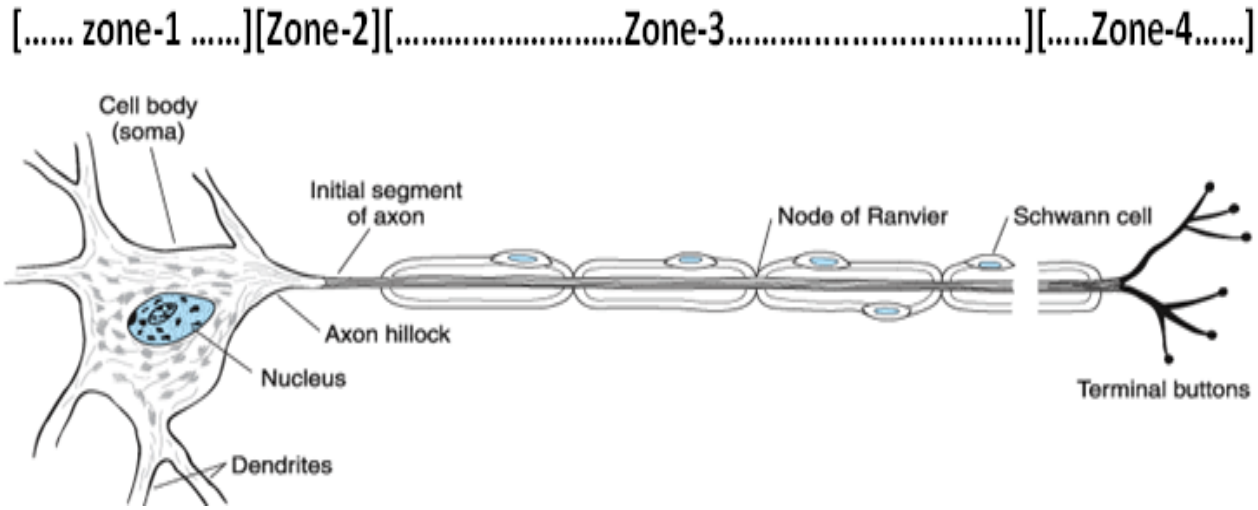
Nerves Physiology

The nervous system consists of nerve cells (neurons) and supporting cells. Neuron is the structural and functional unit of the nervous system. A typical neuron consists of the soma or cell body and two types of processes: the axon and dendrites. These cells functionally divided to four zones:

1. **Receptor Zone:** It is the body cell and its dendrites. Dendrites provide a receptive area that transmits electrical impulses to the cell body.
2. **Impulse origin one:** it is the axon hillock, the origin of the axon near the cell body. Here, the nerve impulses originate.
3. **Impulse transmission zone:** it is the reign extends from the axon hillock to the telodendria, the nerve ending. The nerve impulses transmit to synaptic buttons.
4. **Neurotransmitter secretion zone:** it is telodendria and its synaptic buttons which responsible to transmit the impulses to other cell by secret the neurotransmitters.



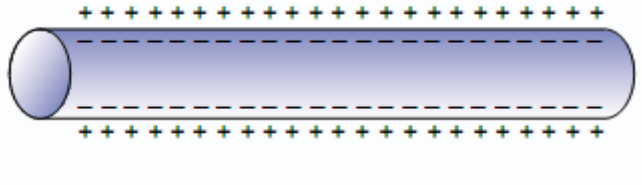
Nerve fibers:

The nerve fibers divided to myelinated and unmyelinated. The myelin sheath formed by oligo dendrocytes. All myelinated axons are surrounded by myelin sheath except Ranvier's nodes, which have 2000-12000 Na^+ chanal/μm^2 axolemma, while in the first one of axone 350-500, in the cell body 50.75, in the myelin sheath 25, in the end of axon 20-75, and in the unmyelinated axons 110. Unmyelinated are smaller than 2µm in diameter, whereas those that are larger are likely to by myelinated. Myelinated axons conduct impulses more rapidly than unmyelinated.

Resting membrane potential (RMP):

An electrical potential difference, or membrane potential, can be recorded across the plasma membrane of living cells. The potential of unstimulated cells, or resting potential, amounts to -9 to 100mV depend of the type of cell. A resting potential is caused by a slightly unbalanced distribution of ions between intracellular fluid (ICF) and extracellular fluid (ECF). The following factors are involved in establishing the membrane potential:

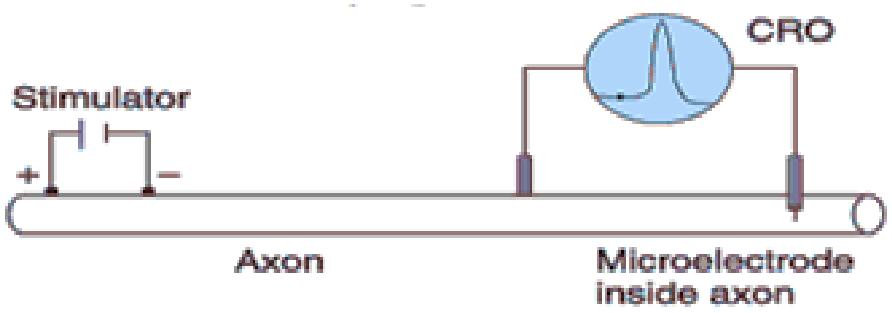
1. **High K^+ conductance:** it is relatively easy for K^+ ions to diffuse across the cell membrane. Because of the steep concentration gradient, K^+ ions diffuse from the ICF to the ECF.
2. **Maintenance of an unequal distribution of ions:** the Na^+-K^+ ATPase continuously pumps Na^+ out of the cell and K^+ into it by active transport. As a result, the intracellular K^+ concentration is around 35 times higher and the intracellular Na^+ concentration is roughly 20 times lower than the extracellular concentration.
3. **Cl^- distribution:** a passive distribution of Cl^- between intra- and extra- cellular spaces exists only as long as there is no active Cl^- uptake into the cell.



Membrane Action Potential (MAP):

An action potential is a signal passed on through an axon that influences other neurons or induces somatic cell. Excitation of a neuron occurs if the membrane potential on the axon hillock changes from its resting value -70mV to a less negative value -55mV, which called threshold potential. This depolarization may be caused by neurotransmitter-induced opening of postsynaptic action channels or by the transmission of stimuli from the surrounding. If the membrane potential of a stimulated cell comes close to threshold potential, rapid voltage-gated Na^+ channels are activated. This results in increased Na^+ conductance, and higher of Na^+ into the cell. This is resulted a high potential value +35mV called Action potential.

To understand the changes in the membrane potential, Cathode RAY Oscilloscope (CRO) was used to record the electric evidences happened in nerve fiber by microelectrodes. One of microelecrtodes was put on the extra-surface of cell membrane of nerve fiber and the other was put in intra-surface. The excitation of nerve was begun by electric excitation. This instrument records the changes by scheme. The excitation of nerve has four periods:



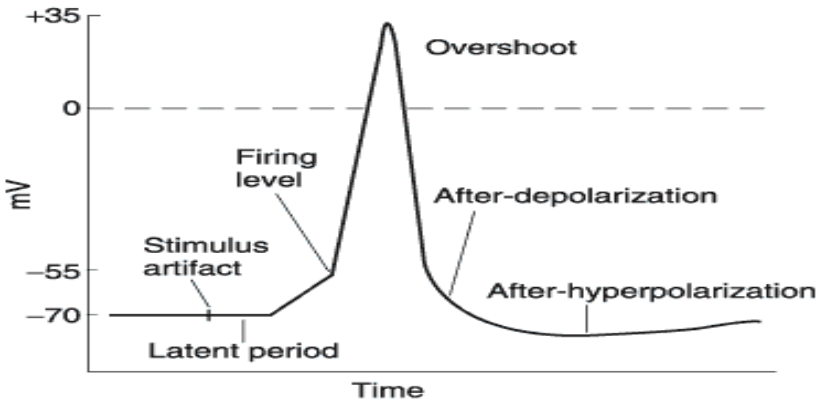
1. **Latent (resting) period:** in this period the membrane potential is stile -70mV (resting potential) to a short or long time according the microelectrodes position.

2. **Depolarization period:** large numbers of Na^+ channels are activated, and the influxing Na^+ accelerates depolarization. As a result, the membrane potential is slowly decreased from -70 to -55mV, which called **threshold** or firing level. After that, the membrane potential is rapidly decreased to (0mV), which called **isopotential**. The membrane potential temporarily reaches positive levels (+35mV).

   There are two types of stimuli:
   a) Threshold stimuli: it is successful to produce active potential, which its intensity is more than 15mV (-70mV, RMB, -55, threshold=15)
   b) Sub-threshold stimuli: its intensity is less than 15mV, which cannot reach the threshold so it cannot produce active potential.

3. **Repolarization period:** because the Na^+ channels are inactivated, the potential reverses, and restoration of the resting potential, the repolarization phase of the action potential, begins. Depolarization has increased the open-probability of voltage gated K^+ channels. This has increased the potassium conductance, thereby accelerating repolarization.

4. **Hyperpolarization period:** in many cases, potassium conductance is still increased after the original resting potential has been restored, resulting in a hyperpolarization afterpotential. Increased Na^+-K^+ ATPase pumping rates can contribute to this afterpotential.



Nerve Impulse: Nerve impulse is an electrochemical phenomenon which includes:

1. Electrical, The movement of active potential by stimuli from stimulation point on the long nerve fiber. This is like electrical flows through a cable when voltage is applied.
2. Chemical, neurotransmitter is released by regulated exocytosis of synaptic vesicles when the action potential reached it to stimulate the adjacent cells.

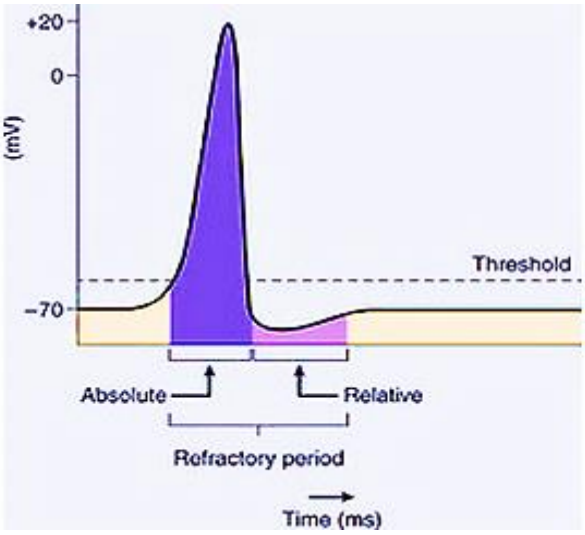
Nerve impulse characteristics are:

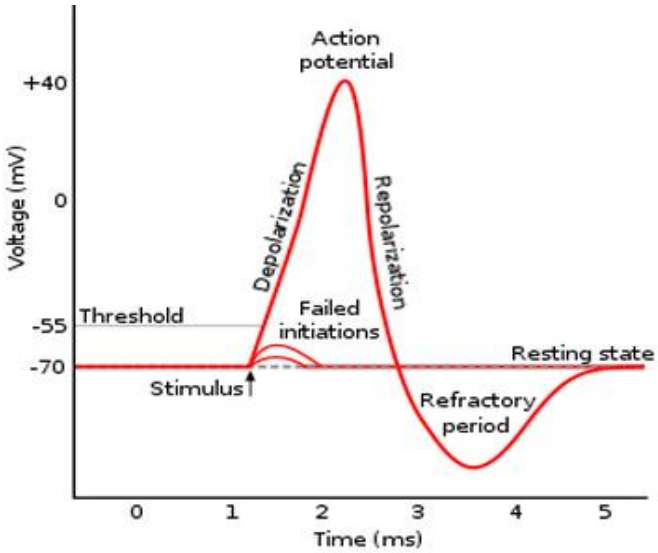
1. All or None Low:

Action potential producing depends on intensity of stimulus and duration of stimulation. All stimuli, which have threshod intensity and enough duration of stimulation, are success to produce action potential. But none, which its intensity is less than threshold, can produce action potential whatever its duration.

2. Refractory period:

During an action potential, the cell remains unresponsive to further stimuli. In **absolute refractory period**, from firing point to repolarization period no other action potential can be triggered, even by extremely strong stimuli, since Na^+ channels in depolarized membranes cannot be activated. This is flowed by **a relative refractory** period during which only action potentials of smaller amplitudes and rates or rise can be generated, even by strong stimuli. The refractory period ends once the membrane potential returns to its resting value.



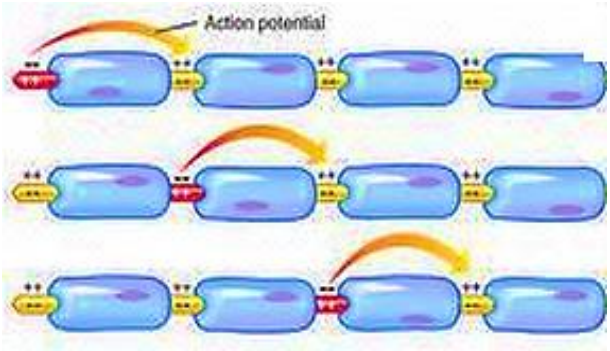


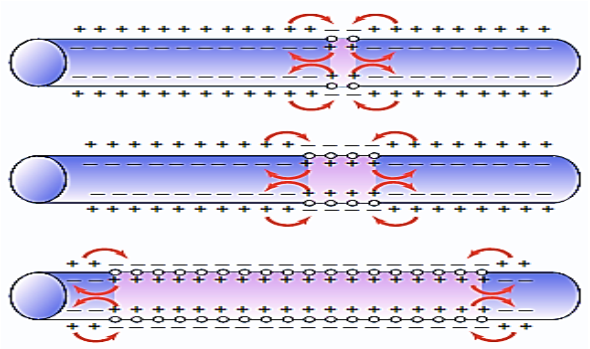
3. Impulse conduction:

The start of an action potential is accompanied by a brief influx of Na^+ into the nerve fiber. The cell membrane that previously was inside negative now becomes positive, thus a longitudinal potential difference with respect to adjacent, still unstimulated nerve segments. This is followed by a passive electrotonic withdrawal of charge from the adjacent segment of

the nerve fiber, causing its depolarization. If it exceeds threshold, another action potential is created in the adjacent segment dissipates.

Action potential normally run forward (**thodromic conduction**) because each segment of nerve fiber becomes refractory when an action potential passes. If, however, the impulse are conducted backwards (**antidromic conduction**) due, for example, to stimulation of nerve fibers from an external source, they will terminate at the next synapse. Although the continuous generation of action potentials in the immediately adjacent fiber segment guarantees a refreshed signal, this process is rather time-consuming. The **continuous conduction or velocity conduction**, in unmyelinated nerve fibers is only around 1m/s. myelinated nerve fibers conduct much faster (up to 80m/s). In the Ranvier's nodes, a myelin sheath insulates the nerve fiber from the surroundings; thus, longitudinal current strong enough to generate action potential can travels further down the axon. This results in more rapid conduction because the action potential is generated only at the Ranvier's nodes, where there is a high density of Na^+ channel. This results in rapid, jump-like passage of the action potential from node to node (**salutatory conduction**).





4. Velocity of conduction: The conduction velocity depends on:

a. Myelination: the conduction velocity of such myelinated nerve fiber is much higher than that of unmyelinated nerve fibers.

b. Diameter: the conduction velocity increases with the diameter of nerve fiber.

Classification of nerve fiber according its conduction velocity:

A) **Type-A-nerve fiber**:

Its conduction velocity is very high (2-80m/s) because it is myelinated and big diameter (1-16µm). It is called fast fiber such as somatic nerve fiber which pressure and touch sensation. It is can triggered the nerve impulse under anesthesia because of myeline sheath, but cannot triggered the nerve impulse under compression because of the big diameter which cause the paralysis.

B) Type-B-nerve fiber:

Their conduction velocity is less than types-A (3-15m/s) because it is myelinated but smaller diameter (3µm). It is called moderate fiber such as visceral nerve fibers which pressure and touch sensation like type A.

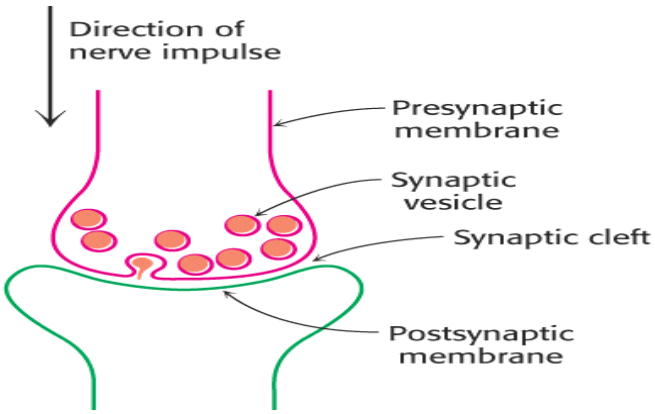
C) Type-C-nerve fiber:

Its conduction velocity is very low (0.25-1.5m/s) because it is unmyelinated and small diameter (0.5-1.5µm).it is called slow fibers such as all nerve fiber which pain and temperature sensation. It is cannot triggered the nerve impulse under anesthesia, because it is unmyelinated; and under compression, because of the small diameter.

5. Compound action potential:

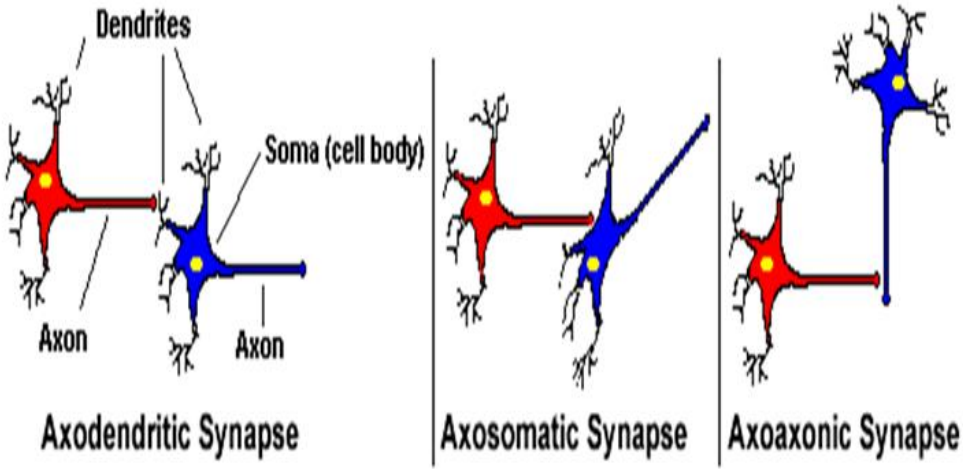
Synaptic transmission:

At the chemical synapse, the arrival of an action potential in the axon triggers the release of transmitter form the presynaptic axon terminals (**presynaptic membrane**). The transmitter then diffuses across the narrow **synaptic cleft** to bind postsynaptically to receptors in the **subsynaptic or postsynaptic membrane** of a neuron or of glandular or muscle cell. Depending on the type of transmitter and receptor involved, the effect on the postsynaptic membrane may either be excitatory or inhibitory. Excitatory neurotransmitters such as Acetyl choline (Ach) and Norepinephrine (NE) open Ca^{2+} channels leading to an increase in the cytosolic Ca^{2+} concentration, which increases the action potential. Inhibitory neurotransmitters such as Glycine and Gamma Amino Butyric Acid (GABA) open K^+ or Cl^- channels, as a result, excitatory postsynaptic potential related depolarization is reduced and stimulation of postsynaptic neurons is inhibited.



A signal excitatory postsynaptic potential normally is not able to generate a postsynaptic (axonal) action potential, but requires the triggering of a large number of local depolarizations in the dendrites. Their depolarizations are transmitted electrotonically across the soma and summed on the axon hillock (spatial summation). Should the individual stimuli arrive at different times, the prior depolarization will not have dissipated before the next one arrives, and summation will

make it easier to reach threshold. This type of temporal summation therefore increases the excitability of the postsynaptic neuron.



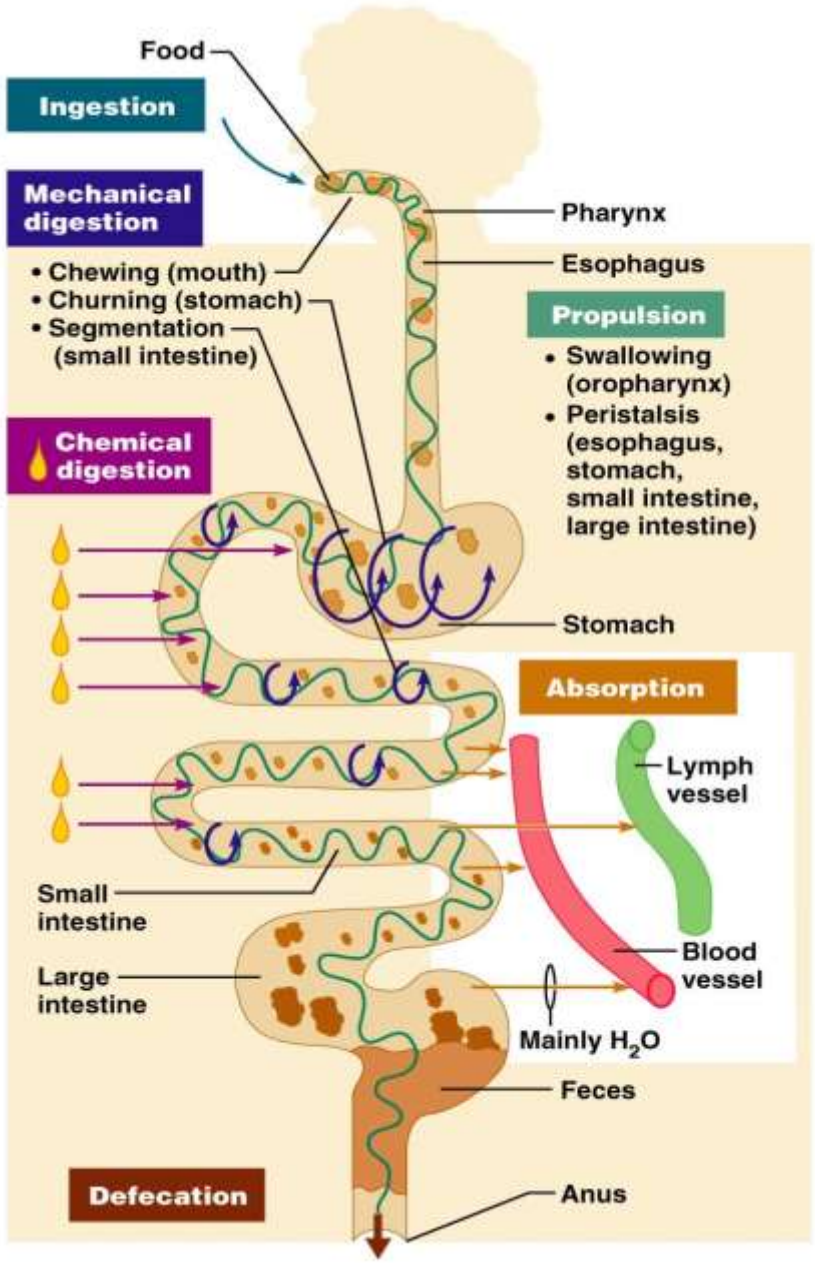
The Digestive System

Dr. Ali Ebneshahidi

Functions of the Digestive System

- **ingestion** – the oral cavity allows food to enter the digestive tract and have mastication (chewing) occurs , and the resulting food bolus is swallowed .
- **Digestion:**
- Mechanical digestion – muscular movement of the digestive tract (mainly in the oral cavity and stomach) physically break down food into smaller particles .
- chemical digestion – hydrolysis reactions aided by enzymes (mainly in the stomach and small intestine) chemically break down food particles into nutrient molecules , small enough to be absorbed . .

- **Secretion** – enzymes and digestive fluids secreted by the digestive tract and its accessory organs facilitate chemical digestion .
- **Absorption** – passage of the end – products (nutrients) of chemical digestion from the digestive tract into blood or lymph for distribution to tissue cells .
- **Elimination** – undigested material will be released through the rectum and anus by defecation .



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Organization of The Digestive System

- Organs of the digestive system are divided into 2 main group : the **gastrointestinal tract (GI tract)** and **accessory structures .**
- GI tract is a continuous tube extending through the ventral cavity from the mouth to the anus – it consists of the mouth , oral cavity , oropharynx , esophagus , stomach , small intestine , large intestine , rectum , and anus .
- Accessory structures include the teeth, tongue (in oral cavity) , salivary glands , liver , gallbladder , and pancreas .

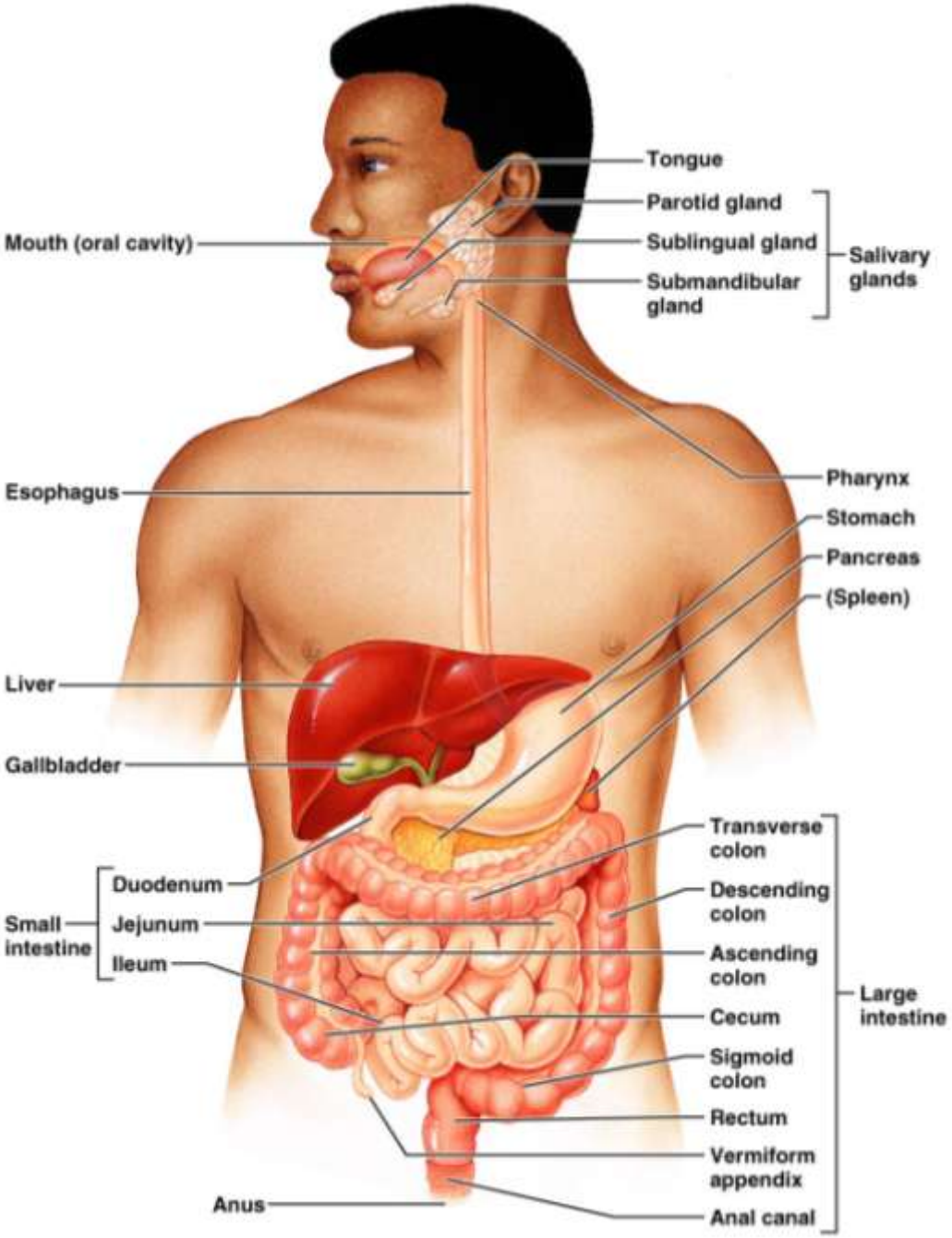


Figure 23.1

Muscular movement of the GI tract

- **Peristalsis** – wavelike movement that occurs from the oropharynx to the rectum , allowing GI tract to push food particles toward the anus .
- **Mixing**—mixing motion in the oral cavity and stomach that allows the GI tract to repeatedly break down food into smaller particles , using mechanical digestion .
- **Segmentation** – regions of the small intestine contracting and relaxing independently , allowing the small intestine to digestive and absorb more efficiently .

Histology of the Alimentary Canal

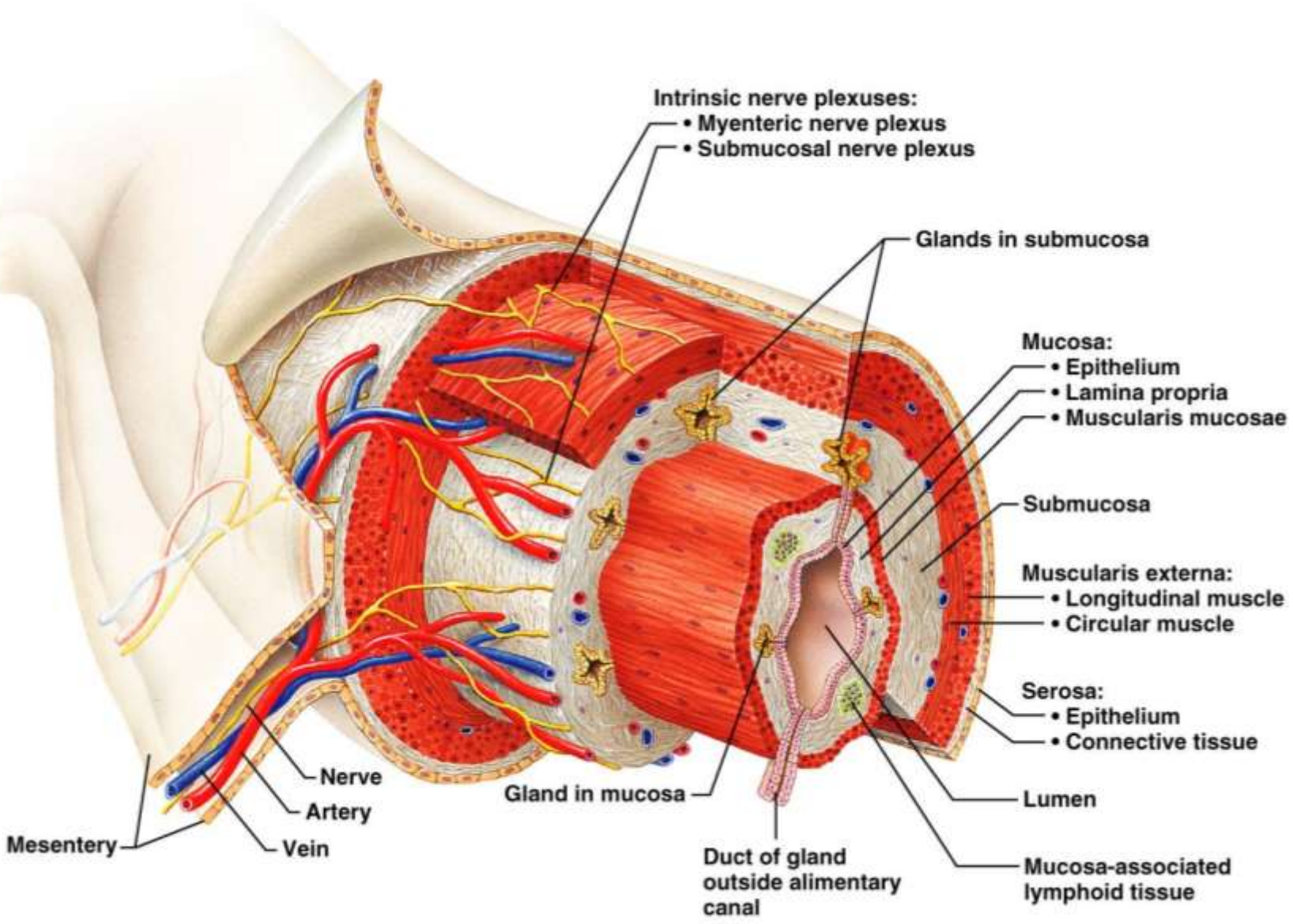


Figure 23.6

Peristalsis and Segmentation

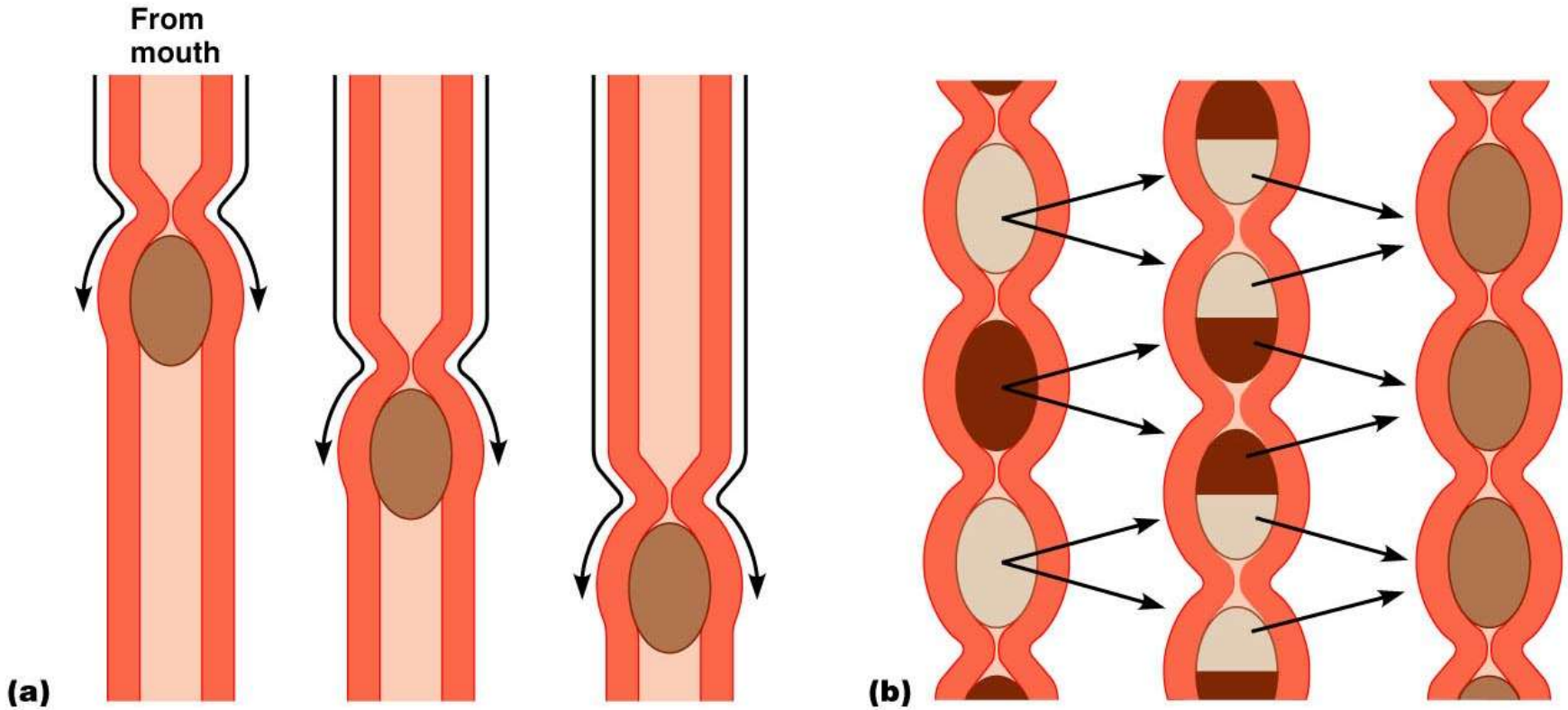
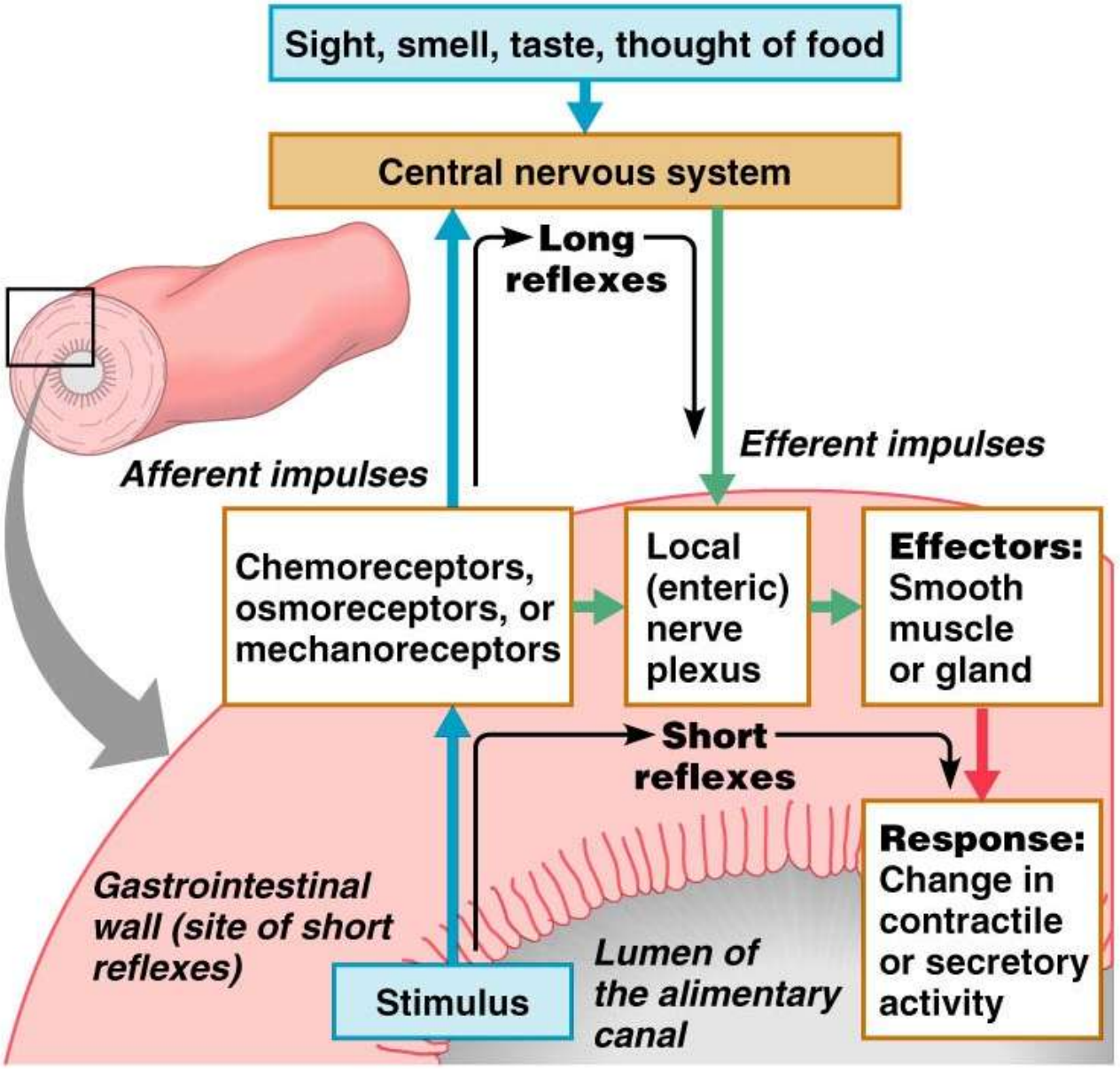


Figure 23.3

Regulation of GI Tract Activities

- **Autonomic nervous system**
  - - parasympathetic nerves stimulate GI tract activities .
  - - sympathetic nerves inhibit GI tract activities .
- **Hormonal control**
  - - hormones from endocrine gland and from GI tract itself help regulate GI tract activities .
- **Reflex mechanism**
  - - regions of the GI tract (especially the stomach and small intestine) use reflexes to stimulate or inhibit one another .

Nervous Control of the GI Tract

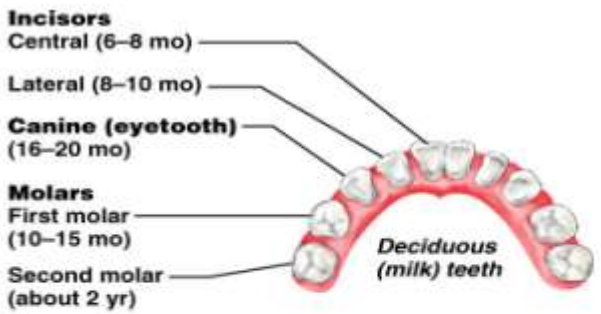


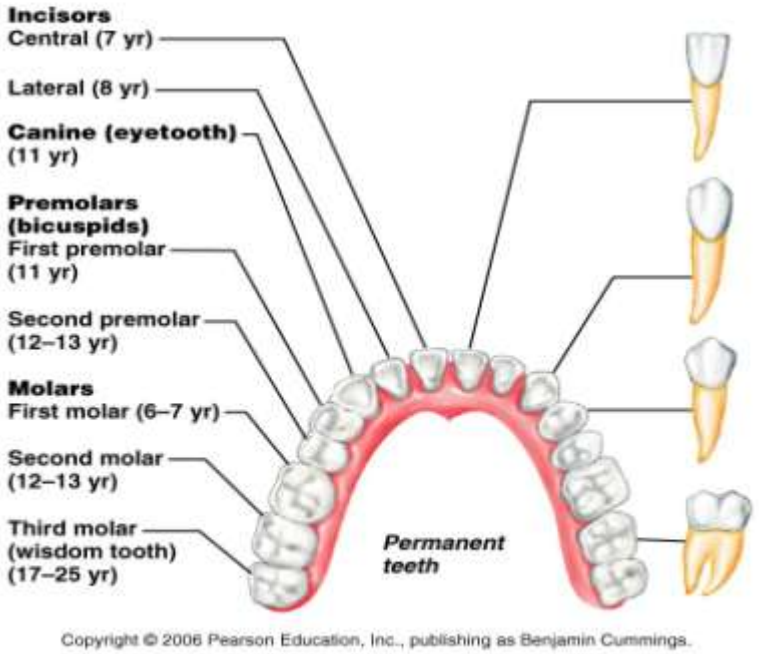
Mouth & Oral Cavity

- Food enters the GI tract by ingestion .
- Food is broken down by mechanical digestion , using mastication .
- One chemical digestive process occur where **amylase** enzyme in saliva breaks down polysaccharide into disaccharides .
- The **tongue** , made of skeletal muscle, manipulates the food during mastication . it also contains taste buds to detect taste sensations(intrinsic) .
- Food particles are mixed with saliva during mastication , resulting in a moist lump called **bolus** for easier passage into or pharynx .

Teeth

- Adapted for **mechanical digestion** (mastication) in the oral cavity .
- 20 deciduous or primary teeth before the age of 6.
- By age 7, 32 permanent or secondary teeth are developed & are divided into 4 types: **incisors** (for cutting) , **Canines** (for tearing) , **Premolars** (for crushing), and **Molars** (for grinding). these teeth follow the human dental formula of 2-1-2-3.





Salivary Glands

- 3 pairs of salivary glands called **parotid , submandibular** , and **sublingual** gland secrete most of the saliva in the oral cavity , using salivary ducts .
- Saliva helps moisten the food during mastication , dissolve the food in forming the bolus , and help cleanse the teeth.
- Saliva consists of 99.5% water , the remaining 0.5% is dissolved substances including **amylase** enzyme (for chemically digesting carbohydrate), bicarbonate ion (HCO_3^-; maintains pH of saliva at 6.5-7.5) , and many electrolytes.

Salivary Glands

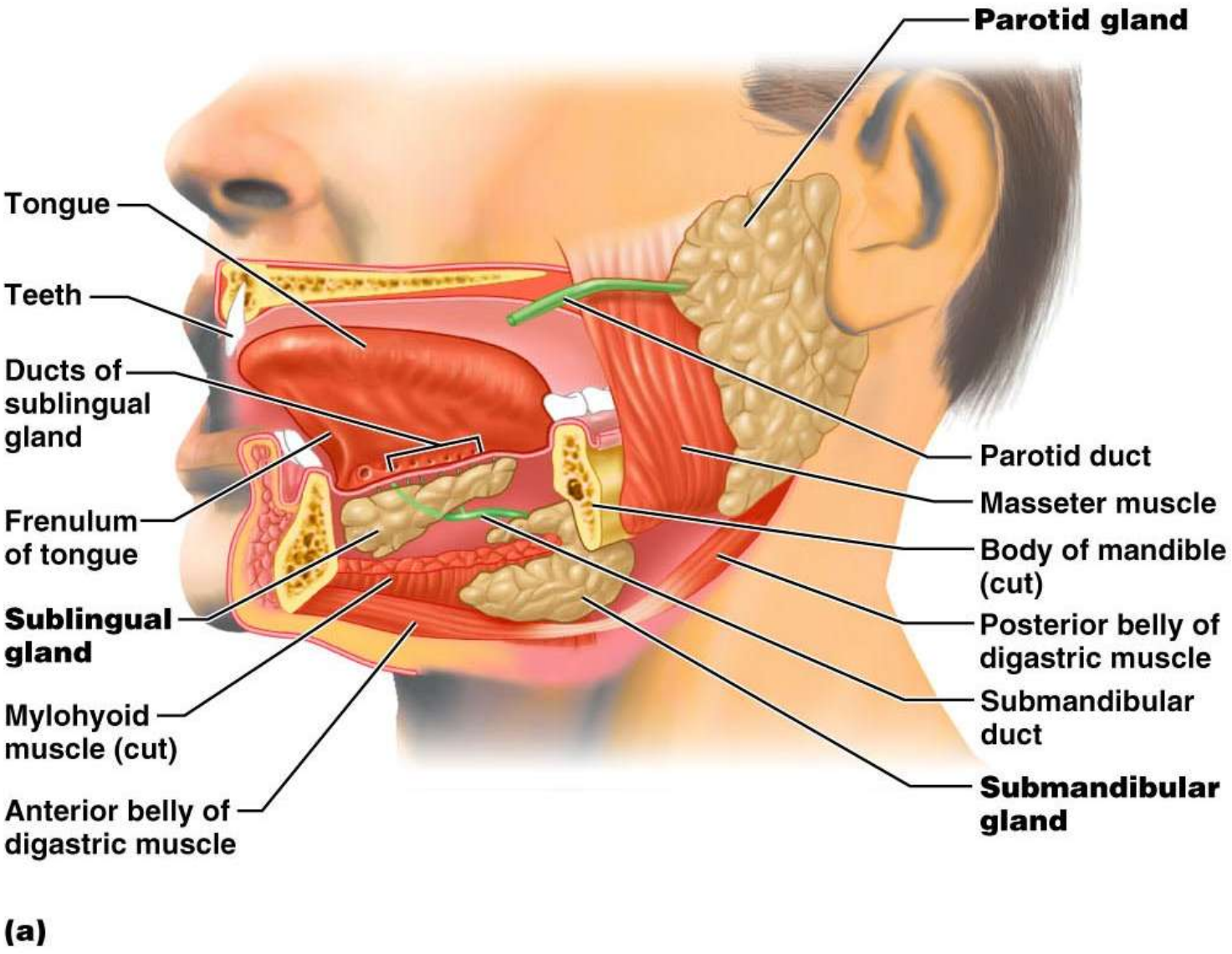
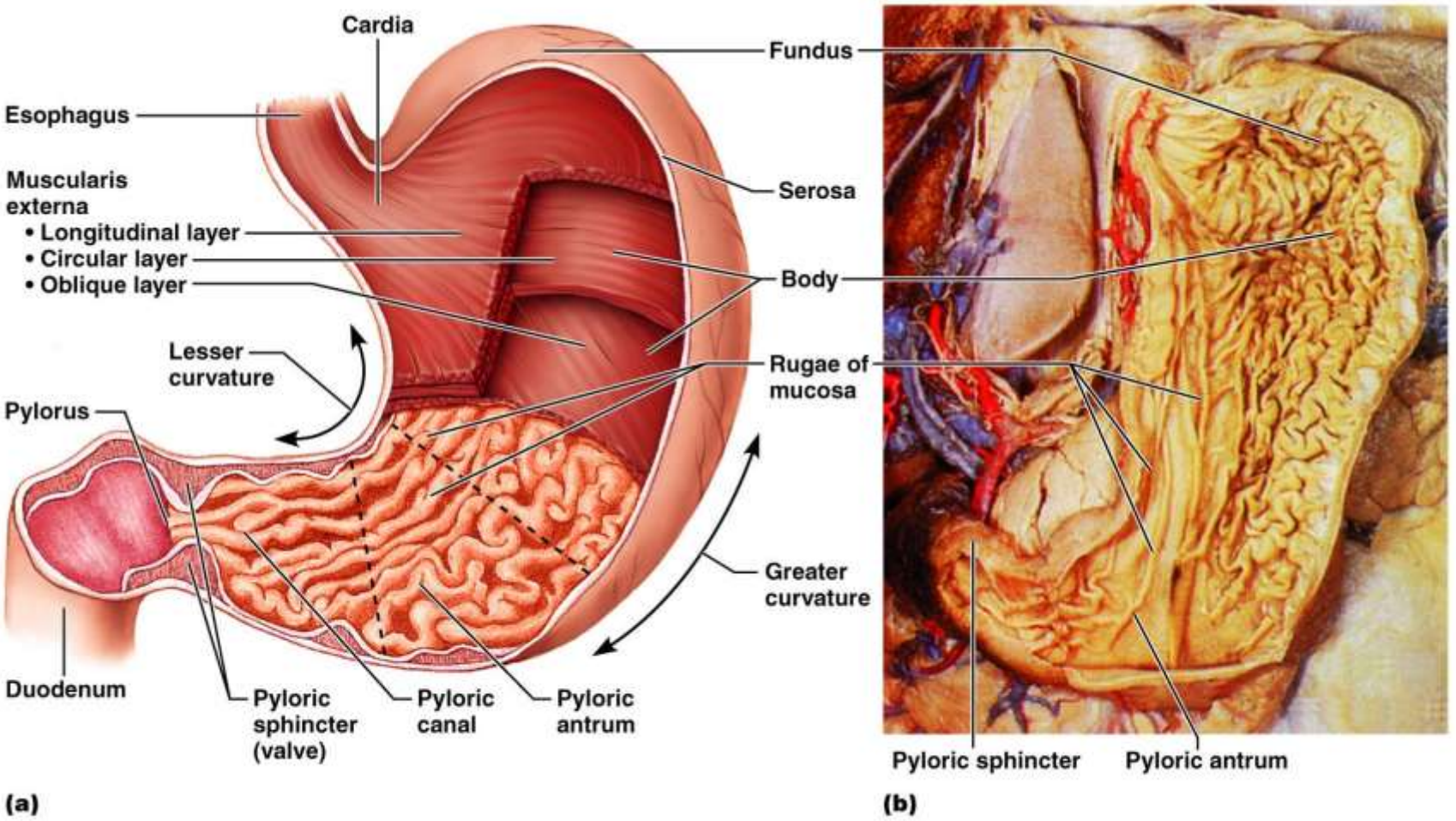


Figure 23.9a

Stomach

- A pouch-like organ primarily designed for food storage (for 2-4 hours) , some mechanical and chemical digestion also occur .
- Contains two sphincters at both ends to regulate food movement – **cardiac sphincter** near the esophagus ,and **pyloric sphincter** near the small intestine .
- Divided into 4 regions : **cardiac stomach** (or cardiac), **fundic stomach** (or funded) , **body of stomach** , and **pyloric stomach** (or Pylorus).
- Contain thick folds called **rugae** at its layer , for providing larger surface area for expansion , secretion , digestion , and some absorption.

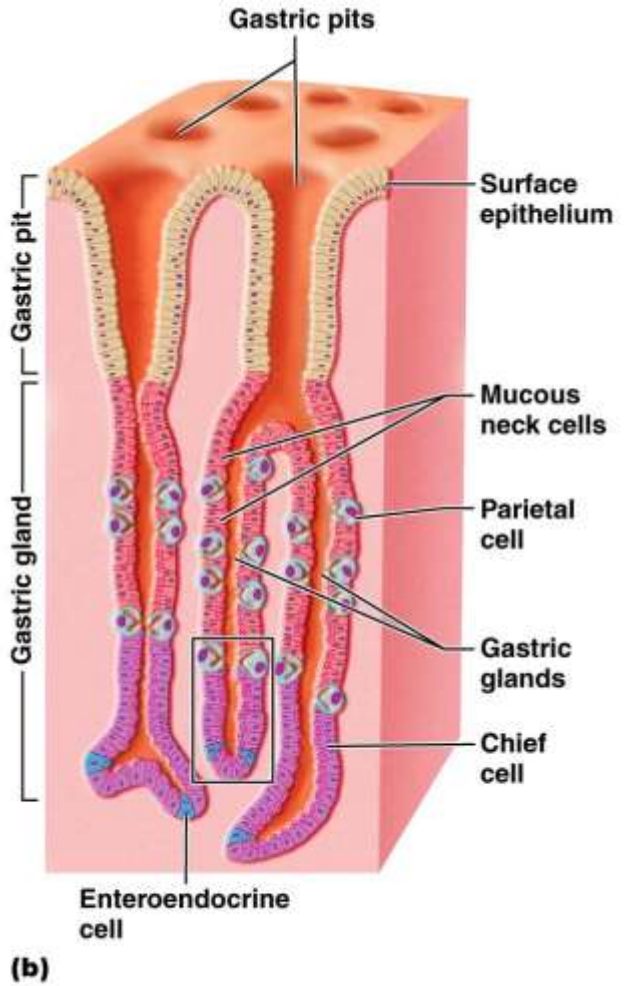
Stomach

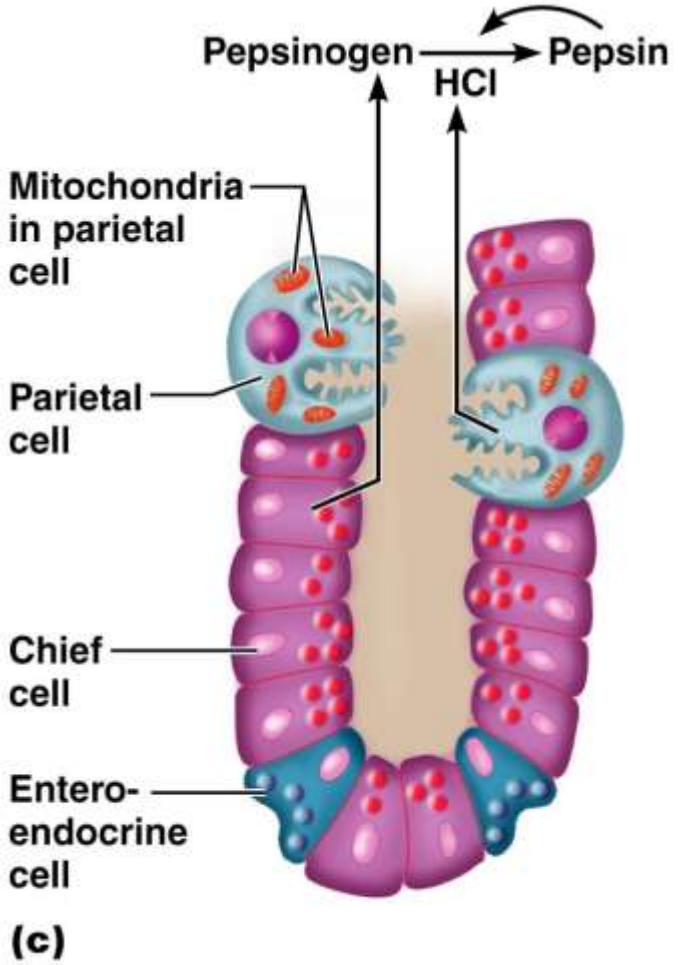


Gastric Secretory Cells

- -**Chief cells:** secrete pepsinogen (an inactive enzyme).
- -**Parietal cells:** secrete hydrochloric and (HCl) and "intrinsic factor" (which helps absorption of vitamin B_{12} in the intestines).
- - **Mucous cells:** secrete mucus and alkaline substances to help neutralize HCl in the gastric juice .
- -**G cells:** secrete a hormone called gastrin , which stimulates the parietal cells and overall gastric secretion .

Gastric Cells





Chemical digestion & absorption in the stomach

- - Carbohydrate digestion is continued with **gastric amylase** , resulting in disaccharides .
- - Protein digestion begins with **pepsin** (activation of pepsinogen by HCl) , resulting in peptides (small chains of protein).
- - Lipid digestion begins with **gastric lipases** which can only break down certain lipids such as butterfat , resulting in fatty acids .
- Absorption in the stomach is limited, where only small and fat-soluble substances can be absorbed—water , alcohol, aspirin , and certain drugs .
- The result of all these mixing , chemical digestion , secretion, and absorption is a yellowish paste called **chyme** , which will be passed on to the small intestine .

Regulation of Gastric Secretion

- Regulation of gastric secretion and activities is by both nervous and hormonal mechanisms – food moving along the oral cavity and esophagus stimulates the **parasympathetic nerves** to activate the secretion in gastric glands , the **gastric hormone** from G cells in turn stimulates the gastric glands for more activities ("positive feedback").
- On the other hand , when food is emptying from the stomach , **sympathetic nerves** inhibit the gastric glands and gastric , and a hormone called **intestinal gastrin** (released by small intestine) inhibits other gastric activities.
- The above regulations occur in 3 overlapping phases:
- **Cephalic Phase**, **Gastric Phase,** & Intestinal Phase.

Cephalic phase

- **Cephalic phase:** involves special senses detect food and uses parasympathetic nerves in the vagus nerve to stimulate gastric activities.
- 1. Sight, Smell , and Taste of food cause stimulation of vagus nuclei in brain.
- 2. Vagus stimulates acid secretion.
- a. Direct stimulation of parietal cells (major effect).
- b. Stimulation of Gastrin secretion (lesser effect).

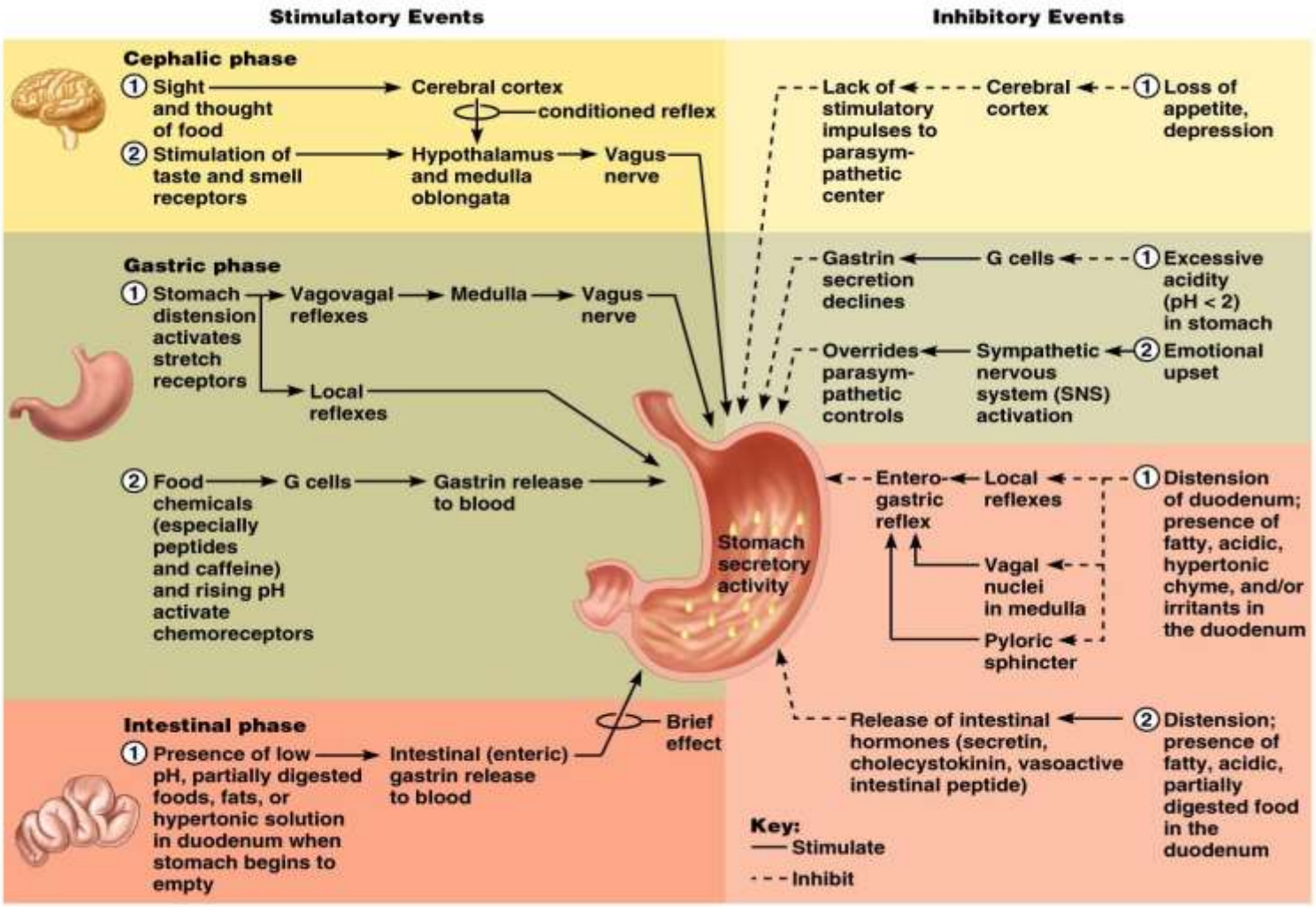
Gastric phase

- **Gastric phase** involves the distention of stomach and stimulates its own activities by the vagus nerve. Distension of stomach (stretch - receptors) stimulates vagus nerve ; vagus stimulates acid secretion .
- Amino acids and peptides in stomach lumen srimulates acid secretion (chemo - receptors)
- Direct stimulation of parietal cells (lesser effect)
- Stimulation of gastrin secretion ; gastrin stimulates acid secretion (major effect)
- Gastrin secretion inhibited when PH of gastric juice falls below 2.5.

Intestinal Phase

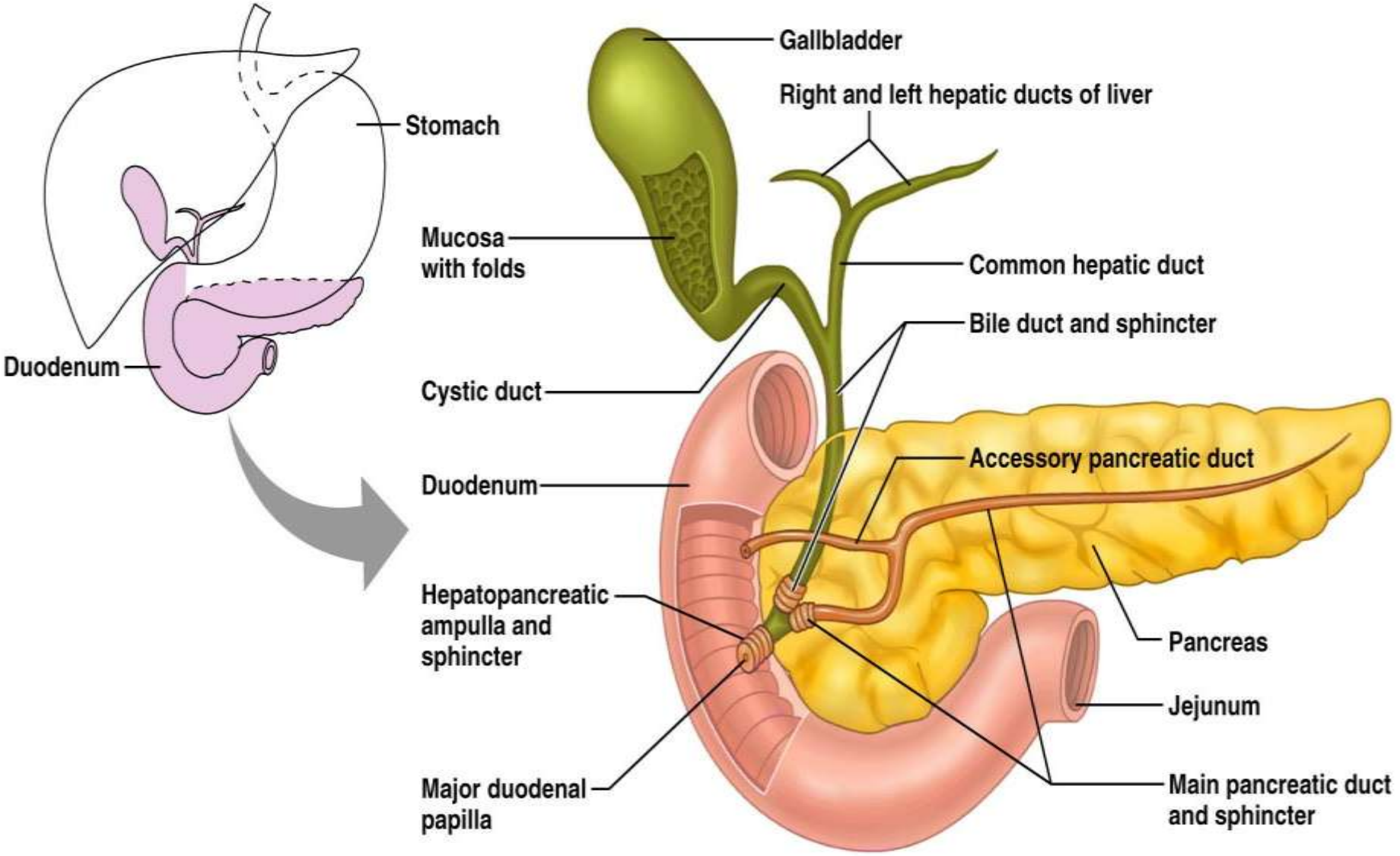
- **intestinal phase** involves acidic chyme passing into the small intestine which secretes intestinal gastrin hormone to inhibit gastric activates.
- Neural inhibition of gastric emptying and acid secretion. Arrival of chyme in duodenum causes distension & an increase in osmotic pressure. These stimuli activate a neural reflex that inhibits gastric activity.
- In response to fat in chyme , duodenum secretes the hormone, **secretin** that inhibits gastric acid secretion.
- The enterogastric reflex: This reflex begins in the small intestine (entero) and ends in the stomach (gastro).
- Duodenum fills with chyme. Sensory stretch receptors are stimulated. Sensory nerve impulses travel to CNS. Nerve impulses from CNS (vagus) inhibit peristalsis in stomach wall.

Stomach: Neural & Hormonal Mechanisms



Pancreas

- Pancreas : most pancreatic enzymes are produced as inactivate molecules , or zymogens , so that the risk of self – digestion within the pancreas is minimized .
- More than 98% of the pancreas mass is devoted to its exocrine function: the secretion of pancreatic juice by the pancreatic acini and their ductile cells. Ductile cells produce **Sodium bicarbonate** which helps neutralize the acidic gastric contents .
- Acinar cells of the exocrine pancreas produce a variety of **digestive enzymes** to break down food substances into smaller absorbable molecules .
- Only 2% of pancreas mass is devoted to the islets of langerham , which produce **insulin** and **glucagon** , hormones that regulate blood sugar and carbohydrate metabolism (they have opposite effects) .

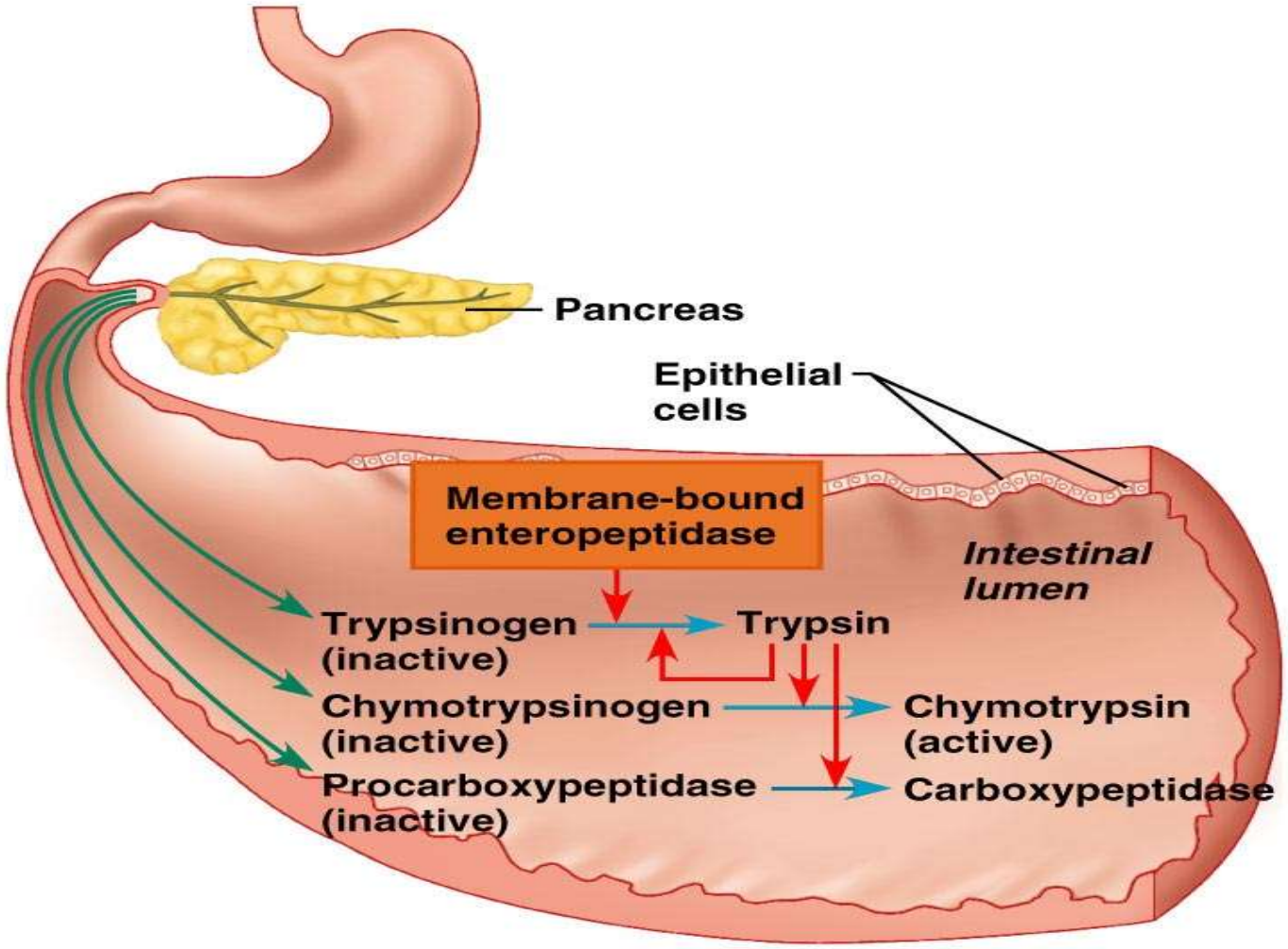


Major pancreatic Enzymes

- -**pancreatic amylase:** digest polysaccharides into disaccharides
- - **pancreatic lipases** digest triglycerides into fatty acids .
- - **pancreatic nucleases** digest nucleic acids into nucleotides .
- -**Pancreatic proteinases** (all secreted in their inactive forms) digest peptides into amino acids:

  Trypsinogen is activated by enterokinase (secreted by duodenum) into **trypsin** , which in turn activates the other 3 enzymes – **chymo-trypsinogen** becomes **chymotrypisn** , **proaminopeptidase** becomes **aminopeptidase**, **and** **procarboxypeptidase** becomes **carboxypeptidase**.

Activation of pancreatic proteases in the small intestine

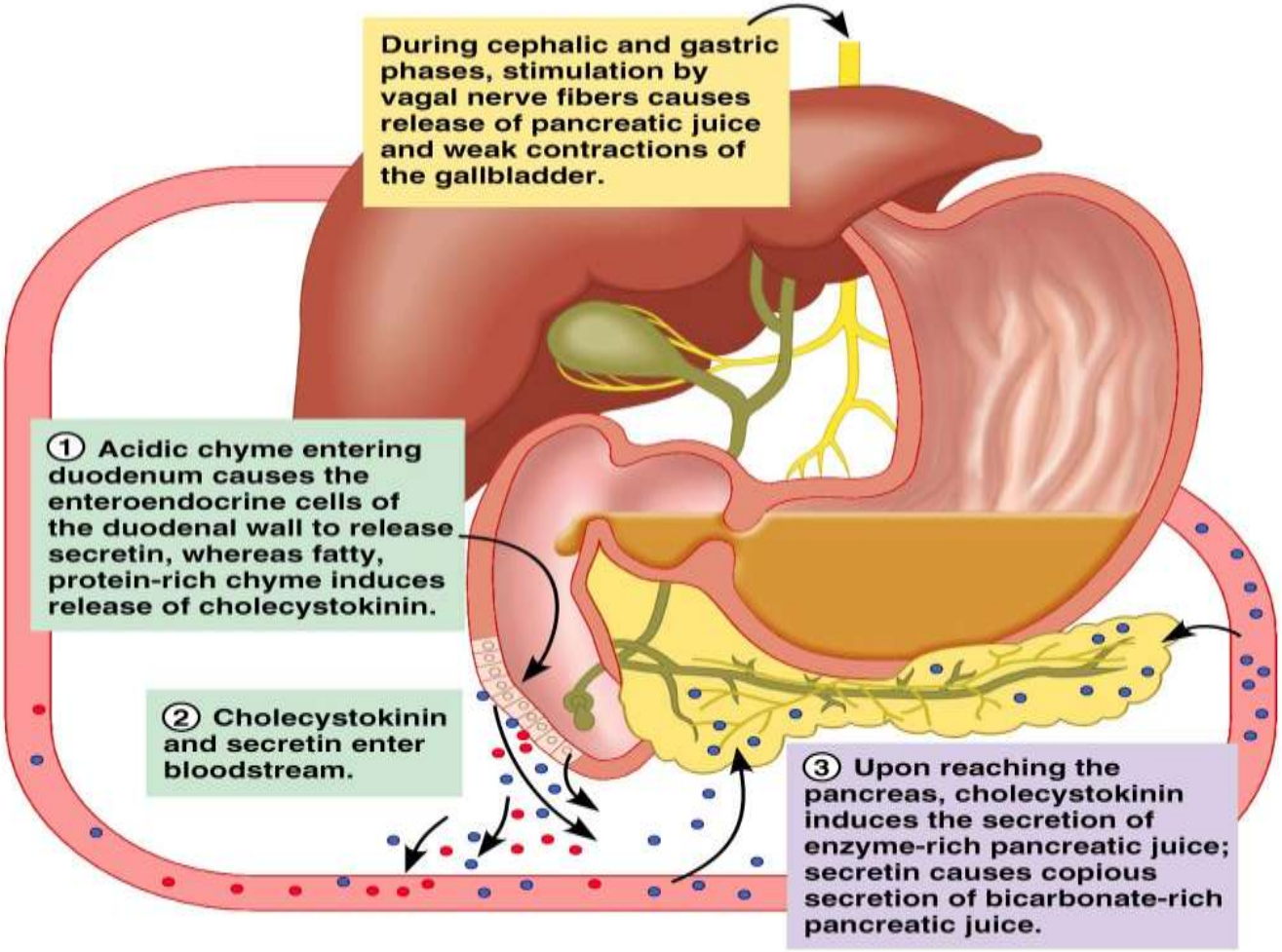


Pancreatic Secretion

- 1.The parasympathetic nervous system increases pancreatic secretion
- 2. Two duodenual hormones also influence pancreatic secretion: Secretin and Cholecystokinin.
- 3. Food entering the small intestine stimulates the secretion of both hormones.
- 4. Secretin stimulates the secretion of pancreatic electrolyte – rich fluid , while CCK enhances the enzymatic secretions of the pancreas .

Regulation of pancreatic Juice

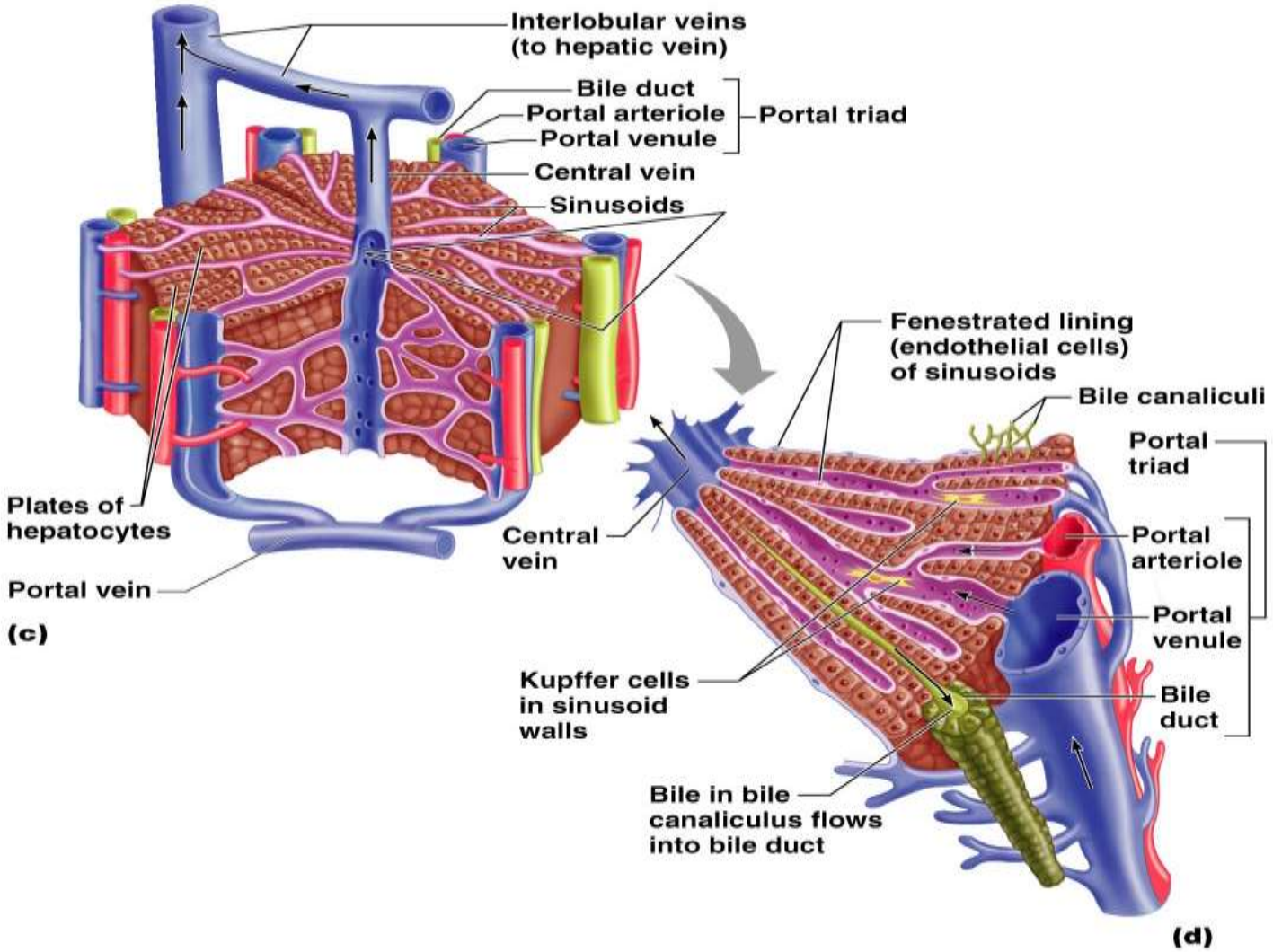
- 1. Acidic chyme enters duodenum.
- 2. Secretin is released into blood stream from intestinal mucosa.
- 3. Secretin stimulates pancreas.
- 4. Pancreas secretes pancreatic juice.
- 5. Pancreatic juice , high in bicarbonate ions , neutralizes acidic chyme.



Functions of The Liver

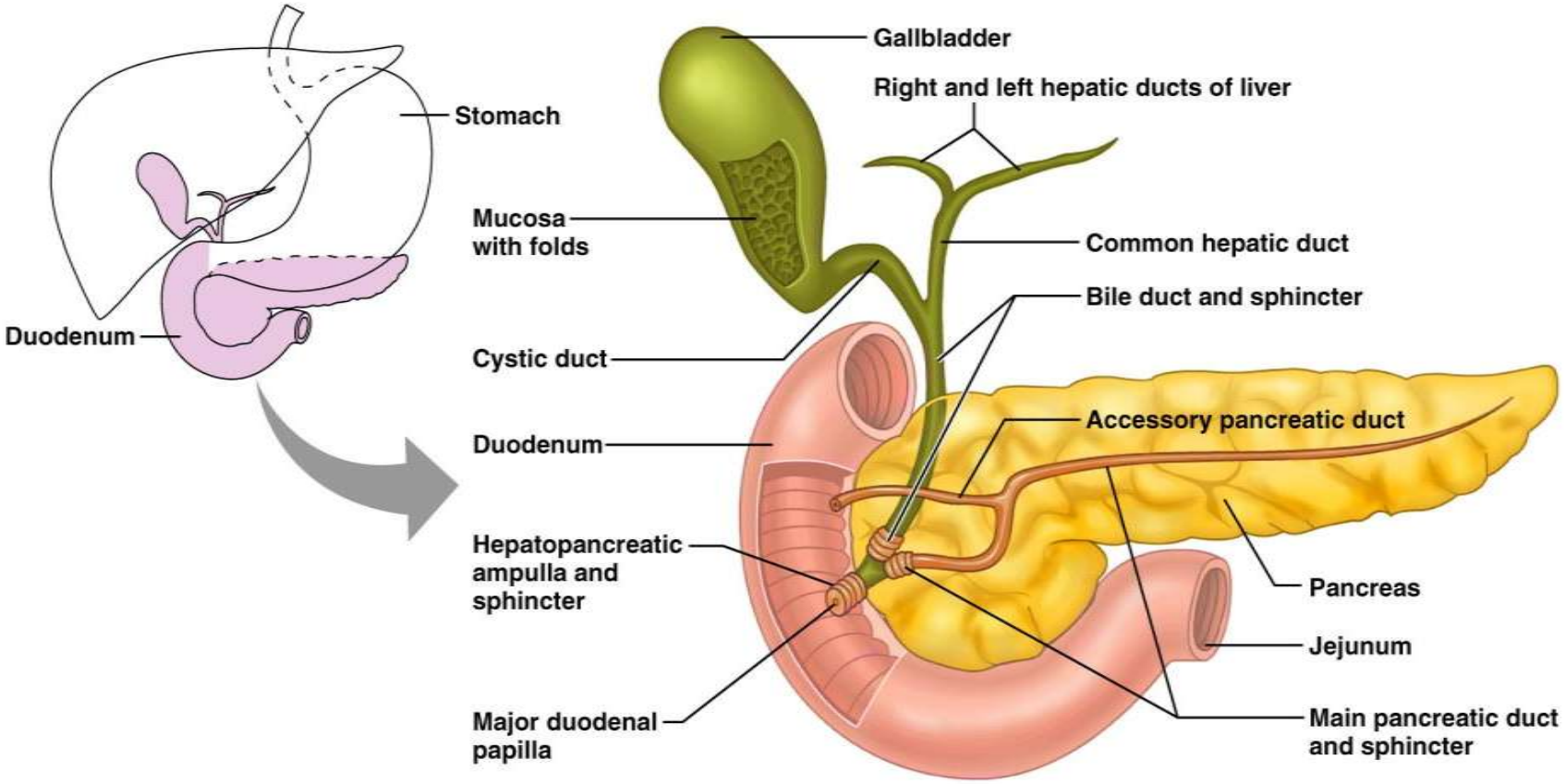
- Important in carbohydrate metabolism where hepatic cells conduct **glycogenesis** (converting glucose into glycogen) **,** and **glycogenolysis** (breaking glycogen down to glucose)**.**
- Also is critical in lipid metabolism where hepatic cells produce **bile** (for fat emulsification), oxidize fatty acids , synthesize various forms of lipids ,and convert glucose to fatty acids (**lipogenesis**) .
- Other functions of the liver include :
- - Storage of glycogen, iron , and vitamins A,D,B_{12}.
- -Contains phagocytes to destroy damaged erythrocytes and foreign substances, using phagocytosis .
- -Detoxifies harmful substances in the blood .
- -Serves as a blood reservoir (contains 7% of blood volume).

Liver



Gall Bladder

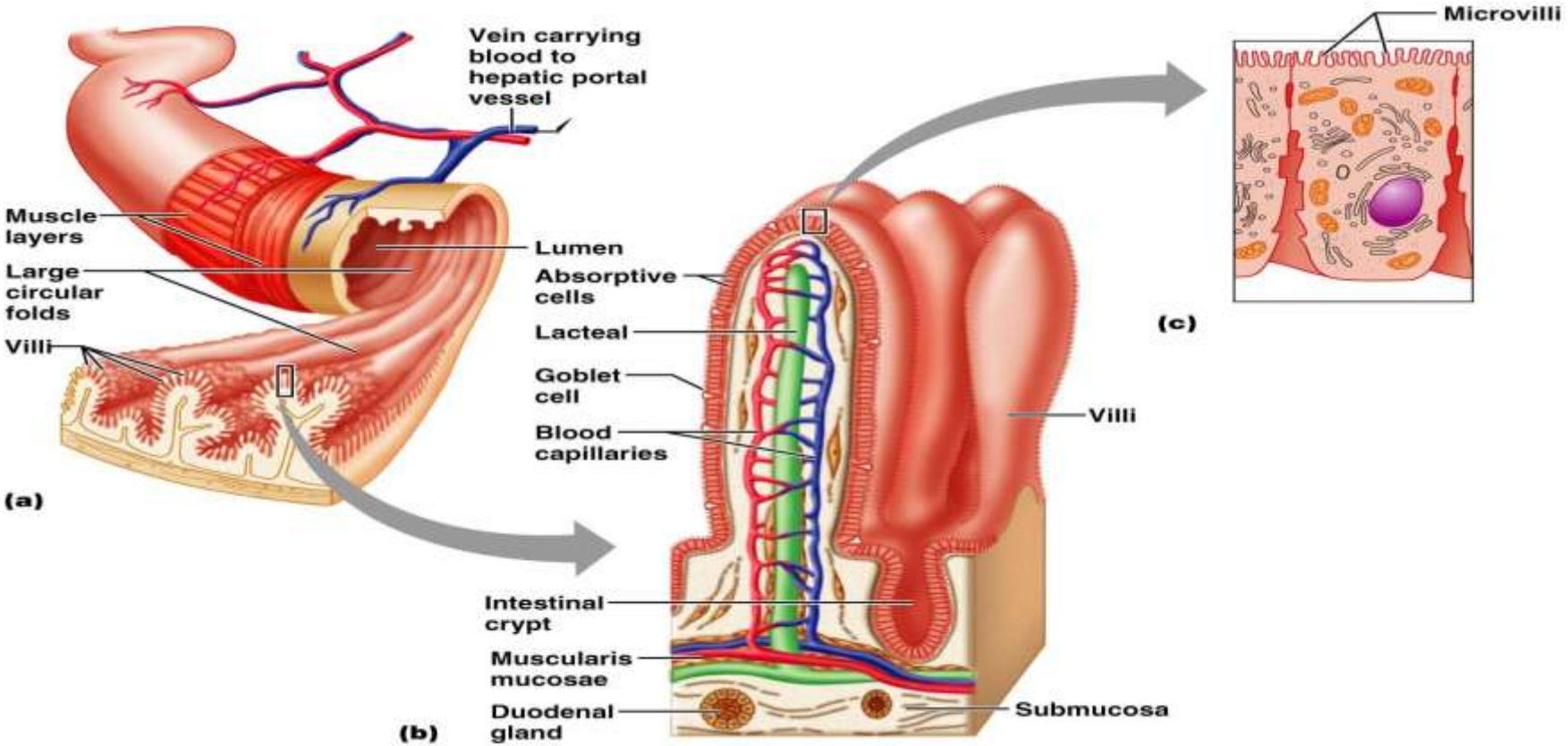
- A small sac located on the inferior , visceral surface of the liver.
- Stores and concentrates bile secreted by the liver.
- **Regulation of Bile Release:**
- 1. **Chyme** with fat enters small intestine.
- 2. Cells of intestinal mucosa secrete the hormone **Cholecystokinin** (CCK) into the blood stream.
- 3. **CCK** stimulates muscular layer of gallbladder wall to contract.
- 4. **Bile** passes down the cystic duct and common bile duct to duodenum .
- 5. Hepatopancreatic sphincter relaxes and **bile** enters duodenum.



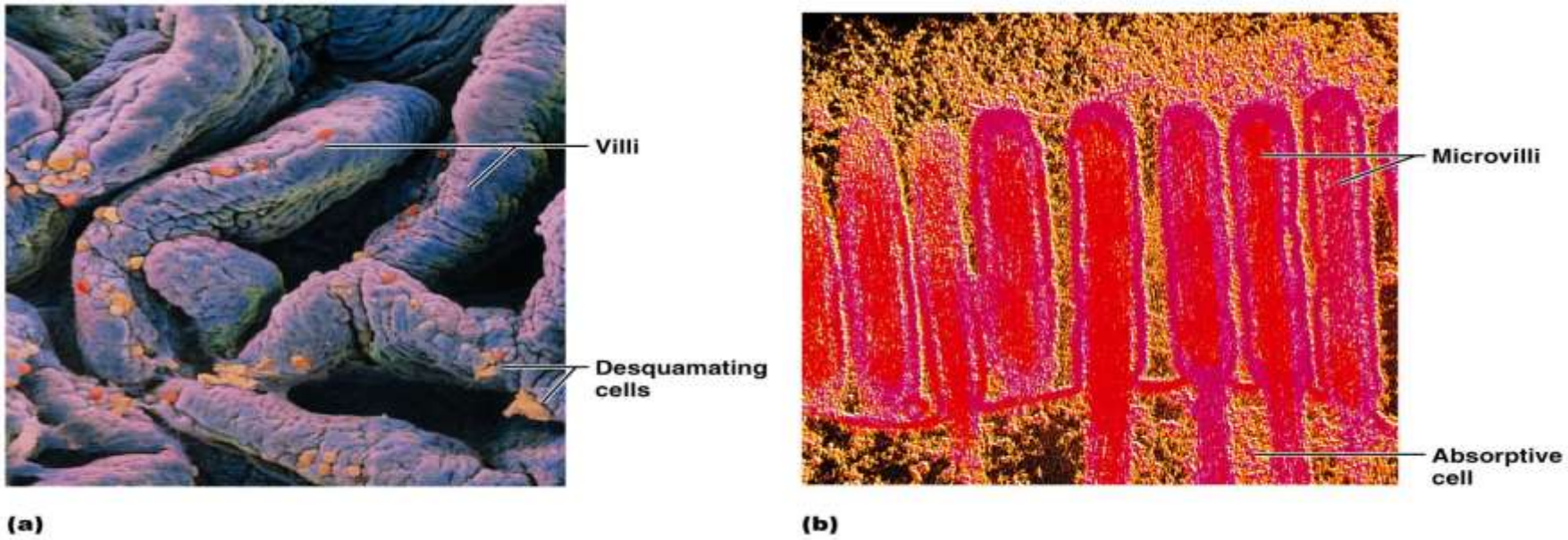
Small Intestine

- A long tube, with a small diameter (about 1 inch), extending from pyloric sphincter to the ileocecal valve .
- Divided into **Duodenum**, **Jejunum**, and **ileum**.
- 1. Secretions of small intestine:
- a. Intestinal glands secrete a watery fluid that lack digestive enzymes but provides a vehicle for moving chyme to villi .Intestinal enzymes include : **maltase** digests maltose into glucose. **sucrose** digests sucrose into glucose and fructose . **lactase** digests sucrose into glucose and glucose. **peptidases** digest peptides into amino acids . **lipases** digest triglycerides into fatty acids and glycerol . **Nucleases** digest nucleotides into nitrogenous bases. **Enterokinase** converts trypsinogen into trypsin.

- b. Digestive enzymes embedded in the surfaces of microvilli split molecules of sugars, proteins and fats .
- c. Regulation of small intestine secretions: secretion is stimulated by gastric juice , chyme , and reflex stimulated by distension of the small intestinal wall .

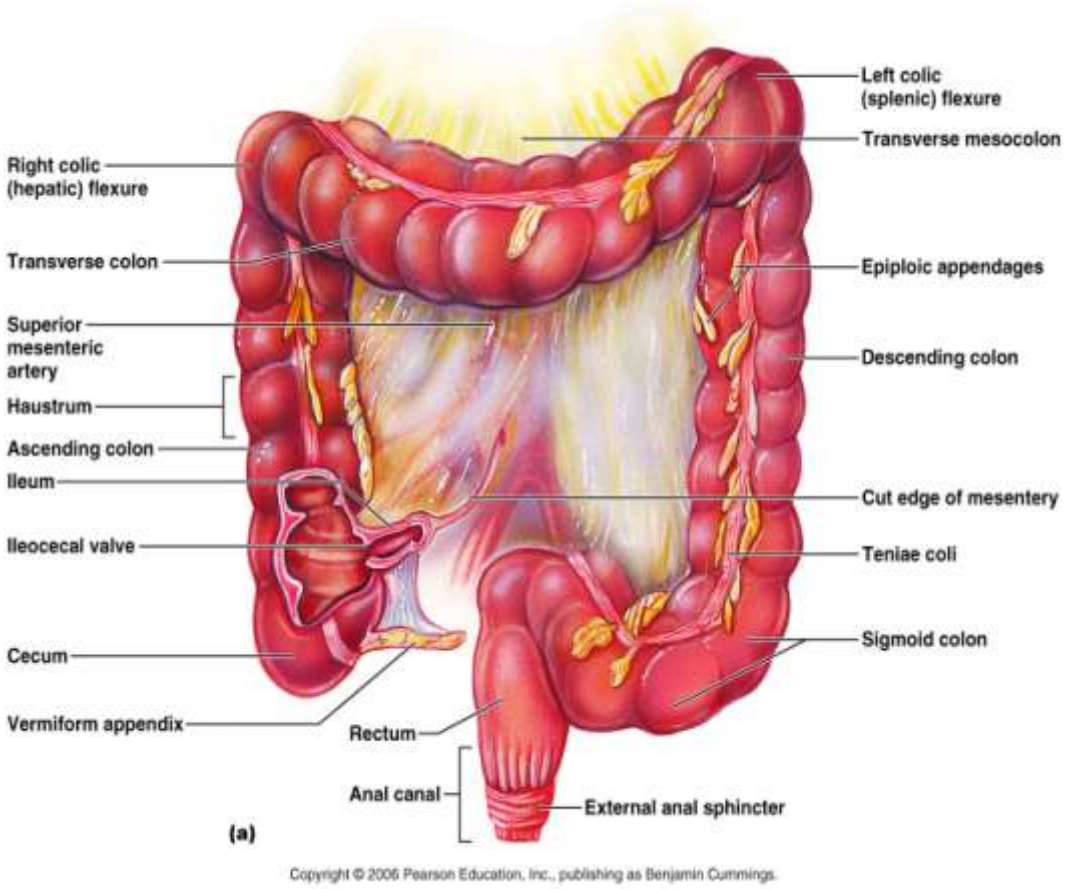


- d. Each villus contains blood capillaries to absorb water , glucose , amino acids , vitamins , minerals , and short-chain fatty acids , and also contains lymphatic capillaries called **lacteals** to absorb long – chain fatty acids in the forms of **micelles** .
- e. Water is absorbed by osmosis , fatty acids are absorbed by diffusion (since they are fat-soluble), and most other nutrients (glucose, amino acids, & minerals) are absorbed by active transport.



Large intestine

- The last segment of the GI tract , with a large diameter (2-3 inches) , extending from the ileocecal valve to the anus .
- Divided into **cecum , ascending colon , transverse colon , descending colon , sigmoid colon , rectum , anal canal** , and **anus.**



- The large intestine has little or no digestive function , although it secretes mucus. Its mucosa has no villa or microvillus , but cotains numerous **goblet cells** for secreting mucus to aid in the formation of feces and maintain an alkaline condition .
- mechanical stimulation and parasympathetic impulses control the rate of mucus secretion .
- The large intestine only absorbs **water**, electrolytes and some vitamins .
- Many **bacteria** inhabit the large intestine , where they break down certain indigestible substances and synthesize certain vitamins .
- feces are formed and stored in the large intestine . **Defecation** involves a reflex mechanism aided by voluntary contraction of the diaphragm , abdominal muscles ,and the external anal sphincter .

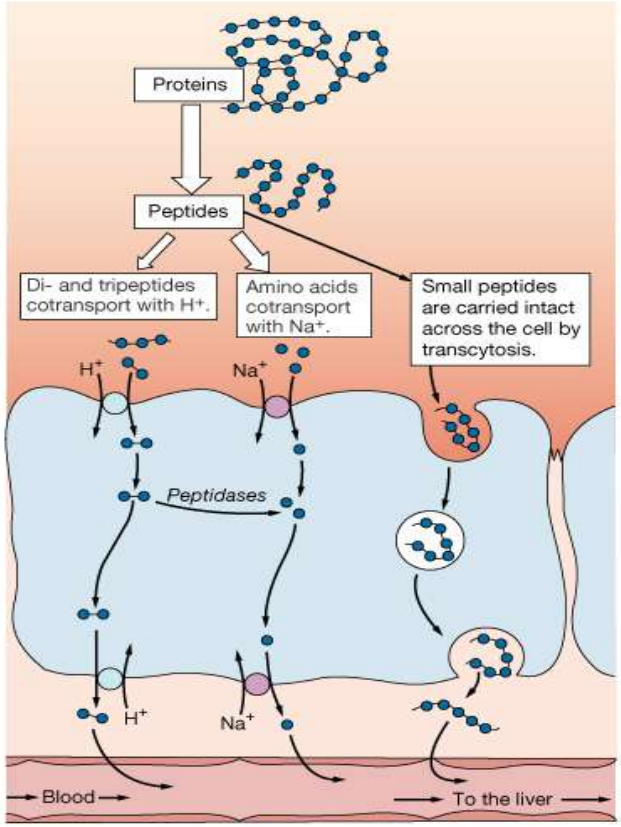
Major Hormones of The Digestive Tract

- 1. Gastrin : (Gastric & intestinal) : released by Gastric cells , in response to the presence of food. Causes Gastric glands to increase their secretory activity.
- 2. Somatostatin : (Gastric inhibitory peptides - GIP): Inhibits secretion of acid by parietal cells.
- 3. Cholecystokinin : released by intestinal wall cells , in response to the presence of proteins and fats in the small intestine. It causes gastric glands to decrease their secretory activity and inhibits gastric motility ; stimulation of pancreas to secrete digestive enzyme; stimulates gall – bladder to contract and release bile.
- 4. Secretin: released by cells in the duodenal wall, in response to acidic chyme entering the small intestine.

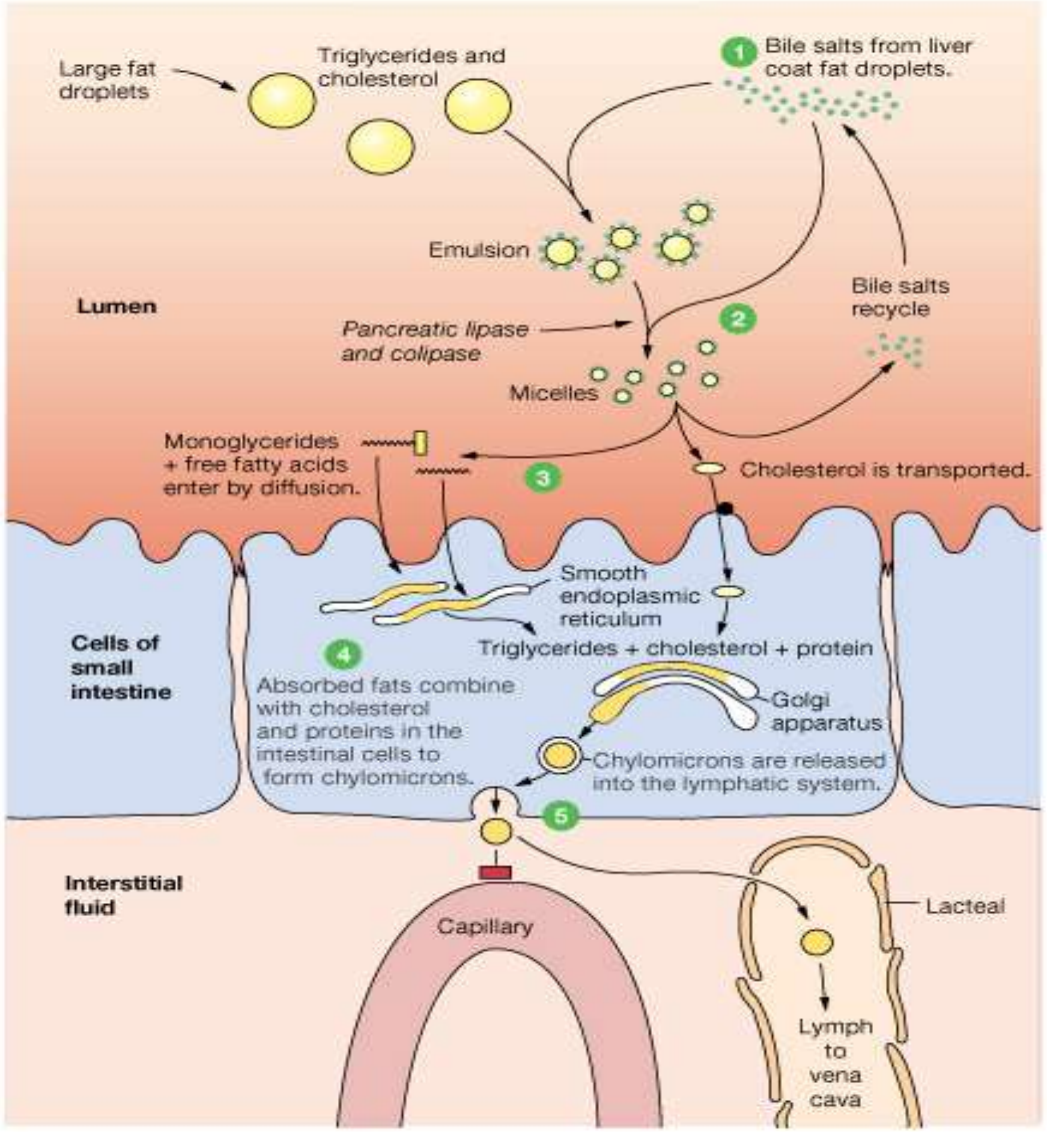
Major Digestive Enzyme

- **Salivary enzyme:** Begins carbohydrates digestion by breaking down starch and glycogen to disaccharides
- **Gastric enzymes:** Pepsin , from Gastric glands – Begins protein digestion . Lipase, from Gastric glands – Begins fat digestion .
- **Pancreatic enzymes:** Amylase , from pancreas – breaks down starch and glycogen into disaccharides. Lipase, from pancreas – breaks down fats into fatty acids and glycerol .
- **Proteolytic enzymes :**
  - Trypsin, Chymotrypsin, and Carboxypeptidase from pancreas breaks down peptides into amino acids . Nucleases, from pancreas- breaks down nucleic acids into nucleotides.

- **Intestinal Enzymes:** Peptidase, from mucosal cells, breaks down peptides into amino acids. Sucrase, maltase, and lactase , from mucosal cells, breaks down disaccharides into monosaccharides. Lipase, from mucosal cells, breaks down fats into fatty acid and glycerol. Enterokinase , from mucosal cells, (breaks down) converts trypsinogen into trypsin .



Fat digestion & Absorption

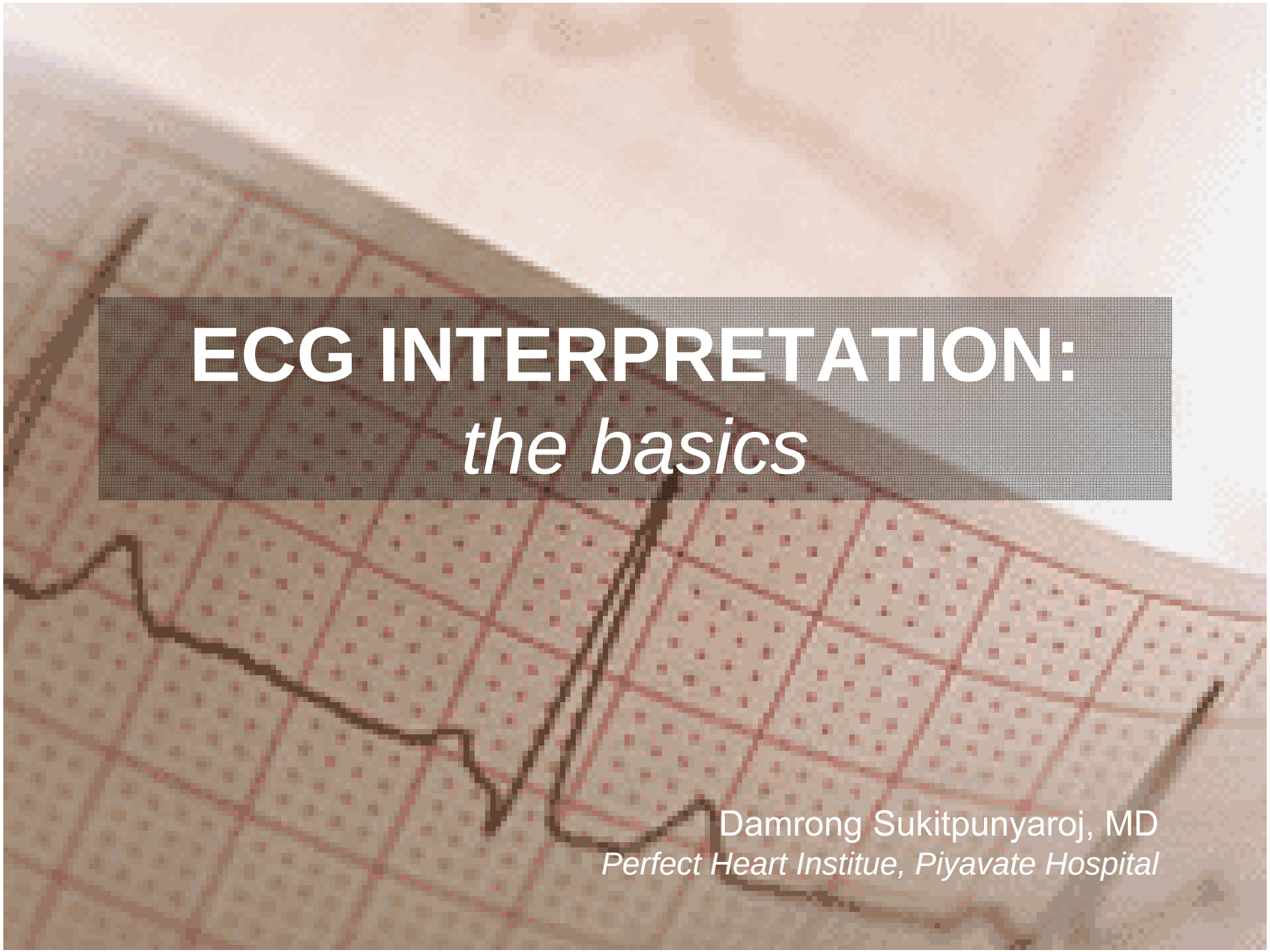


Clinical Terms

- **Achalasia** : failure of the smooth muscle to relax at some junction in the digestive tube.
- **Cholecystitis** : Inflammation of the gallbladder.
- **Chloelithiasis** : stones in the gallbladder.
- **Cholestasis** : Blockage in bile flow from the gallbladder.
- **Cirrhosis** : liver cells degenerate and the surrounding connective tissue thicken.
- **Diverticulitis** : Inflammation of small pouches that sometimes form in the lining and wall of the colon.
- **Dysentery** : Intestinal infection.

Clinical terms

- **Dyspepsia**: Indigestion
- **Dysphasia**: Difficulty in swallowing
- **Enteritis**: Inflammation of the intestine .



ECG INTERPRETATION:
the basics

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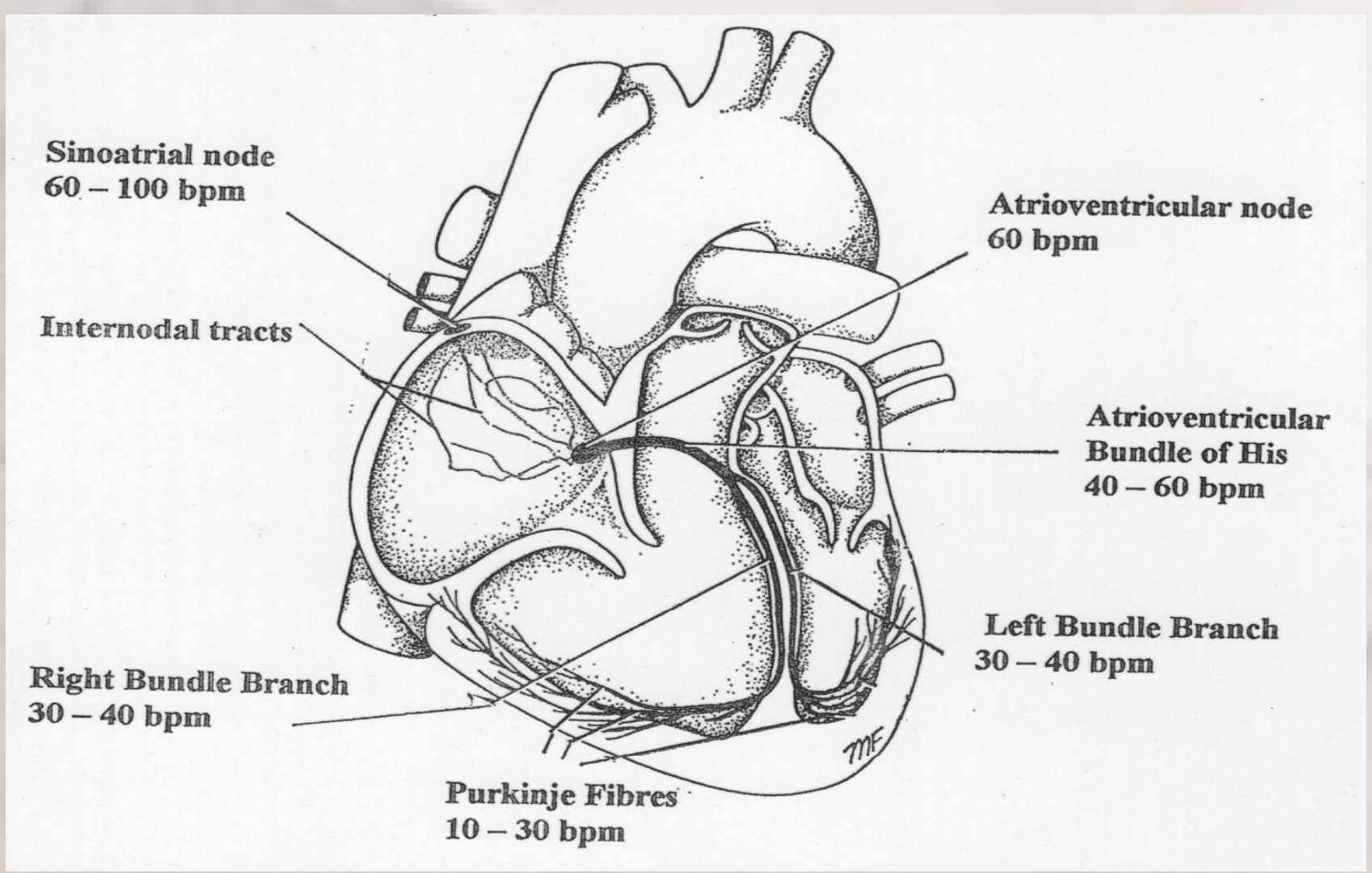
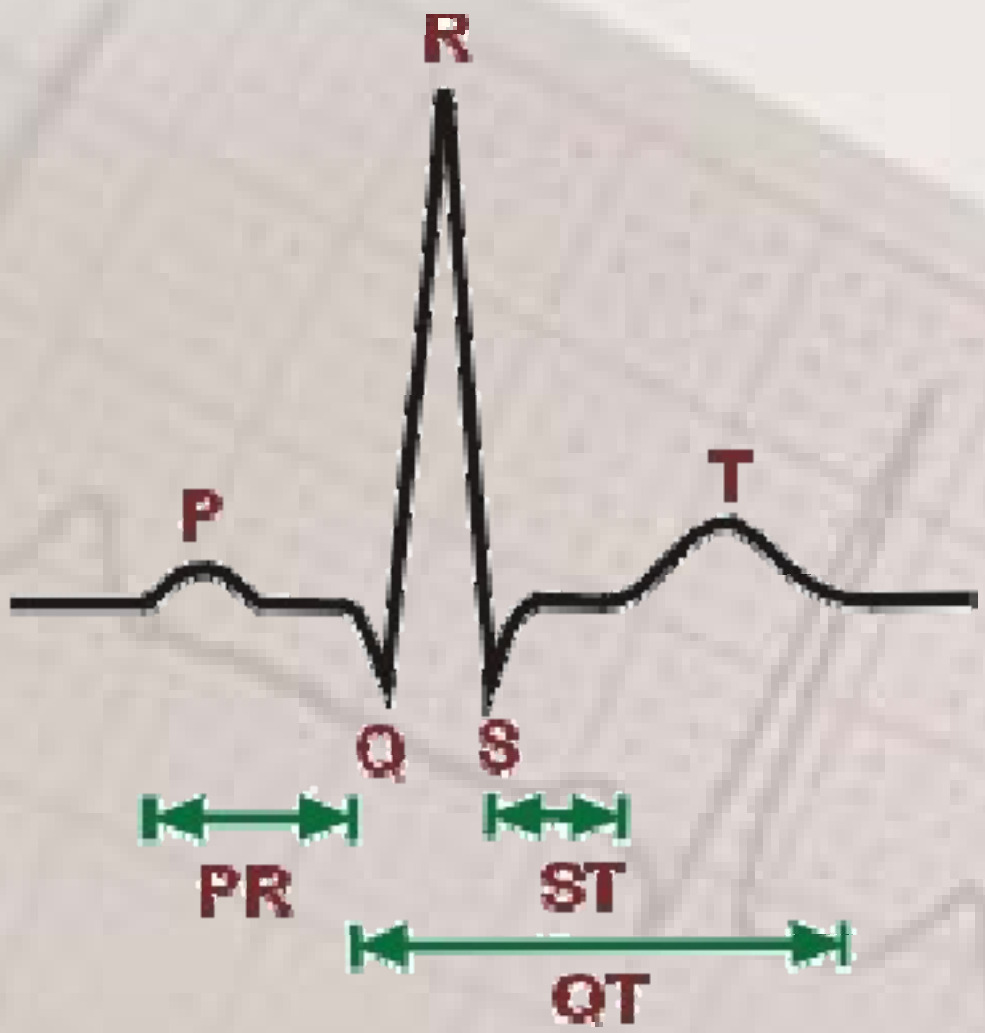
Overview

- Conduction Pathways
- Systematic Interpretation
- Common abnormalities in Critical Care
  - Supraventricular arrhythmias
  - Ventricular arrhythmias

Conduction Pathways



Conduction Pathways



P wave = atrial depolarisation.

PR Interval = impulse from atria to ventricles.

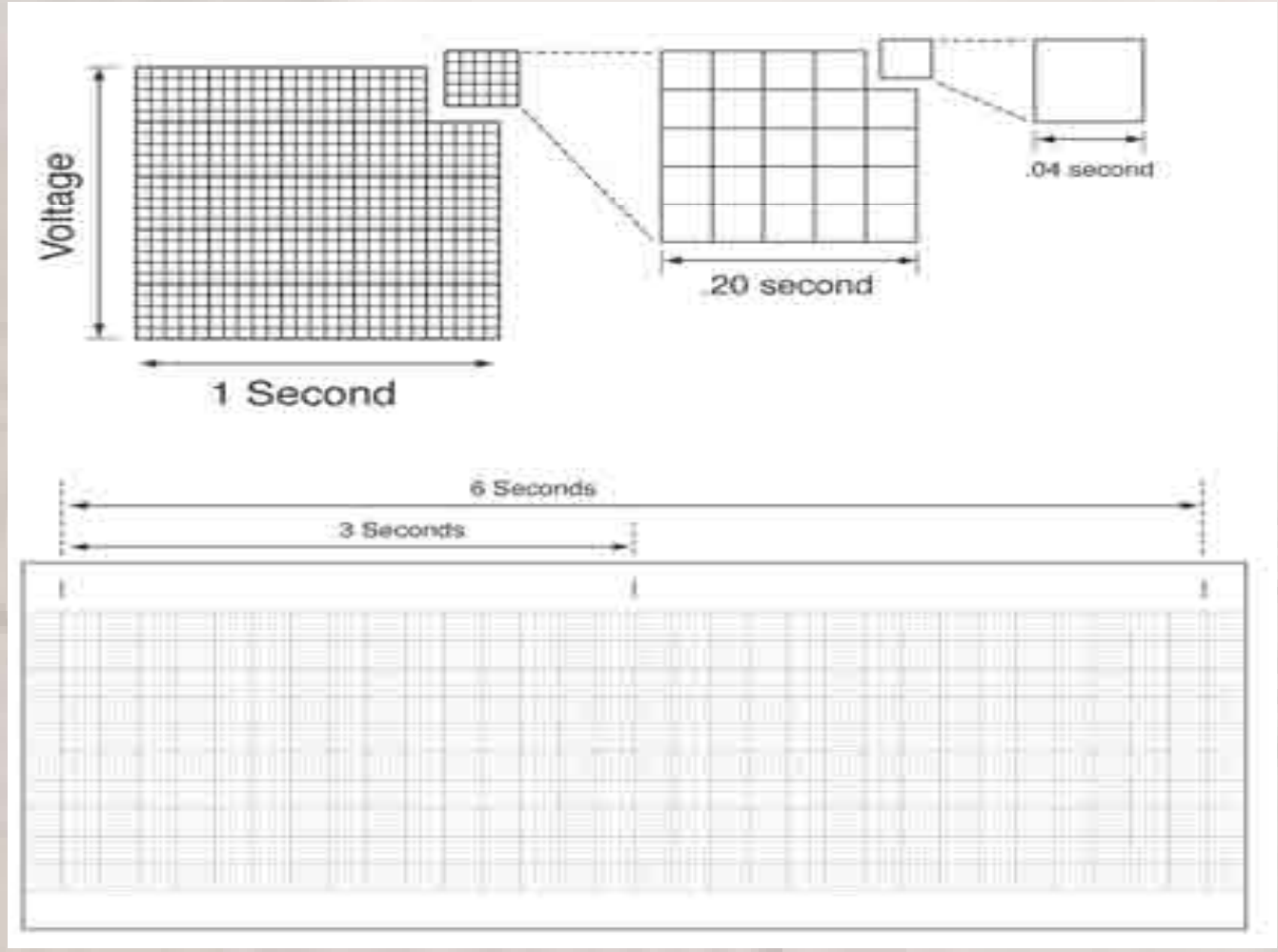
QRS complex = ventricular depolarisation.

ST segment = isoelectric - part of repolarisation.

T wave = usually same direction as QRS - ventricular repolarisation.

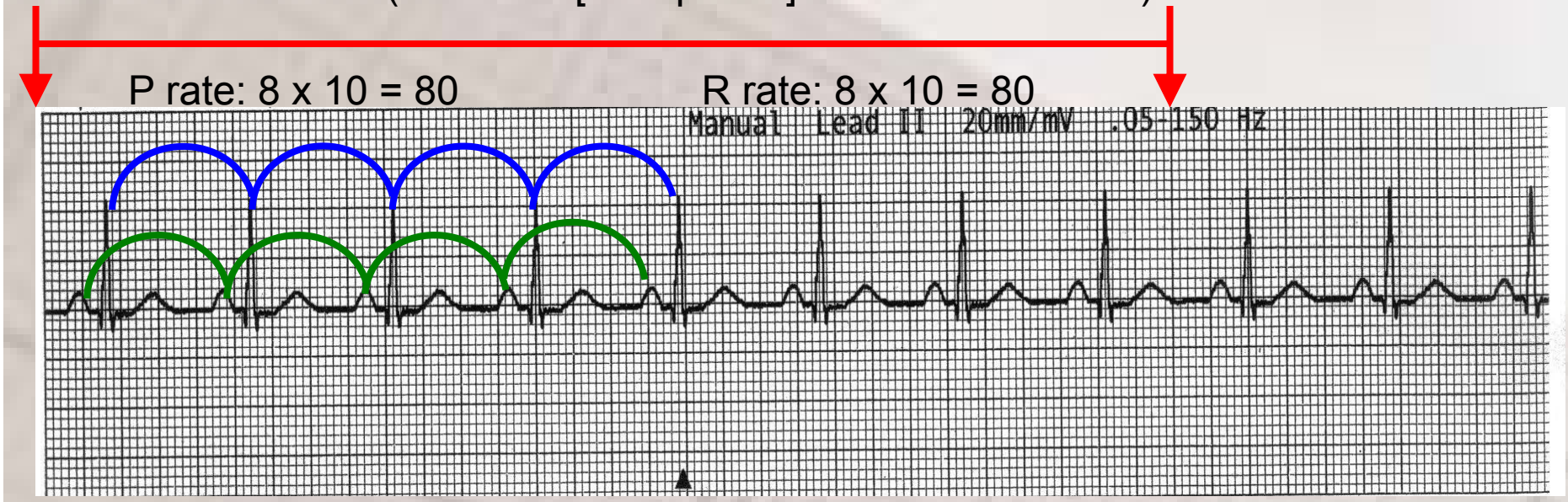
QT Interval = This interval spans the onset of depolarisation to the completion of repolarization of the ventricles.

Interpretation



Interpretation

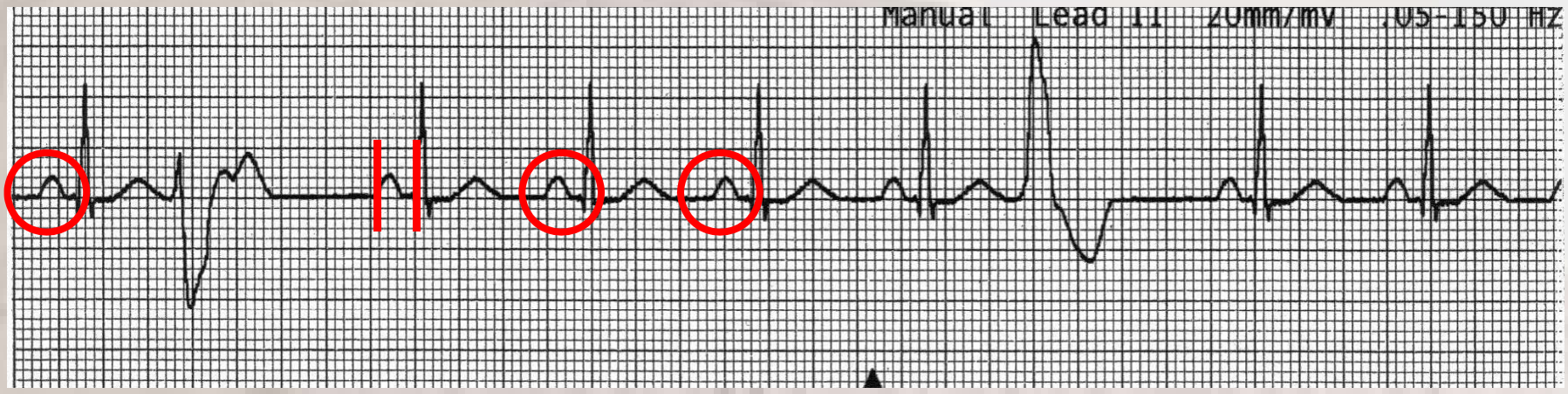
1. Rate = Number of P's (atrial) R's (ventricular) per minute (6 second [30 squares] X 10 = minute rate).



2. Rhythm = Regular or irregular. Map P-P and R-R intervals.

Interpretation

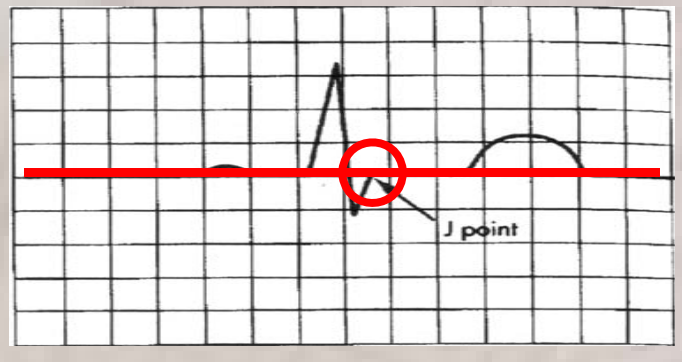
3. <u>P wave</u> = present, 1 per QRS, shape, duration, voltage.

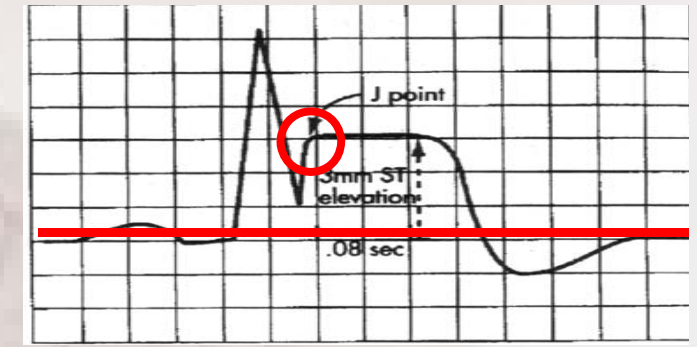


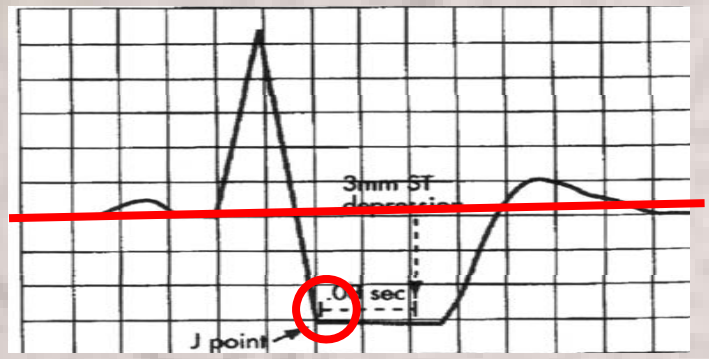
4. <u>P-R interval</u> = length (0.12 - 0.2 sec = <1 big square), isoelectric.

Interpretation

5. <u>QRS</u> = duration (0.06 - 0.10), voltage, q or Q waves



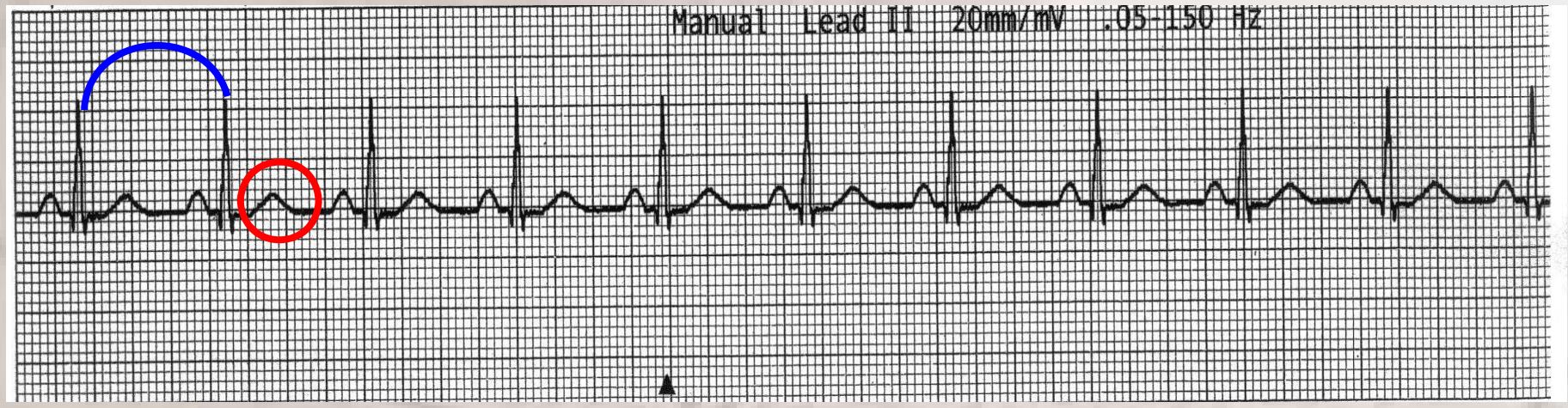




6. <u>ST Segment</u> = shape, isoelectric with PR segment

Interpretation

7. T wave = shape, direction



8. QT interval = length (R-R/2 or QT**c** <0.40 sec)

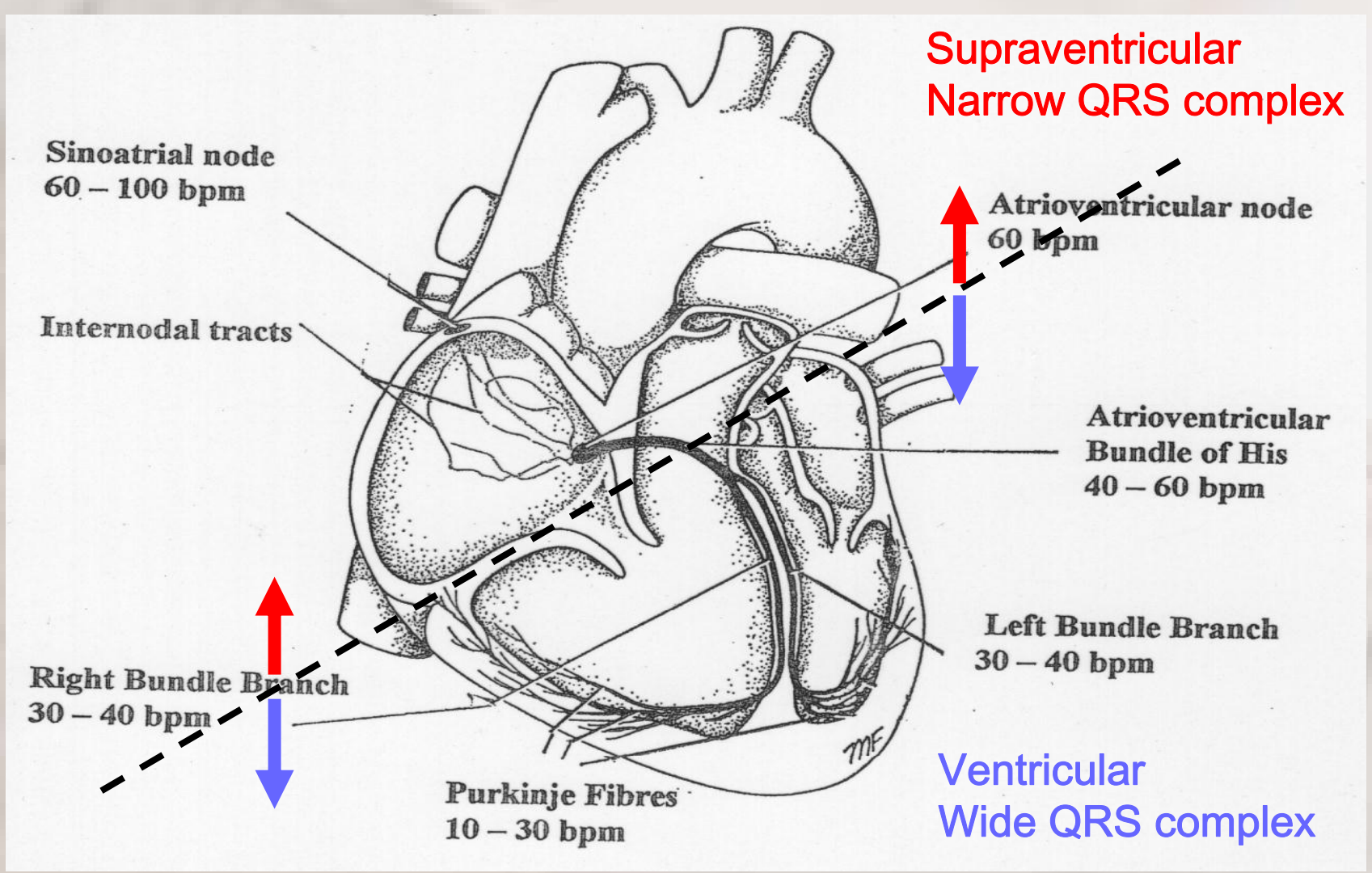
Abnormalities:
Supraventricular arrhythmias

- Atrial Fibrillation
- Atrial Flutter
- Supraventricular Tachycardia (SVT)

Abnormalities:
Ventricular arrhythmias

- Premature Ventricular Complexes (PVCs)
- Ventricular tachycardia (VT)

Conduction Pathways



Abnormalities:
atrial fibrillation

Rhythm: Irregular

Rate: A: 350 – 650; V: varies

P: poorly defined

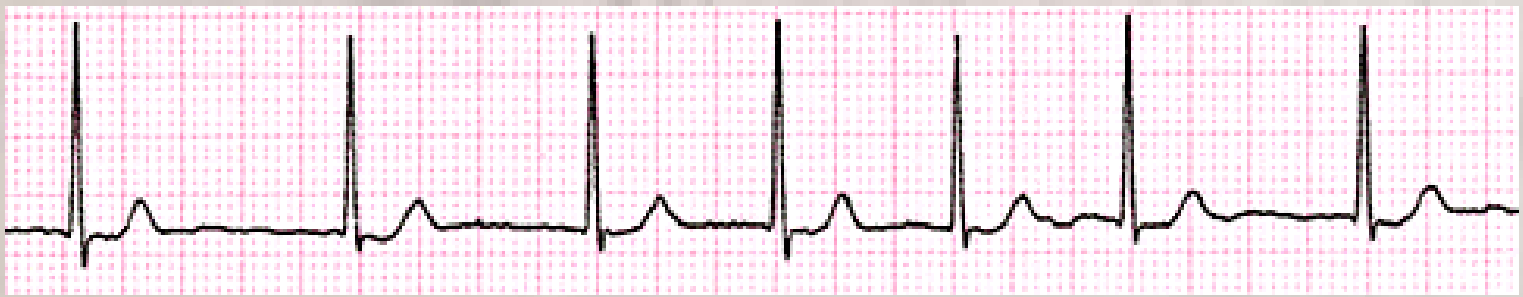
P-R: N/A

QRS: narrow complex

S-T: normal

T: normal

Q-T: normal



Abnormalities:
atrial flutter

Rhythm: Regular / Irregular

Rate: A: 220 – 430; V: <300 (2:1, 3:1 or sometimes 4:1)

P: Saw toothed appearance

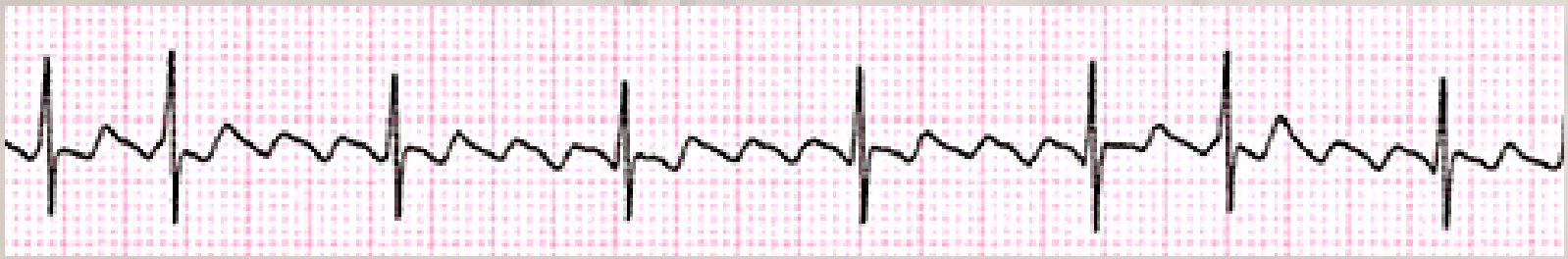
P-R: N/A

QRS: narrow complex

S-T: normal

T: normal

Q-T: normal



Abnormalities:
supraventricular tachycardia (SVT)

Rhythm: Regular

Rate: >100

P: not visible

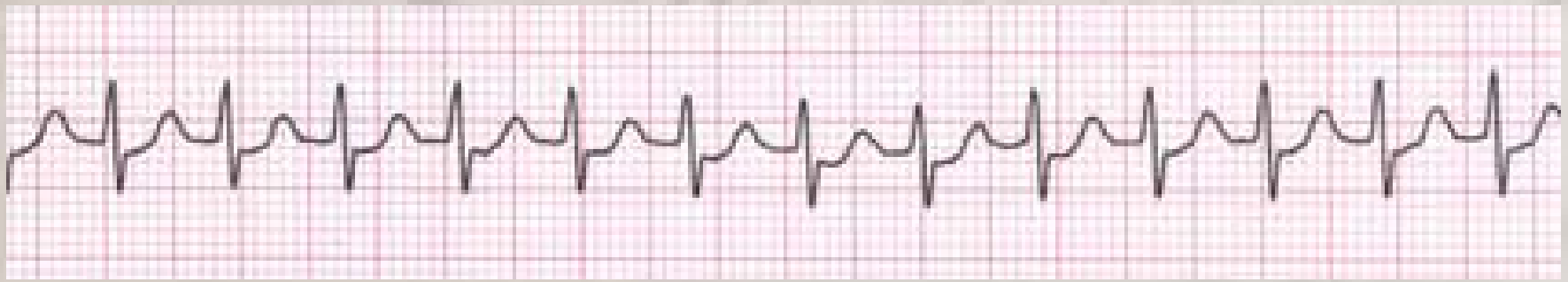
P-R: not defined

QRS: narrow complex

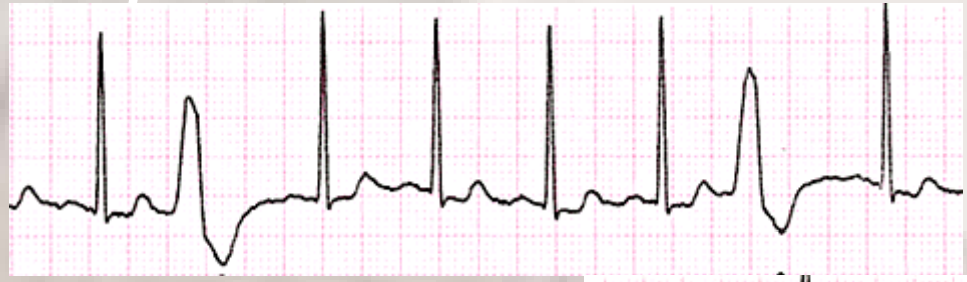
S-T: depression (sometimes)

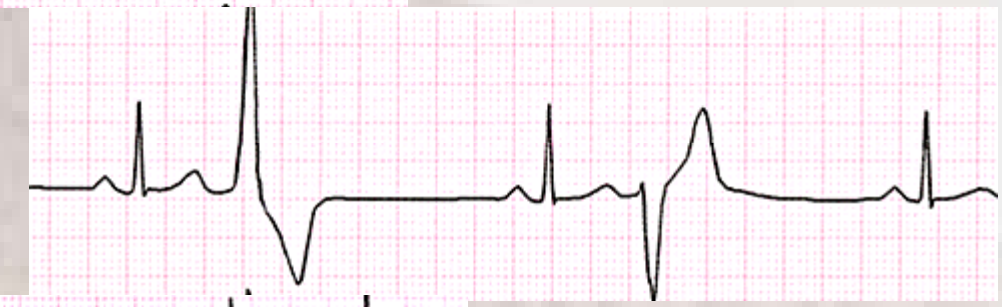
T: normal

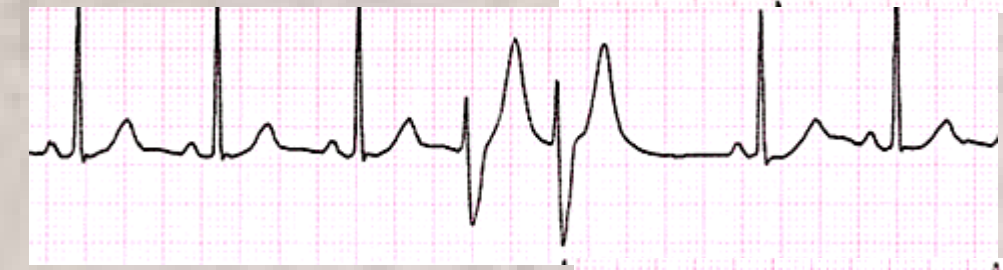
Q-T: prolonged (sometimes)

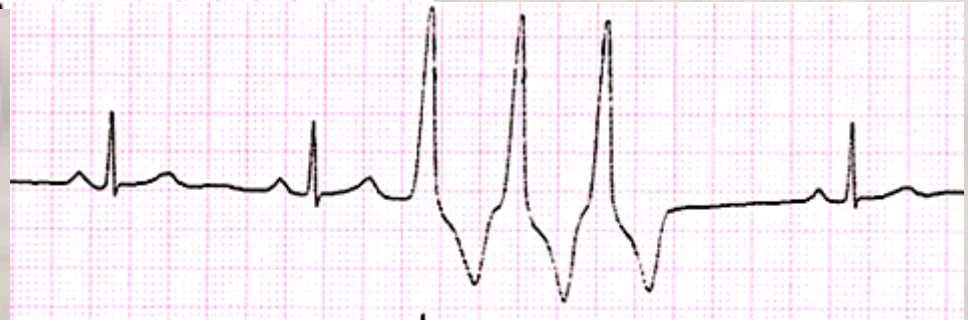


Abnormalities:
premature ventricular complexes

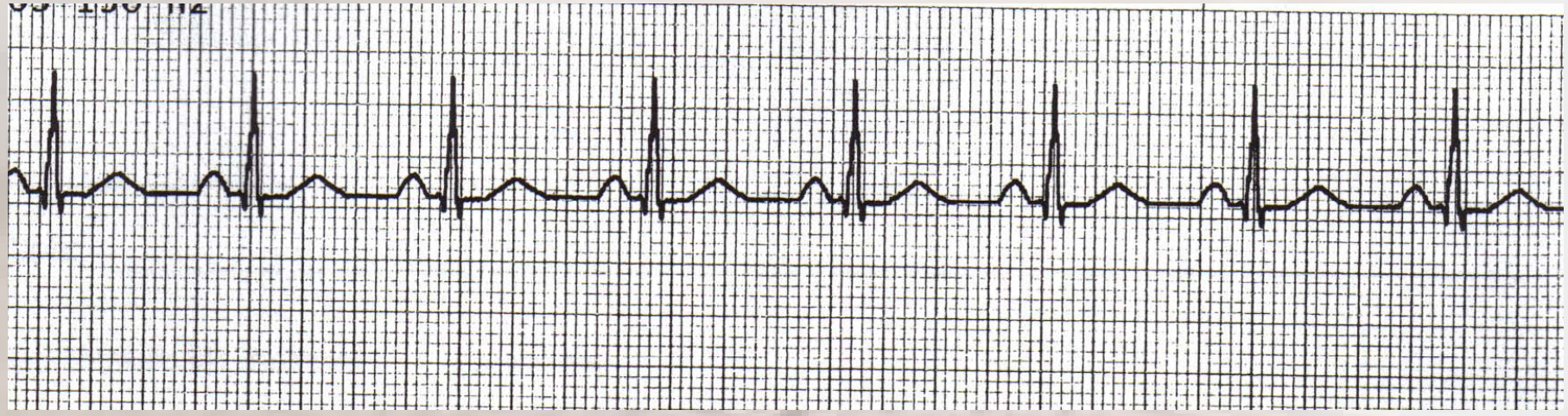


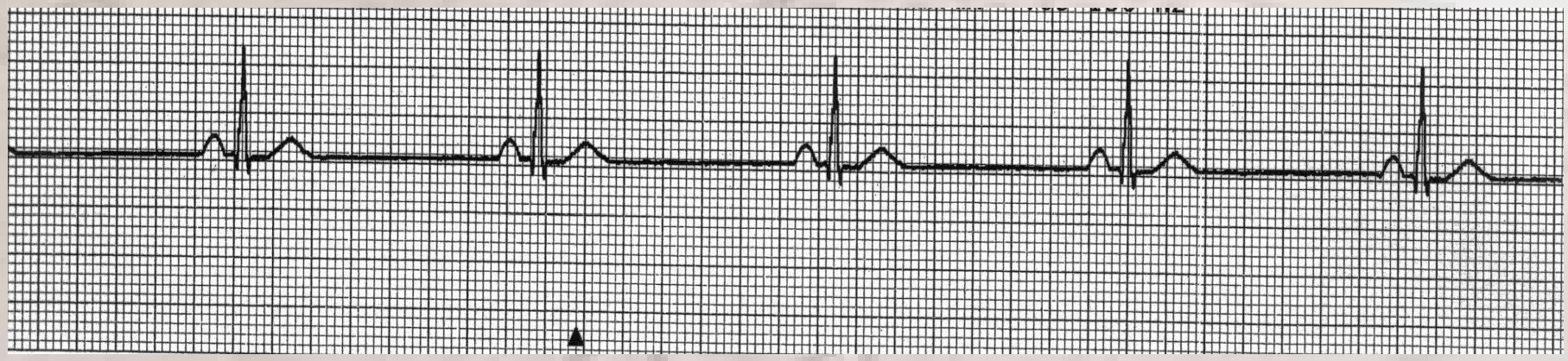




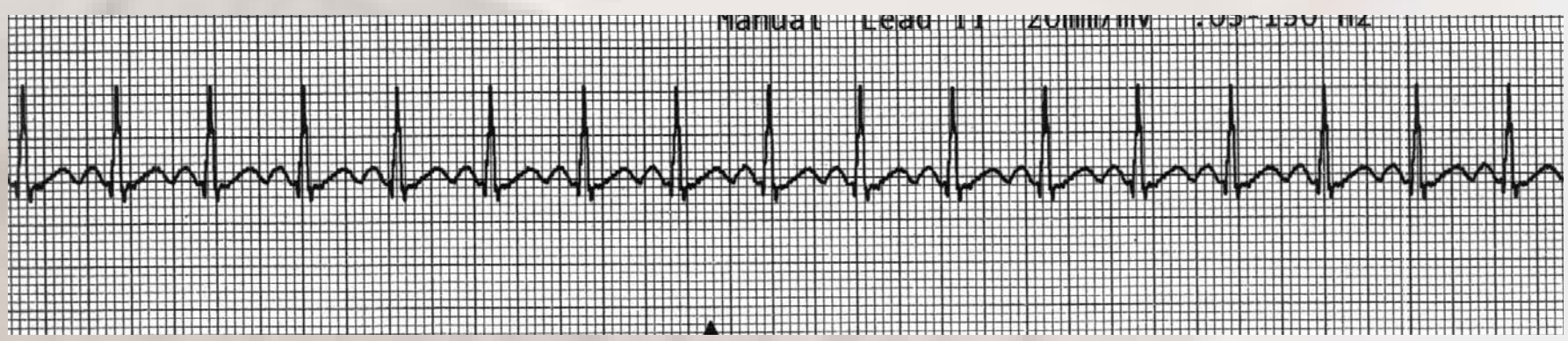


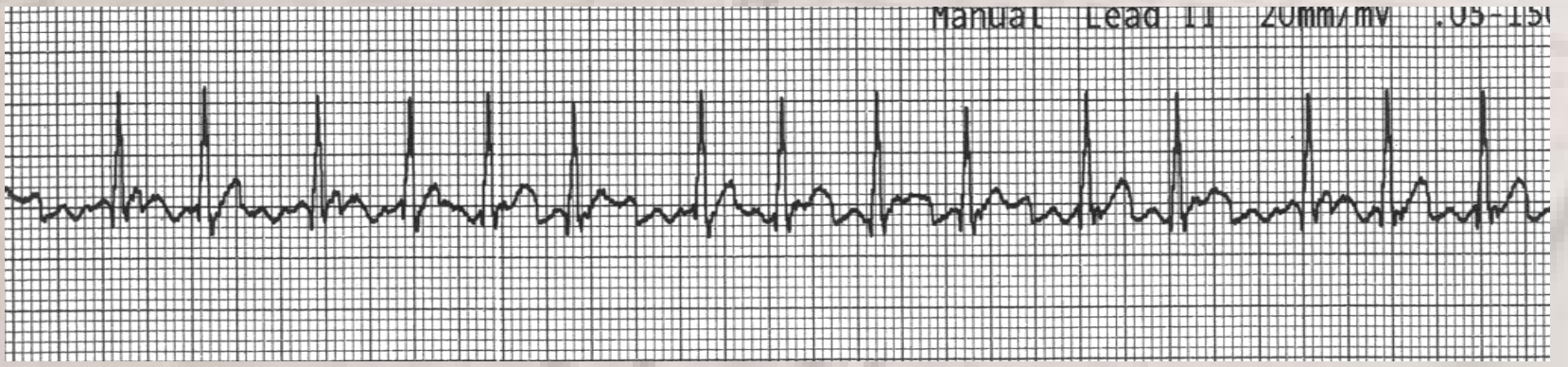
Examples

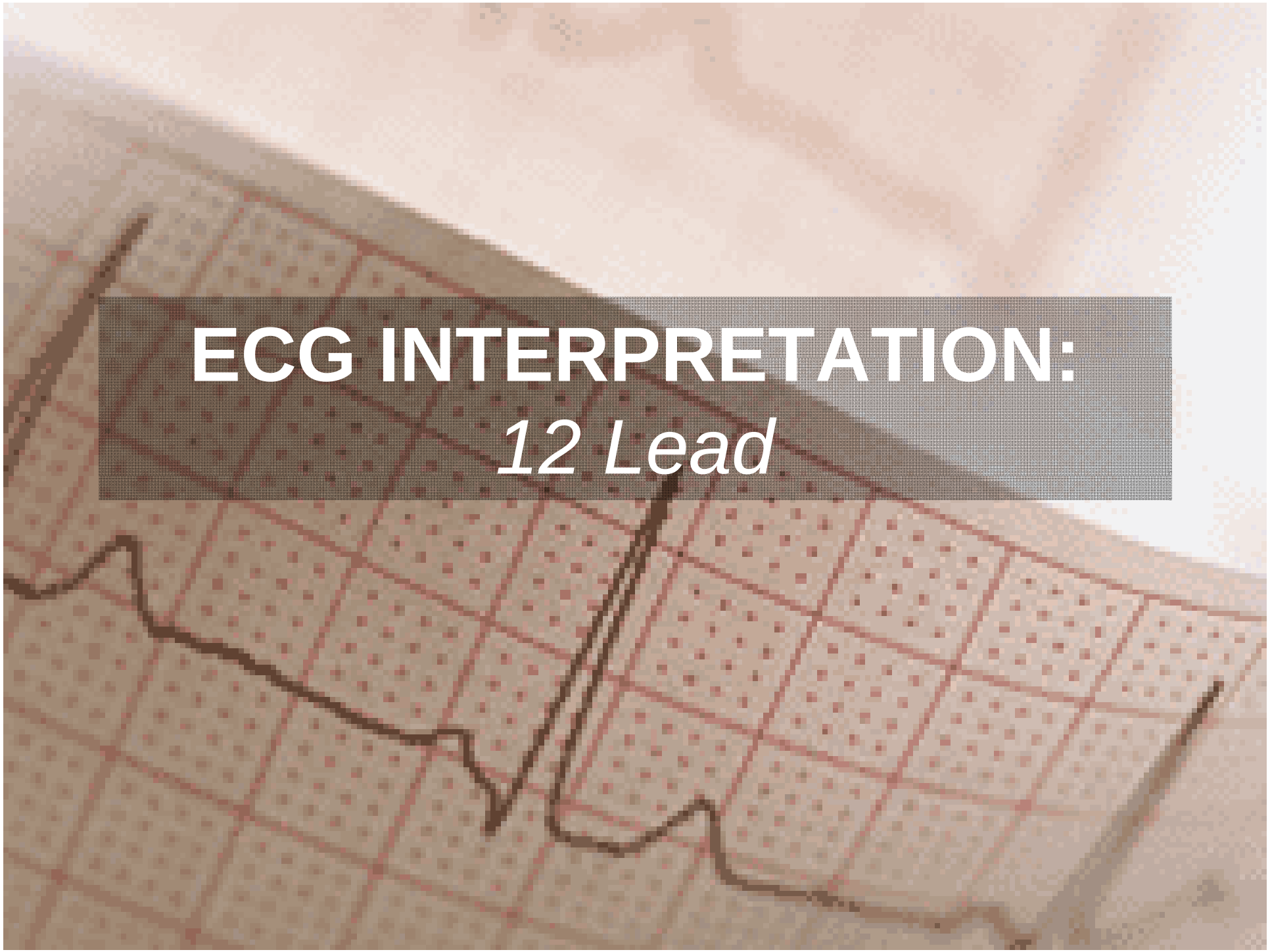




Examples






ECG INTERPRETATION:
12 Lead

Overview

- Lead Placement
- Axis
- Common abnormalities in Critical Care
  - Heart block
  - Bundle branch blocks
  - Life threatening arrhythmias

Lead Placement

V1 = 4th ICS right sternum

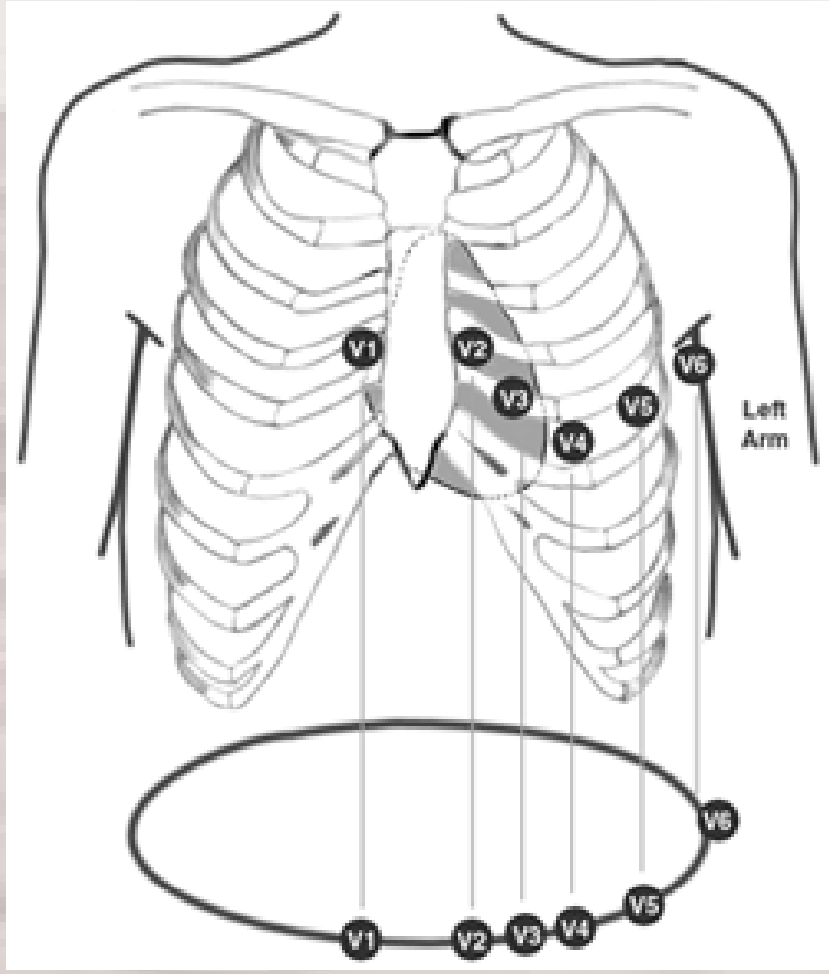
V2 = 4th ICS left sternum

V3 = midway between V2 and V4

V4 = 5th ICS midclavicular

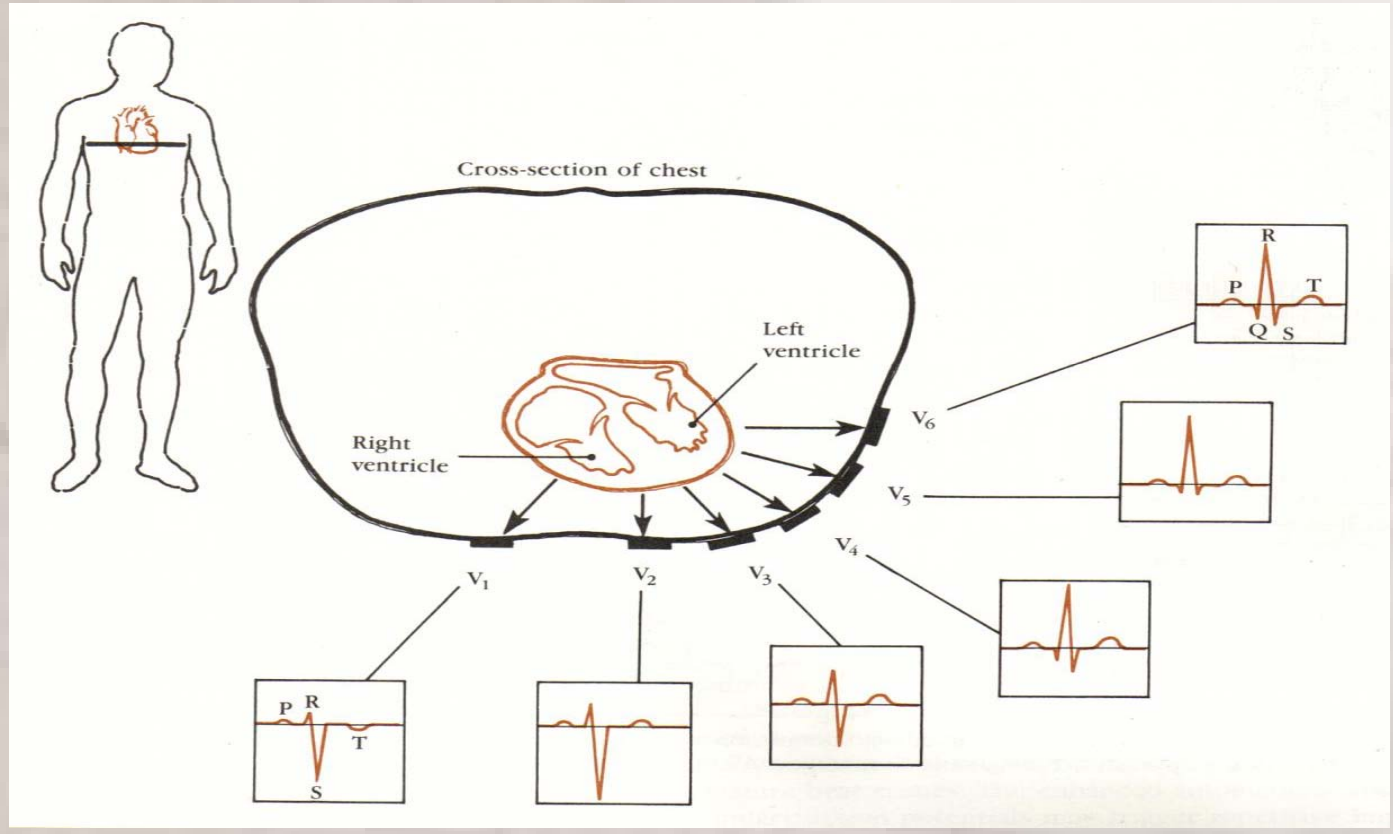
V5 = between V4 and V6 anterior auxiliary line

V6 = midauxillary line lateral to V4 and V5

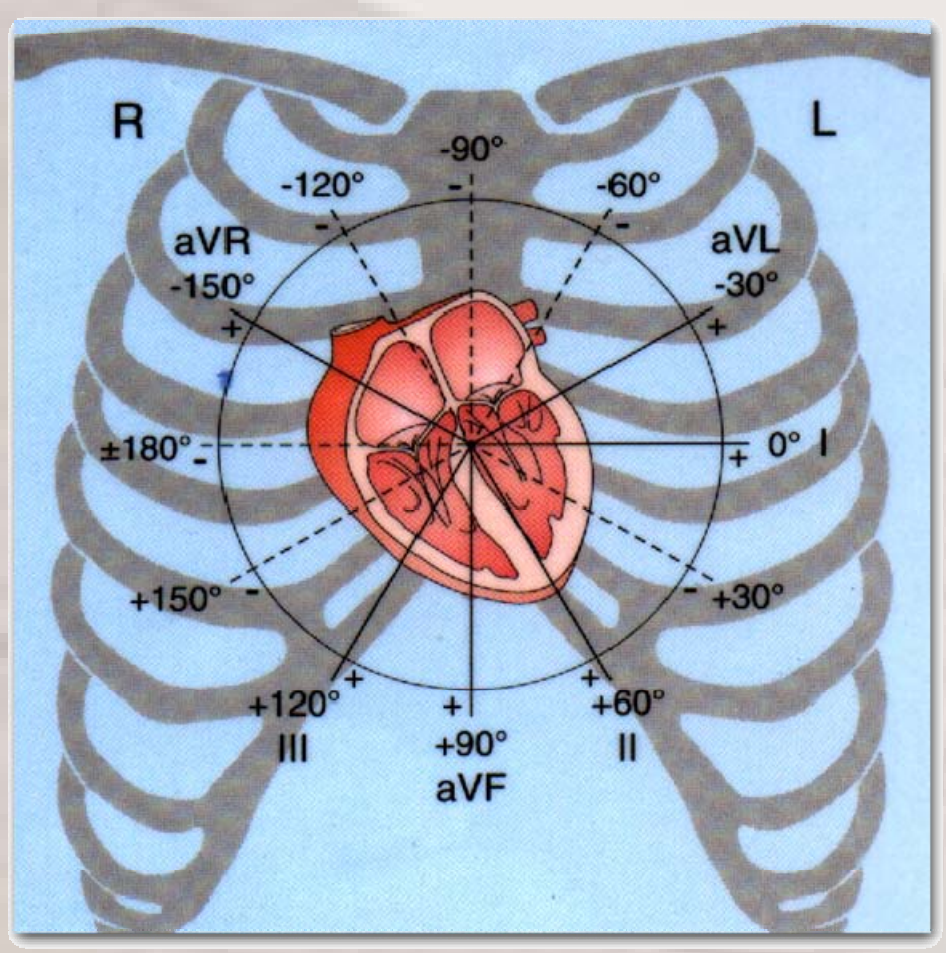


Lead Placement

- Electrical activity towards = ↑
- Electrical activity away = ↓



Lead Placement

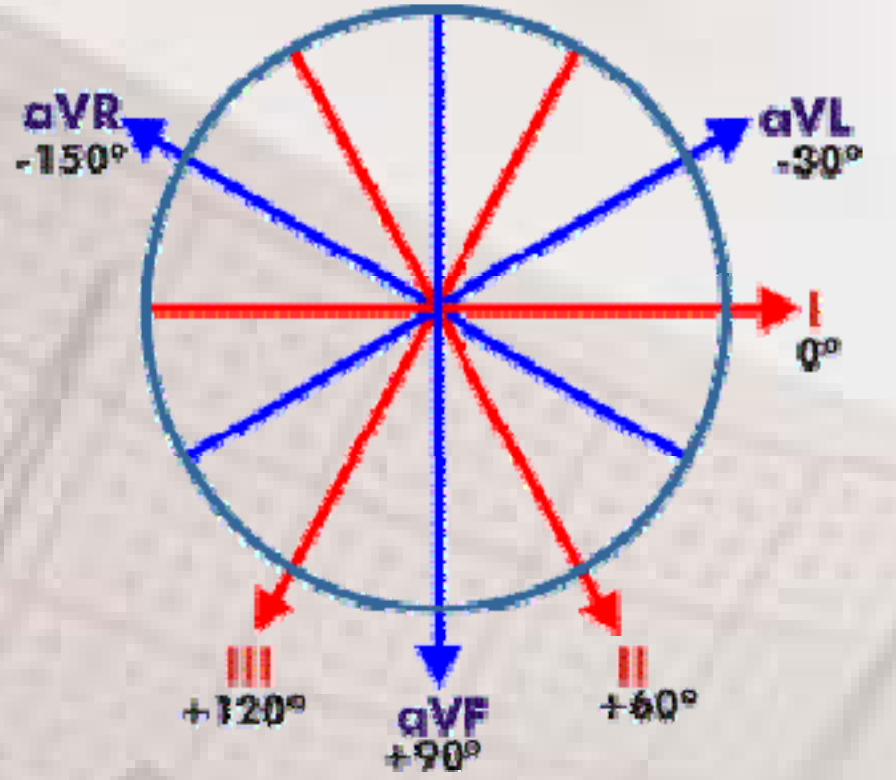


Axis

- The direction of an ECG waveform in the frontal plane measured in degrees
- Represents the flow of the majority of electrical activity
- Normally the QRS complex is measured

Axis

- Each lead has its own axis



Lead Placement

Standard Leads (bipolar)

- I - lateral wall
- II - inferior wall
- III - inferior wall

Augmented leads (unipolar)

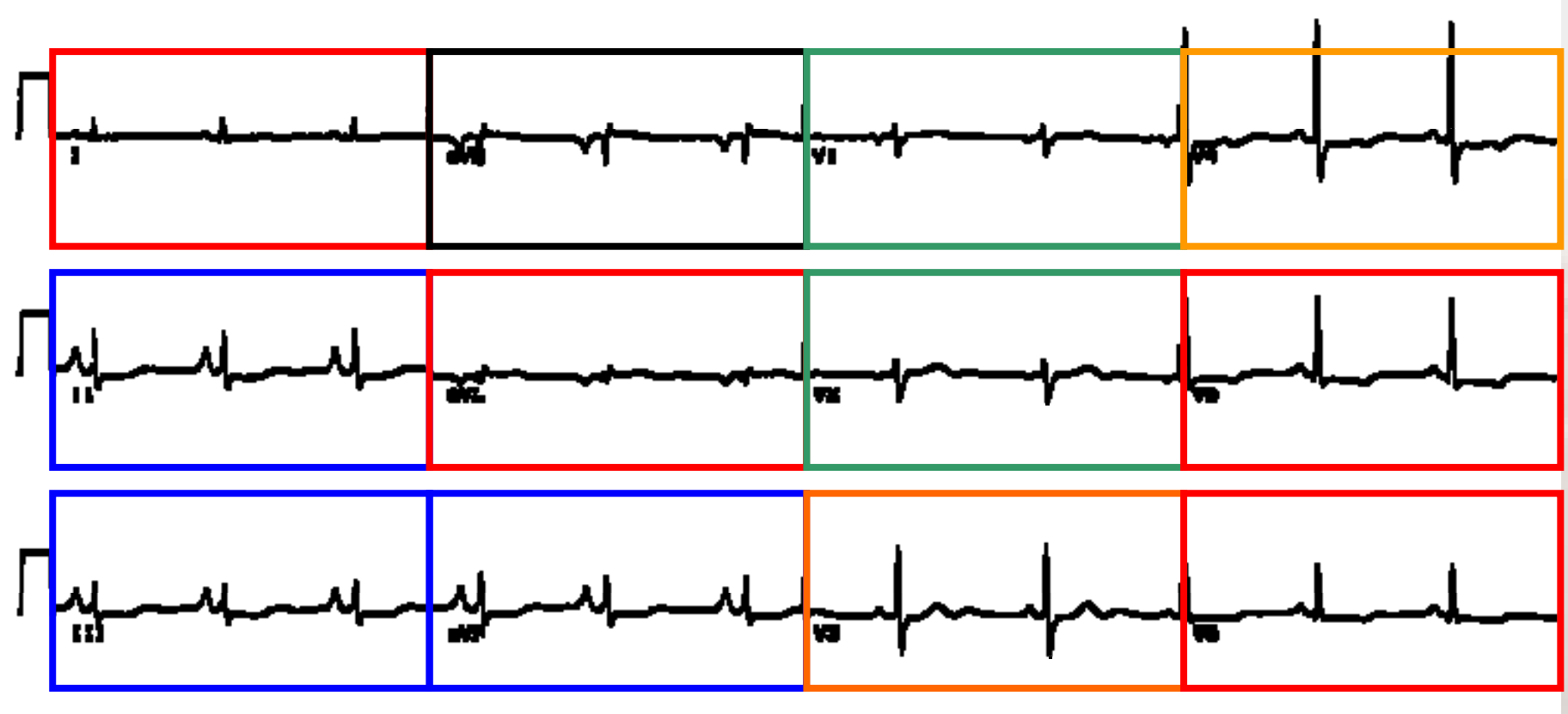
- aVR - no mans land
- aVL - lateral wall
- aVF - inferior wall

Chest Leads (unipolar)

- V1 - septal wall
- V2 - septal wall
- V3 - anterior wall
- V4 - anterior wall
- V5 - lateral wall
- V6 - lateral wall

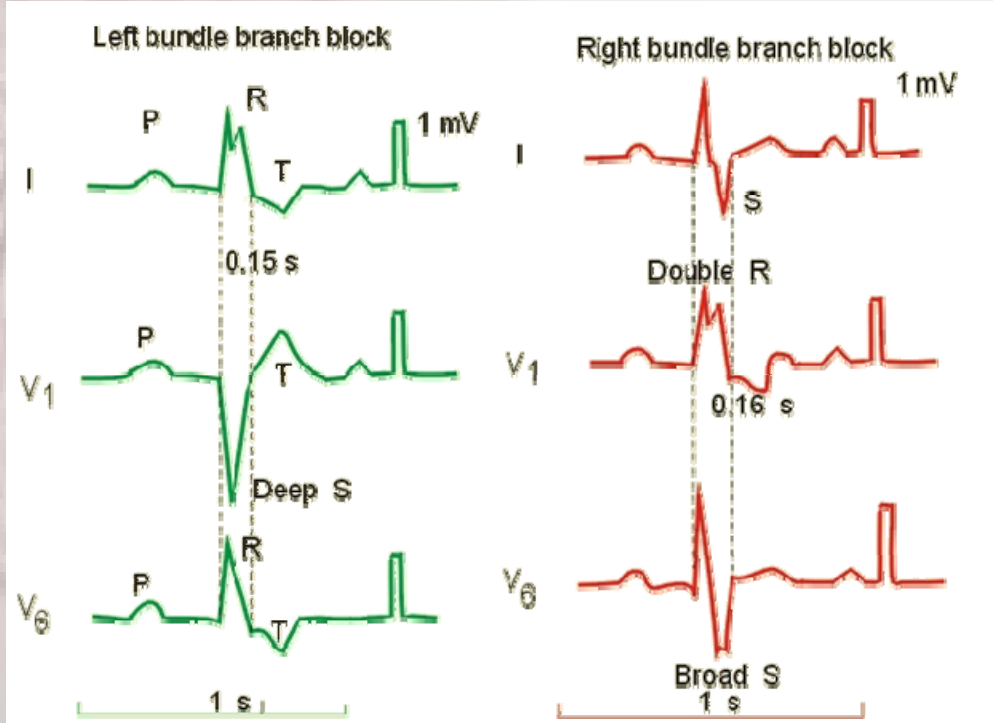
Lead Placement

No-mans land, inferior, lateral, anterior, septal,



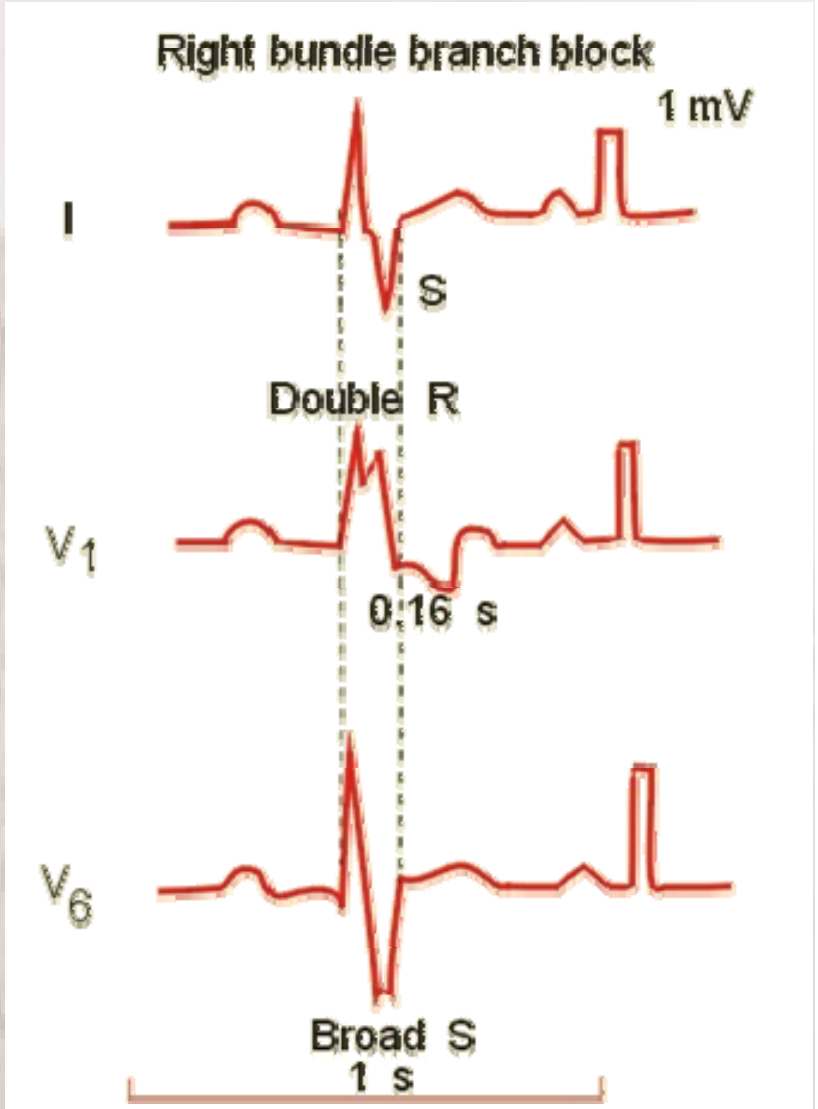
Abnormalities:
bundle branch blocks

- QRS widened, greater than 0.12 secs
- Change in axis
- Difficult to interpret ECG
- Right or Left
- Normal P wave
- Followed by a T wave



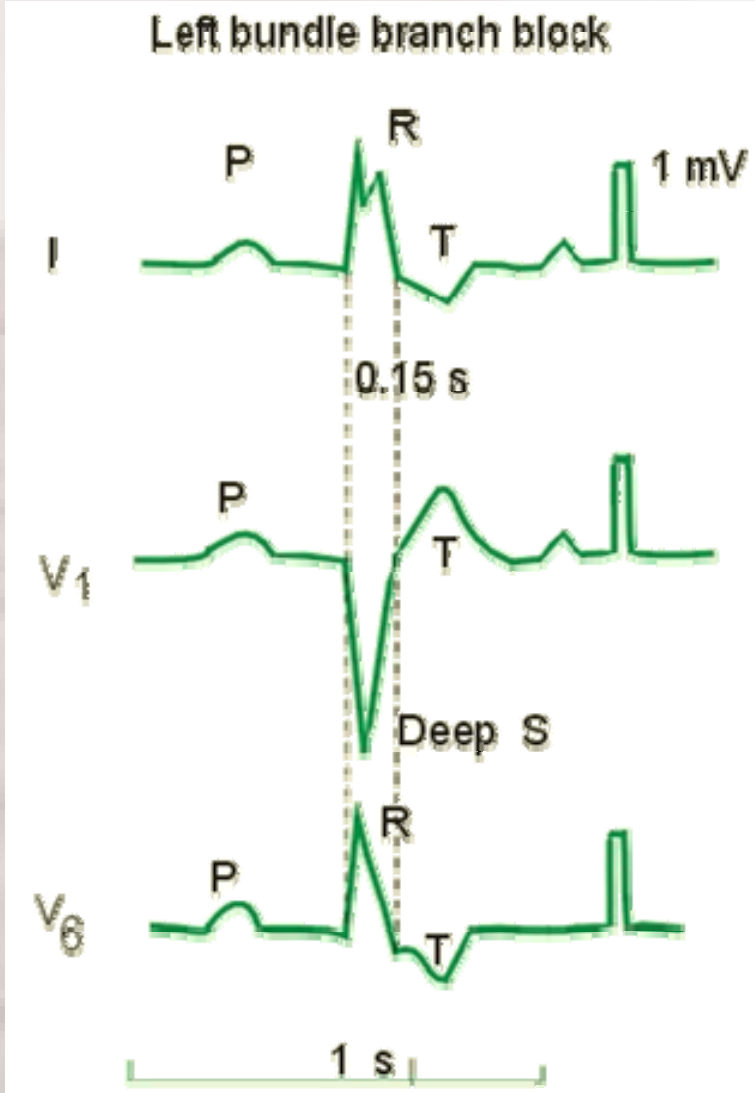
Abnormalities:
right bundle branch blocks

- Indicates conduction problems in the right side of the heart
- May be normal in healthy people
- R wave in V1, ie two R waves in V1
- Q wave in V6
- Lead V1 cats ears



Abnormalities:
left bundle branch blocks

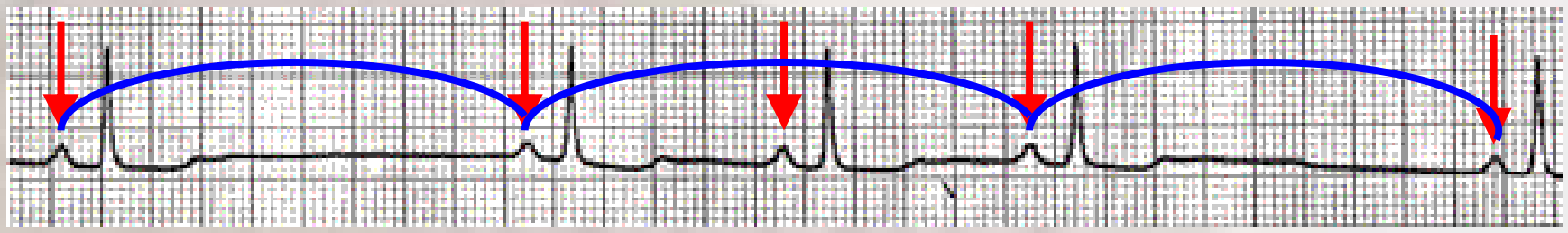
- Always indicates heart disease, usually of the left side of the heart
- Hard to interpret an ECG with LBBB
- Lead V1 Q wave and an S wave
- Lead V6 an R wave followed by another R wave
- Lead V6 Rabbit ears



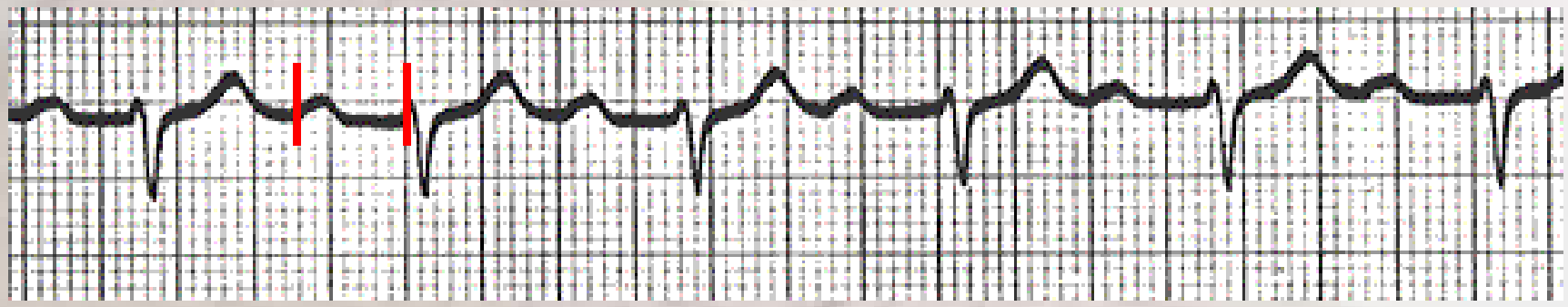
Abnormalities:
heart block

- SA block (exit block)
- 1st degree AV block
- 2nd degree AV block
  - Wenckeback (type I)
  - Mobitz (type II)
- 3rd degree AV block

Abnormalities:
heart block – SA block

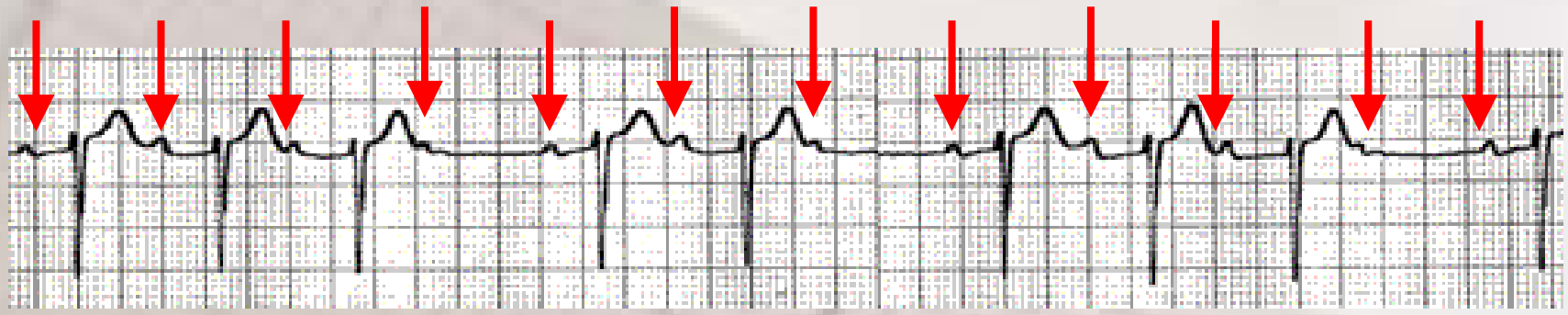


Abnormalities:
heart block – 1st degree AV

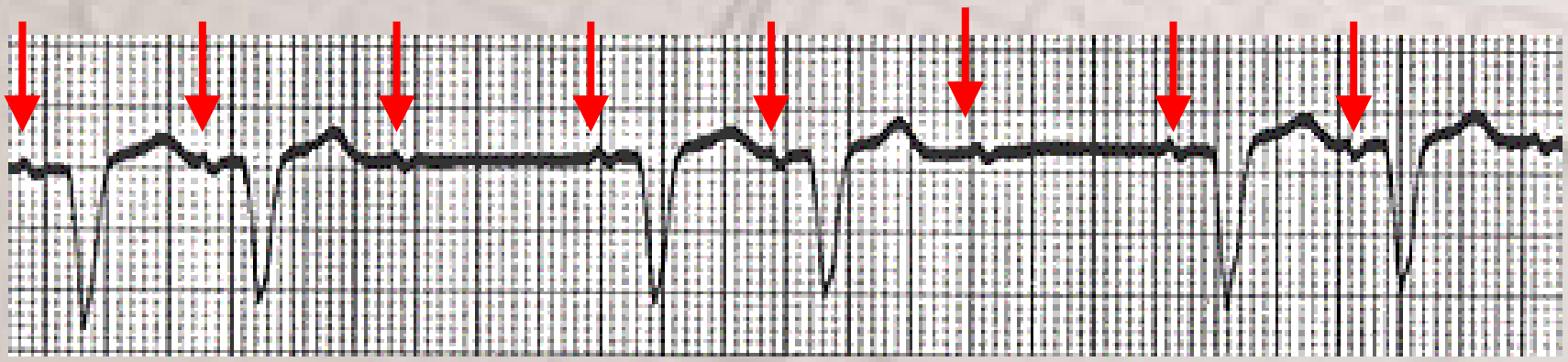


Abnormalities:
heart block – 2nd degree AV

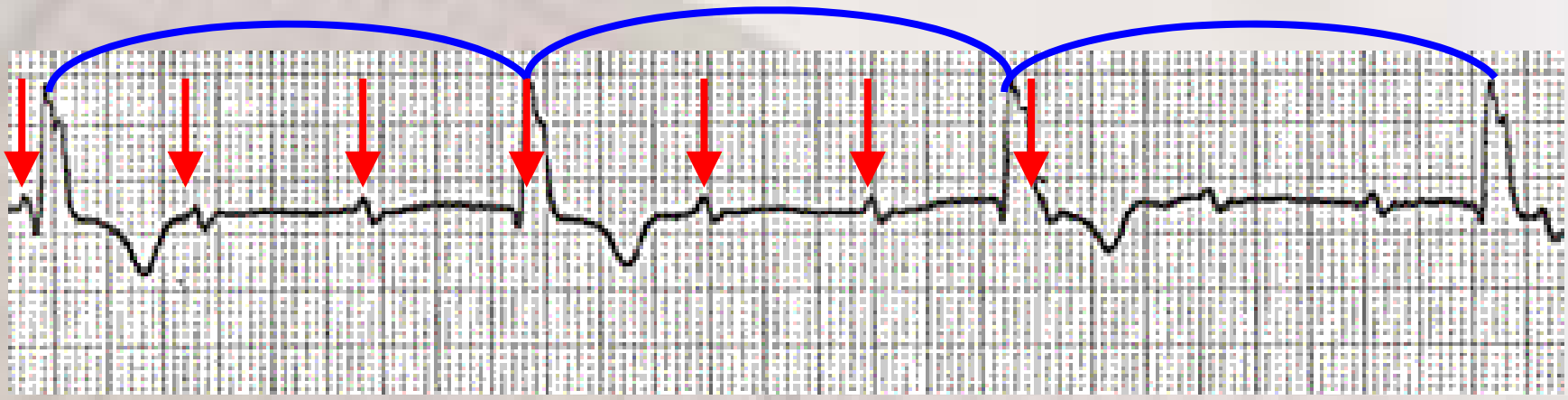
Wenkeback



Mobitz



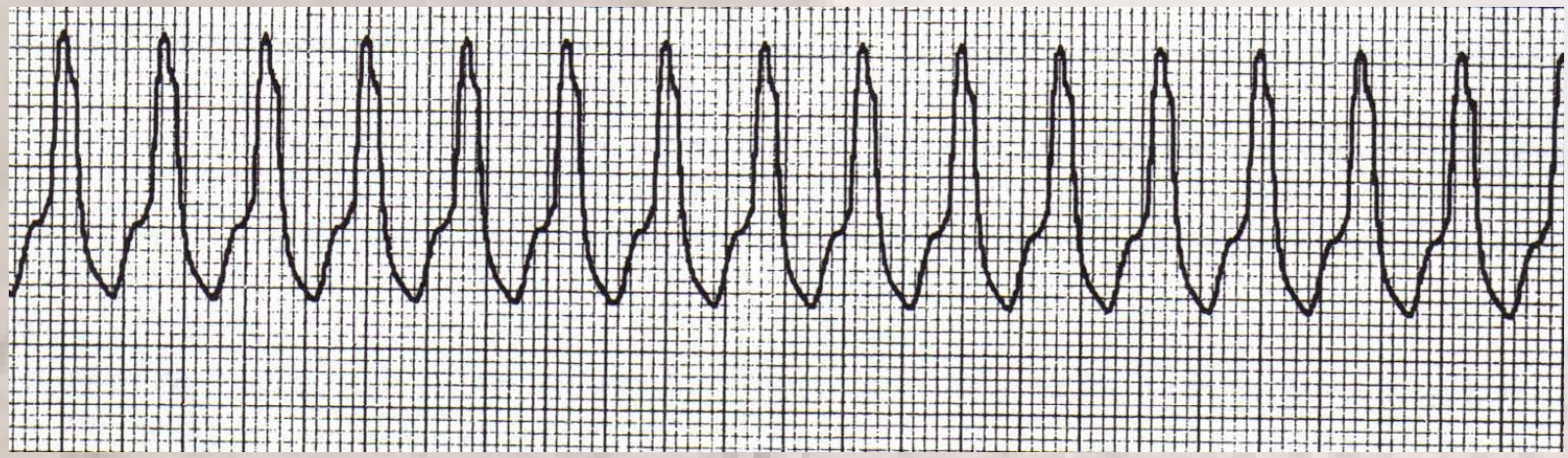
Abnormalities:
heart block – 3rd degree AV



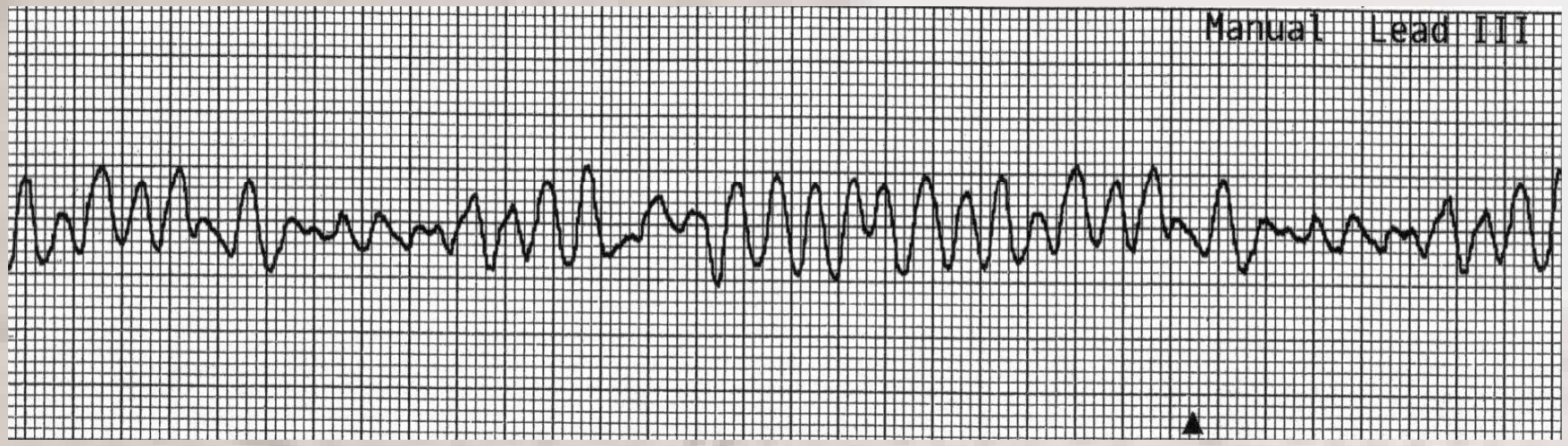
Abnormalities:
life threatening arrhythmias

- Ventricular Tachycardia
- Ventricular Fibrillation
- Asystole

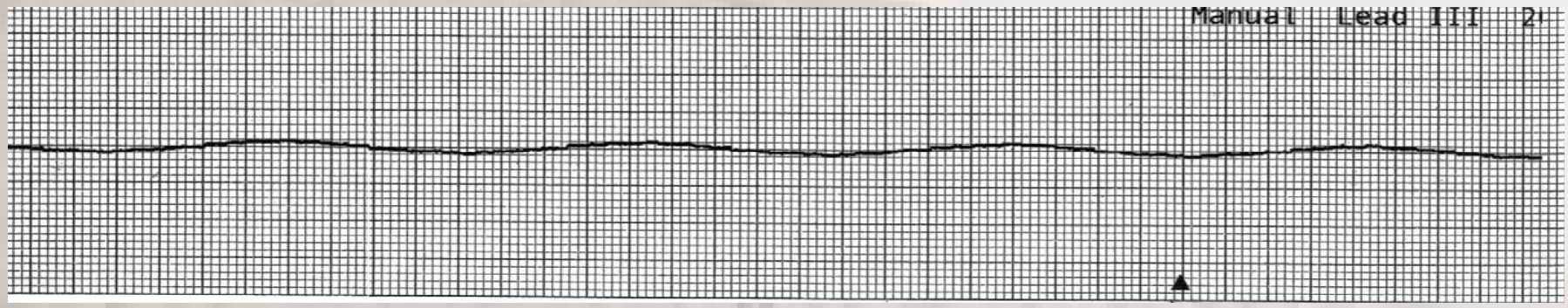
Abnormalities:
life threatening arrhythmias - VT



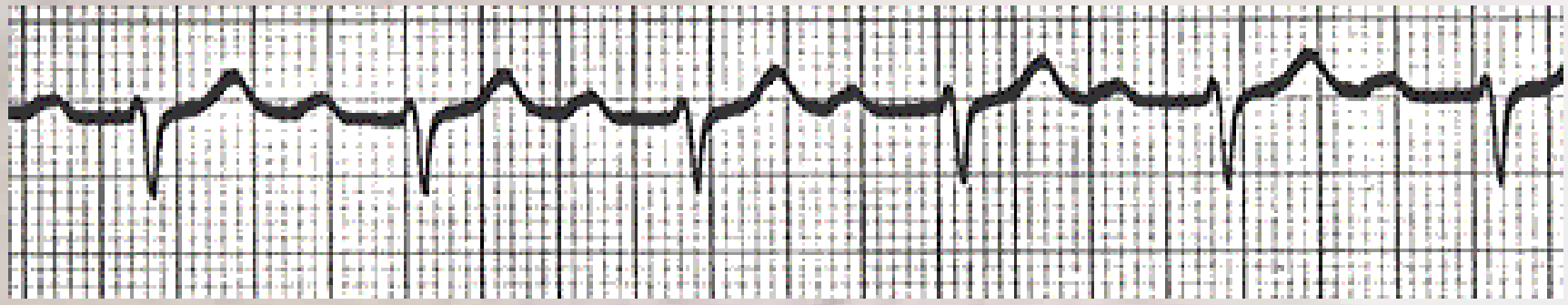
Abnormalities:
life threatening arrhythmias - VF

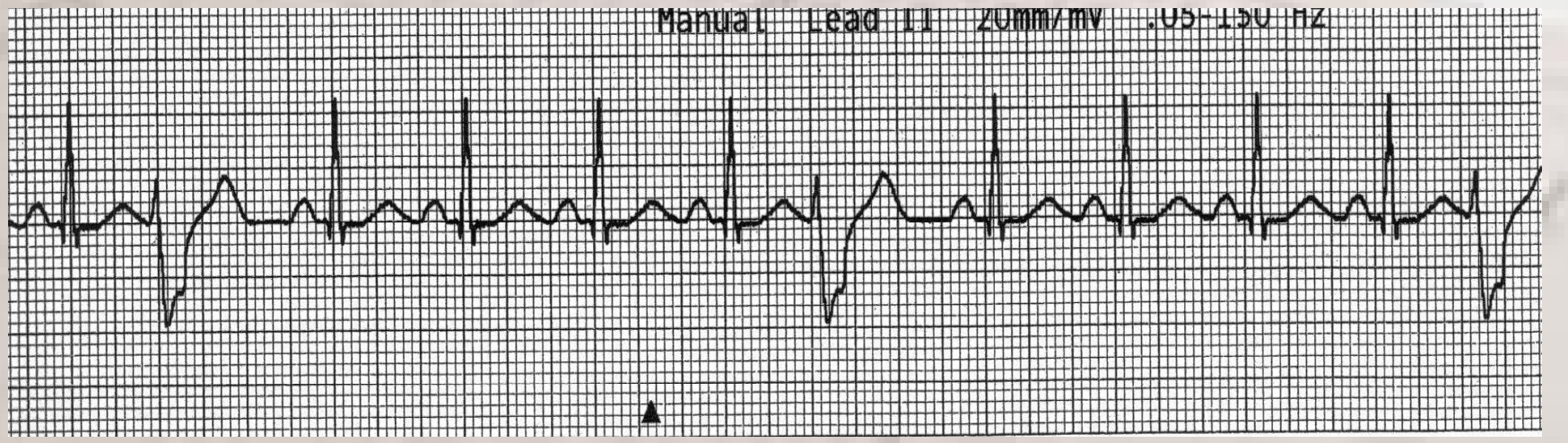


Abnormalities:
life threatening arrhythmias – Asystole

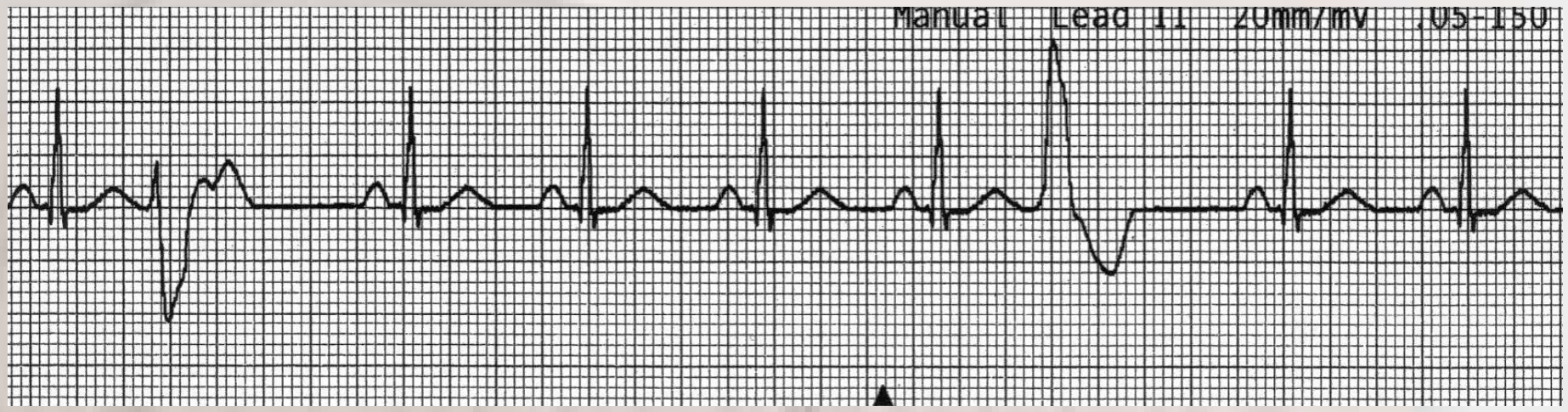


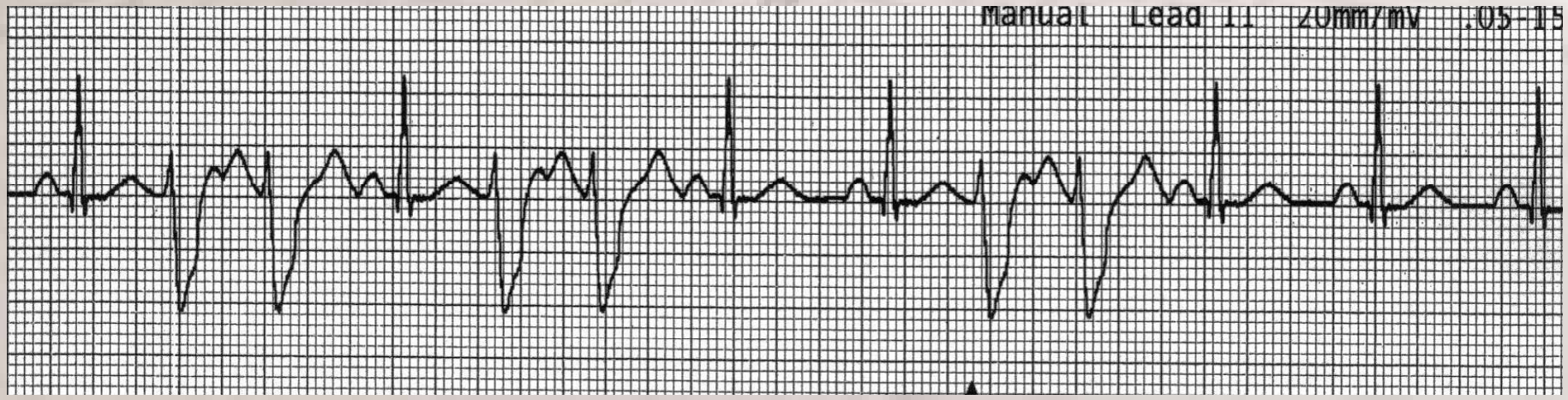
Examples





Examples





Mechanoreception

Introduction

Hair cells : the basic mechanosensory unit

Hair cell structure

Inner ear and accessory organ structures

Vestibule

Otolith organs

Weberian ossicles

Lateral line

Lateral line structure

Receptor organs

Acoustic communication: sound production and reception

Sound production mechanisms

Locomotion and posture

Introduction

A mechanoreceptor is a sensory receptor that responds to mechanical pressure or distortion.

In fishes mechanoreception concerns the inner ear and the lateral line system.

Hair cells are the UNIVERSAL MECHANOSENSORY TRANSDUCERS in both the lateral line and hearing systems.

The INNER EAR is responsible for fish EQUILIBRIUM, BALANCE and HEARING

LATERAL LINE SYSTEM detects DISTURBANCES in the water.

Hair cell structure

EACH HAIR CELL CONSISTS OF TWO TYPES OF "HAIRS" OR RECEPTOR PROCESSES:

Many microvillar processes called STEREOCILIA.

One true cilium called the KINOCILLIUM.

COLLECTIVELY, the cluster is called a CILIARY BUNDLE.

The NUMBER OF STEREOCILIA PER BUNDLE IS VARIABLE, and ranges from a 10s of stereocilia to more than a 100.

The STEREOCILIA PROJECT into a GELATINOUS CUPULA ON THE APICAL (exposed) SURFACE of the cell.

The cilium and villi are ARRANGED IN A STEPWISE GRADATION - the longest hair is the kinocillium, and next to it, the stereocilia are arranged in order of decreasing length.

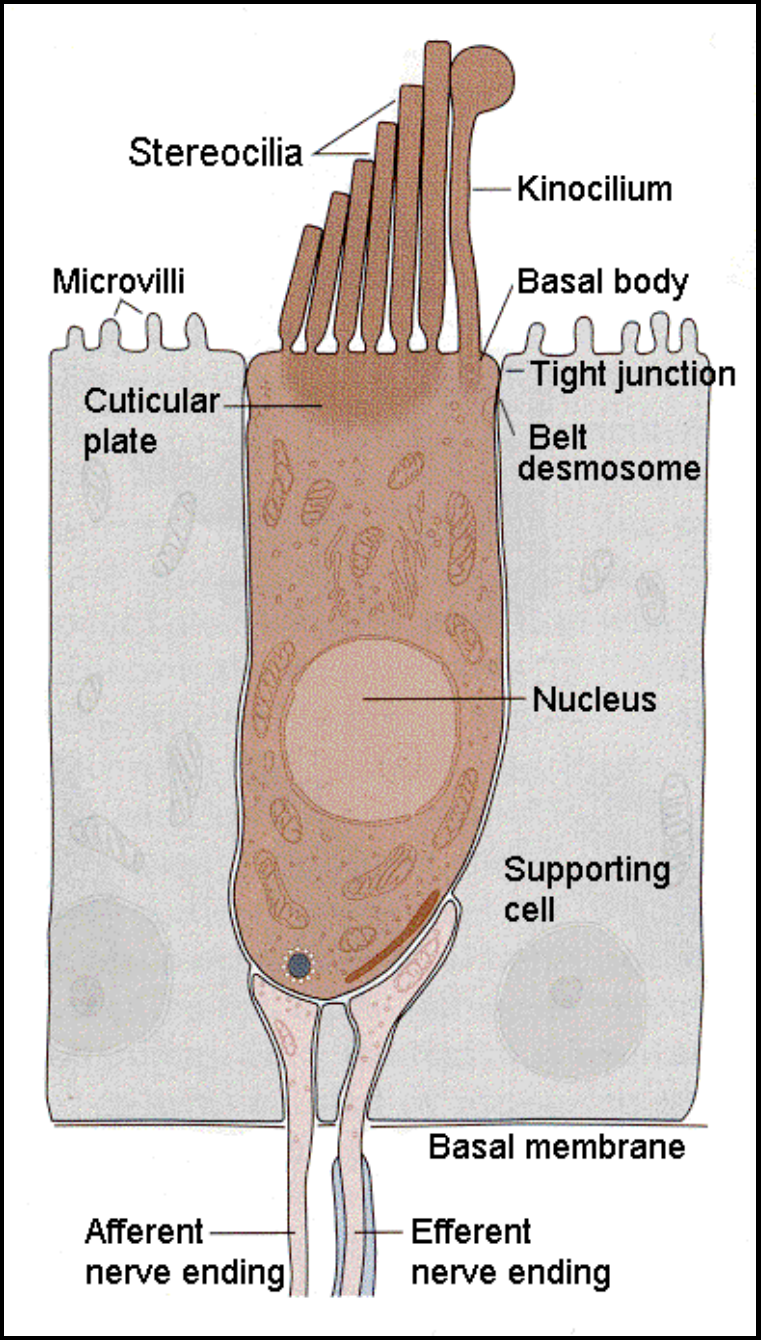
These cells SYNAPSE WITH GANGLION CELLS.

They have DIRECTIONAL PROPERTIES - response to a stimulus depends on the direction in which the hairs are bent.

So, if the displacement causes the stereocilia to bend towards the kinocilium, the cell becomes DEPOLARIZED = EXCITATION.

If the stereocilia bend in the opposite direction, the cell becomes HYPERPOLARIZED = INHIBITION of the cell.

If the hair bundles are bent at a 90^{o} angle to the axis of the kinocilium and stereocilia there will be no response.



The sensory hair cells are GROUPED TOGETHER TO FORM NEUROMAST ORGANS. These are situated on:

1. the body surface,
2. in the LATERAL LINE and HEAD. Here they are buried in pits, canals and grooves,
3. in the inner organs of the ear and on the pouches of otolith organs where they form LARGE FIELDS CALLED THE CRISTA AMPULLARIS

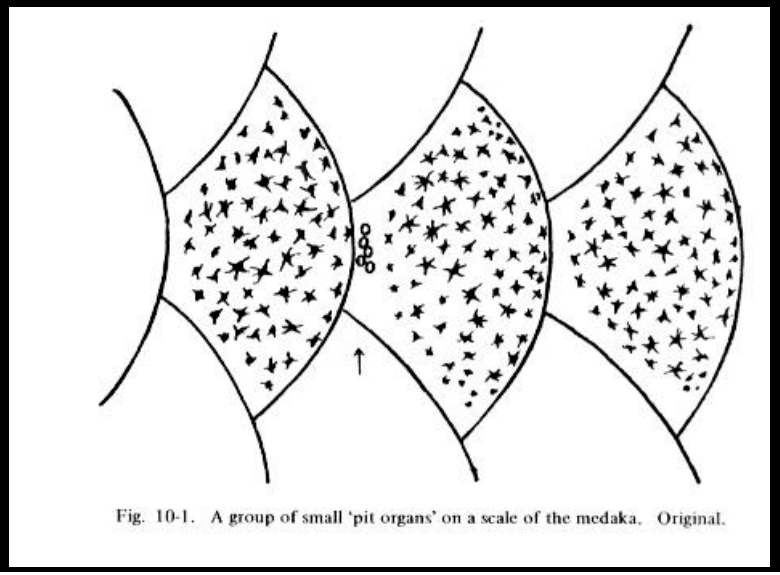


Fig. 10-1. A group of small 'pit organs' on a scale of the medaka. Original.

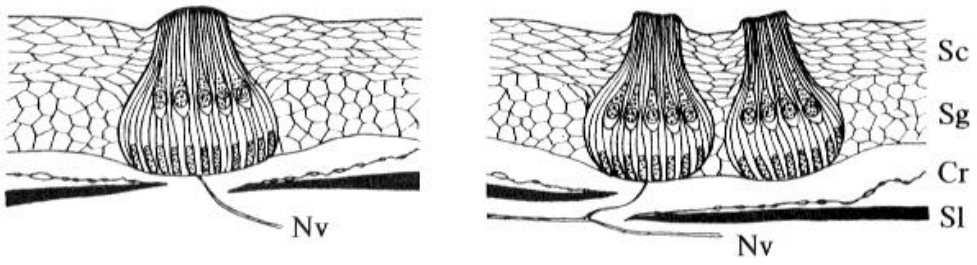


Fig. 10-3. Sections of 'pit organ' in head (left) and trunk (right) in the medaka. Sc, stratum corneum; Sg, stratum germinativum of epidermis; Cr, corium; Sl, scale; Nv, nerve. Original.

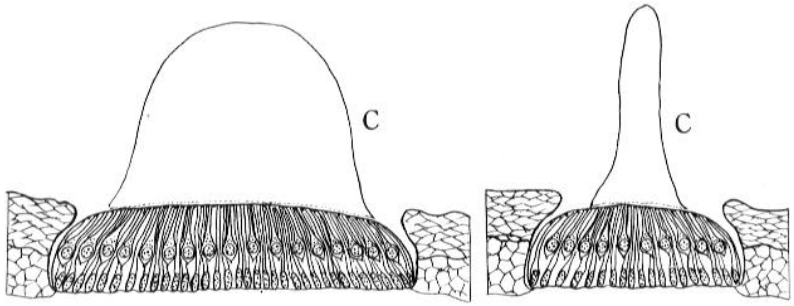


Fig. 10-4. Longitudinal (left) and transverse (right) sections of a groove organ in the head of the medaka. c, cupula. Original.

Inner ear and accessory organ structures

The INNER EAR IS MADE UP OF 3 SEMI-CIRCULAR CANALS (the vestibule) and 3 otolith organs.

The otoliths are found in the UTRICLE, SACCULE AND LAGENA.

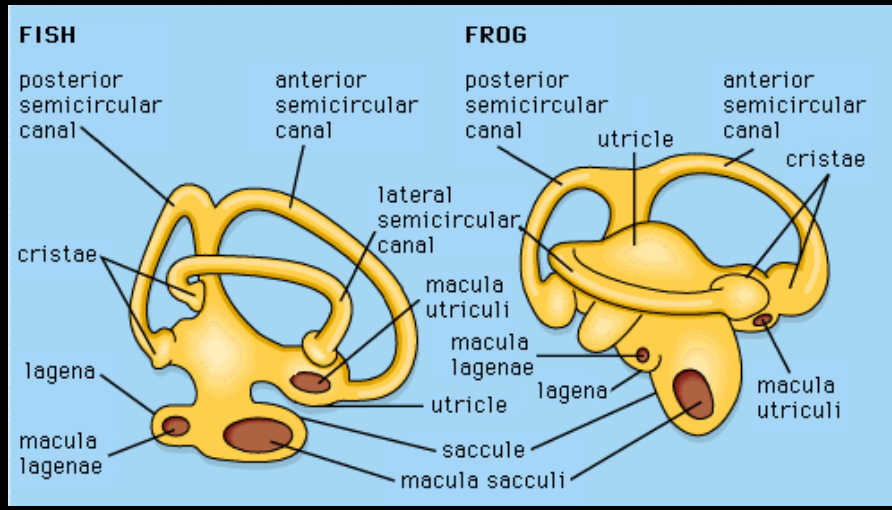
The inner ear is divided into the PARS SUPERIOR and the PARS INFERIOR.

The PARS SUPERIOR IS MADE UP OF THE SEMICIRCULAR CANALS AND THE UTRICLE in bony and cartilaginous fishes. The utricle contains the lapillus (=diminutive of stone)

The PARS INFERIOR IS MADE UP OF THE SACCULE AND THE LAGENA.

Many fishes have an additional organ, the MACULA NEGLECTA, a sensory structure located in Teleostomi in the utriculus of the inner ear near the opening of the ampulla of the posterior vertical semicircular canal, in selachians within a duct (posterior canal duct) through which the posterior vertical semicircular canal connects with the sacculus, while in the batoids it lies in the wall of the sacculus adjacent to the opening of the duct. It may have a neuromast associated with its sensory tissue. This structure has been demonstrated to be a sensitive vibration receptor in Raja. Also called crista neglecta, crista quarta, or papilla neglecta.

All these organs are INNERVATED BY BRANCHES OF CRANIAL NERVES.

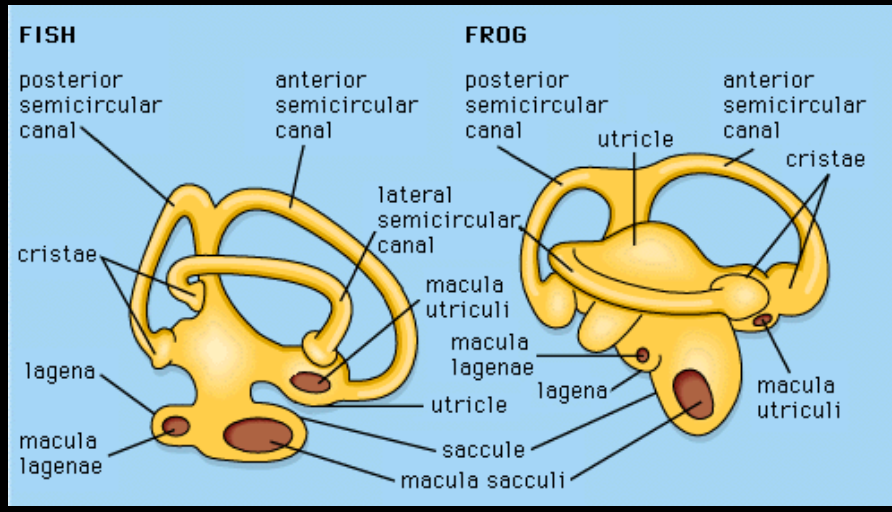


Vestibule

The three semi-circular canal ducts are called the ANTERIOR, POSTERIOR AND HORIZONTAL (or lateral) canals. They all extend from the utricle, and are FILLED WITH ENDOLYMPH. The anterior and posterior canals share a vertical section, called the crus commune.

At the BASE OF EACH CANAL, is a DOME-LIKE ENLARGEMENT CALLED THE AMPULLAE.

WITHIN EACH AMPULLA, is the CRISTA AMPULLARIS. The crista ampullaris forms a high, narrow ridge lying transversely across the ducts, and are covered with sensory hair cells.



Otolith organs

The THREE OTOLITH ORGANS (utricle, saccule and lagena) are FLUID-FILLED POUCHES each CONTAINING AN OTOLITH called the LAPILLUS, SAGITTA AND ASTERICUS.

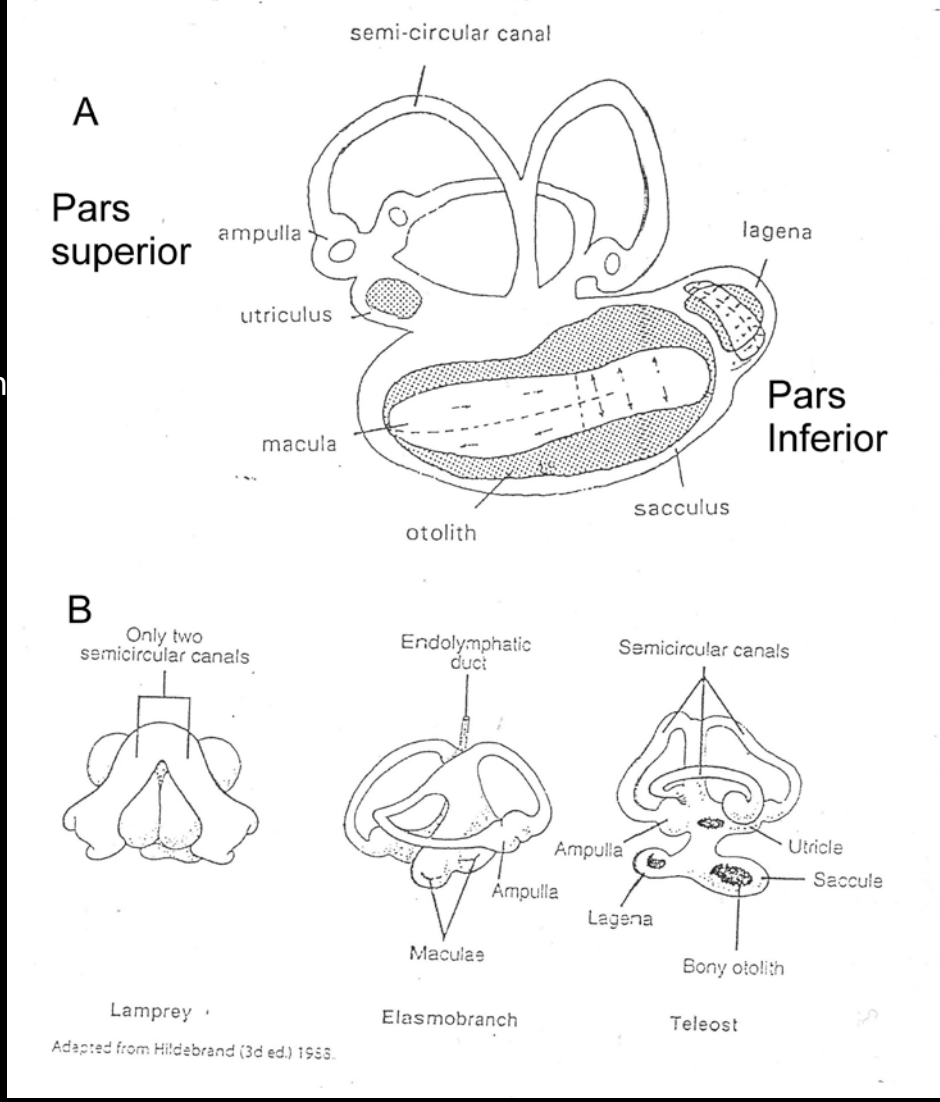
Comprised of calcium carbonate called ARAGONITE and protein called OTOLIN. Both are laid down periodically and under magnification look like a bar-code. Large seasonal differences gives the appearance of banding.

These often have defined elaborate grooves and protrusions that arc.

In ELASMOBRANCHS, the calcifications are more diffuse, forming the OTOCONIA.

Each OTOLITH CHAMBER IS LINED with patches of tissue composed of sensory hair cells called the MACULA. The otolith lies close to the sensory epithelium, and are coupled together by a gelatinous sheet or plate called the otolithic membrane.

The MACULA NEGLECTA is another endorgan of the ear, but it is not found in all fishes. The NEGLECTA CAN BE LARGE IN ELASMOBRANCH SPP, but is generally small in bony fishes.



Weberian ossicles

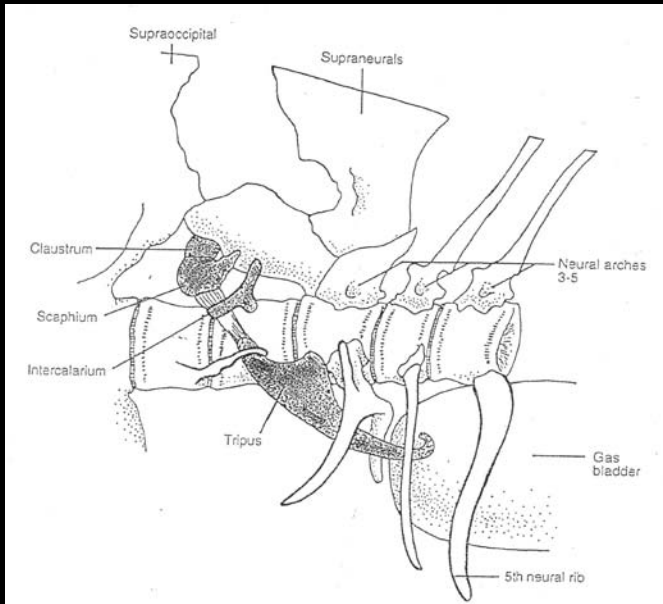
The OSTARIOPHYSIN fish (Characidae, Cyprinidae and Siluriformes) have ACUTE HEARING AND PITCH DISCRIMINATION.

This is due to a SERIES OF SMALL BONES, called the WEBERIAN OSSICLES.

These bones physically CONNECT THE ANTERIOR END OF THE SWIM BLADDER WITH THE FLUID SYSTEM OF THE INNER EAR AT THE MIDLINE, BETWEEN THE SACCULES.

DEFLATION OF THE GAS BLADDER OR DISCONNECTION BETWEEN THE OSSICLES and the bladder causes DECREASED HEARING sensitivity in the fish.

A lateral view of the left side of the anterior portion of the vertebral region of an otophysan fish. The Weberian ossicles transmit sound vibrations from the swim bladder to the inner ear.

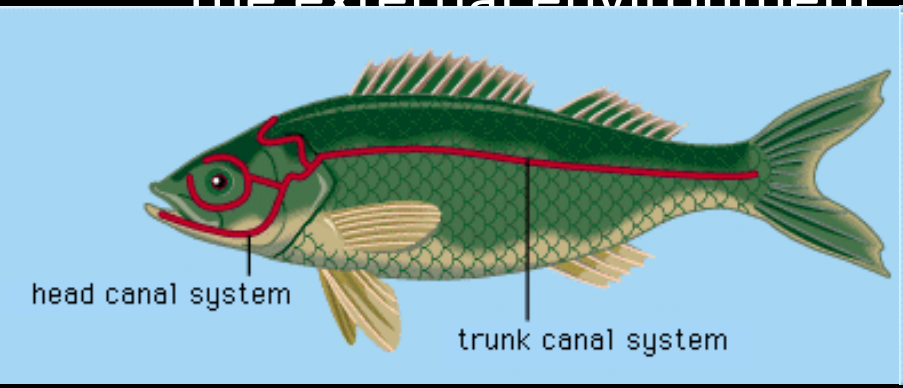


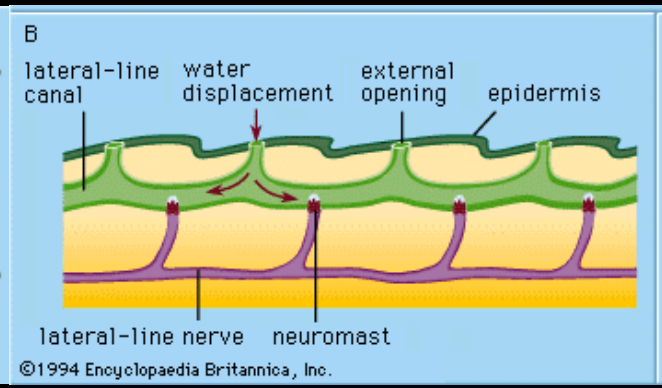
Lateral line system

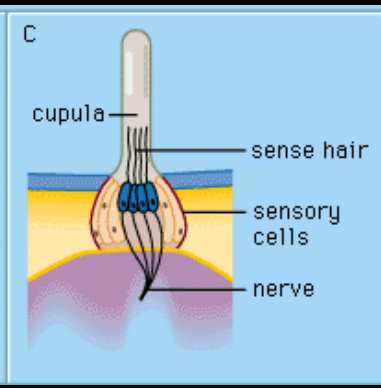
The LATERAL LINE SYSTEM consists of a CANAL SYSTEM ON THE HEAD and a CANAL SYSTEM ON THE TRUNK.

There are often 3 major canals on the head, and a single major trunk canal running along the length of the body.

The CANALS IN TELEOSTS are WELL-OSSIFIED, PIERCED WITH PORES through which the FLUID-FILLED canal is linked to the external environment







The canals on the head can be CLASSIFIED INTO FOUR TYPES: narrow simple, reduced, widened and branched.

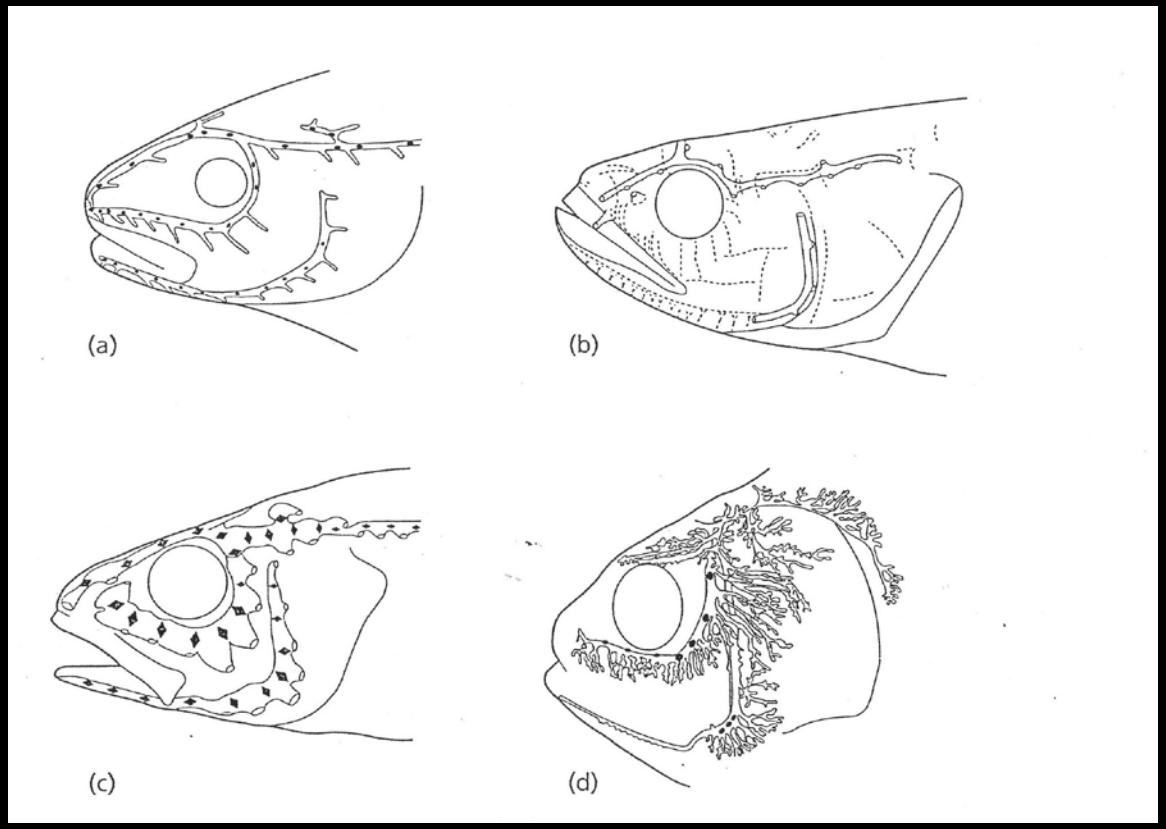
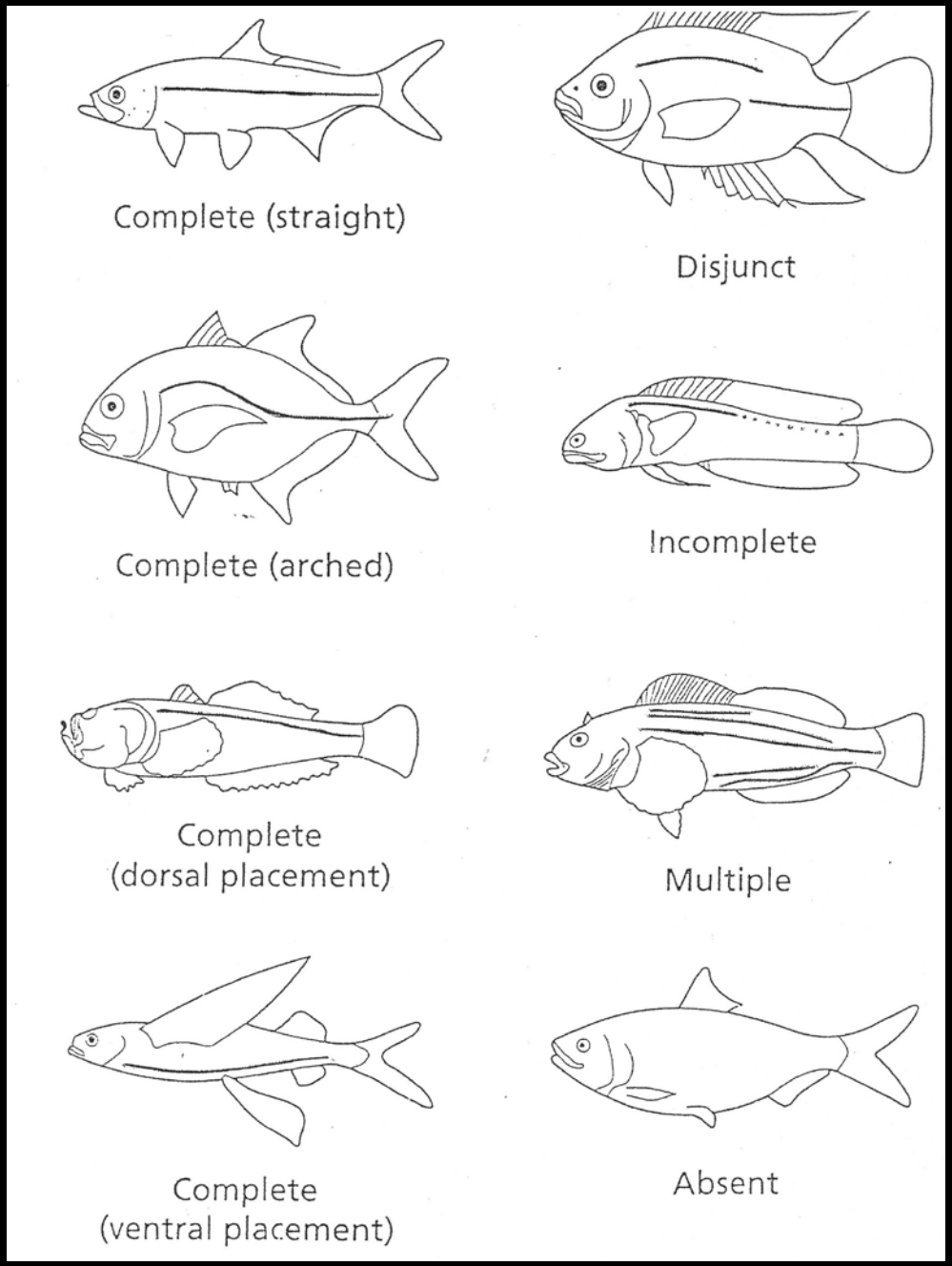


Figure 3.6: Four Types of head canal systems among teleost fishes: (a) narrow-simple canal system; (b) reduced canal system; (c) widened canal system; (d) branched canal system.



There are EIGHT TRUNK CANAL PATTERNS are present in teleost fish.

Receptor organs

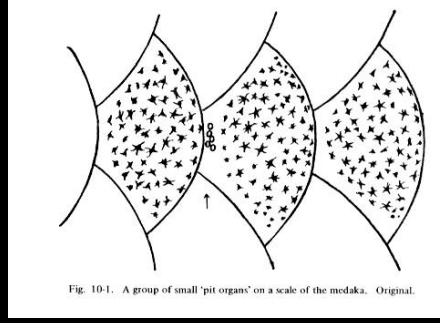


Fig. 10-1. A group of small 'pit organs' on a scale of the medaka. Original.

The lateral line canals are lined by a thin epithelium in which the NEUROMASTS are embedded.

Neuromasts can be classified into different types, depending on their location:

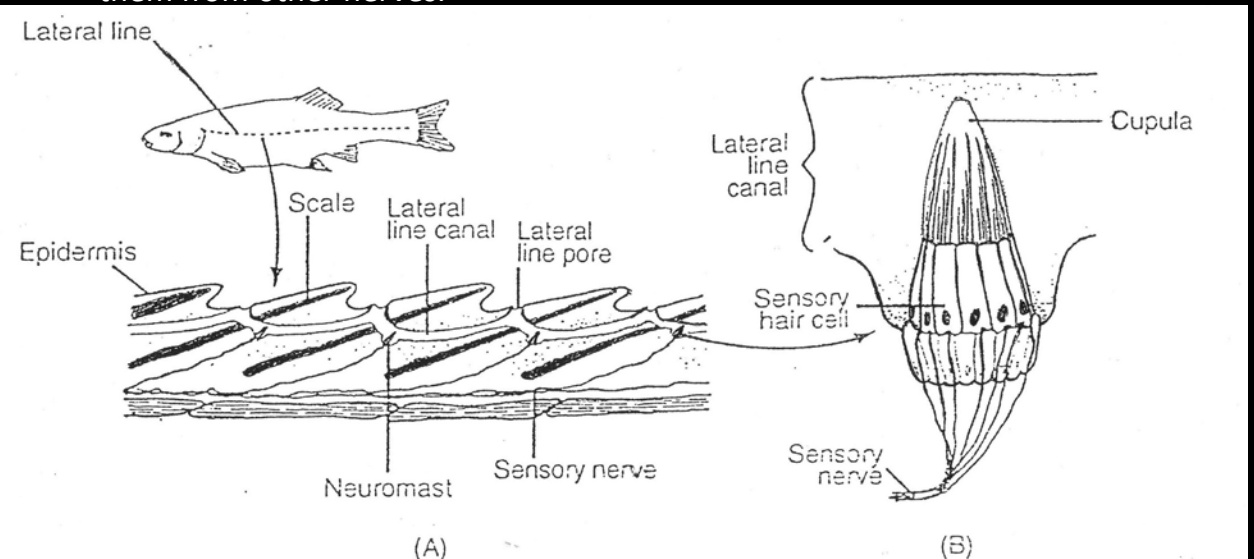
1) FREE OR SUPERFICIAL NEUROMASTS - forms patches on the skin, often in groups or lines called "stitches" or "pit lines".

2) CANAL NEUROMASTS - forms similar patches, but are located within the fluid-filled lateral line canals that lie under the skin.

The HAIR CELLS of the neuromasts are usually ORIENTED IN TWO OPPOSING DIRECTIONS.

The MOVEMENT OF THE FLUID within the canals STIMULATE THE HAIR CELLS, which in turn are innerved by lateral line nerves, specific to the different neuromast regions.

These nerves also have SPECIAL GANGLIA and specific projection sites in the HIND BRAIN, distinguishing them from other nerves.



Cross-section through the trunk of a minnow, showing the distribution and innervation of neuromast receptors and the location of the pores that connect the canal to the external environment. B) Each neuromast is composed of several hair cells, supporting cells and innervating sensory neurons. The apical kinocilia and stereocilia project into the cupula that overlies the entire neuromast.

Acoustic communication: sound production and reception

SOUND is a particularly USEFUL CHANNEL FOR COMMUNICATION in water.

Acoustic signals are NOT AFFECTED BY MURKINESS OR DARKNESS of the environment

SOUND TRAVELS 5 TIMES FASTER IN WATER THAN IN AIR (1500m/s as opposed to 300m/s).

Sound production mechanisms

Fishes from 50 different families are able to produce sound in a variety of ways.

STRIDULATION by pharyngeal teeth or spines and fin rays (Gurnards, grunters).

The swim bladder often acts as a RESONATOR, it increases the amplitude of the sound wave (eg croakers/Kob).

Some marine catfish have special drumming muscles that vibrate the walls of the swim bladder (an 'EXTRINSIC' system)

In other fishes, sound is produced by an 'INTRINSIC' system, the muscles have their origin on the swim bladder, and the frequency of the sound depends on the rate of contraction of the muscle (toadfish, *Opsanus*).

http://www.dosits.org/audio/fishes/barredgrunt/

http://www.dosits.org/audio/fishes/atlanticcroaker/

http://www.dosits.org/audio/fishes/hhseacatfish/

http://www.dosits.org/audio/fishes/oystertoadfish/

Sound reception

Sound reception, how do they hear?

A sound produces TWO TYPES OF STIMULI within water.

Back-and-forth motion of the particles in the medium = PARTICLE DISPLACEMENT

production of SOUND PRESSURE

Head of a FISH VIBRATES in a sound field → OTOLITHS overlying the maculae will also VIBRATE.

Because OTOLITHS ARE DENSER than the surrounding tissue, the vibrations will be smaller than that of the surrounding tissue.

Causes hairs of the HAIR CELLS to BEND.

This bending will fire the hair cells if their polarity is appropriate to the direction of the vibration.

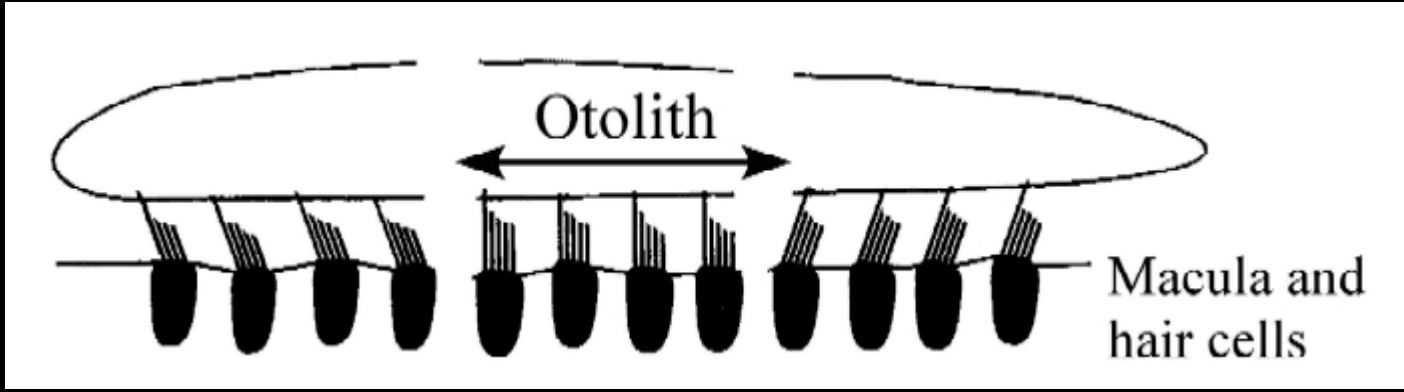
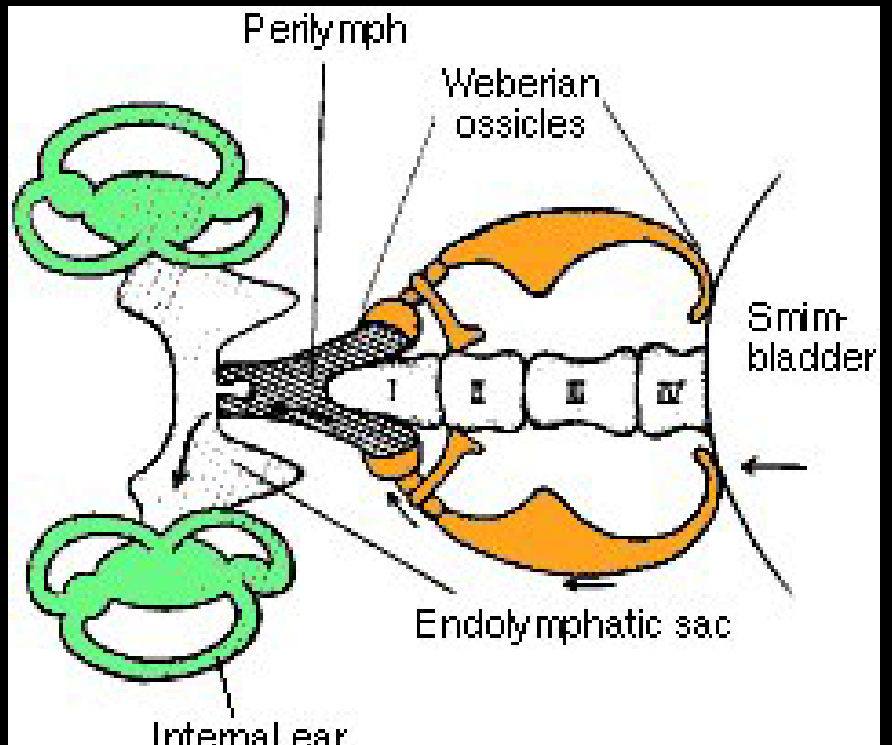


Figure 1 Otolith oscillating above the macular hair cells

The WEBERIAN APPARATUS is a particularly EFFECTIVE STRUCTURAL MODIFICATION that enhances the hearing of otophysan fishes (Cypriniformes, Characiformes, Siluroidei, and Gymnotoidei). Swim bladder pulsates in the SOUND PRESSURE FIELD AND ROCKS THE TRIPUS. Relayed through other bones to a sinus containing perilymph adjacent to the saccular macula.

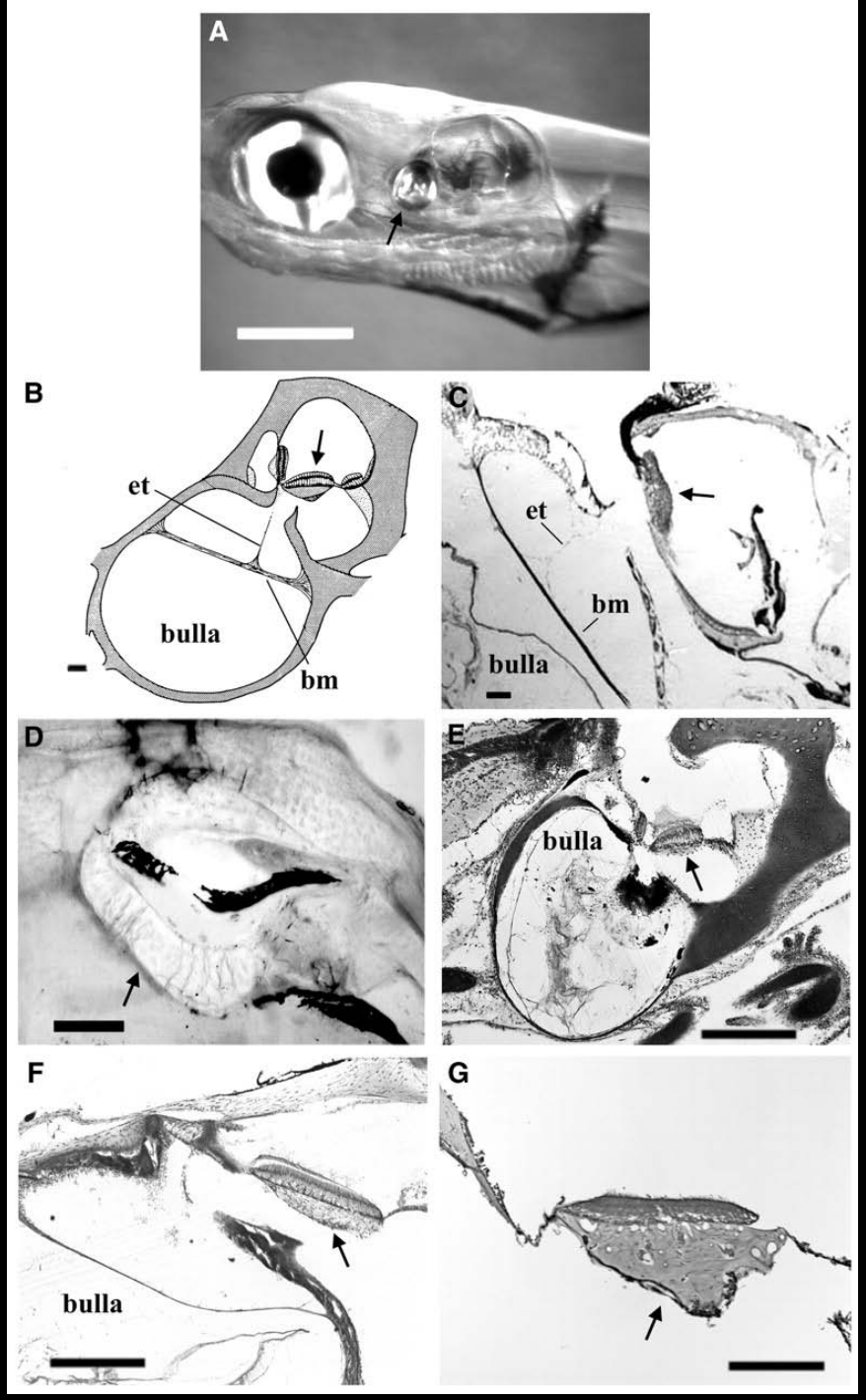
CLUPEOIDS, such as anchovy, have an OTIC BULLA, which is closely associated with the UTRICULUS, on either side of the head.

The bulla ACTS AS A PRESSURE-DISPLACEMENT TRANSDUCTION MECHANISM.



(A) Relationship of the prootic bulla to the inner ear of American shad, as demonstrated in a 12.5 mm *TL* larva. The prootic bulla (arrow) sits just anterior to the utricle. (B) Diagram (modified from Denton and Gray, 1979) and (C) transverse section showing the relationship of the prootic bulla to the utricle in adult American shad. The bulla is connected to the middle macula (arrow) of the utricle by an `elastic thread' (as defined in Denton and Gray, 1979) connected to the bullar membrane. et, elastic thread; bm, bullar membrane. Sections through the utricle of (D) 12 mm *TL*, (E) 16.5 mm *TL*, (F) 26 mm *TL* and (G) adult American shad. Arrows in B, C, E, F, G and H represent the middle utricular epithelium. Scale bar in A=1 mm, in B=100 µm and in C,E–H=10 µm. Orientation of plates B–G is as shown in A (anterior is to the left and dorsal up in all cases).

Higgs, D. M. et al. J Exp Biol 2004;207:155-163



The Journal of Experimental Biology

Locomotion and posture

The VESTIBULAR SYSTEM (pars superior, canals of the ear) is concerned with the MAINTENANCE OF BODY ORIENTATION = control of posture and positioning and movement of the body during locomotion.

Changes in the ACCELERATION OR ORIENTATION will cause the ENDOLYMPH WITHIN THE VESTIBULAE TO MOVE. This causes a DISPLACEMENT OF THE CUPULA that encloses the cilia of the hair cells.

The downward pull of GRAVITY ON THE LAPILLUS (utricle otolith) triggers impulses from the sensory cells. This provides the fish with information regarding its VERTICAL ORIENTATION in the water.

Adaptations: Most fishes maintain their bodies in an upright position.

Flatfish: The VESTIBULAR SYSTEM IS AT 90° RELATIVE to other fishes. In fishes that are oriented "upwards", the utricle is horizontal, and the saccule more vertical.

Upside-down catfish: Synodontus nigriventris often swims with its dorsal side down, while it feeds on the underside of floating vegetation. These fish also show NO STRUCTURAL MODIFICATIONS TO THE INNER EAR, and changes to the central nervous system have been inferred.

Tail-standers or head-standers: These fish can tilt their bodies by as much as 30° - SENSORY MACULA OF THE UTRICULAR OTOLITH IS TILTED.

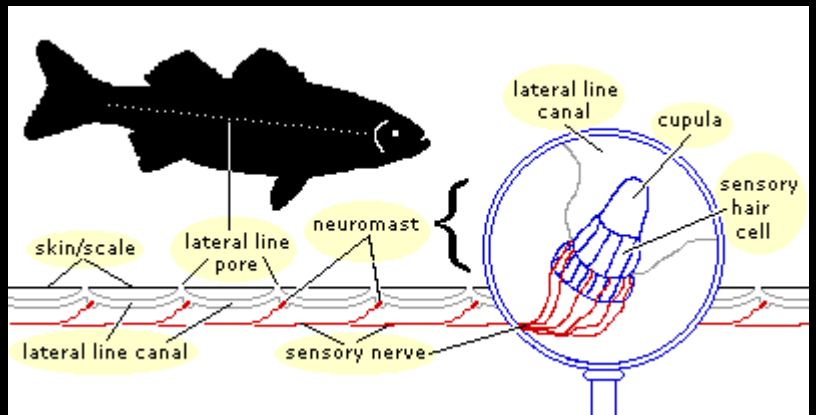
The Lateral line and fish behaviour

DETECTION OF MOVEMENT: Predator and prey

RESPONSE PROPERTIES: Functional differences exist between narrow and widened head canal systems. Widened canals have increased sensitivity and response time. The response properties of wide canals are also similar to that of superficial neuromasts and can explain the evolution of reduced canals, where superficial neuromasts predominate.

DETECTION OF OBSTACLES: When the water moves, a `flow field' occurs around a stationary object.

SCHOOLING: to maintains position and velocity relative to its nearest neighbour



Question - schooling or shoaling?

School - a group of fish that swim in a synchronised manner, i.e. with similar speeds and direction. They also display a consistent Nearest Neighbour Distance (NND), which means they maintain the same distance between all immediately adjacent fish. This NND is usually about 0.5 to 1 times the length of the fish.

Shoal - a group of fish that are randomly orientated within a group and exhibit a variable NND. Shoals of fish on the move nearly always form schools.