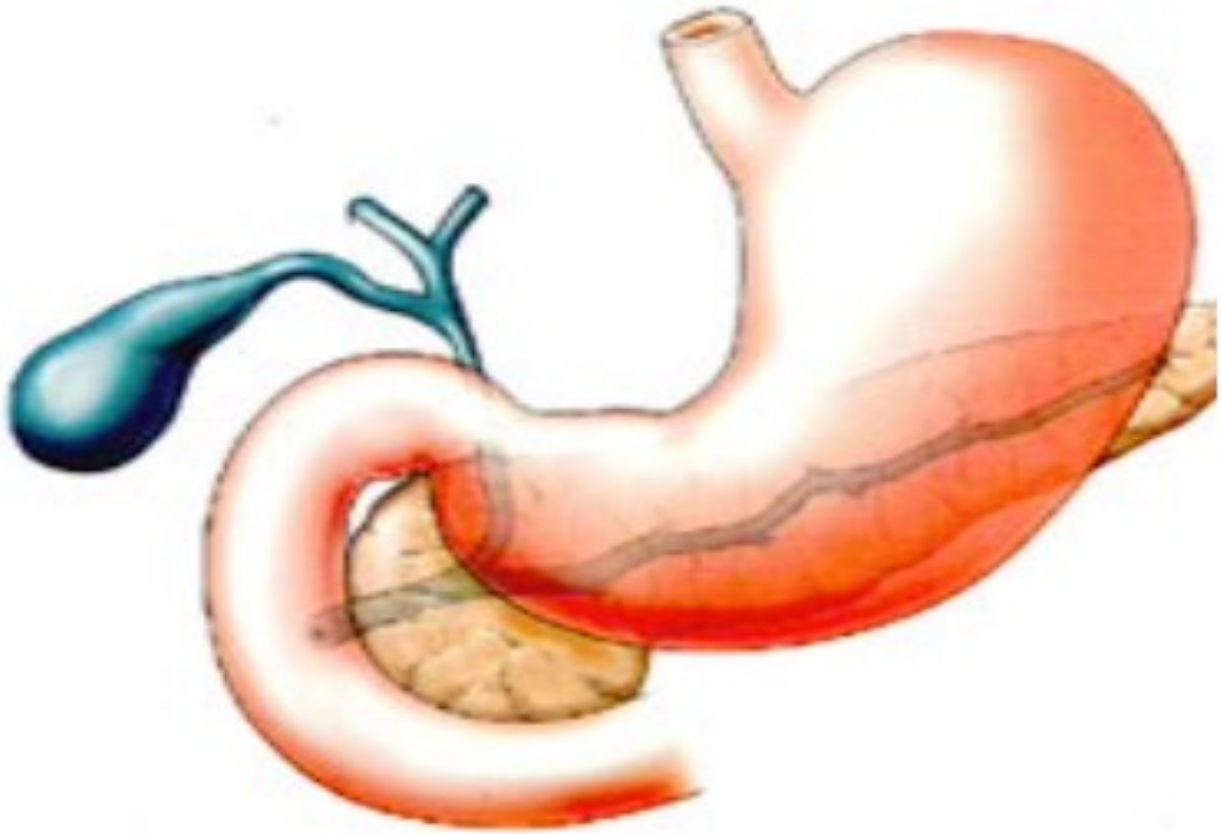
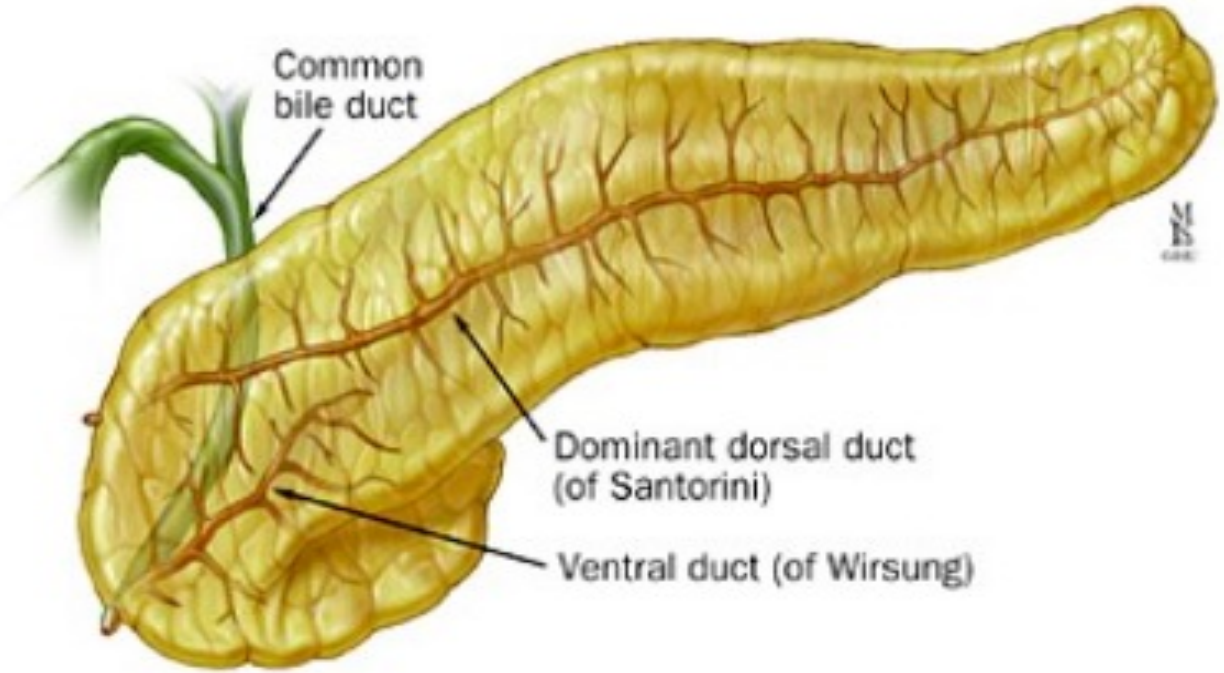
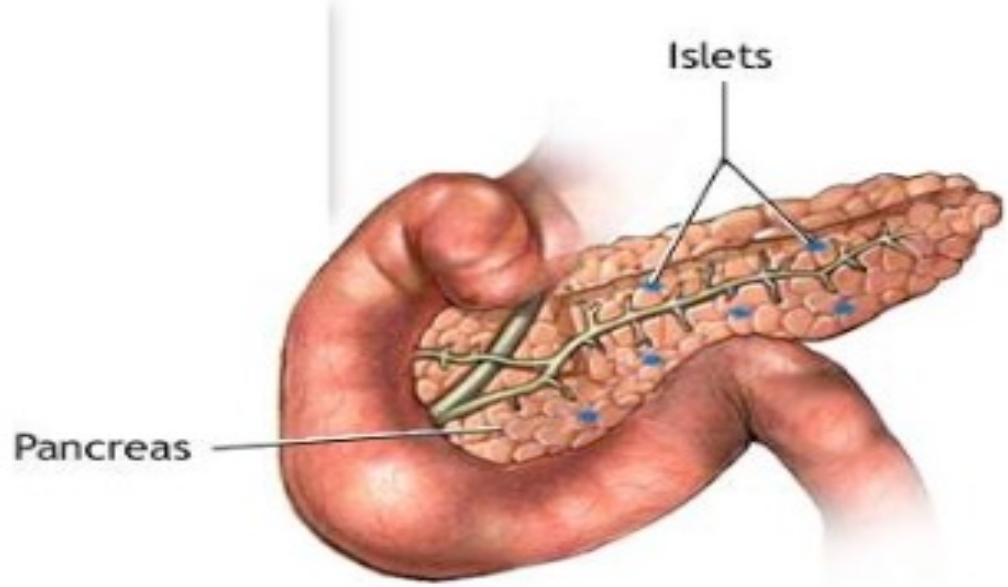
Pancreas Anatomy & Physiology

Dr. Gary Mumaugh




Common bile duct
Dominant dorsal duct (of Santorini)
Ventral duct (of Wirsung)


Islets
Pancreas

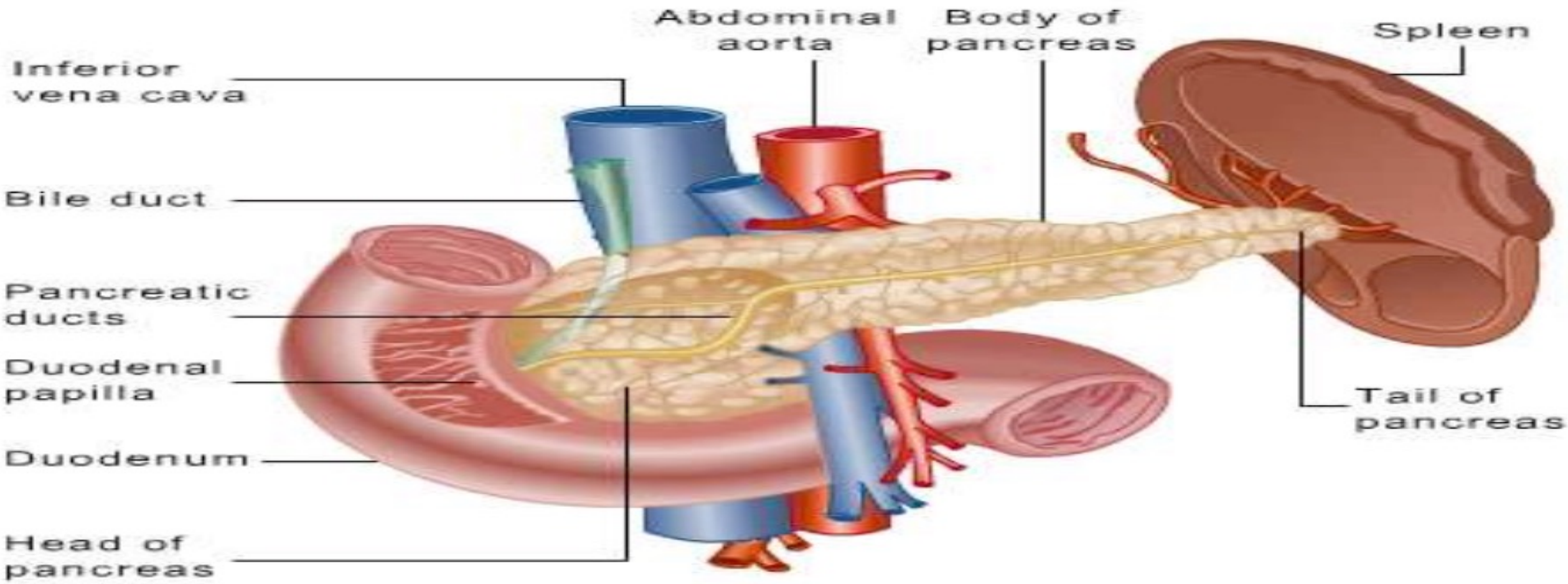
Pancreas Gross Anatomy

- Pancreas means “all flesh”
- Transversely oriented retroperitoneal organ
- Extending from “C” loop of duodenum to the hilum of spleen
- Measures 6-10 inches in length
- Weighs 60 – 95 grams

Pancreas Gross Anatomy

- The pancreas is an elongated, accessory digestive gland that lies retroperitoneally, overlying and transversely crossing the bodies of the L1 and L2 vertebra on the posterior abdominal wall.
- It lies posterior to the stomach between the duodenum on the right and the spleen on the left.
- The transverse mesocolon attaches to its anterior margin.

- Extends in an oblique, transverse position
- Parts of pancreas: head, neck, body and tail



Pancreatic duct system

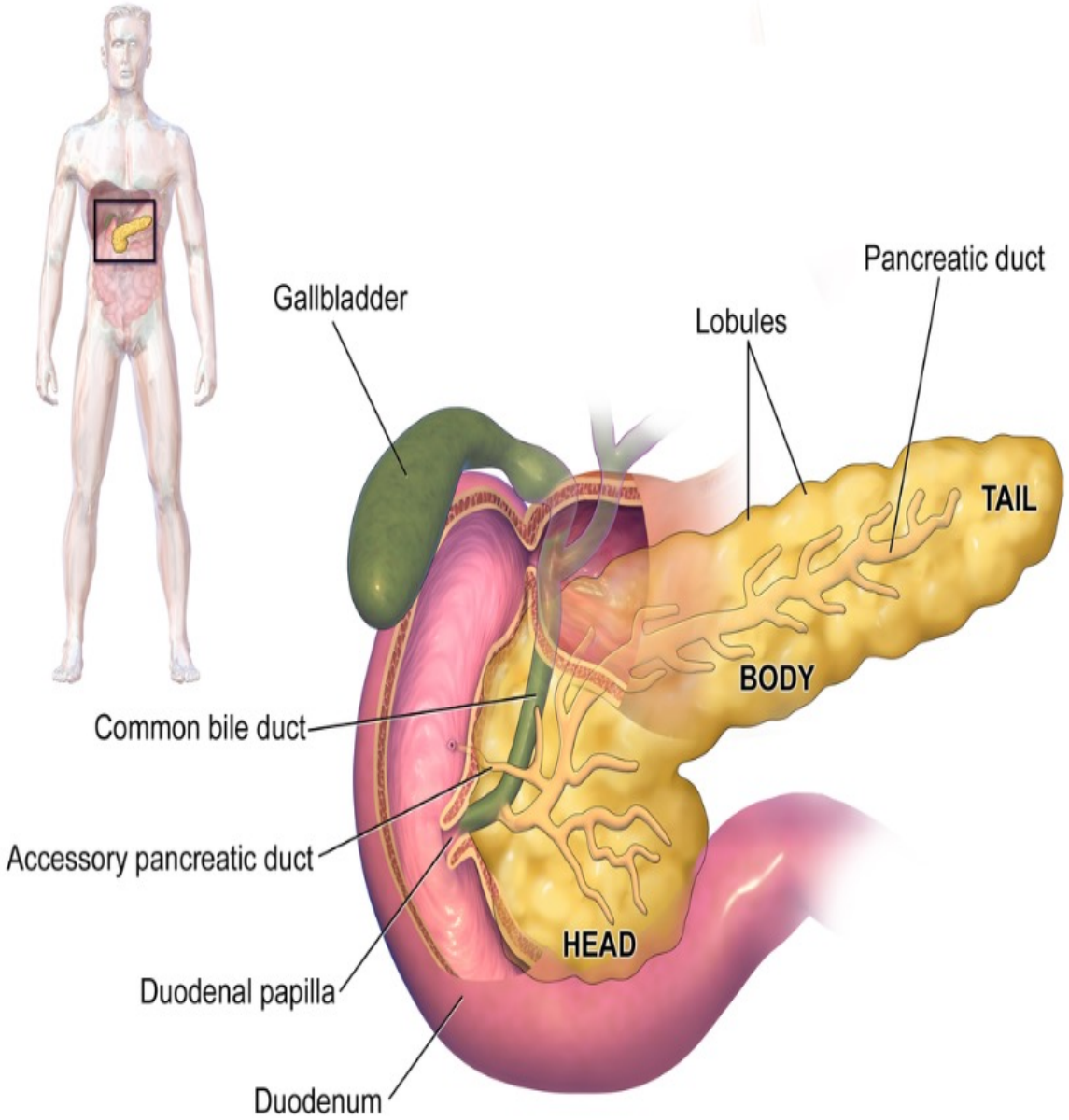
- The pancreatic duct, or duct of Wirsung (also, the major pancreatic duct due to the existence of an accessory pancreatic duct), is a duct joining the pancreas to the common bile duct.
- The pancreatic duct joins the common bile duct just prior to the ampulla of Vater, after which both ducts perforate the medial side of the second portion of the duodenum at the major duodenal papilla.

Accessory Pancreatic Duct

- Most people have just one pancreatic duct. However, some have an additional accessory pancreatic duct, also called the Duct of Santorini.
- An accessory pancreatic duct can be functional or non-functional.
- It may open separately into the second part of the duodenum, and usually (in 70% of people) drains into the duodenum via the minor duodenal papilla.
- In the other 30% of people, it drains into the main pancreatic duct, which drains into the duodenum via the major duodenal papilla.
- The main pancreatic duct and the accessory duct both eventually—either directly or indirectly connect to the second part of the duodenum.

Johann Georg Wirsung (1589-1643) - The shooting of the German anatomist who discovered the pancreatic duct.

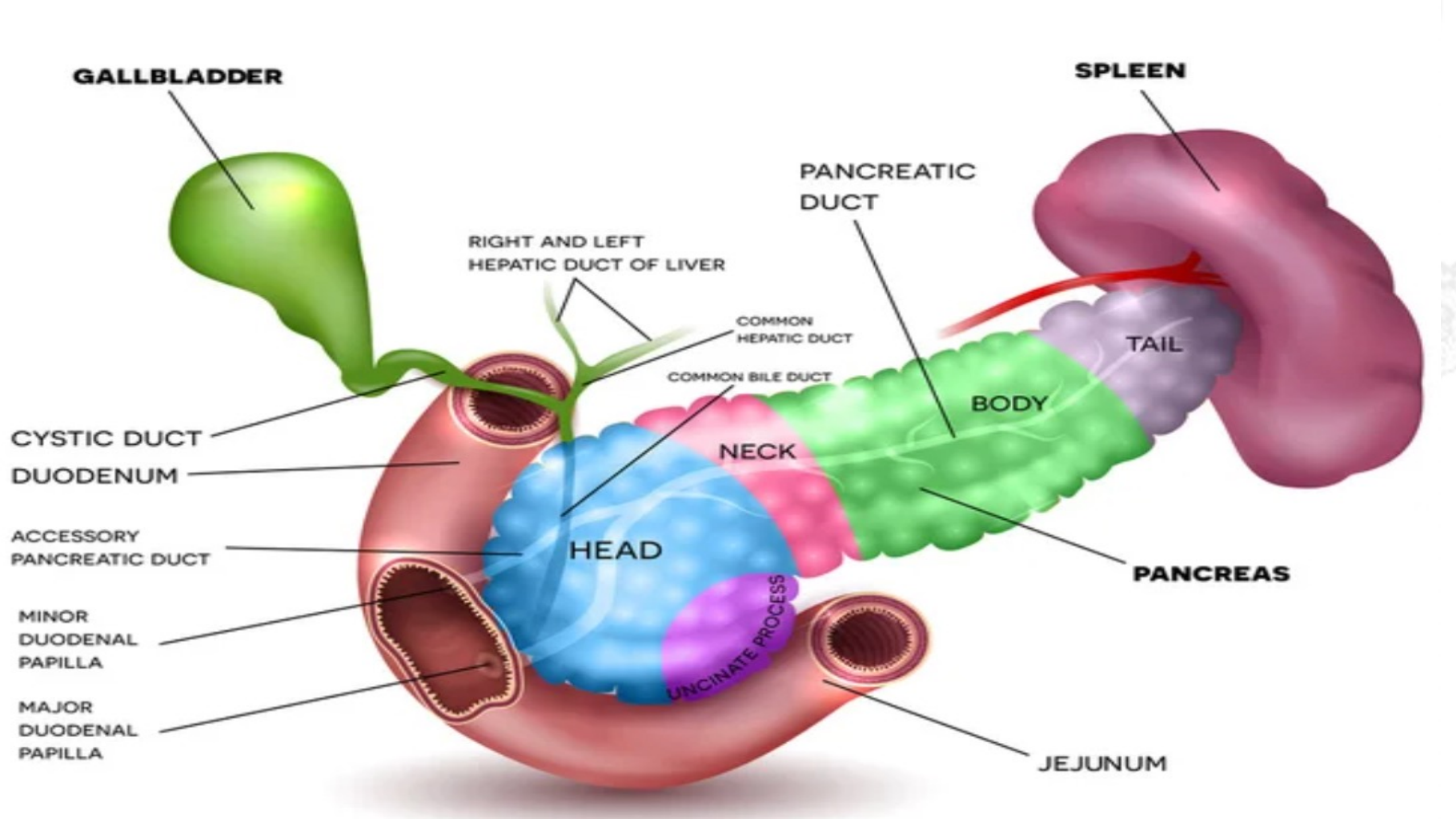
He was murdered by Giacomo Cambier, (his student) over an argument as to who actually made the discovery 1643.

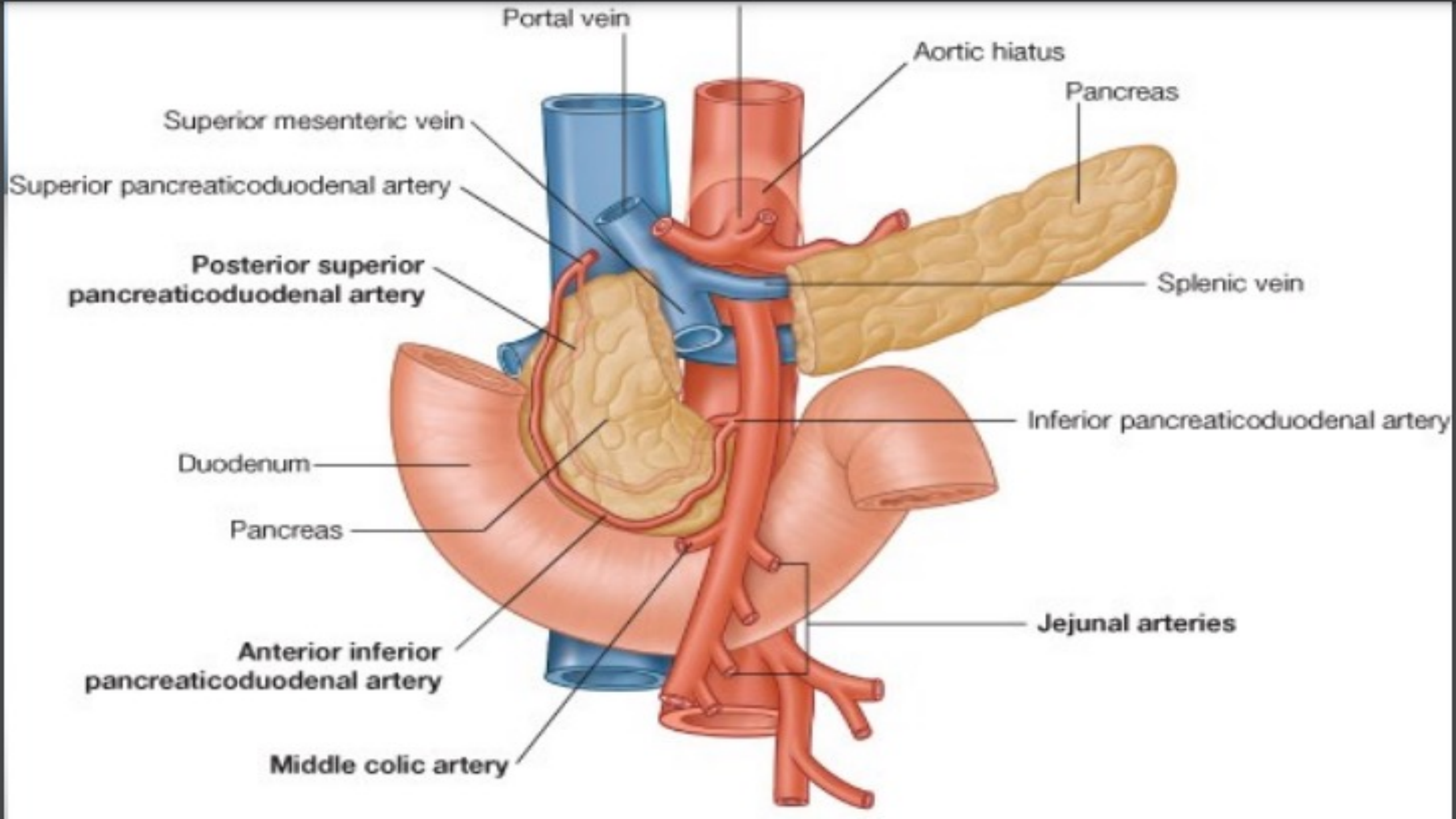


Giovanni Domenico Santorini

Head of Pancreas

- Includes uncinate process (uncinate means hook)
  - The uncinate process is where 2 crucial blood vessels (the superior mesenteric artery and the superior mesenteric vein) intersect.
- Flattened structure, 2 – 3 cm (3/4” – 1”) thick
- Attached to the 2nd and 3rd portions of duodenum on the right
- Merges into neck on the left
- SPDA (Superior Pancreatoduodenal Artery) and IPDA (Inferior Pancreatoduodenal Artery) anastomose between the duodenum and the right lateral border


GALLBLADDER
SPLEEN
PANCREATIC DUCT
RIGHT AND LEFT HEPATIC DUCT OF LIVER
COMMON HEPATIC DUCT
COMMON BILE DUCT
TAIL
BODY
NECK
CYSTIC DUCT
DUODENUM
ACCESSORY PANCREATIC DUCT
HEAD
PANCREAS
MINOR DUODENAL PAPILLA
UNCINATE PROCESS
MAJOR DUODENAL PAPILLA
JEJUNUM


Portal vein
Aortic hiatus
Pancreas
Superior mesenteric vein
Superior pancreaticoduodenal artery
Posterior superior pancreaticoduodenal artery
Splenic vein
Inferior pancreaticoduodenal artery
Duodenum
Pancreas
Jejunal arteries
Anterior inferior pancreaticoduodenal artery
Middle colic artery

Neck of Pancreas

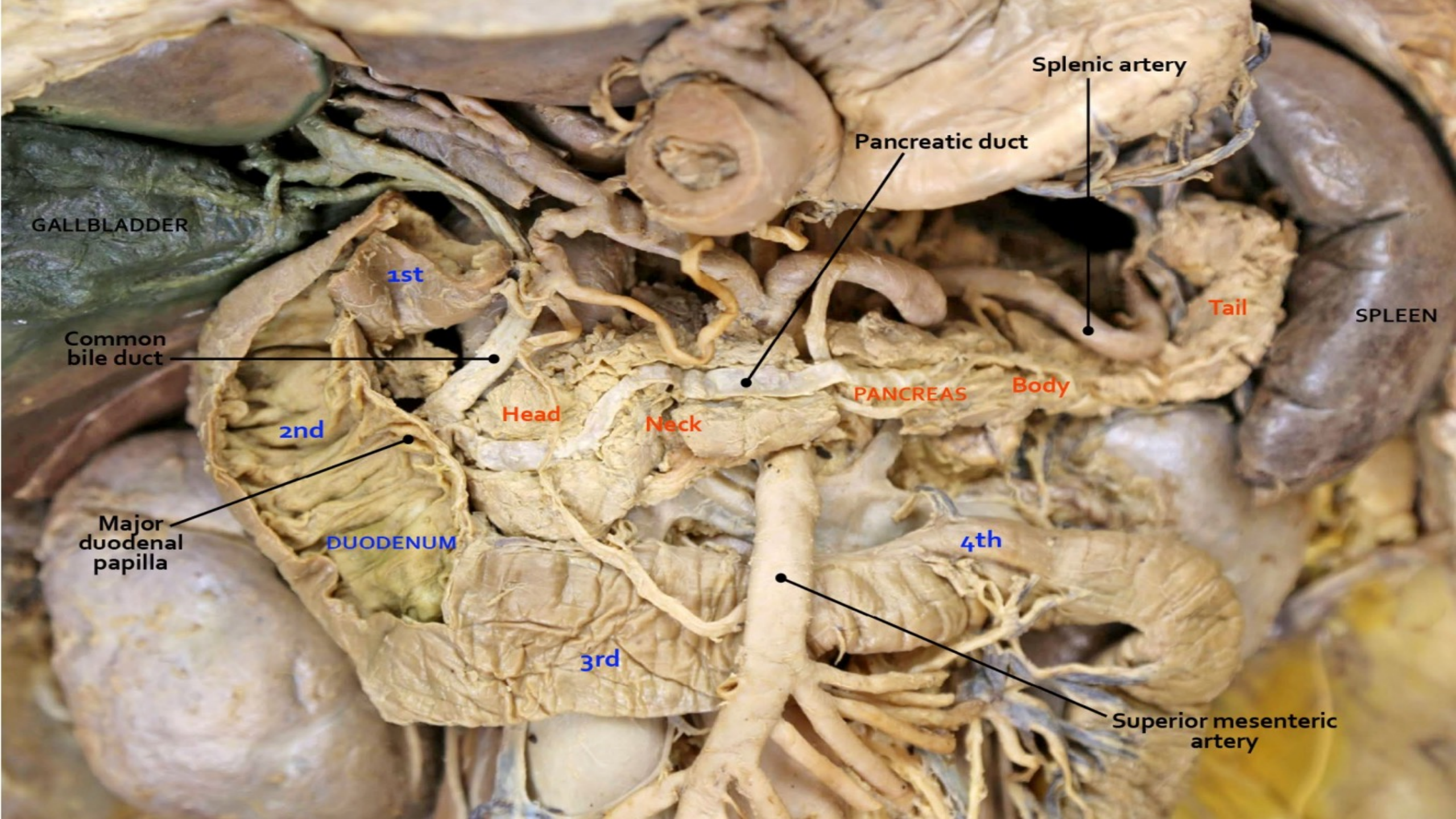
- 2.5 cm (1”) in length
- Straddles SMV (superior mesenteric vein) and PV (portal vein)
- Superior border relates to the pylorus
- Superior mesenteric vessels emerge from the inferior border
- Posteriorly, SMV and splenic vein confluence to form portal vein

Body of Pancreas

- Elongated, long structure
- Passes over the aorta and L2 vertebra, continuing just above the transpyloric plane posterior to the omental bursa.
- Anterior surface, separated from stomach by lesser sac
- Posterior surface, related to aorta, Left adrenal gland, Left renal vessels and upper 1/3rd of Left kidney
- Splenic vein runs embedded in the posterior surface closer to the superior border
- Inferior surface is covered by transverse mesocolon

Tail of Pancreas

- Narrow, short segment
- Lies at the level of the 12th thoracic vertebra
- Ends within the splenic hilum
- Lies in the splenophrenic ligament
- Anteriorly, related to splenic flexure of colon
- May be injured during splenectomy (fistula)


Splenic artery
Pancreatic duct
GALLBLADDER
1st
Tail
SPLEEN
Common bile duct
PANCREAS
Body
Head
Neck
2nd
Major duodenal papilla
DUODENUM
4th
3rd
Superior mesenteric artery

Anterior Relations

- Narrow, short segment
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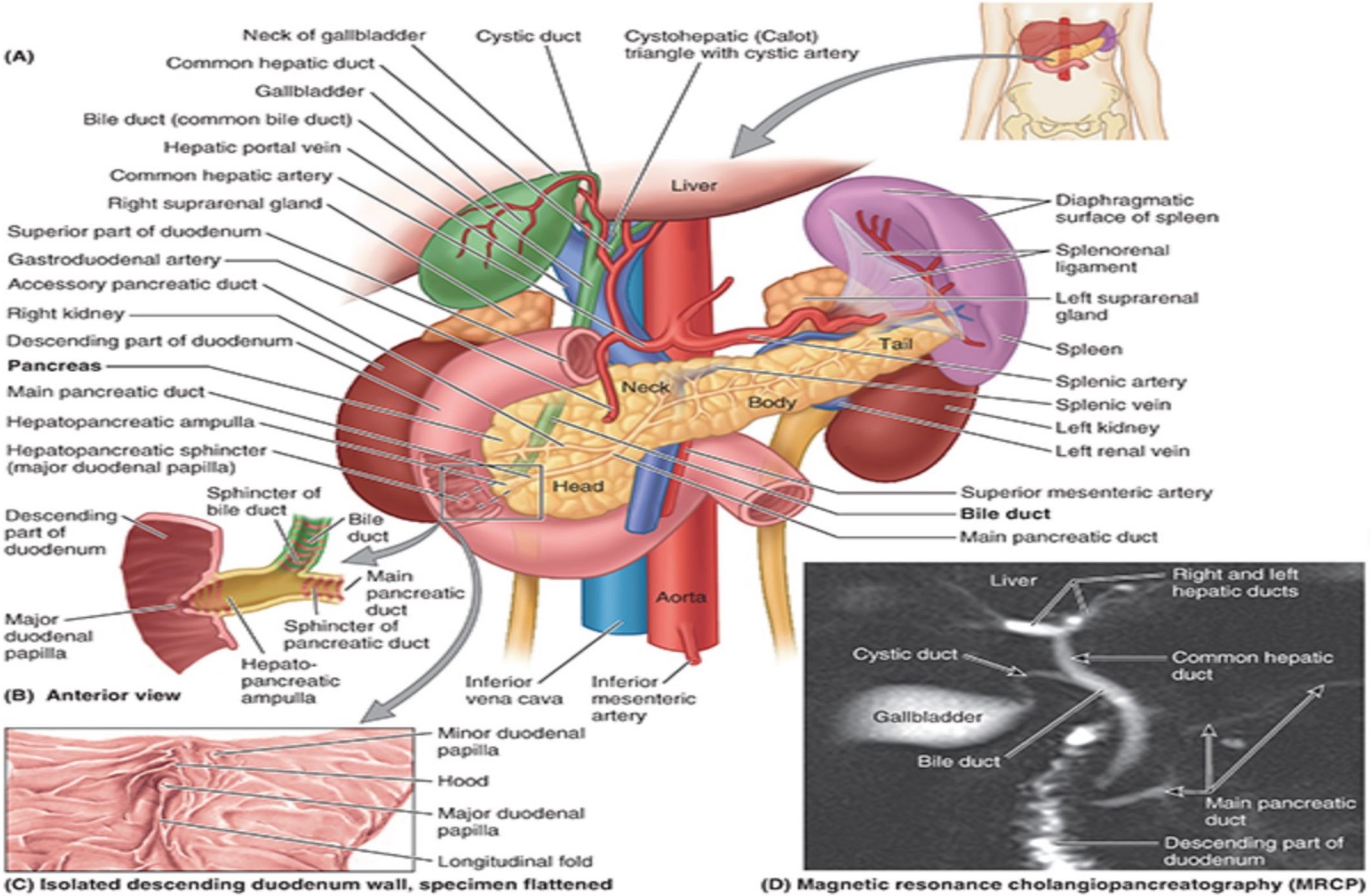

(A)
Neck of gallbladder
Cystic duct
Cystohepatic (Calot) triangle with cystic artery
Common hepatic duct
Gallbladder
Bile duct (common bile duct)
Hepatic portal vein
Common hepatic artery
Right suprarenal gland
Superior part of duodenum
Gastroduodenal artery
Accessory pancreatic duct
Right kidney
Descending part of duodenum
Pancreas
Main pancreatic duct
Hepatopancreatic ampulla
Hepatopancreatic sphincter (major duodenal papilla)
Liver
Diaphragmatic surface of spleen
Splenorenal ligament
Left suprarenal gland
Spleen
Splenic artery
Splenic vein
Left kidney
Left renal vein
Tail
Neck
Body
Head
Superior mesenteric artery
Bile duct
Main pancreatic duct
Aorta
Inferior vena cava
Inferior mesenteric artery
Sphincter of bile duct
Descending part of duodenum
Bile duct
Main pancreatic duct
Sphincter of pancreatic duct
Major duodenal papilla
Hepato-pancreatic ampulla
(B) Anterior view
Minor duodenal papilla
Hood
Major duodenal papilla
Longitudinal fold
(C) Isolated descending duodenum wall, specimen flattened
Liver
Right and left hepatic ducts
Cystic duct
Common hepatic duct
Gallbladder
Bile duct
Main pancreatic duct
Descending part of duodenum
(D) Magnetic resonance cholangiopancreatography (MRCP)

Arterial Supply of Pancreas

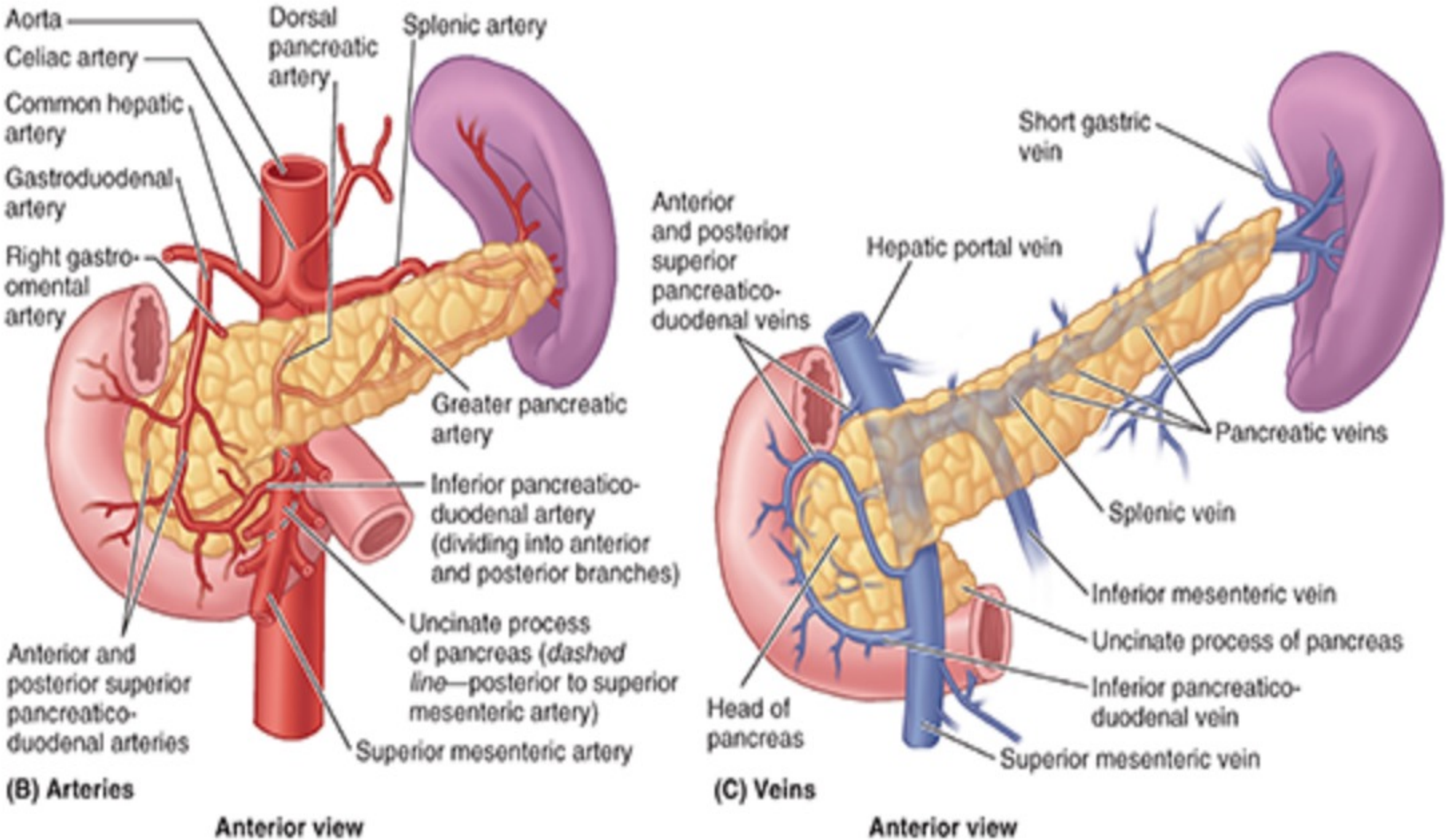
- Variety of major arterial sources (Celiac, Superior Mesenteric Artery and Splenic)
- Celiac → Common Hepatic Artery → Gastroduodenal Artery → Superior pancreaticoduodenal artery which divides into anterior and posterior branches
- SMA → Inferior pancreaticoduodenal artery which divides into anterior and posterior branches

Arterial Supply of Pancreas

- Body and tail supplied by splenic artery by about 10 branches
- Three big branches from splenic are
  - Dorsal pancreatic artery
  - Pancreatica Magna (midportion of body)
  - Caudal pancreatic artery (tail)

Venous Drainage of Pancreas

- Follows arterial supply
- Anterior and posterior arcades drain head and
- the body
- Splenic vein drains the body and tail
- Ultimately, into portal vein


Aorta
Celiac artery
Common hepatic artery
Gastroduodenal artery
Right gastro-omental artery
Dorsal pancreatic artery
Splenic artery
Greater pancreatic artery
Inferior pancreatico-duodenal artery (dividing into anterior and posterior branches)
Uncinate process of pancreas (dashed line—posterior to superior mesenteric artery)
Anterior and posterior superior pancreatico-duodenal arteries
Superior mesenteric artery
(B) Arteries
Anterior view
Short gastric vein
Anterior and posterior superior pancreatico-duodenal veins
Hepatic portal vein
Pancreatic veins
Splenic vein
Inferior mesenteric vein
Uncinate process of pancreas
Inferior pancreatico-duodenal vein
Head of pancreas
Superior mesenteric vein
(C) Veins
Anterior view

Lymphatic Drainage of Pancreas

- Rich periacinar network that drain into 5 nodal groups
- – Superior nodes
  – Anterior nodes
  – Inferior nodes
  – Posterior PD nodes
  – Splenic nodes

  Ultimately drain into Celiac and Superior mesenteric Lymph nodes

Innervation of Pancreas

- Sympathetic fibers from the splanchnic nerves
- Parasympathetic fibers from the vagus
- Both give rise to intrapancreatic periacinar plexuses
- Parasympathetic fibers stimulate both exocrine and endocrine secretion
- Sympathetic fibers have a predominantly inhibitory effect

Innervation of Pancreas

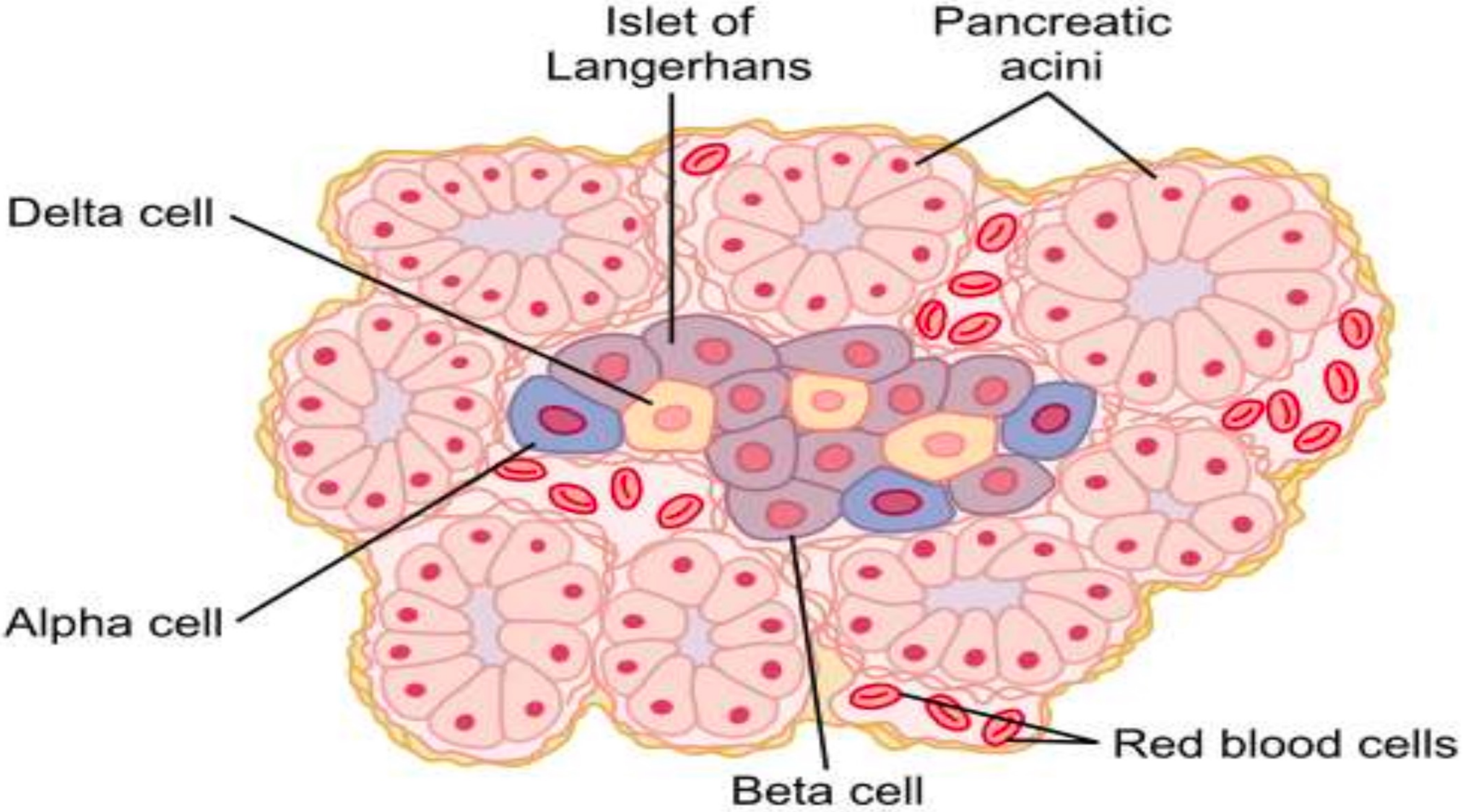
- Rich afferent sensory fiber network
- Ganglionectomy or celiac ganglion blockade interrupt these somatic fibers (pancreatic pain)
- However, the origin of pancreatic pain is difficult to explain anatomically

Functional Anatomy

- Complex lobulated organ
- Distinct exocrine & endocrine components
- Exocrine - 90 to 95% of pancreas.
  - Exocrine - about 1 million acinar cells & a series of ductules & ducts
- Endocrine - 1 to 2%
  - Endocrine - about 1million clusters of cells- islets of Langerhans

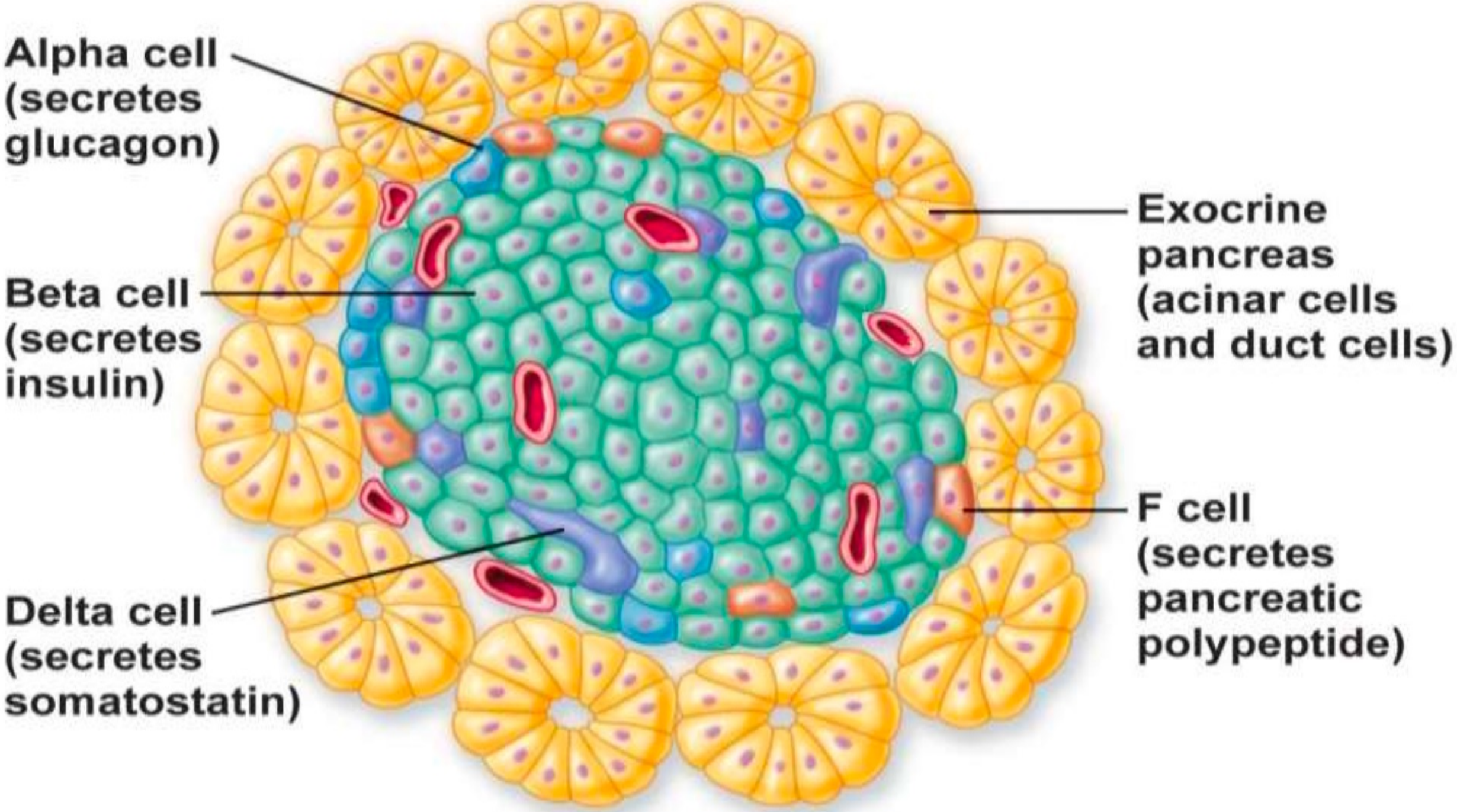
Functional Anatomy of Pancreas

- Two major pancreas tissues
  - Pancreatic acini cells
    - Secretes digestive enzymes into the duodenum
  - Islets of Langerhans
    - Secretes Insulin and Glucagon into blood
    - 1 - 2 million islets are arranged around capillaries to secrete into the blood
      - Each islet contains approximately 3000 cells and ranging in diameter from 40 μm to 1 mm.

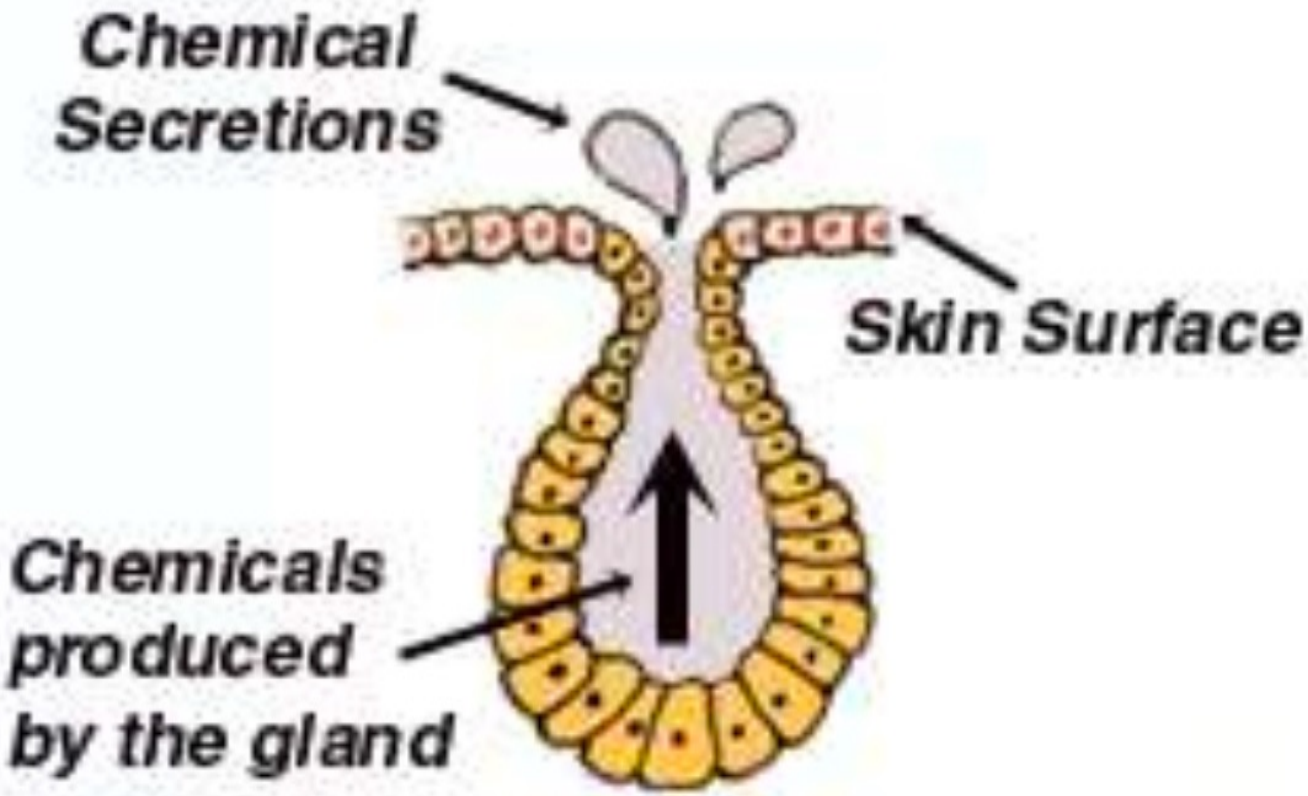

Islet of Langerhans
Pancreatic acini
Delta cell
Alpha cell
Beta cell
Red blood cells

Islets of Langerhans

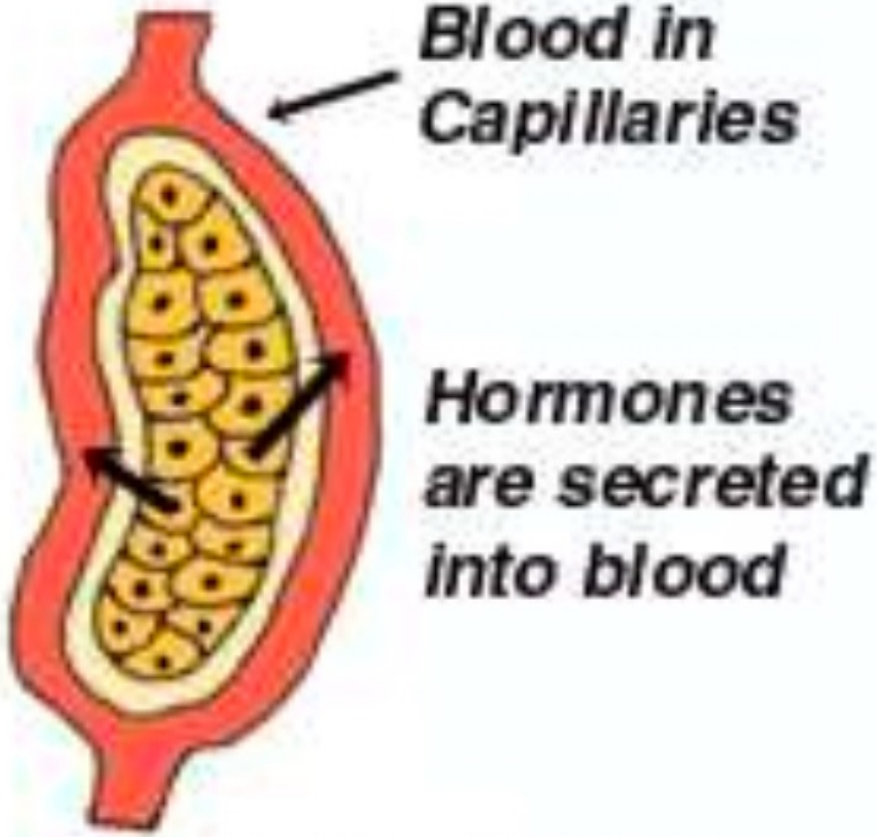
- Contains four types of cells:
  - Alpha cells secrete glucagon - about 25%
  - Beta cells secrete insulin and amyline - about 60%
    - Located in the middle of the islets
  - Delta cells secrete somatostatin - about 10%
  - Another cell, the PP or F cells, is present in small amounts in the islets and secretes pancreatic polypeptide


Alpha cell (secretes glucagon)
Beta cell (secretes insulin)
Delta cell (secretes somatostatin)
Exocrine pancreas (acinar cells and duct cells)
F cell (secretes pancreatic polypeptide)

Difference Between Exocrine & Endocrine Glands



Exocrene Gland



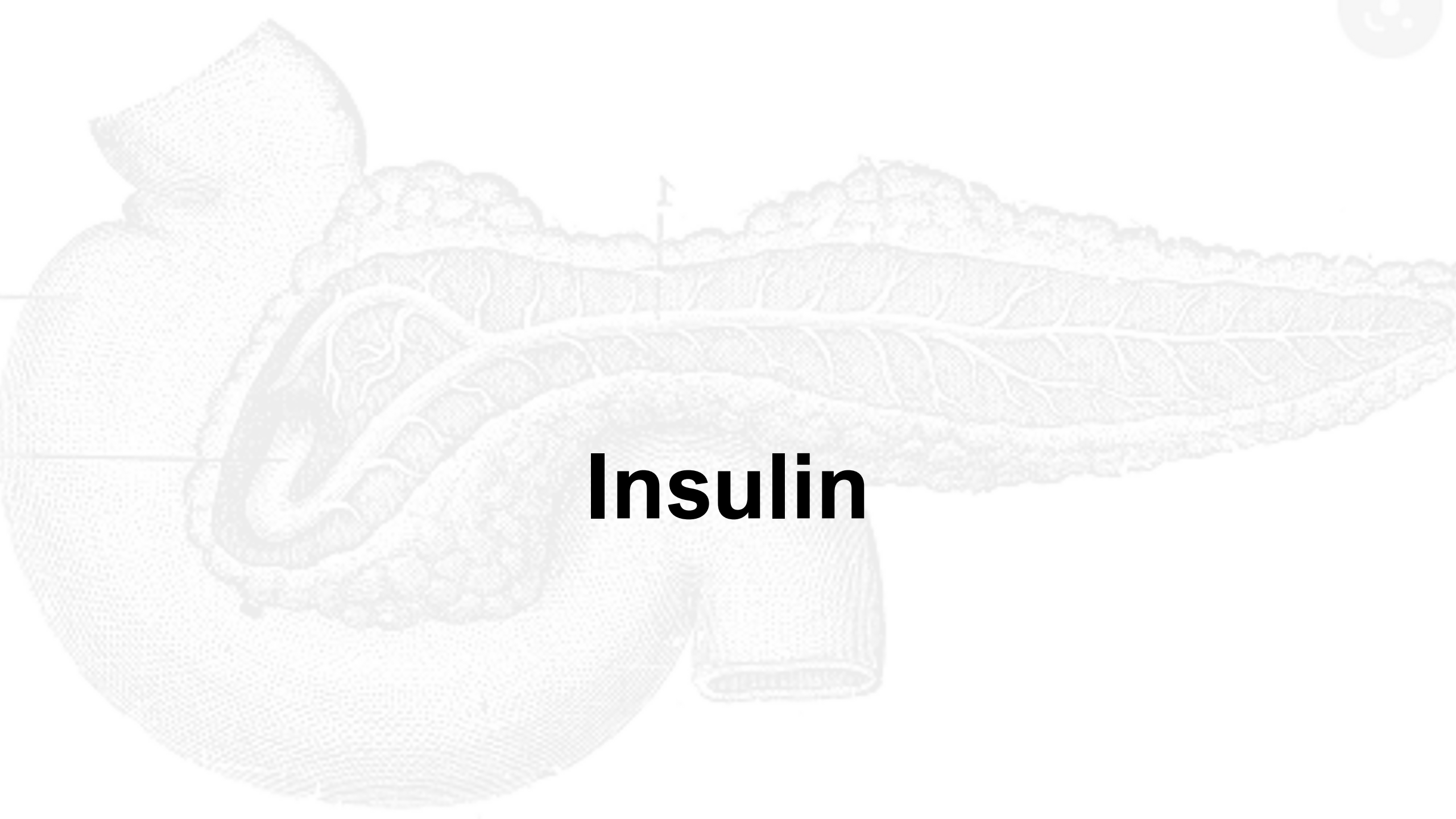
Endocrine Gland

Exocrine Glands

- Secrete their essential product by way of a duct to some environment external to itself, either inside the body or on a surface of the body.
- Examples
  - Salivary Glands
  - Tear Glands
  - Anal Glands
  - Stomach Pit

Endocrine Glands

- Secrete their products, hormones, directly into the blood rather than through a duct.
- Examples
  - Pituitary Gland
  - Pineal Gland
  - Thyroid Gland
  - Adrenal Gland
  - Pancreas
  - Testes & Ovary, etc,.



Insulin

Insulin and its metabolic effects

- Insulin was first isolated from the pancreas in 1922 by Banting and Best
- Associated with “blood sugar”
- Insulin has effects on carbohydrate metabolism
- Insulin affects fat and protein metabolism

Insulin is a hormone associated with energy abundance

- When there is great abundance of energy-giving foods in the diet, especially excess amounts of carbohydrates, insulin is secreted in great quantity.
- Insulin plays an important role in storing the excess energy.
- In the case of excess carbohydrates, it causes them to be stored as glycogen mainly in the liver and muscles.

Insulin is a hormone associated with energy abundance

- Excess carbohydrates is also converted under the stimulus of insulin into fats and stored in the adipose tissue.
- Insulin has a direct effect in promoting amino acid uptake by cells and conversion of these amino acids into protein.
- In addition, it inhibits the breakdown of the proteins that are already in the cells.

Effect of Insulin on Carbohydrate Metabolism

- Immediately after a high-carbohydrate meal is consumed, glucose that is absorbed into the blood causes rapid secretion of insulin.
- Insulin Promotes Muscle Glucose Uptake and Metabolism
  - During much of the day, muscle tissue depends not on glucose but on fatty acids for its energy.

Storage of Glycogen in Muscle

- If the muscles are not exercised after a meal and yet glucose is transported into the muscle cells in abundance, most of the glucose is stored in the form of muscle glycogen, up to a limit of 2 to 3 percent concentration.
- The glycogen can be used by the muscle later for energy.
- Glycogen is especially useful for short periods of extreme energy by the muscles

Insulin Promotes Liver Uptake, Storage, and Use of Glucose

- One of the most important of all the effects of insulin is to cause most of the glucose absorbed after a meal to be rapidly stored in the liver in the form of glycogen.
- Between meals, when food is not available and the blood glucose concentration begins to fall, insulin secretion decreases rapidly and the liver glycogen is split back into glucose, which is released back into the blood to keep the glucose concentration from falling too low.

Glucose Is Released From the Liver Between Meals

- When the blood glucose level begins to fall to a low level between meals, several events transpire that cause the liver to release glucose back into the circulating blood:
  - The decreasing blood glucose causes the pancreas to decrease its insulin secretion.
  - The lack of insulin then reverses all the effects listed earlier for glycogen storage.
  - The lack of insulin activates an enzyme which causes the splitting of glycogen into glucose phosphate.

- The enzyme glucose phosphatase now becomes activated by the lack of insulin and causes the phosphate radical to split away from the glucose, allowing the free glucose to diffuse back into the blood.
- The liver removes glucose from the blood when it is present in excess after a meal and returns it to the blood when the blood glucose concentration falls between meals.
- Ordinarily, about 60 percent of the glucose in the meal is stored in this way in the liver and then returned later.

Lack of Effect of Insulin on Glucose Uptake and Usage by the Brain

- The brain is quite different from most other tissues of the body in that insulin has little effect on uptake or use of glucose.
- Most of the brain cells are permeable to glucose and can use glucose without the intermediation of insulin.
- The brain cells are also quite different from most other cells of the body in that they normally use only glucose for energy.

- It is essential that the blood glucose level always be maintained above a critical level, which is one of the most important functions of the blood glucose control system.
- When the blood glucose level falls too low, into the range of 20 to 50 mg/100 ml, symptoms of hypoglycemic shock develop, characterized by progressive nervous irritability that leads to fainting, seizures, and even coma.

Insulin on Carbohydrate Metabolism in Other Cells

- Insulin increases glucose transport into and glucose usage by most other cells of the body in the same way that it affects glucose transport and usage in muscle cells.

Effect Of Insulin On Fat Metabolism

- Although not quite as visible as the acute effects of insulin on carbohydrate metabolism, the effects of insulin on fat metabolism are, in the long run, equally important.
- Especially dramatic is the long-term effect of insulin deficiency in causing extreme atherosclerosis, often leading to heart attacks, cerebral strokes, and other vascular accidents.

Effect of Insulin on Fat Metabolism

Insulin Promotes Fat Synthesis and Storage

- Insulin has several effects that lead to fat storage in adipose tissue.
- Insulin increases the utilization of glucose by body
- Insulin promotes fatty acid synthesis, in liver cells
- Fatty acids are then transported from the liver by way of the blood lipoproteins to the adipose cells to be stored

Role of Insulin in Storage of Fat in the Adipose Cells

- Insulin has two other essential effects that are required for fat storage in adipose cells:
  - Insulin inhibits the action of hormone-sensitive lipase.
    - Lipase is the enzyme that causes the hydrolysis of triglycerides already stored in fat cells.
    - Therefore, release of fatty acids from the adipose tissue into the circulating blood is inhibited.
  - Insulin promotes glucose transport through the cell membrane into fat cells in the same way that it promotes glucose transport into muscle cells.

Insulin Deficiency Increases Use of Fat for Energy

- All aspects of fat breakdown and use for providing energy are greatly enhanced in the absence of insulin.
- This occurs even normally between meals when secretion of insulin is minimal, but it becomes extreme in diabetes mellitus .
- Insulin Deficiency Causes Lipolysis of Storage Fat and Release of Free Fatty Acids.

Insulin Deficiency Increases Plasma Cholesterol and Phospholipid Concentrations

- The excess of fatty acids in the plasma associated with insulin deficiency also promotes conversion by the liver of some of the fatty acids into phospholipids and cholesterol.
- This high lipid concentration (especially the high concentration of cholesterol) promotes the development of atherosclerosis in people with severe diabetes.

Insulin Promotes Protein Synthesis and Storage

- Proteins, carbohydrates, and fats are stored in the tissues during the few hours after a meal.
- When excess quantities of nutrients are available in the circulating blood; insulin is required for this storage to occur.
- Insulin stimulates transport of many of the amino acids into the cells.

- Insulin inhibits catabolism of proteins, thus decreasing the rate of amino acid release from the cells, especially from muscle cells.
- In the liver, insulin depresses the rate of gluconeo-genesis by decreasing activity of the enzymes that promote gluconeogenesis.
- In summary, insulin promotes formation of protein and prevents degradation of proteins.

Insulin and Growth Hormone Interact Synergistically to Promote Growth

- Because insulin is required for the synthesis of proteins, it is as essential for growth of an animal as growth hormone is.
- A combination of these hormones causes dramatic growth.
- Thus, it appears that the two hormones function synergistically to promote growth each performing a specific function that is separate from that of the other.

Factors and Conditions That Increase Insulin Secretion

- Increased blood glucose
- Increased blood free fatty acids
- Increased blood amino acids
- Gastrointestinal hormones (gastrin, cholecystokinin, secretin, gastric inhibitory peptide)
- Glucagon, growth hormone, cortisol
- Parasympathetic stimulation; acetylcholine
- β-Adrenergic stimulation
- Insulin resistance; obesity
- Sulfonylurea drugs (glyburide, tolbutamide)

Factors and Conditions That Decrease Insulin Secretion

- Decreased blood glucose
- Fasting
- Somatostatin
- α-Adrenergic activity
- Leptin

Mechanism of Glucagon Action

- Main target tissues: liver, muscle, and adipose tissue
- Glucagon prevents hypoglycemia by increasing cell production of glucose
- Liver is primary target to maintain blood glucose levels
  - Gluconeogenesis
  - Glycogenolysis

- Glucagon is also called hyperglycemic hormone
- Glucagon promotes hyperglycemia
- Greatly enhance the availability of glucose to the organs of the body
- Glucagon stimulates glycogenolysis:
  - Glucagon has immediate and pronounced effects on the liver to increase glycogenolysis and the release of glucose into the blood.
  - This effect is achieved through activation of liver phosphorylase and simultaneous inhibition of glycogen synthase.

- Glucagon stimulates gluconeogenesis:
  - Glucagon increases the hepatic extraction of amino acids from the plasma and increases the activities of key gluconeogenic enzymes.
  - Consequently, glucagon has delayed actions to promote glucose output by the liver.

Other Effects of Glucagon

- Occurs only when its concentration rises well above the maximum normally found in the blood.
- Activates adipose cell lipase, making increased quantities of fatty acids available to the energy systems of the body.
- Glucagon also inhibits the storage of triglycerides in the liver, which prevents the liver from removing fatty acids from the blood.
- Enhances the strength of the heart
- Increases blood flow in some tissues, especially the kidneys
- Enhances bile secretion
- Inhibits gastric acid secretion.

Regulation of Glucagon Secretion

- Increased Blood Glucose Inhibits Glucagon Secretion
- Increased Blood Amino Acids Stimulate Glucagon Secretion
- Exercise Stimulates Glucagon Secretion
- Somatostatin Inhibits Glucagon and Insulin Secretion

Somatostatin Inhibits Glucagon and Insulin Secretion

- The delta cells of the islets of Langerhans secrete the hormone somatostatin.
- It has an extremely short half-life of only 3 minutes in the circulating blood.
- Almost all factors related to the ingestion of food stimulate somatostatin secretion.
  - These factors include
    (1) increased blood glucose
    (2) increased amino acids
    (3) increased fatty acids
    (4) increased concentrations of several of the gastrointestinal hormones released from the upper gastrointestinal tract in response to food intake.

- In turn, somatostatin has multiple inhibitory effects, as follows:
  - Somatostatin acts locally within the islets of Langerhans themselves to depress secretion of both insulin and glucagon.
  - Somatostatin decreases motility of the stomach, duodenum, and gallbladder.
  - Somatostatin decreases both secretion and absorption in the gastrointestinal tract.

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