

THE PANCREAS: A DUAL-ROLE ORGAN IN HUMAN PHYSIOLOGY

A Review of Structure and Function

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Abstract

The pancreas is an indispensable retroperitoneal organ with a unique dual functionality, acting as both an exocrine and an endocrine gland. This comprehensive review synthesizes current knowledge on the macroscopic and microscopic anatomy of the pancreas, correlating its intricate structure with its vital physiological roles in digestion and metabolism. Macroscopically, the gland is divided into the head, neck, body, and tail, with a complex ductal system for exocrine secretion. Microscopically, the organ is a heterocrine gland composed of two distinct components: the exocrine acini and the endocrine Islets of Langerhans. The exocrine tissue produces and secretes potent digestive enzymes—including amylase, lipase, and proteases—critical for the breakdown of carbohydrates, fats, and proteins in the small intestine. The endocrine tissue, though constituting only 1-2% of the total mass, is a metabolic powerhouse, primarily secreting insulin (from β cells) and glucagon (from α cells) to precisely regulate blood glucose homeostasis. Dysfunctions in either the exocrine or endocrine compartments, such as in pancreatitis or diabetes mellitus, underscore the essential nature of the pancreas and its delicate structural-functional balance. Continued research into the cellular and molecular mechanisms of the

pancreas remains crucial for developing advanced therapeutic strategies for pancreatic diseases.

Keywords: Pancreas, Exocrine Function, Endocrine Function, Islets of Langerhans, Insulin, Glucagon, Acinar Cells, Histology, Metabolism, Digestion.

1. Introduction

The pancreas (from Greek: pan-, all, and kreas, flesh) is an elongated, flattened organ situated deep within the upper abdomen, predominantly located retroperitoneally, lying transversely across the posterior abdominal wall at the level of the first and second lumbar vertebrae [2.2, 2.3, 2.9]. Despite its relatively small size—typically measuring 12-20 cm in length in adults—it is an organ of paramount physiological importance [2.2]. Its classification as a heterocrine gland highlights its distinct dual role, simultaneously governing two primary biological processes: exocrine secretion for external digestion and endocrine secretion for internal metabolic regulation [2.2, 2.8].

Understanding the intricate relationship between the pancreatic structure and its diverse functions is fundamental to comprehending human metabolism and gastrointestinal health [2.7]. Disorders affecting the pancreas, such as acute and chronic pancreatitis, cystic fibrosis, and diabetes mellitus, are widespread and often life threatening, emphasizing the necessity of a detailed morphological and physiological review.

The objective of this article is to provide a comprehensive overview of the gross and microscopic structure of the human pancreas and to detail the vital exocrine and endocrine functions that collectively define its indispensable role in human physiology.

2. Macroscopic and Microscopic Structure

2.1. Gross Anatomy and Location

The pancreas is an elongated organ often described as having a tadpole-like or “flat leaf” shape [2.1, 2.7, 2.9]. It is anatomically divided into four main regions: the head, neck, body, and tail [2.3].

1. Head: The widest part, nestled within the C-shaped curve of the duodenum [2.3, 2.7]. It also includes the uncinate process, a hook-like projection that extends medially beneath the body [2.4].
2. Neck: A short, constricted region connecting the head and body.
3. Body: The central and largest part, lying behind the stomach and anterior to the aorta [2.3].
4. Tail: The thinnest part, extending toward and closely related to the splenic hilum [2.1, 2.3].

The exocrine secretions are collected by a complex ductal system. The main channel is the pancreatic duct (Duct of Wirsung), which runs the length of the gland, collecting fluid from lobules. This duct typically joins the common bile duct to form the hepatopancreatic ampulla (of Vater), which empties into the duodenum at the major duodenal papilla [2.4]. An accessory duct, the Duct of Santorini, may also be present.

2.2. Microscopic Histology: The Dual Parenchyma

The histological architecture of the pancreas is uniquely adapted to its dual function, consisting of two structurally and functionally distinct tissue types:

2.2.1. The Exocrine Pancreas

Constituting approximately 80-85% of the organ's mass, the exocrine pancreas is classified as a lobulated, serous, compound tubuloacinar gland [2.2, 2.8].

- Acinar Cells: These are the primary secretory cells, arranged in spherical clusters known as acini (or alveoli) [2.2]. Acinar cells are polarized epithelial cells, packed with rough endoplasmic reticulum (RER) for protein synthesis and large, dense zymogen granules containing inactive digestive enzyme precursors (zymogens) [2.8].

- Duct System: The initial parts of the ducts are lined by centroacinar cells, which reside within the acinus itself. These, along with cells in the intercalated ducts, secrete a bicarbonate-rich, iso-osmotic fluid that neutralizes the acidic chyme entering the duodenum from the stomach, creating the optimal pH for the digestive enzymes to act [2.8].

2.2.2. The Endocrine Pancreas

Embedded within the sea of exocrine tissue are 1-2 million clusters of cells, the Islets of Langerhans, which represent the endocrine portion [2.2]. Though relatively few in number, these highly vascularized cellular islands are crucial for systemic metabolism. The major cell types in the islets include:

- **Alpha Cells:** Secrete glucagon (~ 15-20% of islet cells), which raises blood glucose levels by promoting hepatic glycogenolysis and gluconeogenesis [2.3, 2.7, 2.10].
- **Beta Cells:** The most numerous (~ 70-80% of islet cells), they secrete insulin, the primary hormone that lowers blood glucose by facilitating its uptake by body cells [2.3, 2.7, 2.10].
- **Delta Cells:** Secrete somatostatin, which acts locally (paracrine) to inhibit the secretion of both insulin and glucagon, thereby modulating the overall islet activity [2.10].
- **PP (Pancreatic Polypeptide) Cells:** Secrete pancreatic polypeptide, which primarily regulates pancreatic exocrine secretion and gastrointestinal motility [2.10].

3. Physiological Functions

The pancreas performs its essential physiological roles through its distinct secretory mechanisms.

3.1. Exocrine Function: Digestion

The primary role of the exocrine pancreas is to produce and secrete pancreatic juice, which is indispensable for the chemical digestion of food in the small intestine [2.1, 2.8]. Approximately 1.0-4.0 liters of pancreatic juice are secreted daily, primarily in response to the hormones secretin and cholecystokinin (CCK) released from the duodenal mucosa [2.1].

The main components of the exocrine secretion are:

- **Digestive Enzymes:** Synthesized and stored in the zymogen granules of acinar cells, these are secreted as inactive precursors (zymogens) to prevent autodigestion of the pancreas. Key enzymes include:
 - **Amylase:** Breaks down starches (carbohydrates) into smaller sugars [2.8].

- **Lipase:** Breaks down triglycerides (fats) into fatty acids and monoglycerides [2.8].

- **Proteases (Trypsinogen, Chymotrypsinogen):** After being activated in the duodenum by the enzyme enterokinase, they break down proteins into peptides and amino acids [2.2].

- **Bicarbonate (HCO_3):** Secreted by the ductal cells, this alkaline substance neutralizes the gastric acid, protecting the duodenal lining and establishing the optimal neutral pH required for the pancreatic enzymes to function [2.8].

3.2. Endocrine Function: Metabolic Regulation

The endocrine pancreas is the central coordinator of systemic energy metabolism, with its hormones controlling the flux of nutrients, particularly glucose, in and out of the bloodstream [2.5, 2.7].

- **Insulin:** Released in response to elevated blood glucose (e.g., after a meal), its primary action is to promote the uptake of glucose by target cells (muscle, fat, and liver) for storage as glycogen or use as energy, thus lowering blood sugar [2.1, 2.7]. It is the principal anabolic hormone.

- **Glucagon:** Released when blood glucose levels fall too low (e.g., during fasting), its primary action is on the liver, where it stimulates the breakdown of stored glycogen (glycogenolysis) and the synthesis of new glucose (gluconeogenesis), thus raising blood sugar [2.1, 2.7].

The dynamic and antagonistic interplay between insulin and glucagon, along with the modulatory effects of somatostatin, ensures that blood glucose concentrations are maintained within a very narrow, healthy range—a critical homeostatic process [2.7].

4. Clinical Significance and Conclusion

The intricate and synchronized operations of the pancreatic structure and function are vital. When this balance is disrupted, severe pathologies arise. For instance, the destruction of beta cells leads to Type 1 Diabetes Mellitus due to absolute insulin deficiency [2.10]. Conversely, inflammation of the exocrine tissue, or pancreatitis, often caused by gallstones

or alcohol abuse, results from the premature activation of digestive enzymes within the gland itself, leading to autodigestion and tissue damage [2.4].

In summary, the pancreas is a morphological and physiological masterpiece, with its specialized exocrine acini and dispersed endocrine islets allowing it to simultaneously manage two distinct and essential bodily functions: external digestion and internal metabolic control. The precise compartmentalization of these functions—with powerful digestive enzymes sequestered and transported via ducts, while metabolic hormones are released directly into the blood—is a testament to evolutionary efficiency. Continued research, particularly at the molecular and cellular level, is imperative to fully unravel the mechanisms governing pancreatic health and to develop more effective treatments for the debilitating and life-threatening conditions resulting from its dysfunction.

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