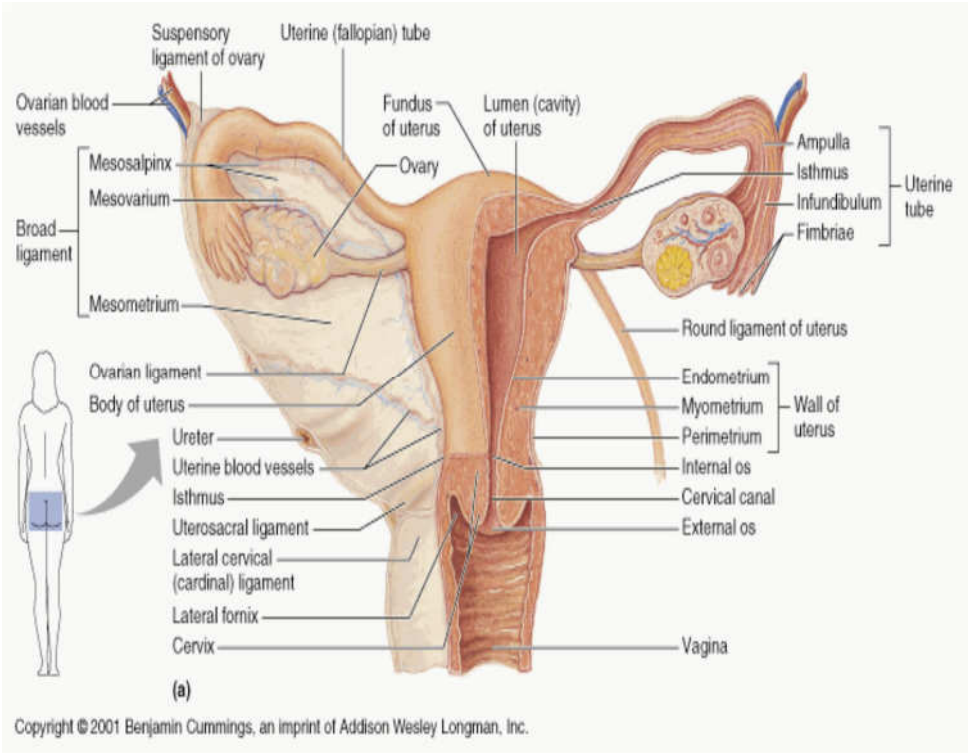

Fig 3: Female Reproductive Organs

Ovaries: Produce oocytes and hormones: Oestrogens and Progesterone.

Uterine tubes: Deliver oocytes or embryo to uterus; normal site of fertilization

Uterus: Site of embryonic development and exchange between maternal and embryonic bloodstreams.

Vagina: Site of sperm deposition; acts as birth canal at delivery; provides passageway for fluids during menstruation.

External genitalia (Clitoris): Contains erectile tissue; produces pleasurable sensations during sexual activities.

Labia: Contain glands that lubricate entrance to vagina.
Mammary glands: Produce milk that nourishes newborn infant.

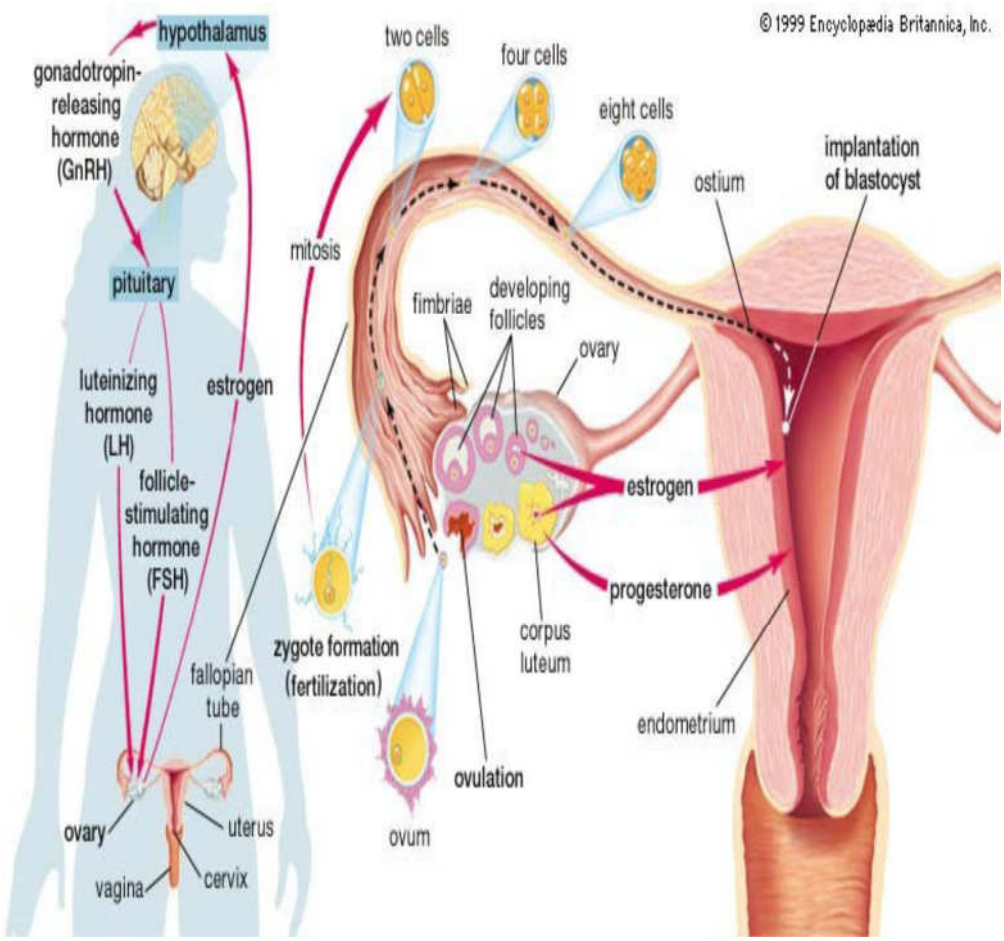

Fig 4: **Female reproductive Hormones and their roles**
Source: 1999 Encyclopedia Britannica, Inc

The reproductive process

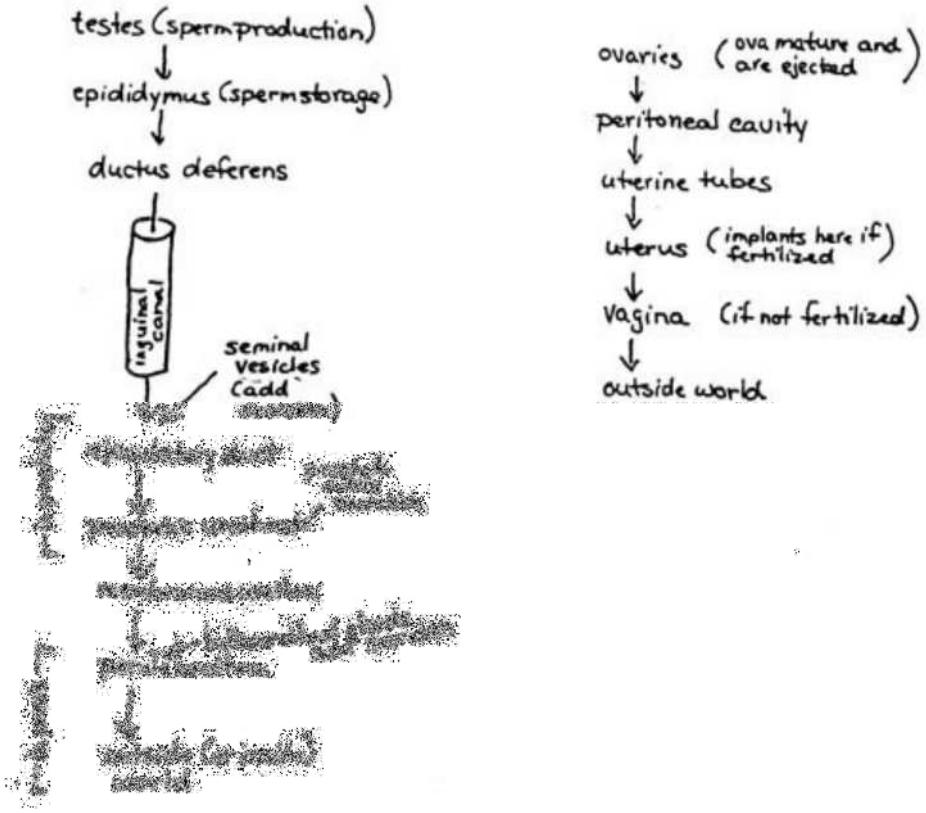

Fig 5: Illustration of the reproductive process
Source: www.relief/manual

SELF-ASSESSMENT EXERCISE

i. Name five parts of the female reproductive system.
ii. What is the role of the uterus?

4.0 CONCLUSION

The reproductive system, though not important to being alive, is very important for procreation**.**

5.0 SUMMARY

In this unit we have learnt that the Reproductive system is different for the male and female, the reproductive hormones are also different.

6.0 TUTOR-MARKED ASSIGNMENT

1. List four male reproductive hormones.
2. Describe the reproductive process.

7.0 REFERENCES/FURTHER READING

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MODULE 4 URINARY SYSTEM

UNIT 1 INTRODUCTION TO THE URINARY SYSTEM

CONTENTS

1.0 INTRODUCTION

Excretion is the process by which the unwanted substances and metabolic wastes are eliminated from the body. The urinary system is the entire system of ducts and channels that conduct urine from the kidneys to the exterior. It includes the ureters, the urinary bladder and the urethra. The main function of the urinary system is to maintain homeostasis of blood composition, volume and pressure.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- discuss the overall function of the urinary system
- identify the major organs of the urinary system and describe their functions
- describe the mechanism of action of the urinary system.

3.0 MAIN CONTENT

3.1 Introduction to the Major Organs of the Urinary System

The major organs of the Urinary system are the:

Kidneys
Ureters
Urinary bladder
Urethra

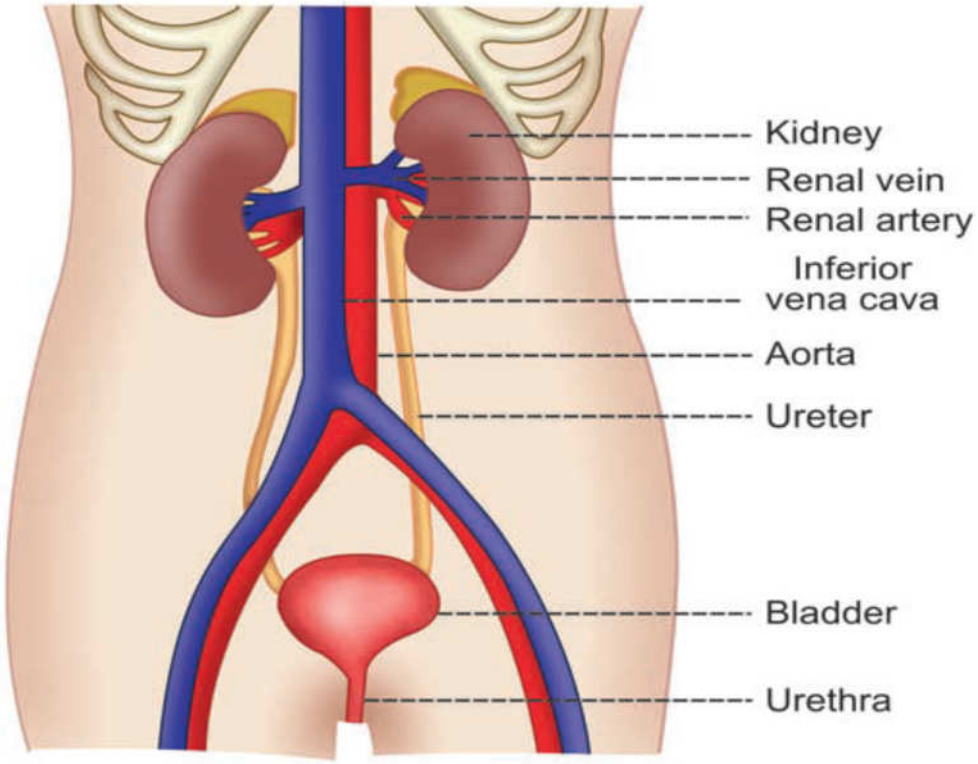

Figure 1: Urinary system

They are located in the abdomen, pelvis and perineum and are responsible for the formation elimination of urine and other waste materials from the body.

3.2 Introduction to the Structure and Function of the Kidney

- Hilum –This is the entrance to renal sinus.
- Renal pelvis – An expansion of the ureter.
- Calyces (major and minor) – These are tubes emanating from renal pelvis.
- Inner medullary region – This contains renal columns and pyramids (site of nephrons).
- Outer cortex - Forms the outer cover and renal columns.

- Renal columns –This is the portion of cortex extending between renal pyramids
- Renal pyramids – The number is approximately 8-18 regions per kidney.

The Major Functions of the Kidney

The kidney:

- Regulates blood volume and composition
- Regulates blood pressure as it monitors renal blood pressure and the secretion of rennin
- Regulates certain aspects of metabolism like gluconeogenesis.

3.3 An Overview of the Nephron

There are two principal types of nephrons: cortical nephron and juxtamedullary nephron.

Each nephron has two major portions:

1. Renal corpuscle.
2. Renal tubule.

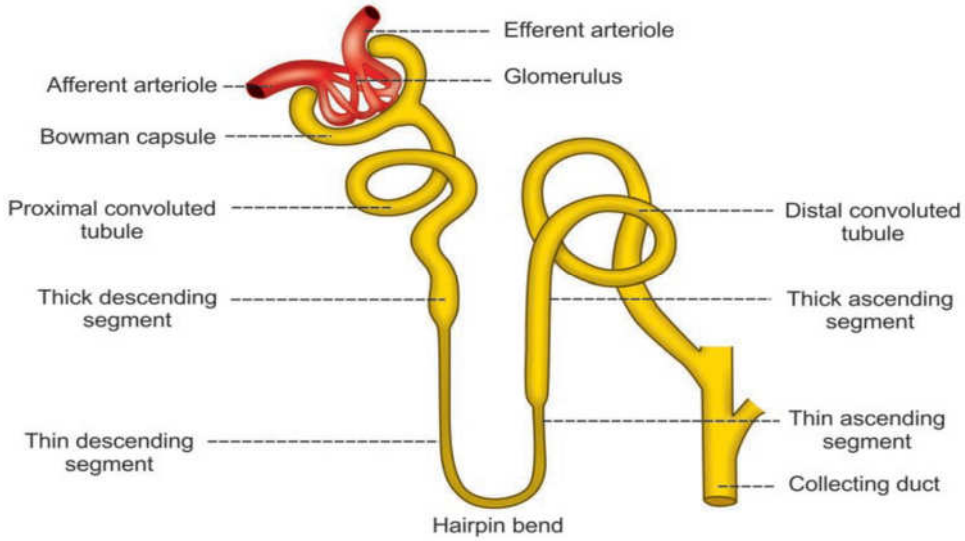

Figure 2: The nephron of human kidney

3.4 Filtrate Production

This is a three-step process:

1. Glomerular filtration: Filters fluid and waste solutes out of the blood.
2. Tubular reabsorption: Returns important solutes to the blood.

3. Tubular secretion: Selective secretion of more solutes into filtrates.

The one major factor affecting the glomerular filtration rate (GFR) is the glomerular hydrostatic pressure (HPg), which is determined by the diameter of afferent/efferent arterioles. The major mechanisms regulating GFR are:

1. Renal autoregulation
2. Hormonal regulation, like aldosterone and antidiuretic hormone (ADH)
3. Neuronal regulation

SELF- ASSESSMENT EXERCISE

i. What are the three major functions of the kidneys?
ii. The four major organs of the urinary system are ----------
---------, ---------- and ----------

4.0 CONCLUSION

The kidney is very essential to life because it helps to get rid of substances that are toxic to the body, and also helps to maintain homeostasis.

5.0 SUMMARY

This unit has shown that the urinary system consists of the kidneys, the ureters, the urinary bladder and the urethra. The important role played by the nephron is the process of glomerular filtration.

6.0 TUTOR-MARKEDASSIGNMENT

1. What is the basic function of a nephron?
2. Write out the three steps of renal filtration.

7.0 REFERENCES/FURTHER READING

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UNIT 2 THE STRUCTURE OF THE KIDNEY

CONTENTS

1.0 INTRODUCTION

The urinary system is also called the excretory system of the body because one of its functions is to remove waste products from the blood and eliminate them from the body. The urinary system consists of two kidneys which are the organs that extract wastes from the blood, balance body fluids and form urine. The two ureters are tubes which conduct urine from the kidneys to the urinary bladder while the urinary bladder is a reservoir that receives and stores the urine brought to it by the two ureters. The urethra is a tube that conducts urine from the bladder to the outside of the body for elimination.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- Discuss the structure & functions of the kidney
- Describe Accessory excretory structures of the urinary system
- Discuss Urine and urination

3.0 MAIN CONTENT

3.1 Structure and functions of the Kidney

This is a pair of reddish brown, bean shaped organ located in the posterior wall of the abdominal region, one in each side of the vertebral column. They usually span between T12 to L3. They are protected at least partially by the last pair of ribs and capped by the adrenal gland. The bean shape of the kidney is medially concave and laterally convex. On the medial concave border is the hilus (small indented area) where blood vessels,

nerves & ureters enter and leave the kidney. Covering and supporting each kidney are three layers of tissue:

- Renal capsule – innermost, tough, fibrous layer
- Adipose or fatty capsule – the middle layer composed of fat, giving the kidney protective cushion.
- Renal fascia – is outer sub-serous connective tissue layer.

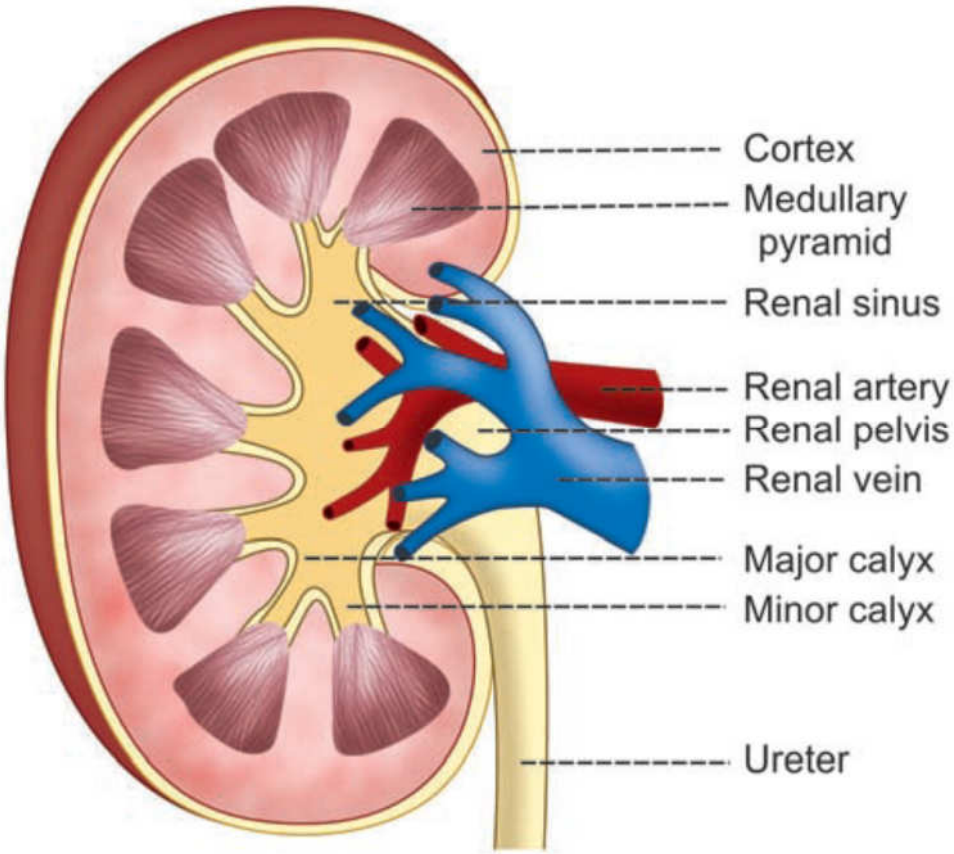

Fig. 3: the structure of kidney

The kidneys are slightly protected by the ribs and are surrounded by fat for protection.

3.1.1 Internal Anatomy of the kidney

A sagittal section of the kidney reveals three distinct regions called pelvis, medulla and cortex from inside to out.

The **renal pelvis** is the large collecting space within the kidney formed from the expanded upper portion of the ureters. The pelvis branches into two levels of cavities; these are 2-3 major calyces and 8 to 18 minor calyces.

The **Renal medulla** is the middle portion of the kidney. It consists of 8 to 18 renal pyramids, which are longitudinally striped, cone-shaped areas.

The base of each pyramid is adjacent to the outer cortex. The apex of each renal pyramid ends in a papilla, which opens to a minor calyx. Pyramids contain tubules and collecting ducts of the nephron. The tubules are involved in transportation and re-absorption of filtered materials. Th **renal cortex** is the outermost portion of the kidney. It is divided into two regions: the outer cortical and the inner juxtamedullary region. The cortical tissue that penetrates between the pyramids forms ***Renal Columns***. The renal columns are composed of mainly collecting tubules.

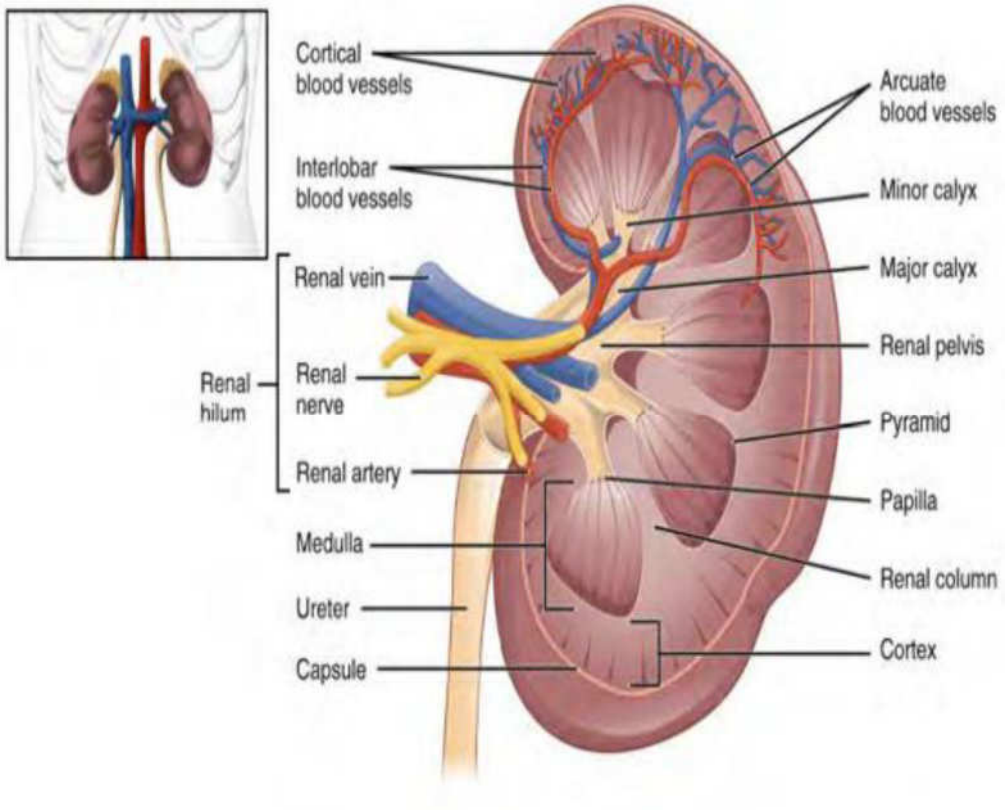

Figure 4: **Internal structure of the Kidney**

3.1.2 Functions of the Kidney

All the functions are directly or indirectly related to the formation of urine. The series of events leads to:

- Elimination of wastes
- Regulation of total body water balance.
- Control of the chemical composition of blood and other body fluids
- Control of acid base balance

The processes in urine formation are: -

1. Blood filtration; every day the kidneys filter 1700 liters of blood
2. Tubular re-absorption

3. Tubular secretion

The relative amounts of filtration, re-absorption and excretion in the kidney tubular system is influenced by daily diet, fluid intake, weather factors and exercise, all of which determine the composition of urine.

3.2 Accessory Excretory structures

Urine is formed in the kidney, but accessory structures are required to transfer, store and eventually eliminate urine from the body. These structures are the two ureters, urinary bladder and urethra.

3.2.1 Ureters

Attached to each kidney are two tubes called the ureters. Ureters transport urine from the renal pelvis to the urinary bladder. The ureters spass between the parietal peritoneum and the body wall to the pelvic cavity, where they enter the pelvic cavity. It is narrow at the kidney and widen near the bladder. The wall of the ureters is composed of three layers:

a. Innermost Tunica Mucosa
b. The middle Tunica Muscularis (made of smooth muscle)
c. The outer Tunica Adventitia

3.2.2 Urinary bladder

Urinary bladder is a hollow, muscular organ that collects urine from the ureters and store it until it is excreted. It usually accumulates 300 to 400 ml of urine but it can expand twice as much. It is located on the floor of the pelvic cavity like the kidneys and ureters. It is ***Retroperitoneal***. In males it is anterior to the rectum and above the prostate gland. In females, it is located somewhat lower, anterior to the uterus and upper vagina.

3.2.3 Urethra

Urethra is a tube of smooth muscle lined with mucosal layer. It leaves the bladder at its inferior surface (base) and transports urine outside the body during urination. It is an average of 4 cm long in females and 12 cm in length in males. In females it opens between the vagina and clitoris. In males, it passes through the prostate, membranous portion (pelvic diaphragm muscle), spongy portion (that passes through corpus spongiosus muscle) and open at the tip of penis. The spongy portion is joined by ducts from the bulbo-uretheral gland (Mucus secreting gland).

3.3 Urine & urination

Composition of urine varies depending on the diet, exercise, water consumption and other. However, it is composed of mainly water, urea, chloride, potassium, sodium, creatinin, phosphate, sulfates and uric acid. Proteins, glucose, casts (decomposed blood) and calculi from minerals are abnormal if present in urine. The PH of urine is 5.0 to 8.0 (mostly acidic) and has translucent (clear, not cloudy) color. To maintain the proper osmotic concentration of the extra cellular fluid to excrete wastes and to maintain proper kidney function the body must excrete at least 450ml of urine per day. A healthy person excretes 1000 to 1800 ml of urine daily. The volume and concentration of urine is controlled by:

- Antidiuretic hormone
- Aldestrone
- The Renin – angiotensin mechanism

3.3.1 Micturition

Urination is emptying of the bladder; it is the process of conscious andunconscious nerve control. Steps of urination are:

- Conscious desire to urinate
- Pelvic diaphram muscles relax
- Urinary bladder neck moves down, outlet opens
- Wall stretches
- Receptors are stimulated
- Smooth muscle of Urinary bladder Contracts & urine ejects.

4.0 CONCLUSION

Urine is a fluid of variable composition that requires specialized structures to remove it from the body safely and efficiently. Blood is filtered, and the filtrate is transformed into urine at a relatively constant rate throughout the day. This processed liquid is stored until a convenient time for excretion. All structures involved in the transport and storage of the urine are large enough to be visible to the naked eye. This transport and storage system not only stores the waste, but it protects the tissues from damage due to the wide range of pH and osmolarity of the urine, prevents infection by foreign organisms, and for the male, provides reproductive functions.

5.0 SUMMARY

In this unit, we have discussed the structure & functions of the kidney, accessory excretory structures of the urinary system, Urine and urination.

6.0 TUTOR-MARKED ASSIGNMENT

Discuss the external structures of kidney
Briefly discuss the structures involved in removing urine from the body

7.0 REFERENCES/FURTHERREADING

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MODULE 5 THE SPECIAL SENSES

UNIT 1 THE TONGUE AND THE SENSE OF TASTE

CONTENTS

1.0 INTRODUCTION

Taste is mainly a function of the *taste buds* in the mouth, but it is common experience that one's sense of smell also contributes strongly to taste perception. In addition, the texture of food, as detected by tactual senses of the mouth, and the presence of substances in the food that stimulate pain endings, such as pepper, greatly alter the taste experience. The importance of taste lies in the fact that it allows a person to select food in accord with desires and often in accord with the body tissues' metabolic need for specific substances.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- discuss the anatomy of the tongue and the function of each part.
- describe how taste sensations are created and interpreted
- discuss the five primary taste sensations
- describe the histology and function of a typical taste bud
- explain the neuronal pathways for the sensation

3.0 MAIN CONTENT

3.1 Functions of Taste

Substances called **tastants** dissolve in saliva, enter the taste pores, and by various mechanisms cause the taste cells to depolarize. For example, the diffusion of the positively charged ions Na+ and H+ into the taste cells causes depolarization. The binding of tastants to receptors on the taste hairs activates G proteins, which results in depolarization by causing Ca2+ channels to open or K+ channels to close. When the taste cells depolarize, they release neurotransmitters that diffuse to sensory neurons associated with the taste cells. The neurotransmitters stimulate action potentials in the sensory neurons, which are conducted to the brain, where the sense of taste is perceived. Five **primary tastes** have been identified in humans: salty, sour, sweet, bitter, and umami (a Japanese term loosely translated as savoury). The salty taste is stimulated by Na+; sour by acids; sweet by sugars, some other carbohydrates, and some proteins; bitter by alkaloids (bases); and umami by the amino acid glutamate and related compounds. The umami taste sensation is most intense when coupled with the salty taste, hence the popularity of adding salt to tomatoes, ketchup, soy sauce, and the food additive monosodium glutamate (MSG). Even though only five primary tastes have been identified, humans can perceive a fairly large number of different tastes, presumably by combining the five basic taste sensations. Thresholds for the five primary taste stimuli vary. Sensitivity for bitter substances is the highest. Many alkaloids are poisonous, and the high sensitivity for bitter tastes may be protective because of the avoidance of bitter foods. On the other hand, humans tend to crave sweet, salty, and umami tastes, perhaps in response to the body's need for sugars, carbohydrates, proteins, and minerals. Many of the sensations thought of as being tastes are strongly influenced by olfactory sensations.

This phenomenon can be demonstrated by pinching one's nose to close the nasal passages while trying to taste something. With olfaction blocked, it is difficult to distinguish between the taste of a piece of apple and the taste of potato. Much of the "taste" is lost by this action. This is one reason that a person with a cold has a reduced sensation of taste. The tongue can detect other stimuli besides taste, such as temperature and texture, and these stimuli can influence the sensation of taste. Food served at the wrong temperature is perceived as distasteful. Stimulationense of taste of hot receptors by capsaicin or black pepper is interpreted as hot or spicy, and stimulation of cold receptors is perceived as fresh or minty.

3.2 Location of Taste Buds

The taste buds are found on three types of papillae of the tongue, as follows:

(1) A large number of taste buds are on the walls of the troughs that surround the circumvallate papillae, which form a V line on the surface of the posterior tongue.
(2) Moderate numbers of taste buds are on the fungiform papillae over the flat anterior surface of the tongue.
(3) Moderate numbers are on the foliate papillae located in the folds along the lateral surfaces of the tongue. Additional taste buds are located on the palate, and a few are found on the tonsillar pillars, on the epiglottis, and even in the proximal esophagus. Adults have 3000 to 10,000 taste buds, and children have a few more. Beyond the age of 45 years, many taste buds degenerate, causing taste sensitivity to decrease in old age.

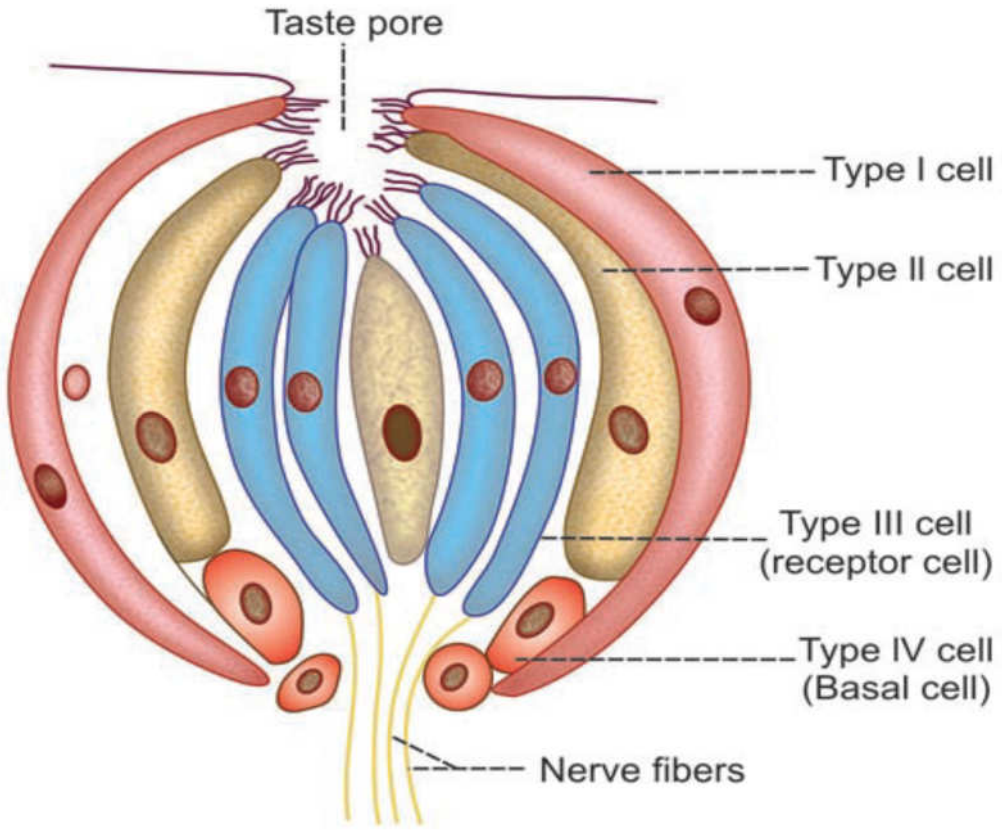

FIGURE 1: Taste bud

3.3 Histology of Taste Buds

Each of the 10,000 taste buds on a person's tongue consists of three major types of specialised epithelial cells. The sensory cells of each taste bud consist of about 50 taste cells. Each taste cell has several microvilli, called taste hairs, extending from its apex into a tiny opening

in the epithelium called the taste pore. The remaining two nonsensory cell types are basal cells and supporting cells. Like olfactory cells, the cells of the taste buds are replaced continuously, each having a normal life span of about 10 days.

3.4 Taste Preference and Control of Diet

Taste preference simply means that an animal will choose certain types of food in preference to others, and the animal automatically uses this to help control the diet it eats. Furthermore, its taste preferences often change in accord with the body's need for certain specific substances. The following experiments demonstrate the ability of animals to choose food in accord with the needs of their bodies.

First, adrenalectomies, salt-depleted animals automatically select drinking water with a high concentration of sodium chloride in preference to pure water, and this is often sufficient to supply the needs of the body and prevent salt depletion death.

Second, an animal given injections of excessive amounts of insulin develops a depleted blood sugar, and the animal automatically chooses the sweetest food from among many samples.

Third, calcium-depleted parathyroidectomies animals automatically choose drinking water with a high concentration of calcium chloride. Also, human beings reject any food that has an unpleasant affective sensation, which in many instances protects our bodies from undesirable substances. The phenomenon of taste preference almost certainly results from some mechanism located in the central nervous system and not from a mechanism in the taste receptors themselves, although the receptors often become sensitised in favour of a needed nutrient. An important reason for believing that taste preference is mainly a central nervous system phenomenon is that previous experience with unpleasant or pleasant tastes plays a major role in determining one's taste preferences. For instance, if a person becomes sick soon after eating a particular type of food, the person generally develops a negative taste preference, or taste aversion, for that particular food thereafter; the same effect can be demonstrated in lower animals

3.5 Clinical Correlates

Much of what is perceived as a taste defect is truly a primary defect in olfaction resulting in an alteration in taste.

SELF-ASSESSMENT EXERCISE

At the histology laboratory, examine the histological structure of the papillae with taste buds on the taste bud slide.

4.0 CONCLUSION

In this unit, you learnt the main function of the *taste buds* in the mouth, and the common experience that one's sense of smell also contributes strongly to taste perception.

5.0 SUMMARY

- Taste is mainly a function of the *taste buds* in the mouth, but it is common experience that one's sense of smell also contributes strongly to taste perception.
- Receptors on the hairs detect tastants (dissolved substances). Five basic types of taste exist sour, salty, bitter, sweet, and umami.
- Taste buds usually are associated with papillae – circumvallate, fungiform and foliate papillae.
- Taste buds consist of taste cells, basilar cells, and supporting cells. The taste cells have taste hairs that extend into taste pores.
- Taste preference simply means that an animal will choose certain types of food in preference to others, and the animal automatically uses this to help control the diet it eats. Furthermore, its taste preferences often change in accord with the body's need for certain specific substances.

6.0 TUTOR-MARKED ASSIGNMENT

1. Taste cells
   a. are found only on the tongue.
   b. extend through tiny openings called taste buds.
   c. have no axons but release neurotransmitters when stimulated.
   d. have axons that extend directly to the taste area of the cerebral cortex.
2. Which of these is *not* one of the basic tastes?
   a. spicy
   b. salty
   c. bitter
   d. umami
   e. sour

3. What are the three kinds of lingual papillae, and where are they located?

4. Do taste receptors undergo adaptation?
5. Describe taste preference in relation to diet control.

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UNIT 2 THE NOSE AND THE SENSE OF SMELL

CONTENTS

1.0 INTRODUCTION

Smell is the least understood of our senses. This results partly from the fact that the sense of smell is a subjective phenomenon that cannot be studied with ease in lower animals. Another complicating problem is that the sense of smell is poorly developed in human beings in comparison with the sense of smell in many lower animals.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- describe the histological structure and function of the olfactory epithelium and the olfactory bulb
- explain how the perception of many different odours is possible
- describe the neuronal pathways for the sense of smell.

3.0 MAIN CONTENT

3.1 Olfactory Epithelium and Bulb

A small superior part of the nasal cavity is lined with olfactory epithelium. Ten million olfactory neurons are present within the olfactory epithelium. Olfactory neurons are bipolar neurons with dendrites extending to the epithelial surface of the nasal cavity. The ends of the dendrites are modified into bulbous enlargements with long, specialised cilia, called olfactory hairs, which lie in a thin mucous film on the epithelial surface. The mucus keeps the nasal epithelium moist traps and dissolves molecules, and facilitates the removal of molecules

and particles from the olfactory epithelium. Airborne odorants become dissolved in the mucus on the surface of the epithelium and bind to molecules on the membranes of the olfactory hairs called **olfactory receptors.** The odorants must first be dissolved in fluid in order to reach the olfactory receptors. When an odorant binds to its receptor, a G protein associated with the receptor is activated. As a result of activation of the G protein, Na+ and Ca2+ channels in the membrane open. The influx of ions into the olfactory hairs results in depolarization and the production of action potentials in the olfactory Neurons. Once an odorant binds to its receptor, however, the receptor accommodates and does not respond to another odorant for some time.

3.2 Threshold for detection of odors

The threshold for the detection of odours is very low, so very few odorants bound to an olfactory neuron can initiate an action potential. Methylmercaptan, which has nauseating odour similar to that of rotten cabbage, is added to natural gas at a concentration of about one part per million. A person can detect the odour of about 1/25 billionth of a milligram of the substance and therefore is aware of the presence of the more dangerous but odourless natural gas. There are approximately 1000 different odorant receptors, which can react to odorants of different sizes, shapes, and functional groups. The average person can distinguish among approximately 4000 different smells. It has been proposed that the wide varieties of detectable odors are actually combinations of a smaller number of **primary odours.** The seven primary odours are camphoraceous (e.g., moth balls), musky, floral, peppermint, ethereal (e.g., fresh pears), pungent, and putrid. It is very unlikely, however, that this list is an accurate representation of all primary odours, and some studies point to the possibility of as many as 50 primary odours.

3.3 Neuronal Pathways for Olfaction

Axons from olfactory neurons form the **olfactory nerves (I),** which pass through the olfactory foramina of the cribriform plate and enter the **olfactory bulb**. There they synapse with interneurons that relay action potentials to the brain through the **olfactory tracts.** Each olfactory tract terminates in the **olfactory cortex** and the **amygdala** in the temporal lobe. It is here that the sensation of smell is perceived. The olfactory cortex is part of the limbic system, projecting to the hypothalamus, amygdala, and hippocampus of the cerebrum. Odours can produce strong emotional reactions, memories, and other responses

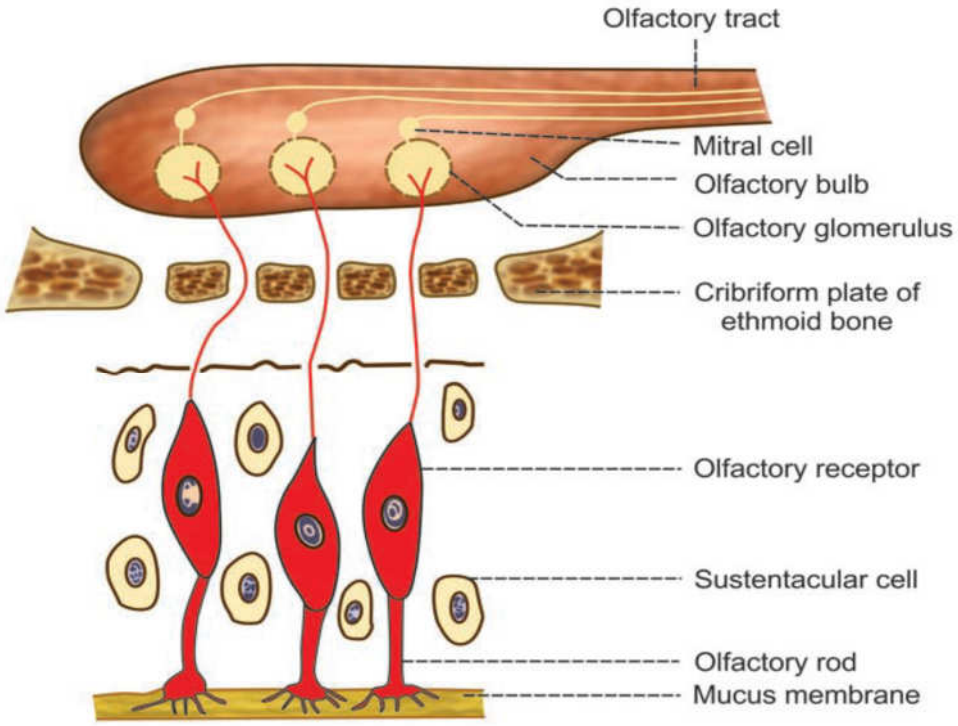

Figure 2: Olfactory mucus membrane and pathway for olfactory sensation

3.4 Clinical Correlates

i. **Anosmia -** a complete loss of smell
ii. **Hyposmia –** partial loss of smell or decreased sensation of smell
iii. **Hyperosmia –** enhanced smell sensitivity
iv. **Dysosmia –** distortion in odour perception(includes parosmia and phantosmia)
v. **Parosmia –** distortion of perception of an external stimulus
vi. **Phantosmia –** smell perception with no external stimulus.

Common causes of smell disorders include:

Aging, sinus and other respiratory infections, smoking, growths in nasal cavities, head injury, hormonal disturbances, dental problems, exposure to certain chemicals, such as insecticides and solvents, radiation for treatment of head and neck cancers.

4.0 CONCLUSION

In this unit, you have learnt that the sense of smell is a subjective phenomenon that cannot be studied with ease in lower animals.

5.0 SUMMARY

- Olfaction is the sense of smell.
- Olfactory neurons in the olfactory epithelium are bipolar neurons.
  Their distal ends have olfactory hairs. The olfactory hairs have receptors that respond to dissolved substances. There are approximately 1000 different odorant receptors.
- The receptors activate G proteins, which results in ion channels opening and depolarization.
- At least seven (perhaps 50) primary odours exist. The olfactory neurons have a very low threshold and accommodate rapidly.
- Axons from the olfactory neurons extend as olfactory nerves to the olfactory bulb, where they synapse with interneurons. Axons from these cells form the olfactory tracts, which connect to the olfactory cortex.

The olfactory bulbs and cortex accommodate to odours.

SELF-ASSESSMENT EXERCISE

At the histology laboratory, examine the olfactory cells slides under the microscope.

At the gross anatomy laboratory, identify the location of the olfactory epithelium and its relationship to the olfactory bubs and the cribriform plate on the sagittal head model.

6.0 TUTOR-MARKED ASSIGNMENT

1. Olfactory neurons

a. have projections called cilia. b. have axons that combine to form the olfactory nerves.
b. connect to the olfactory bulb.
c. have receptors that react with odorants dissolved in fluid.
d. all of the above.

2 What are the characteristics of an odorant—a chemical molecule that stimulates a smell receptor?

3. Does adaptation of smell receptors occur?

4. Do all of the volatile chemicals in the nose stimulate smell receptors?

5 Which of the cranial nerves innervate the olfactory mucosa?

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Hutchinson, M., Mallat, J., Marieb, E.N., Wilhelm P.B. (2007). *A Brief Atlas of the Human Body*. Sna Franscisco: Pearson Education Inc.

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UNIT 3 THE EAR AND SENSE OF HEARING AND BALANCE

CONTENTS

1.0 INTRODUCTION

The organs of hearing and balance are divided into three parts: the external, middle, and inner ear. The **external ear** is the part extending from the outside of the head to the **tympanic membrane,** or **eardrum.** The **middle ear** is an air-filled chamber medial to the tympanic membrane. The **inner ear** is a set of fluid-filled chambers medial to the middle ear. The external and middle ears are involved in hearing only, whereas the inner ear functions in both hearing and balance.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- describe the anatomy of the ear and the function of each part
- explain how sounds travel through the ear and are interpreted in the brain
- explain the role of the ear in maintaining equilibrium
- describe various disorders of the ear.

3.0 MAIN CONTENT

3.1 Auditory Structures

External Ear/Auricle

The auricle is the fleshy part of the external ear on the outside of the head. The auricle opens into the external acoustic meatus, a passageway that leads to the tympanic membrane. The auricle collects sound waves and directs them toward the external acoustic meatus, which transmits

them to the tympanic membrane. The external acoustic meatus is lined with hairs and ceruminous glands, which produce cerumen, a modified sebum commonly called earwax. The hairs and cerumen help prevent foreign objects from reaching the delicate tympanic membrane. The tympanic membrane is a thin membrane separating the external ear from the middle ear. It consists of a thin layer of connective tissue sandwiched between two epithelial layers. Sound waves reaching the tympanic membrane cause it to vibrate.

Middle Ear

Medial to the tympanic membrane is the air-filled cavity of the middle ear. Two covered openings, the **oval window** and the **round window** on the medial side of the middle ear, connect the middle ear with the inner ear. The middle ear contains three **auditory ossicles**: the **malleus, incus**, and **stapes.** These bones transmit vibrations from the tympanic membrane to the oval window. The malleus is attached to the medial surface of the tympanic membrane. The incus connects the malleus to the stapes. The base of the stapes is seated in the oval window and is surrounded by a flexible ligament. Two small muscles in the middle ear help dampen vibrations of the auditory ossicles caused by loud noises. The **tensor tympani** muscle is attached to the malleus and is innervated by the trigeminal nerve (V). The **stapedius** muscle is attached to the stapes and is innervated by the facial nerve (VII). Two openings provide air passages from the middle ear. One passage opens into the **mastoid air cells** in the mastoid process of the temporal bone. The other passageway is the **auditory tube,** also called the **pharyngotympanic tube** or the **eustachian tube.** The auditory tube opens into the pharynx and enables air pressure to be equalised between the outside air and the middle ear cavity. When a person changes altitude, air pressure outside the tympanic membrane changes relative to the air pressure in the middle ear. With an increase in altitude, the pressure outside the tympanic membrane becomes less than the air pressure inside the middle ear and the tympanic membrane is pushed outward. With a decrease in altitude, the air pressure outside the ear becomes greater than in the middle ear and the tympanic membrane is pushed inward. Distortion of the tympanic membrane can make sounds seem muffled and stimulate pain. These symptoms can be relieved by opening the auditory tube to allow air to pass through the auditory tube to equalise air pressure. Swallowing, yawning, chewing, and holding the nose and mouth shut while gently trying to force air out of the lungs are methods use to open the auditory tube.

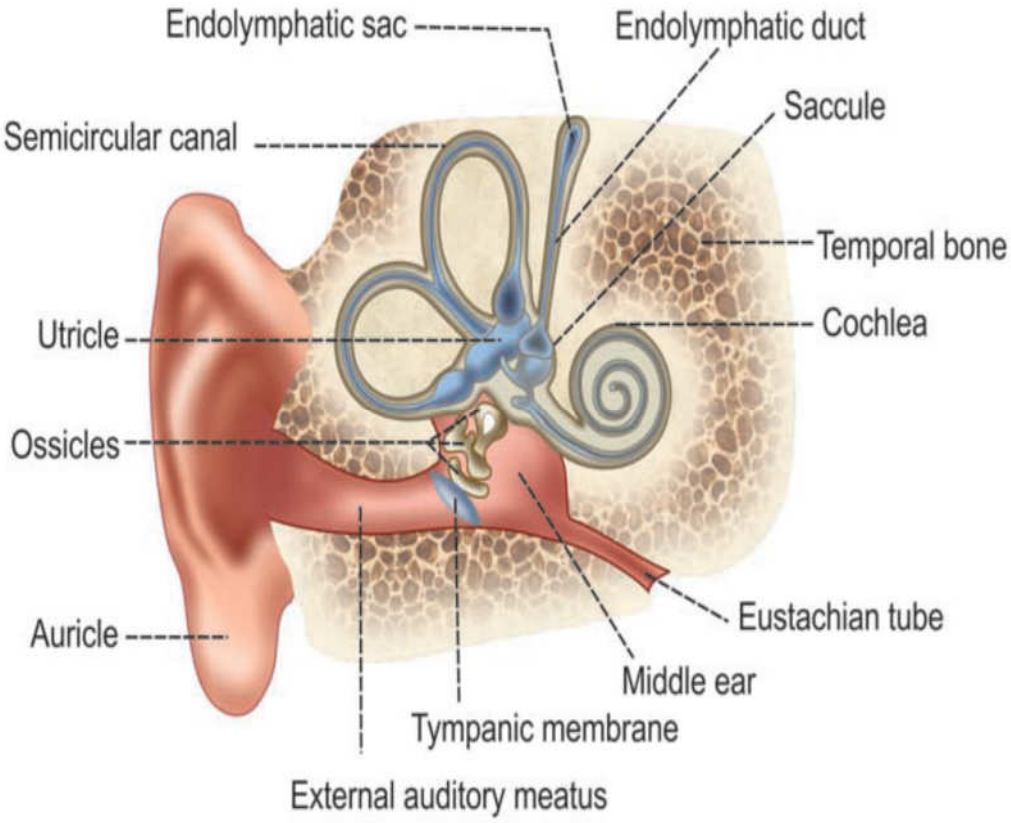

Fig.3: Major Parts of the Ear

Inner Ear

The inner ear contains the sensory organs for hearing and balance. It consists of interconnecting, fluid-filled tunnels and chambers within the temporal bone called the bony labyrinth. The bony labyrinth is lined with endosteum. When the inner ear is drawn, it is the endosteum that is depicted. The bony labyrinth is divided into three regions: cochlea, vestibule, and semicircular canals. The vestibule and semicircular canal are involved primarily in balance, and the cochlea is involved in hearing. Inside the bony labyrinth is a similarly shaped but smaller set of membranous tunnels and chambers called the membranous labyrinth. The membranous labyrinth is filled with a clear fluid called endolymph, and the space between the membranous and bony labyrinths is filled with a fluid called perilymph. Perilymph is very similar to cerebrospinal fluid, but endolymph has a high concentration of potassium and a low concentration of sodium, which is opposite to perilymph and cerebrospinal fluid. The membranous labyrinth of the cochlea separates the bony labyrinth into two parts. The cochlea is shaped like a snail shell—that is, a coiled tube. The base of the cochlea connects to the vestibule and the apex of the cochlea is the end of the coiled tube. The bony core of the cochlea, around which the tube coils, is shaped like a screw with threads called the spiral lamina. A Y-shaped, membranous complex divides the cochlea into three portions. The base of the Y is the

spiral lamina. One branch of the Y is the vestibular membrane, and the other branch is the basilar membrane. The space between these membranes is called the cochlear duct.

3.2 Neuronal Pathway for Hearing and Balance

The axons of the sensory neurons supplying hair cells form the cochlear nerve. These sensory neurons are bipolar neurons, and their cell bodies are in the cochlear, or spiral, ganglion, located in the bony core of thecochlea. The cochlear nerve joins the vestibular nerve to become the vestibulocochlear nerve (VIII), which traverses the internal acoustic meatus and enters the cranial cavity. The special senses of hearing and balance are both transmitted by the vestibulocochlear (VIII) nerve. The term *vestibular* refers to the vestibule of the inner ear, which is involved in balance. The term *cochlear* refers to the cochlea of the inner ear, which is involved in hearing. The vestibulocochlear nerve functions as two separate nerves carrying information from two separate but closely related structures. The auditory pathways within the CNS are very complex, with both crossed and uncrossed tracts. Unilateral CNS damage therefore usually has little effect on hearing. The neurons from the cochlear ganglion synapse with CNS neurons in the cochlear nucleus in the medulla oblongata. These neurons in turn either synapse in or pass through the superior olivary nucleus in the medulla oblongata. Neuronsterminating in the superior olivary nucleus may synapse with efferent neurons returning to the cochlea to modulate pitch perception. Nerve fibers from the superior olivary nucleus also project to the trigeminal (V) nucleus, which controls the tensor tympani, and the facial (VII) nucleus, which controls the stapedius muscle. This is part of the sound attenuation reflex pathway. Ascending neurons from the superior olivary nucleus synapse in the inferior colliculi, and neurons from there project to the thalamus, where they synapse with neurons that project to the cortex. These neurons terminate in the auditory cortex. Neurons from the inferior colliculi also project to the superior colliculi, where reflexes that turn the head and eyes in response to loud sounds are initiated.

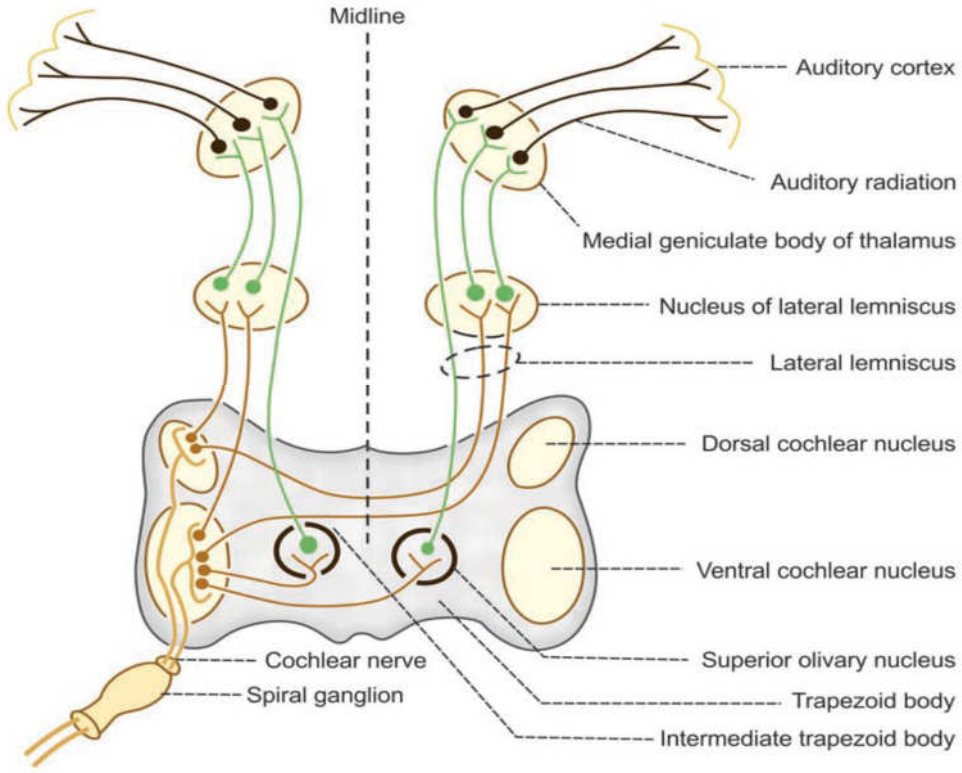

Figure 4: Auditory pathway. Blue = First order neuron, Red = Second order neuron,
Green =Third order neuron, Black = Auditory radiation.

3.3 Clinical Correlates

a. Tympanic Membrane Rupture
b. Chorda Tympani
c. Human Speech and Hearing Impairment
d. Loud Noises and Hearing Loss
e. Meniere Disease

4.0 CONCLUSION

In this unit you learnt about the organs of hearing and balance which are divided into three parts: the external, middle, and inner ear.

5.0 SUMMARY

- The osseous labyrinth is a canal system within the temporal bone that contains perilymph contains perilymph and the membranous labyrinth. Endolymph is inside the membranous labyrinth.
- The external ear consists of the auricle and external acoustic meatus. The middle ear connects the external and inner ears. The tympanic membrane is stretched across the external acoustic meatus.

- The malleus, incus, and stapes connect the tympanic membrane to the oval window of the inner ear.
- The auditory tube connects the middle ear to the pharynx and equalises pressure. The middle ear is connected to the mastoid air cells. The inner ear has three parts: the semicircular canals; the vestibule, which contains the utricle and the saccule; and the cochlea.
- The cochlea is a spiral-shaped canal within the temporal bone. The cochlea is divided into three compartments by the vestibular and basilar membranes. The scala vestibuli and scala tympani contain perilymph. The cochlear duct contains endolymph and the spiral organ.
- The spiral organ consists of inner hair cells and outer hair cells, which attach to the tectorial membrane.
- Pitch is determined by the frequency of sound waves and volume by the amplitude of sound waves. Timbre is the resonance quality (overtones) of sound.
- Axons from the vestibulocochlear nerve synapse in the medulla. Neurons from the medulla project axons to the inferior colliculi, where they synapse. Neurons from this point project to the thalamus and synapse. Thalamic neurons extend to the auditory cortex.

SELF-ASSESSMENT EXERCISE

Identify the major anatomical features of the ear models provided.

6.0 TUTOR-MARKED ASSIGNMENT

1. Name the three parts of the ear, and state their functions.
2. Describe the structural components of the *middle ear* and their functions.
3. Which of these structures is found within or is a part of the external ear?
   a. oval window
   b. auditory tube
   c. ossicles
   d. external acoustic meatus
   e. cochlear duct
4. Given these auditory ossicles:
   - incus(1)
   - malleus(2)
   - stapes(3)

   Choose the arrangement that lists the auditory ossicles in order from the tympanic membrane to the inner ear.
   a. 1,2,3
   b. 1,3,2

c. 2,1,3
d. 2,3,1
e. 3,2,1

5. The spiral organ is found within the
   a. cochlear duct.
   b. scala vestibuli.
   c. scala tympani.
   d. vestibule.
   e. semicircular canals.
6. An increase in the loudness of sound occurs as a result of an increase in the sound wave.
   a. frequency
   b. amplitude
   c. resonance
   d. both a and b
7. Interpretation of different sounds is possible because of the ability of it to vibrate at different frequencies and stimulate the:
   a. vestibular membrane, vestibular nerve
   b. vestibular membrane, spiral organ
   c. basilar membrane, vestibular nerve
   d. basilar membrane, spiral organ

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UNIT 4 THE EYES AND THE SENSE OF VISION

CONTENTS

1.0 INTRODUCTION

The visual system includes the eyes, the accessory structures, and the sensory neurons that project to the cerebral cortex where action potentials conveying visual information are interpreted. The **eye** consists of the **eyeball,** or globe of the eye, and the optic nerve. Much of the information we obtain about the world around us is detected by the visual system. Our education is largely based on visual input and depends on our ability to read words and numbers. Visual input includes information about light and dark, movement, colour, and hue.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- list the accessory structures of the eye, and explain their functions
- describe the anatomy of the eye
- describe the focusing system of the eye and how it adjusts to see distant and near objects
- explain the structure of the retina, and how light entering the eye results in action potentials in the optic nerve
- outline the neuronal pathways for vision.

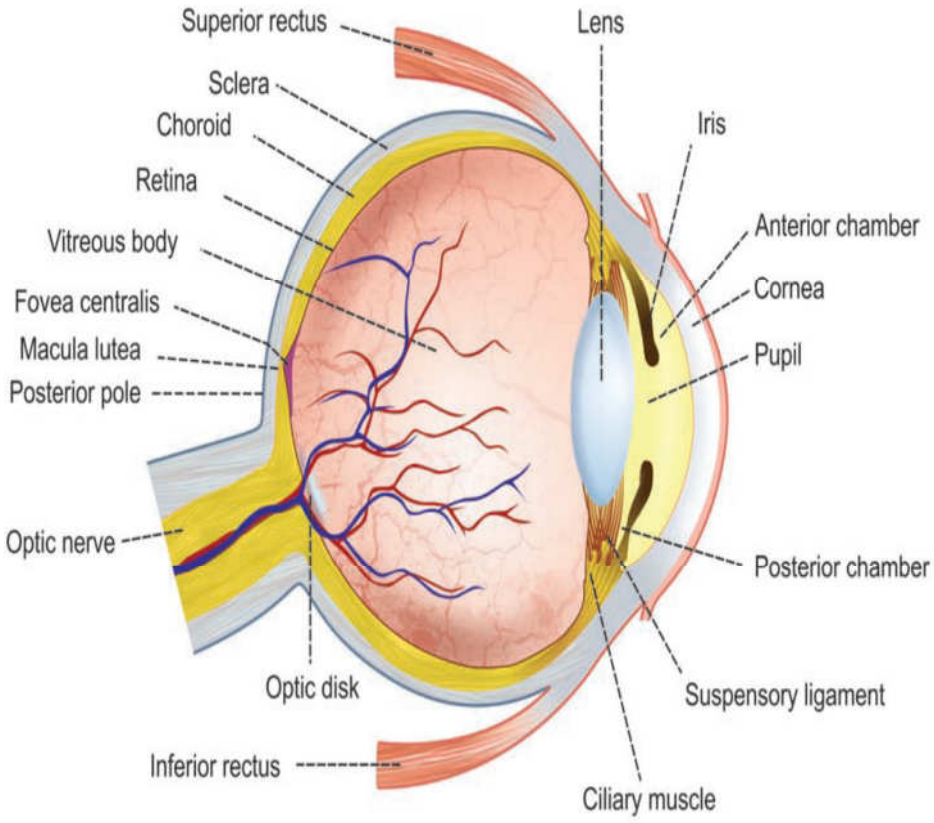

Fig. 4: Sagittal Section of the Eye

3.1 Anatomy of the Eye

The eyeball is composed of three layers. From superficial to deep they are the **fibrous layer, vascular layer,** and **retina**. The fibrous layer consists of the sclera and cornea; the vascular layer consists of the choroid, ciliary body, and iris.

Fibrous Layer

The **sclera** is the firm, opaque, white, outer layer of the posterior fivesixths of the eyeball. It consists of dense collagenous connective tissue with elastic fibers. The sclera helps maintain the shape of the eyeball, protects its internal structures, and provides an attachment point for the extrinsic eye muscles. A small portion of the sclera can be seen as the “white of the eye”. The sclera is continuous with the **cornea**, the anterior sixth of the eyeball. The cornea is avascular and transparent, permitting light to enter the eye. The focusing system of the eye refracts, or bends, light and focuses it on the nervous layer (retina). The cornea is responsible for most of the refraction of light entering the eye. The cornea consists of a connective tissue matrix containing collagen, elastic fibers, and proteoglycans, with a layer of stratified squamous epithelium covering the outer surface and a layer of simple squamous epithelium on the inner surface. The outer epithelium is continuous with

the conjunctiva over the sclera. The transparency of the cornea results from its low water content. In the presence of water, proteoglycans trap water and expand, which scatters light. In the absence of water, the proteoglycans decrease in size and do not interfere with the passage of light through the matrix.

Vascular Layer

The vascular layer of the eye is so named because it contains most of the blood vessels of the eye. The posterior portion of the vascular layer, associated with the sclera, is the **choroid**. This is a very thin structure consisting of a vascular network and many melanin-containing pigment cells so that it appears black in colour. The black colour absorbs light so that it is not reflected inside the eye. If light were reflected inside the eye, the reflection would interfere with vision. The interiors of cameras are black for the same reason. The choroid is continuous anteriorly with the ciliary body, which consists of an outer ciliary ring and an inner group of ciliary processes. The ciliary ring and the base of the ciliary processes contain smooth muscle called ciliary muscles. Suspensory ligaments attach the ciliary ring and processes to the lens of the eye, and contraction of the ciliary muscles can change the shape of the lens. The ciliary process also produces aqueous humour. The ciliary body is continuous anteriorly with the iris of the eye, which is the “coloured part” of the eye. The iris is a contractile structure, consisting mainly of smooth muscle, surrounding an opening called the pupil. Light enters the eye through the pupil, and the iris regulates the amount of light by controlling the size of the pupil. The iris contains two groups of smooth muscles: a circular group called the sphincter pupillae and a radial group called the dilator pupillae. The sphincter papillae are innervated by parasympathetic fibers from the oculomotor nerve (III). When they contract, the pupil constricts and less light enters the eye. The dilator pupillae are innervated by sympathetic fibers. When they contract, the pupil dilates and more light enters the eye. The ciliary muscles, sphincter pupillae, and dilator pupillae are sometimes referred to as the intrinsic eye muscles. The colour of the eye differs from person to person. A large amount of melanin in the iris causes it to appear brown or even black. Less melanin results in light brown, green, or gray irises. Even less melanin causes the eyes to appear blue. If there is no pigment in the iris, as in albinism, the iris is pink because blood vessels in the eye reflect light back to the iris. The genetics of eye colour is quite complex.

Retina

The retina is the inner layer of the eye, covering the inner surface of the eye posterior to the ciliary body. The retina has over 126 million

photoreceptor cells, which respond to light. As a result, action potentials are generated and conducted by the optic nerve (II) out of the eye to the cerebral cortex, where the sense of vision takes place. When the posterior region of the retina is examined with an ophthalmoscope, several important features can be observed. Near the center of the posterior retina is a small, yellow spot approximately four (4) mm in diameter, the macula. In the center of the macula is a small pit, the fovea centralise. The fovea, followed by the macula, has the highest concentration of photoreceptor cells in the retina. Thus, they are the part of the retina most sensitive to light. Just medial to the macula is a white spot, the optic disc, through which the central retinal artery enters and the central retinal vein exits the eyeball. Branches from these vessels spread over the surface of the retina. The optic disc is also the place where axons from the neurons of the retina converge to form the optic nerve, which exits the posterior eye. The optic disc contains only axons and no photoreceptor cells. Therefore, it does not respond to light and is called the blind spot of the eye.

Chambers of the Eye

The interior of the eye is divided into three chambers:

- **Anterior chamber**
- **posterior chamber,** and
- **vitreous chamber**

Lacrimal Apparatus

The **lacrimal apparatus** consists of a lacrimal gland, lacrimal canaliculi, and a nasolacrimal duct. The lacrimal apparatus produces tears, releases the tears onto the surface of the eye, and removes excess tears from the surface. The **lacrimal gland** is in the superolateral corner of the orbit and is innervated by parasympathetic fibers from the facial nerve (VII). The lacrimal gland produces tears, which leave the gland through several **lacrimal ducts** and pass over the anterior surface of the eyeball. The lacrimal gland produces tears constantly at the rate of about one (1) mL/day to moisten the surface of the eye, lubricate the eyelids, and wash away foreign objects. Tears are mostly water, with some salts, mucus, and lysozyme, an enzyme that kills certain bacteria. Most of the fluid produced by the lacrimal glands evaporates from the surface of the eye, but excess tears are collected in the medial corner of the eye by small tubes called the **lacrimal canaliculi.** One lacrimal canaliculus opens on the inner, medial surface of the upper eyelid, and the other lacrimal canaliculus opens on the inner, medial surface of the lower eyelid. The lacrimal canaliculi connect to the **nasolacrimal duct,** which

opens into the inferior meatus of the nasal cavity beneath the inferior nasal concha.

Extrinsic Eye Muscles

The extrinsic eye muscles attach to the outside of the eyeball and cause it to move. There are four rectus muscles,

1. the superior,
2. inferior,
3. medial, and
4. lateral rectus muscles**.**

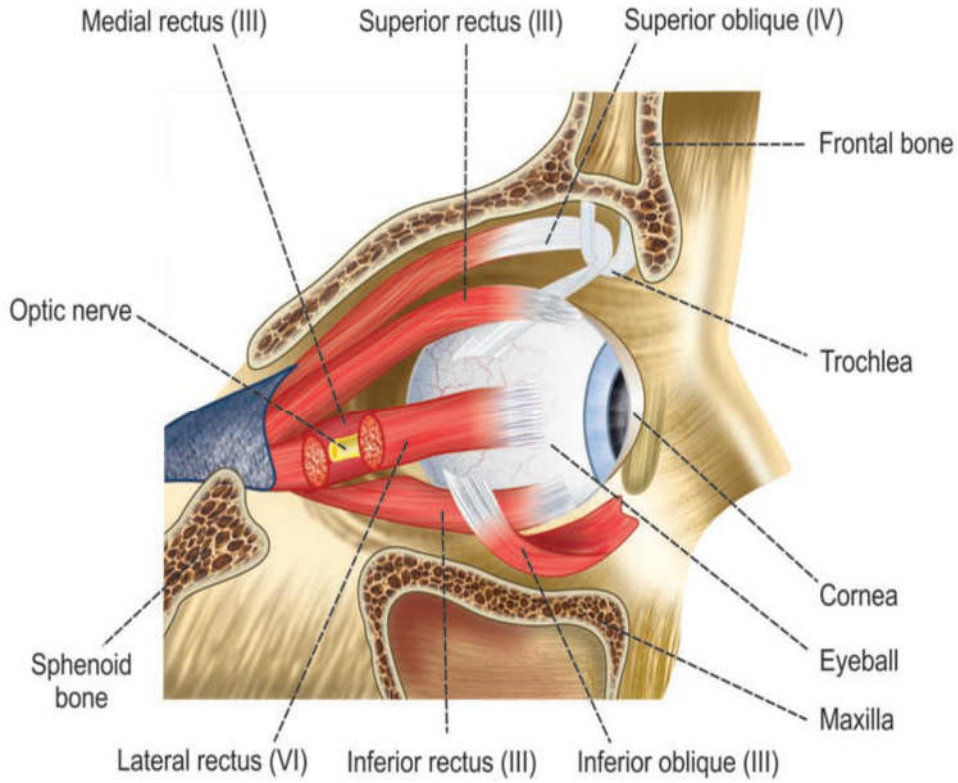

Fig. 6: The Extrinsic Muscles of the Right Eye

3.2 Functions of the Eye

The eye receives light and produces action potentials. When the brain interprets the action potentials, it results in vision.

Properties of Light

The **electromagnetic spectrum** is the entire range of wavelengths, or frequencies, of electromagnetic radiation. Gamma waves have the shortest wavelength and radio waves the longest wavelength.

Visible light, the portion of the electromagnetic spectrum that can be detected by the human eye, is a small part of the electromagnetic spectrum. Within the visible spectrum, each colour has a different wavelength. An important characteristic of light is that it can be refracted, or bent**.** As light passes from air to a denser substance, such as glass or water, its speed is reduced. If the surface of that substance is at an angle other than 90 degrees to the direction the light rays are traveling, the rays are bent as a result of variation in the speed of light as it encounters the new medium. This bending of light is called **refraction.** The greater the curvature of the surface, the greater is the refraction of light. If the surface of a lens is concave, with the lens thinnest in the center, the light rays diverge as a result of refraction. If the surface is convex, with the lens thickest in the center, the light rays converge. As light rays converge, they finally reach a point at which they cross. This point is called the **focal point (FP),** and causing light to converge is called **focusing.** If light rays strike an object that is not transparent, they bounce off the surface. This phenomenon is called **reflection.** The images we see result from light reflected from objects.

The Eye as a Camera

The eye is optically equivalent to the usual photographic camera. It has a lens system, a variable aperture system (the pupil), and a retina that corresponds to the film. The lens system of the eye is composed of four refractive interfaces:

(1) the interface between air and the anterior surface of the cornea,
(2) the interface between the posterior surface of the cornea and the aqueous humour,
(3) the interface between the aqueous humour and the anterior surface of the lens of the eye, and
(4) the interface between the posterior surface of the lens and the vitreous humour. The internal index of air is 1; the cornea, 1.38; the aqueous humour, 1.33; the crystalline (ovraverage), 1.40; and the vitreous humour, 1.34.

Focusing System of the Eye

The light entering the eye passes through the focusing system of the eye to strike the retina. The **focusing system of the eye,** which refracts light, is the cornea, aqueous humour, lens, and vitreous humour. Light passing through the focusing system is refracted, producing a focal point. No image is produced at the focal point. Past the focal point is a place where the image passing through the focusing system can be clearly seen. In a normal eye, the focused image falls on the retina. The image is inverted and reversed right to left because the light rays cross at the

focal point. The cornea and lens are the most important elements of the focusing system of the eye. The cornea is responsible for most of the refraction of light because the greatest contrast in media density is between the air and the cornea. The shape of the cornea and its distance from the retina are fixed, however, so that no adjustment in the location of the focused image can be made by the cornea. Fine adjustments to the location of the focused image are accomplished by changing the shape of the lens. Increasing the curvature of the lens increases the refraction of light, moving the focused image closer to the lens. Decreasing the curvature of the lens decreases the refraction of light, moving the focused image farther from the lens. In cameras, microscopes, and telescopes, focusing is not accomplished by changing lens shape. Instead, focusing is accomplished by moving the lens closer to or farther from the point at which the image will be focused.

Distant and Near Vision

Distant vision occurs when looking at objects 20 feet or more from the eye, whereas **near vision** occurs when looking at objects that are less than 20 feet from the eye. In distant vision, the ciliary muscles in the ciliary body are relaxed. The suspensory ligaments, however, maintain elastic pressure on the lens, thereby keeping it relatively flat. The condition in which the lens is flattened so that nearly parallel rays from a distant object are focused on the retina is referred to as **emmetropia** and is the normal resting condition of the lens. The point at which the lens does not have to thicken for focusing to occur is called the **far point of vision** and normally is 20 feet or more from the eye. When an object is brought closer than 20 feet to the eye, the image falling on the retina is no longer in focus. Three events occur to bring the image into focus on the retina: accommodation by the lens, constriction of the pupil, and convergence of the eyes.

1. Accommodation.

When the eye focuses on a nearby object, the ciliary muscles contract as a result of parasympathetic stimulation from the oculomotor nerve (III). This sphincter like contraction pulls the choroid toward the lens to reduce the tension on the suspensory ligaments. This allows the lens to assume a more spherical form because of its own elastic nature. The more spherical lens has a more convex surface, causing greater refraction of light, which brings the image back into focus on the retina. This process is called accommodation. As an object is brought closer and closer to the eye, accommodation becomes more and more difficult because the lens cannot become any more convex. At some point, the eye no longer can focus the object, and it is seen as a blur. The point at which this blurring occurs is called the near point of vision, which is

usually about two to three inches from the eye for children, four to six inches for a young adult, 20 inches for a 45-year old adult, and 60 inches for an 80-year-old adult. This increase in the near point of vision is called presbyopia. It occurs because the lens becomes more rigid with increasing age, which is why some older people say they could read with no problem if they only had longer arms.

2. Pupil constriction

When we look at a close-up object, the pupil diameter decreases, which increases the depth of focus. The depth of focus is the greatest distances through which an object can be moved and still remain in focus on the retina. The main factor affecting depth of focus is the size of the pupil. If the pupillary diameter is small, the depth of focus is greater than if the pupillary diameter is large. With a smaller papillary opening, an object may therefore be moved slightly nearer or farther from the eye without disturbing its focus. This is particularly important when viewing an object at close range because the interest in detail is much greater, and therefore the acceptable margin for error is smaller. When the pupil is constricted, the light entering the eye tends to pass more nearly through the center of the lens and is more accurately focused than light passing through the edges of the lens. Pupillary diameter also regulates the amount of light entering the eye. The smaller the pupil diameter, the less light entering the eye. As the pupil constricts during close vision, therefore, more light is required on the object being observed.

3. Convergence

Because the light rays entering the eyes from a distant object are nearly parallel, both pupils can pick up the light rays when the eyes are directed more or less straight ahead. As an object moves closer, however, the eyes must be rotated medially so that the object is kept focused on corresponding areas of each retina. Otherwise, the object appears blurry. This medial rotation of the eyes is accomplished by a reflex that stimulates the medial rectus muscle of each eye. This movement of the eyes is called convergence.

Structure and Function of the Retina

The retina consists of an inner, neural layer and an outer, pigmented layer. The **neural layer** contains three layers of neurons: photoreceptor, bipolar, and ganglionic. The photoreceptor layer contains **rods** and **cones,** which are the photoreceptor cells that respond to light. The rods and cones synapse with **bipolar cells,** which in turn synapse with **ganglion cells.** Axons from the ganglion cells pass over the inner surface of the retina, converge at the optic disc (blind spot), and exit the

eye as the optic nerve (CN II) The neural layers are separated by the plexiform (like a braid) layers. The outer plexiform layer is where the photoreceptor cells synapse with the bipolar cells and the inner plexiform layer is where the bipolar cells synapse with the ganglion cells. The **pigmented layer** consists of **retinal pigment epithelium (RPE)**, a single layer of cuboidal epithelial cells filled with melanin. It rests on the **Bruch membrane,** which is the inner layer of the choroid consisting of collagen and elastic fibers. Cells of the RPE phagocytize the spent tips of rods and cones and produce retinal from vitamin A. Along with the choroid, the pigmented layer provides a black-brown matrix that enhances visual acuity by isolating individual photoreceptors and reducing light scattering.

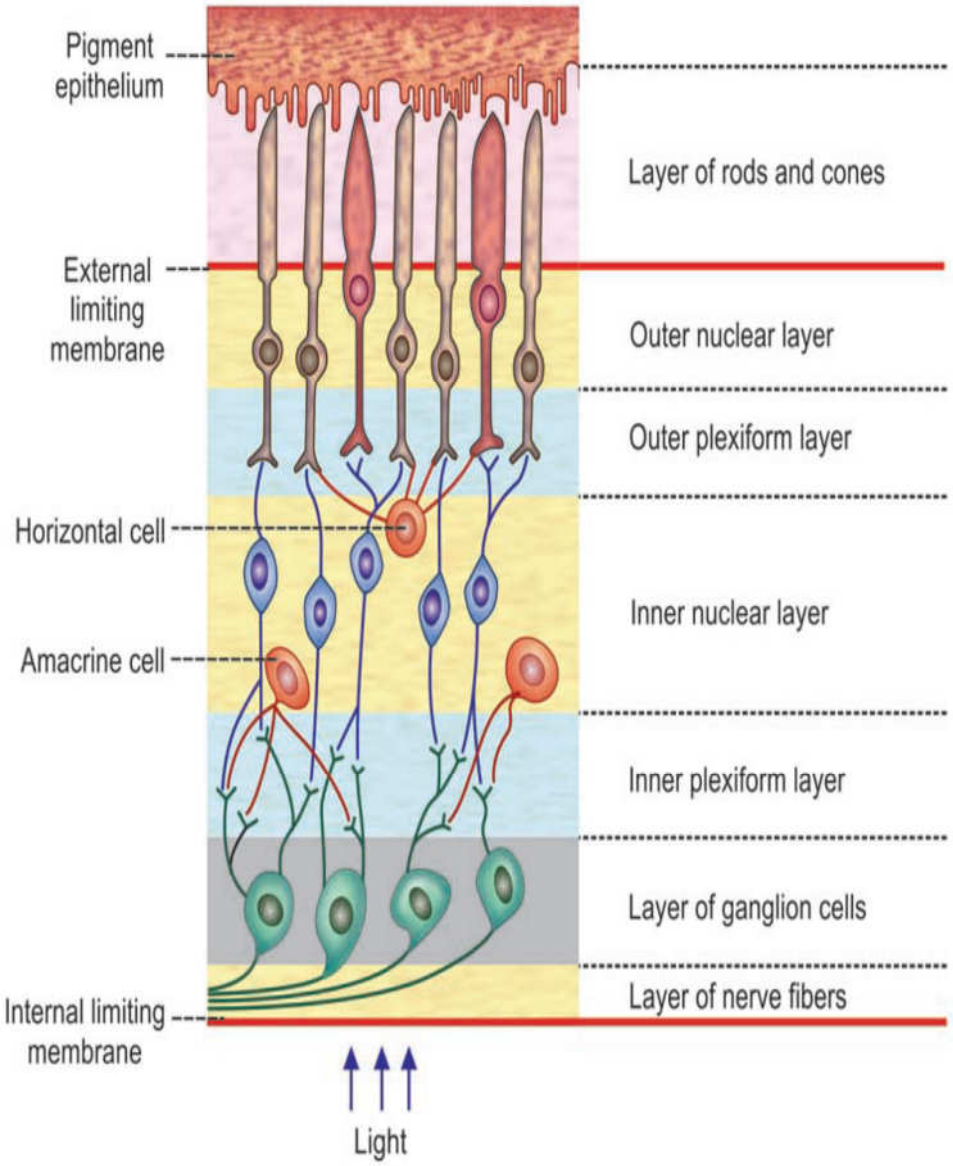

Fig. 6: Layers of Retina

Rods

Rods are responsible for non - colour vision and vision under conditions of reduced light. Even though rods are very sensitive to light, they cannot detect colour, and sensory input reaching the brain from rods is interpreted by the brain as shades of gray. Rods are bipolar neurons with modified, light-sensitive dendrites, which are cylindrical in shape.

Cones

Cones are responsible for colour vision and visual acuity. Colour is a function of the wavelength of light, and each colour results from a certain wavelength of visible light Cones require relatively bright light to function. As the light decreases, so does the colour of objects that can be seen until, under conditions of very low illumination, the objects appear gray. This occurs because, as the light decreases, the number of cones responding to the light decreases but the number of rods increases. Cones are bipolar photoreceptor cells with a conical, light-sensitive part that tapers slightly from base to apex.

Distribution of Rods and Cones in the Retina

Each eye has approximately 120 million rods and six to seven million cones. The cones are most concentrated in the fovea centralis and the macula. The fovea centralis has approximately 35,000 cones and no rods. The rest of the macula has more cones than rods. Cones are involved in visual acuity, in addition to their role in colour vision. When one is looking at an object directly in front of the eye, the focusing system of the eye places the image on the macula and fovea centralis. The high concentration of cones makes it possible to see fine details. The rods are 10–20 times more plentiful than cones over most of the retina away from the macula. The high number of rods enables them to "collect" light, and they are more important in low-light conditions.

Inner Layers of the Retina

Within the inner layers of the retina, interneurons modify the signals from the photoreceptor cells before the signal leaves the retina. **Horizontal cells** in the outer plexiform layer synapse with photoreceptor cells and bipolar cells. **Amacrine cells** in the inner plexiform layer synapse with bipolar and ganglion cells. **Interplexiform cells** connect cells in the outer and inner plexiform layers, forming feedback loops. The interneurons are either excitatory or inhibitory onthe cells with which they synapse. By increasing the signal from some photoreceptors and decreasing the signal from others, these

interneurons increase the differences between boundaries, such as the edge of a dark object against a light background.

3.3 Visual Pathway

The optic nerve (II) leaves the eye and exits the orbit through the optic foramen to enter the cranial cavity. Just anterior to the pituitary gland, the optic nerves are connected to each other at the **optic chiasm**. Ganglion cell axons from the nasal (medial) retina cross through theoptic chiasm and project to the opposite side of the brain. Ganglion cell axons from the temporal (lateral) retina pass through the optic chiasm and project to the brain on the same side of the body without crossing. Beyond the optic chiasm, the axons form the **optic tracts**. Most of the optic tract axons terminate in the thalamus. Some axons do not terminate in the thalamus but separate from the optic tracts to terminate in the **superior colliculi,** the center for visual reflexes. Neurons from the thalamus form the fibers of the **optic radiations,** which project to the **visual cortex** in the occipital lobe. Neurons of the visual cortex integrate the messages coming from the retina into a single message, translate that message into a mental image, and then transfer the image to other parts of the brain, where it is evaluated and either ignored or acted on. The image seen by each eye is the **visual field** of that eye. The visual field of each eye can be divided into temporal (lateral) and nasal (medial) parts. The temporal part of a visual field projects onto the nasal retina, which projects to the visual cortex on the opposite side of the brain. The nasal part of a visual field projects onto the temporal retina, which projects to the same side of the brain. The nerve pathways are arranged in such a way that images entering the eye from the right part of each visual field (right temporal and left nasal) project to the left side of the brain. Conversely, the left part of each visual field (left temporal and right nasal) projects to the right side of the brain. The visual pathway

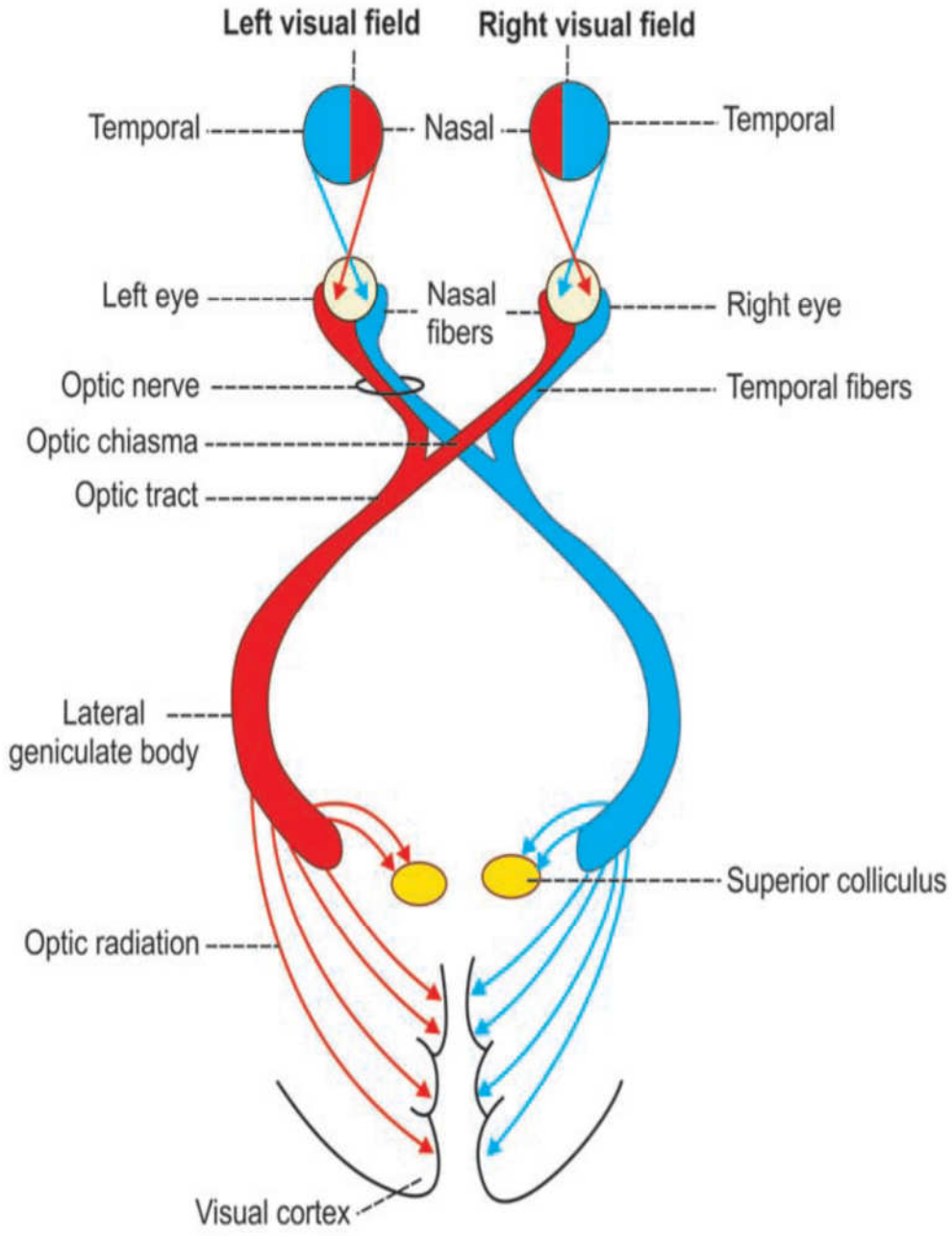

Fig.7: The Visual Pathway

3.4 Clinical Correlates

1. Myopia
2. Hypermetropia
3. Presbyopia
4. Astigmatism
5. Night Blindness
6. Glaucoma

4.0 CONCLUSION

You learnt that the visual system includes the eyes, the accessory structures, and the sensory neurons that project to the cerebral cortex where action potentials conveying visual information are interpreted.

5.0 SUMMARY

- The fibrous layer is the outer layer of the eyeball. It consists of the sclera and cornea. The sclera is the posterior four-fifths of the eyeball. It is white connective tissue that maintains the shape of the eyeball and provides a site for muscle attachment. The cornea is the anterior one-fifth of the eye. It is transparent and refracts light that enters the eye.
- The vascular layer is the middle layer of the eyeball. The black choroid prevents the reflection of light inside the eye. The iris is smooth muscle regulated by the autonomic nervous system. It controls the amount of light entering the pupil. The ciliary muscles control the shape of the lens. The ciliary process produces aqueous humour.
- The retina is the inner layer of the eyeball and contains neurons sensitive to light. The macula (fovea centralis) is the area of greatest sensitivity to light. The optic disc is the location through which nerves exit and blood vessels enter the eye. It has no photosensory cells and is therefore the blind spot of the eye.
- The eyeball has three chambers: anterior, posterior, and vitreous. The anterior and posterior chambers are filled with aqueous humour, which circulates and leaves by way of the scleral venous sinus. The vitreous chamber is filled with vitreous humour.
- Accessory structures of the eye are the eyebrows, the eyelids, the conjunctiva and lacrimal glands.
- Visual pathway comprises ganglion cell axons form the optic nerve, optic chiasm, and optic tracts. They extend to the thalamus, where they synapse. From there, neurons form the optic radiations that project to the visual cortex.

SELF-ASSESSMENT EXERCISE

In the anatomy laboratory, examine the eye model and identify the accessory structures of the eye.

6.0 TUTOR-MARKED ASSIGNMENT

1. Tears
   a. are released onto the surface of the eye near the medial corner of the eye.
   b. in excess are removed by the scleral venous sinus.
   c. in excess can cause a sty.
   d. can pass through the nasolacrimal duct into the oral cavity.
   e. contain water, salts, mucus, and lysozyme.
2. The fibrous layer of the eye includes the
   a. conjunctiva.
   b. sclera.
   c. choroid.
   d. iris.
   e. retina.
3. Concerning axons in the optic nerve from the right eye,
   a. they all go to the right occipital lobe.
   b. they all go to the left occipital lobe.
   c. they all go to the thalamus.
   d. they all go to the superior colliculus.
   e. some go to the right occipital lobe and some go to the left occipital lobe.
4. Contraction of the smooth muscle in the ciliary body causes the
   a. lens to flatten.
   b. lens to become more spherical.
   c. pupil to constrict.
   d. pupil to dilate.
5. Given these events:
   a. medial rectus contracts
   b. lateral rectus contracts
   c. pupils dilate
   d. pupils constrict
   e. lens of the eye fl attens
6. lens of the eye becomes more spherical

   Assume you are looking at an object 30 feet away. If you suddenly look at an object that is one (1) foot away, which events occur?
   a. 1,3,6
   b. 1,4,5
   c. 1,4,6
   d. 2,3,6
   e. 2,4,5
6. Why do you get a “runny nose” when you cry?
7. What are the layers of the retina?
8. Which are more numerous, rods or cones?

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