The Digestive System

Lecture 3

Neutralisation of Acid in Duodenum

- Bicarbonate (HCO_3) secretion from Brunner's Gland duct cells (submucosal glands)

$$H^+ + HCO_3^- \leftrightharpoons H_2CO_3 \leftrightharpoons H_2O + CO_2$$

Control of Duodenal HCO_3 Secretion

Acid in duodenum triggers…

A Long (vagal) & short (ENS) reflexes ⇒ HCO_3 secretion

B Release of secretin from S cells ⇒ HCO_3 secretion

- Secretin ⇒ HCO_3 secretion from pancreas & liver
- Acid neutralisation ⇒ inhibits secretin release (negative feedback control)

Exocrine Pancreas

Responsible for digestive function of pancreas

- Anatomical Structure

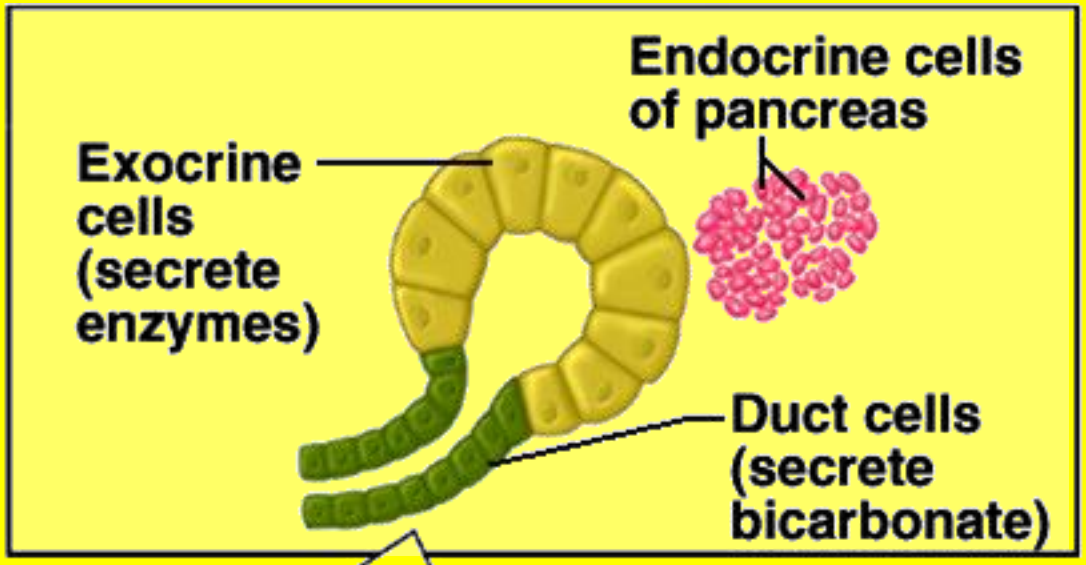
  Acini ⟶ Ducts ⟶ Pancreatic Duct

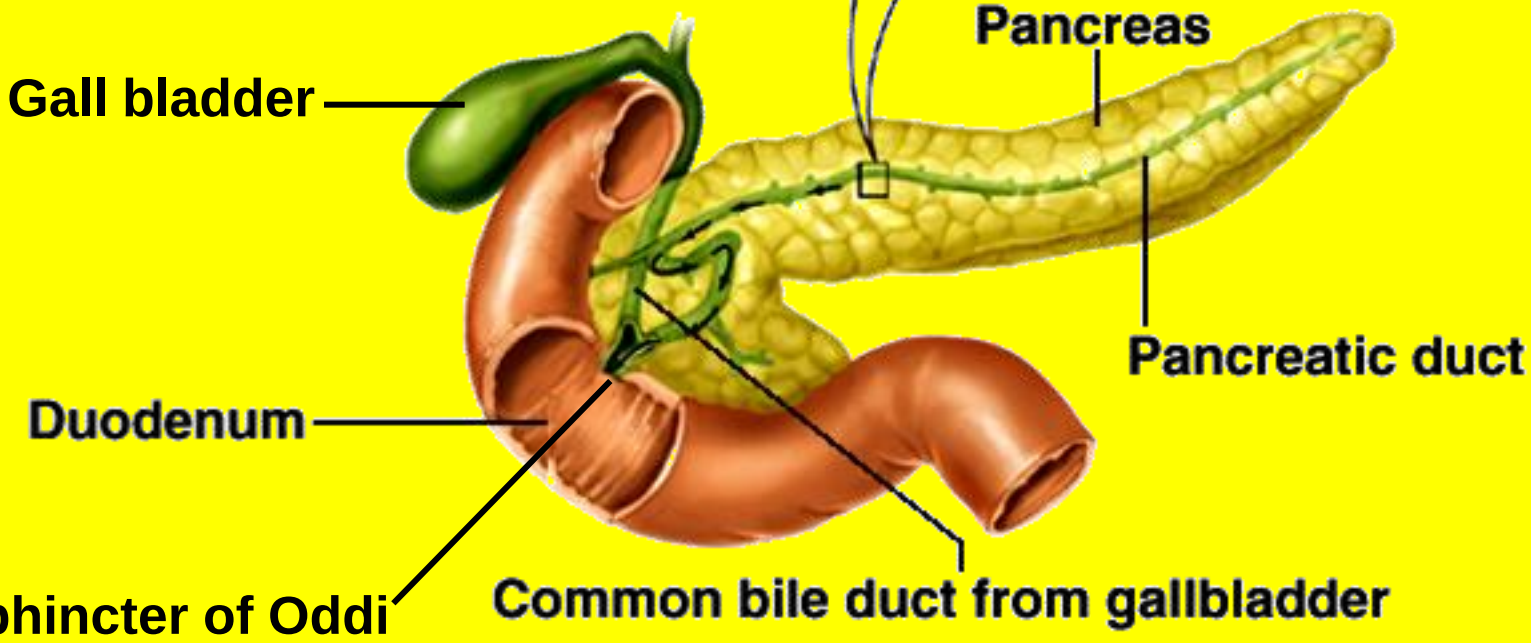
- Function

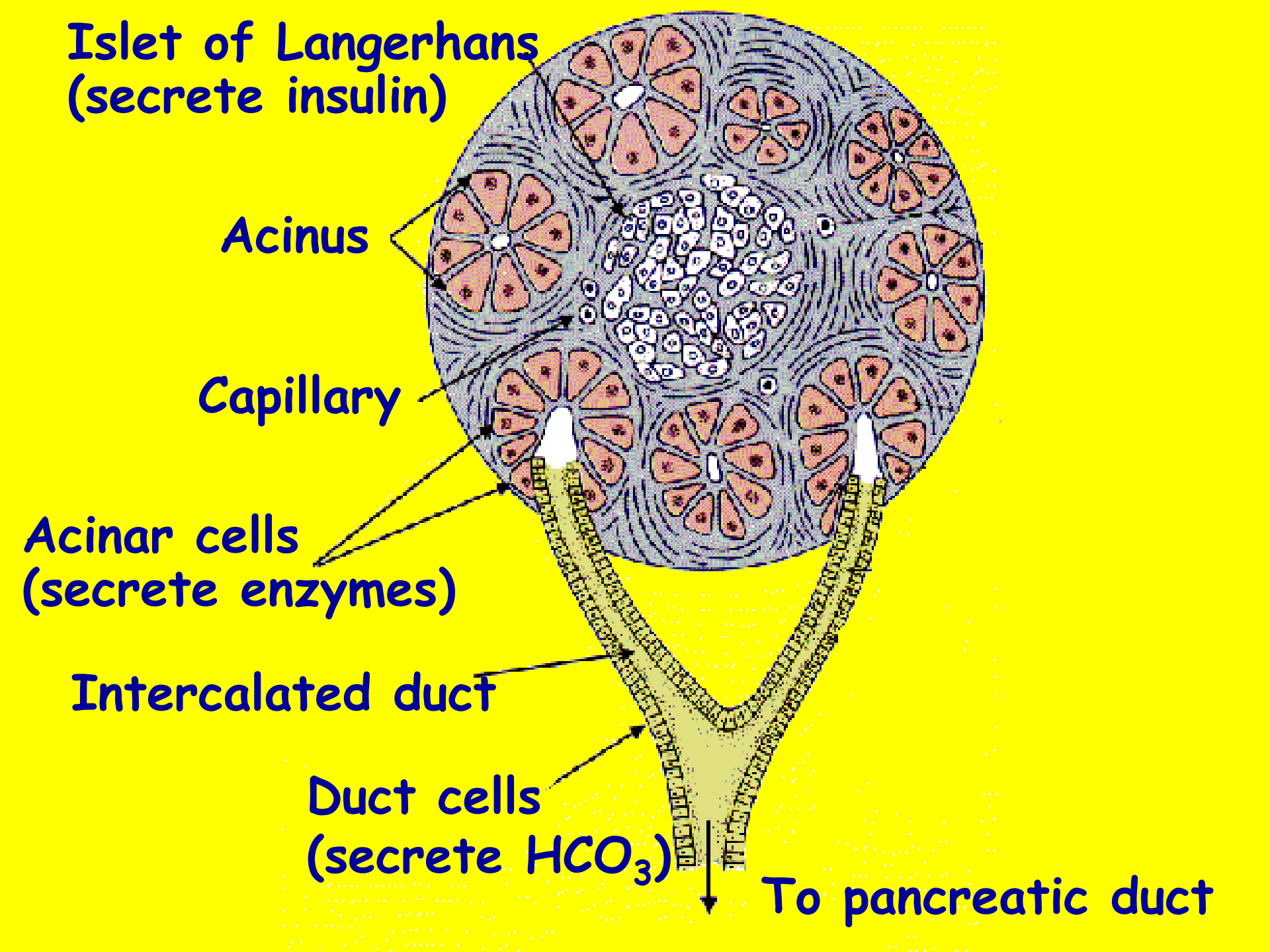
  Secretion of bicarbonate by duct cells

  Secretion of digestive enzymes by acinar cells

Structure of the pancreas






Islet of Langerhans
(secrete insulin)
Acinus
Capillary
Acinar cells
(secrete enzymes)
Intercalated duct
Duct cells
(secrete HCO_3)
To pancreatic duct

Composition and Function of Pancreatic Juice

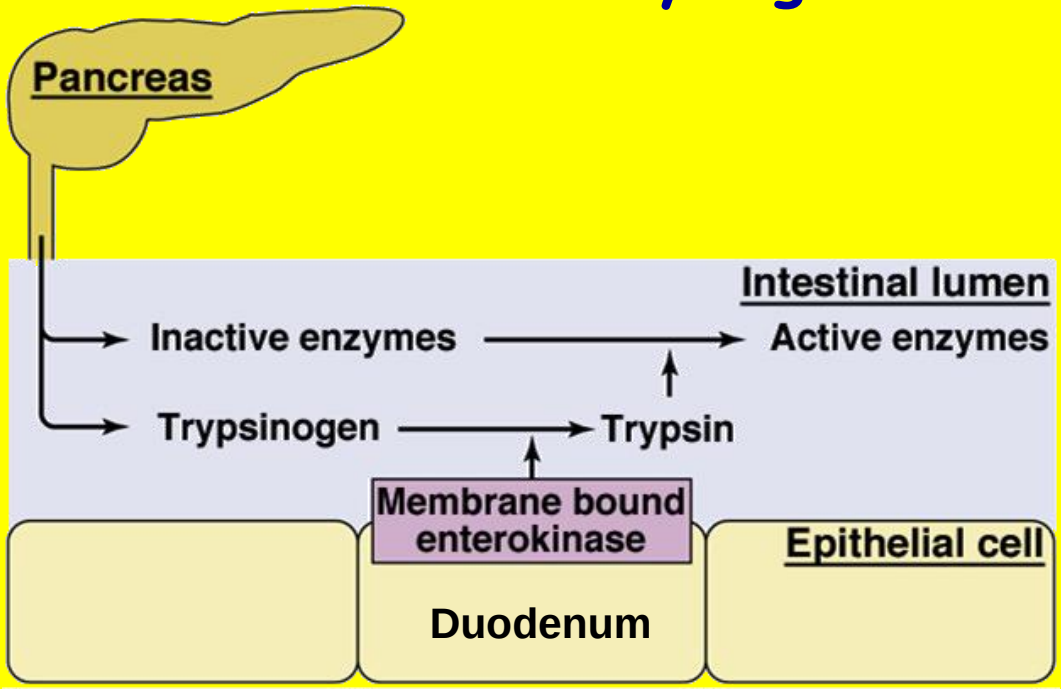
- Water solution of enzymes and electrolytes (primarily HCO_3)
  - Neutralizes acid chyme
  - Provides optimal environment for pancreatic enzymes
- Enzymes are released in inactive form and activated in the duodenum

Composition and Function of Pancreatic Juice

- Examples include
  - Trypsinogen is activated to trypsin
  - Procarboxypeptidase is activated to carboxypeptidase
- Active enzymes secreted
  - Amylase, lipases, and nucleases
  - These enzymes require ions or bile for optimal activity

Zymogens

- Acinar cells contain digestive enzymes stored as inactive zymogen granules
- Prevents autodigestion of pancreas
- Enterokinase (bound to brush border of duodenal enterocytes) converts trypsinogen to trypsin
- Trypsin converts all other zymogens to active forms



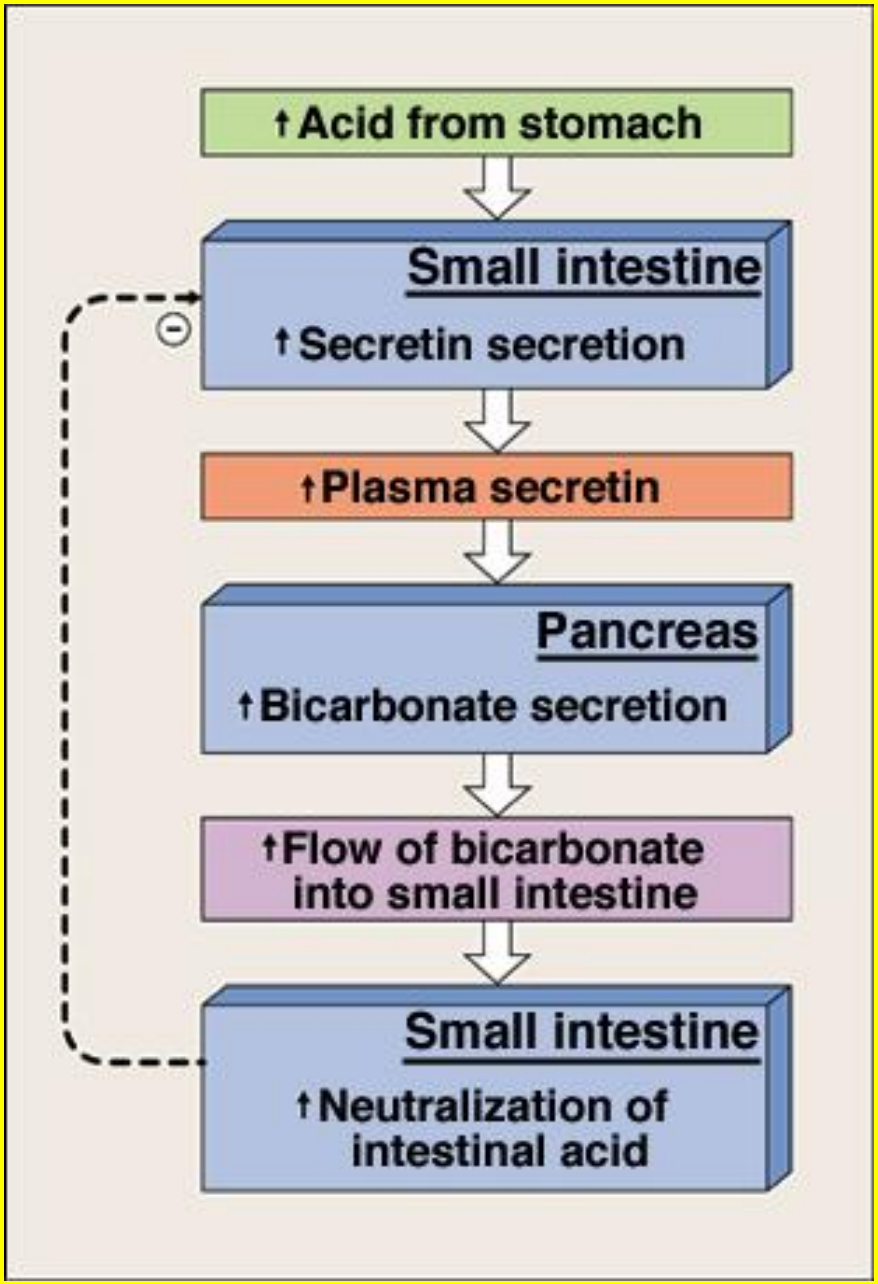
Categories of Pancreatic Enzymes

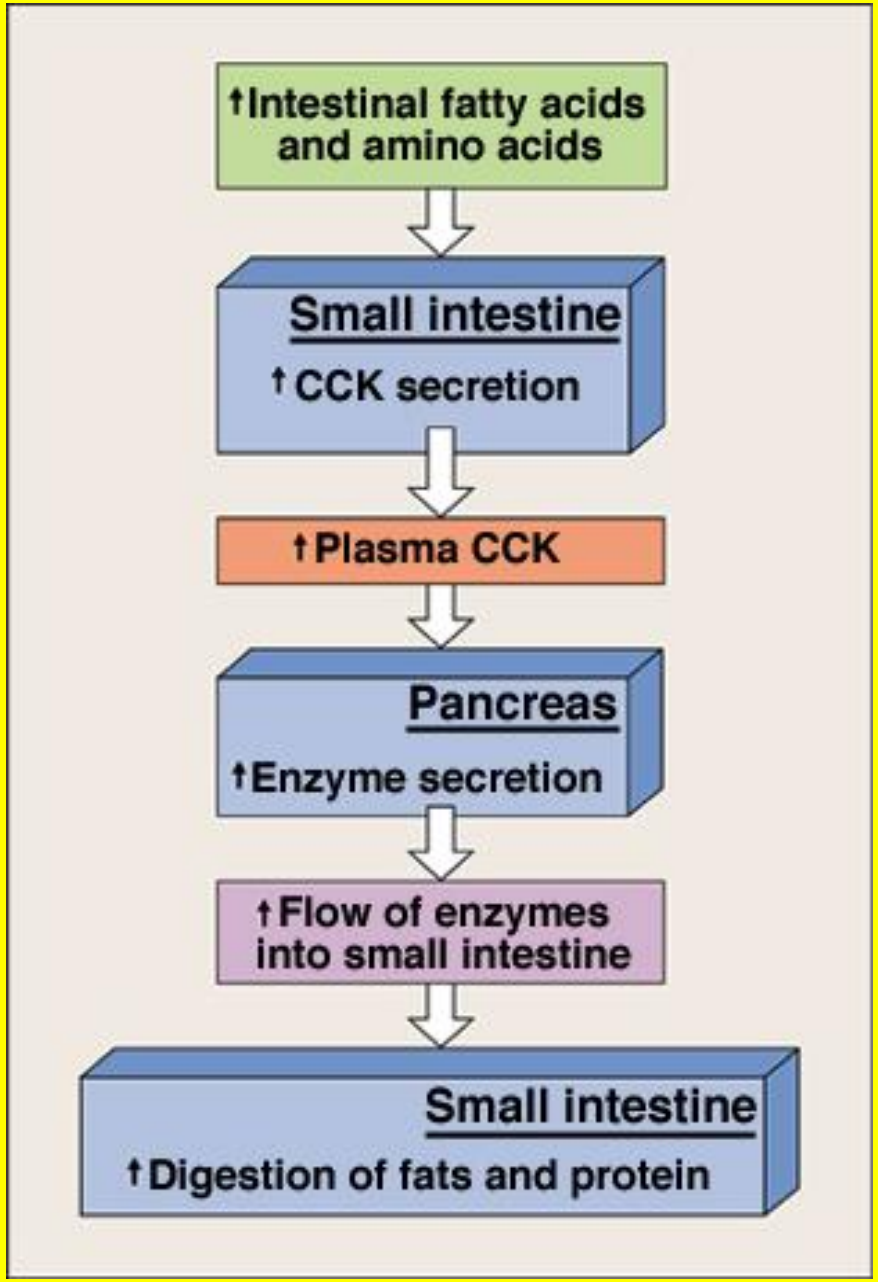
Proteases	Cleave peptide bonds
Nucleases	Hydrolyse DNA/RNA
Elastases	Collagen digestion
Phospholipases	Phospholipids to fatty acids
Lipases	Triglycerides to fatty acids+ glycerol
α-Amylase	Starch to maltose + glucose

Control of Pancreatic Function

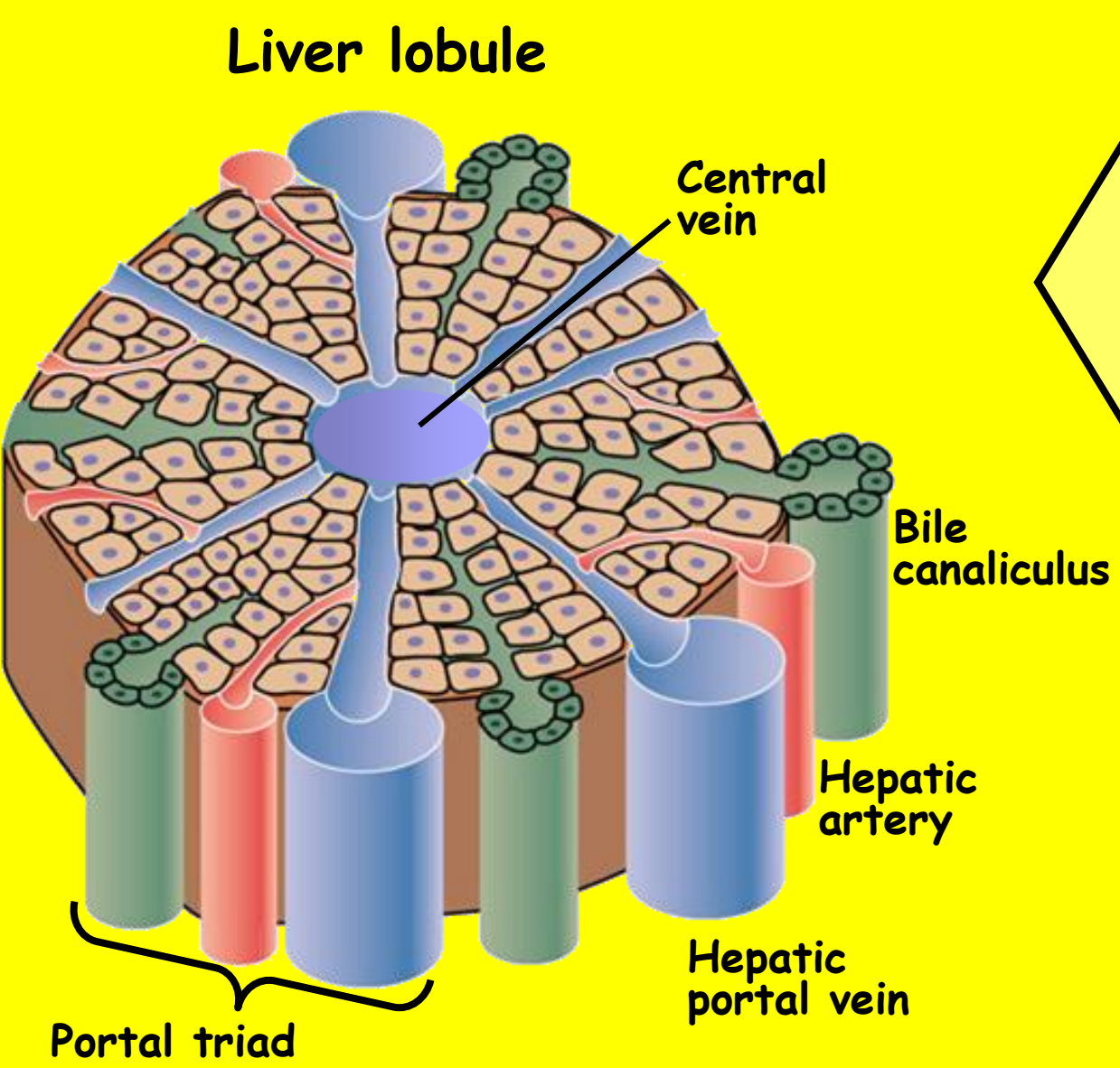
- Bicarbonate secretion stimulated by secretin
- Secretin released in response to acid in duodenum
- Zymogen secretion stimulated by cholecystokinin (CCK)
- CCK released in response to fat/amino acids in duodenum
- Also under neural control (vagal/local reflexes) – triggered by arrival of organic nutrients in duodenum

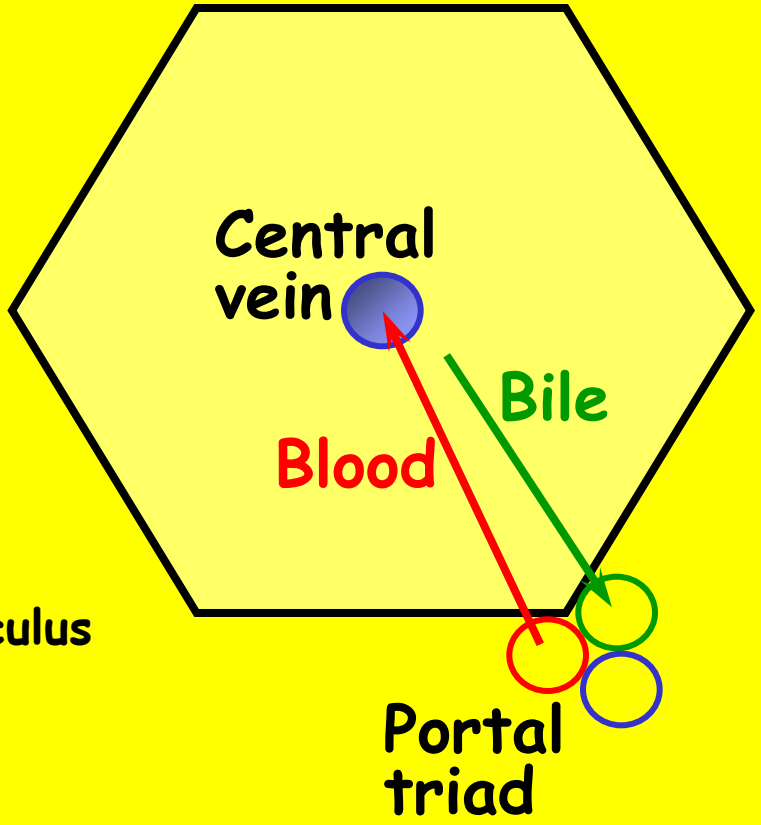
Control of Pancreatic Function





Structure/Function of Liver



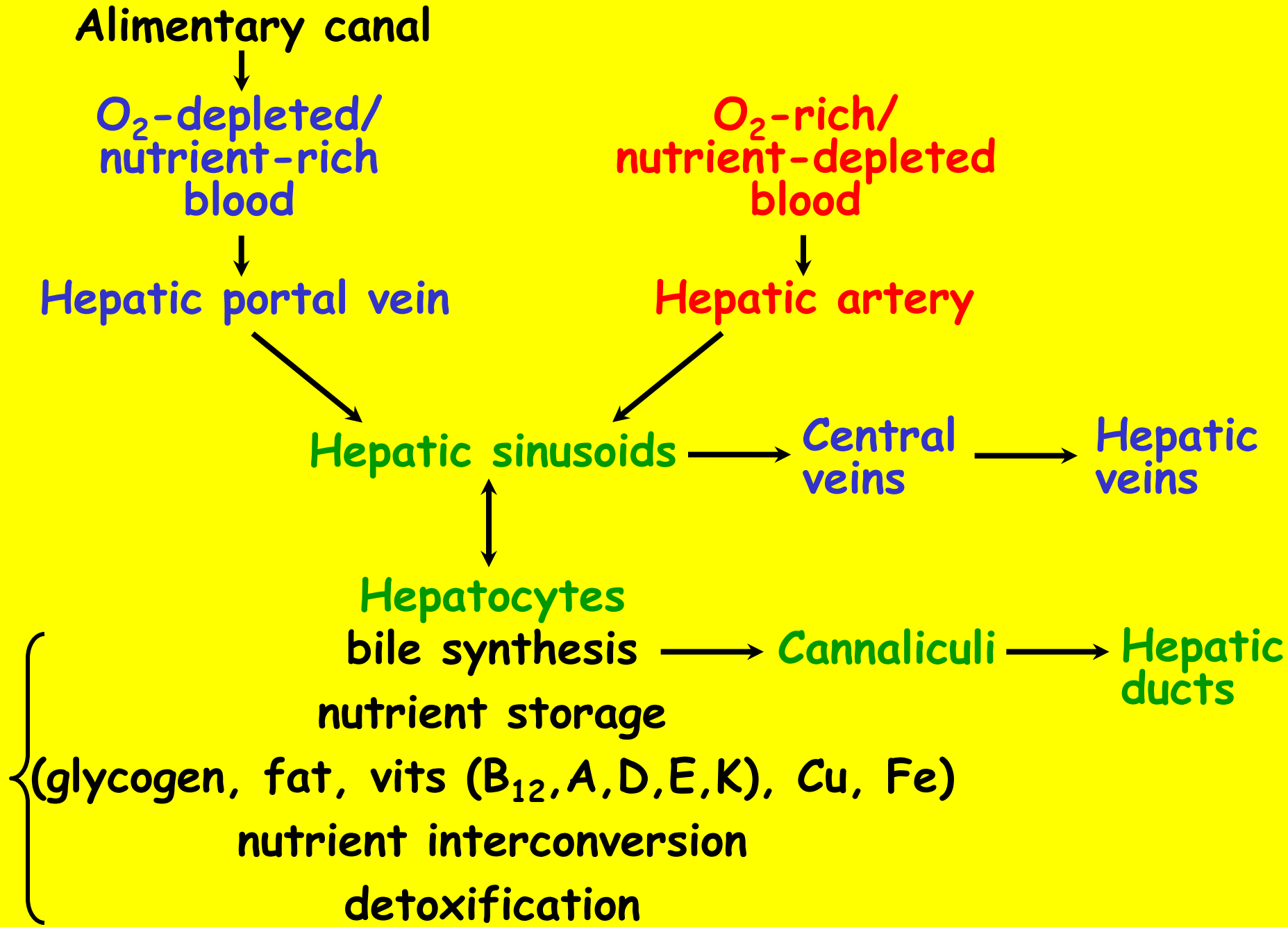


Microscopic Anatomy of the Liver

- Hexagonal-shaped liver lobules are the structural and functional units of the liver
  - Composed of hepatocyte (liver cell) plates radiating outward from a central vein
  - Portal triads are found at each of the six corners of each liver lobule
- Portal triads consist of a bile duct and
  - Hepatic artery – supplies oxygen-rich blood to the liver
  - Hepatic portal vein – carries venous blood with nutrients from digestive viscera

Microscopic Anatomy of the Liver

- Liver sinusoids – enlarged, leaky capillaries located between hepatic plates
- Kupffer cells – hepatic macrophages found in liver sinusoids
- Hepatocytes' functions include:
  - Production of bile
  - Processing bloodborne nutrients
  - Storage of fat-soluble vitamins
  - Detoxification
- Secreted bile flows between hepatocytes toward the bile ducts in the portal triads


Alimentary canal
O_2-depleted/ nutrient-rich blood
O_2-rich/ nutrient-depleted blood
Hepatic portal vein
Hepatic artery
Hepatic sinusoids
Central veins
Hepatic veins
Hepatocytes
bile synthesis
Cannaliculi
Hepatic ducts
nutrient storage
(glycogen, fat, vits (B_{12},A,D,E,K), Cu, Fe)
nutrient interconversion
detoxification

Function of Liver

Alimentary role of liver = production & secretion of bile

Six components of bile:

(1) Bile acids (2) Lecithin (3) Cholesterol	Synthesised in liver Solubilise fat
(4) Bile Pigments	Bilirubin (from haemoglobin)
(5) Toxic Metals	Detoxified in liver
(6) Bicarbonate	Neutralisation of acid chyme

(1) ⇒ (5) secreted by hepatocytes (liver cells)

HCO_3 secreted by duct cells

Composition of Bile

- A yellow-green, alkaline solution containing bile salts, bile pigments, cholesterol, neutral fats, phospholipids, and electrolytes
- Bile salts are cholesterol derivatives that:
  - Emulsify fat
  - Facilitate fat and cholesterol absorption
  - Help solubilize cholesterol
- Enterohepatic circulation recycles bile salts
- The chief bile pigment is bilirubin, a waste product of heme

Bile Pigments

- Breakdown products of haemoglobin from old/damaged erythrocytes

- Bilirubin (predominant bile pigment) - extracted from blood by hepatocytes and secreted into bile
  ⇒ yellow bile

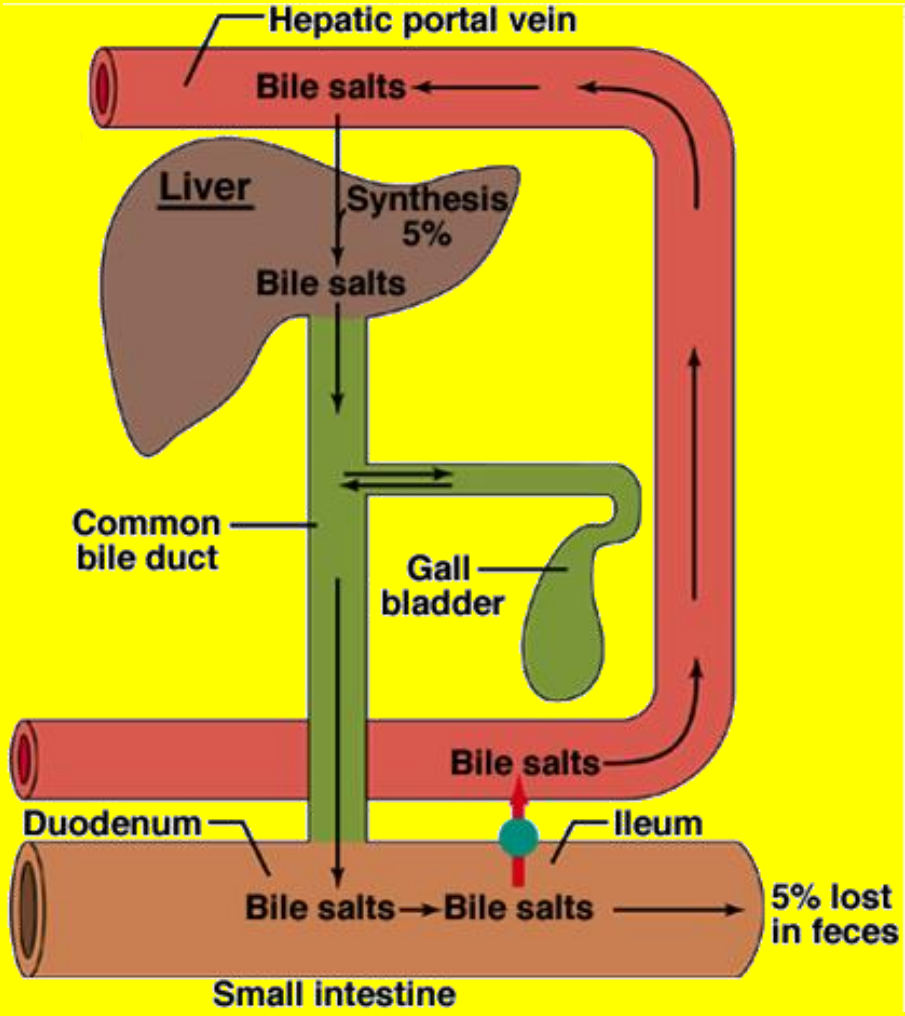
- Bilirubin modified by bacterial enzymes ⇒ brown pigments
  ⇒ brown faeces

- Reabsorbed bilirubin excreted in urine
  ⇒ yellow urine

Bile Acids

- Synthesised in liver from cholesterol (0.5g/day)
- Before secretion, bile acids *conjugated* with glycine or taurine ⇒ Bile Salts (↑ solubility)
- Secreted bile salts recycled via enterohepatic circulation

Liver ⇒ bile duct ⇒ duodenum ⇒ ileum ⇒ hepatic portal vein ⇒ liver etc...



Control of Bile Secretion

Sphincter of Oddi

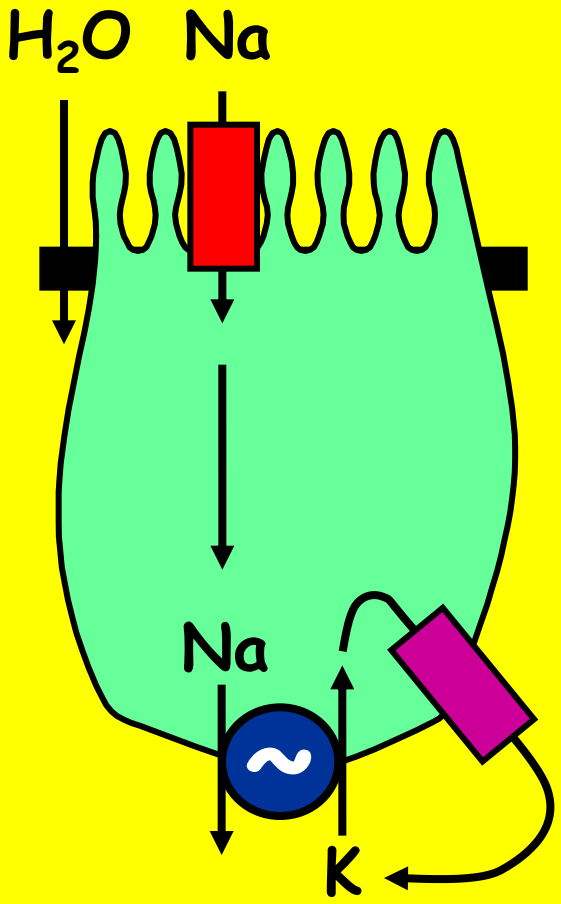
- Controls release of bile and pancreatic juice into duodenum
- When contracted (closed) ⇒ bile forced back into gallbladder
- Gallbladder concentrates bile 5-20 times (absorbs Na^+ & H_2O)
- Fat in duodenum ⇒ release of CCK

  CCK ⇒ (A) Sphincter of Oddi relaxes

  (B) Gallbladder contracts
- Discharge of bile into duodenum ⇒ fat solubilisation

  CCK ⇒ Pancreatic enzyme secretion

  ⇒ Bile secretion



Summary of Actions of Secretin & CCK

Secretin

Acid in duodenum

⇓

Secretin

⇓

↓ Gastric acid secretion

↓ Gastric emptying

↑ Duodenal HCO_3 secretion

↑ Pancreatic HCO_3 secretion

↑ Bile duct HCO_3 secretion

Cholecystokinin

Fat/amino acids in duodenum

⇓

CCK

⇓

↓ Gastric emptying

↑ Pancreatic enzyme secretion

Gallbladder contraction

Relaxation of Sphincter of Oddi

Neutralisation

Digestion

Homeostatic Imbalance

- Gallstones – crystallization of cholesterol which can obstruct the flow of bile
- Current treatments include: dissolving the crystals with drugs, pulverizing them with ultrasound, vaporizing them with lasers, and surgical removal of the gallbladder
- Obstructive jaundice – yellowish skin caused by bile pigments deposited in the skin
  - Due to blocked bile ducts