HSR (LONDON),
HOUGHTON STREET REVIEW JOURNAL
ISSN: 2058-5519|Impact factor-15.9
http://houghtonstreetreview.com/index.php/hsr

HISTOLOGICAL AND ULTRASTRUCTURAL FEATURES OF PANCREATIC ISLETS AND THEIR ROLE IN ENDOCRINE REGULATION

Kurbanova Nilufar
Department of Medical Biology and Histology, Andijan State Medical institute
doi:https://doi.org/10.5281/zenodo.23959657

Abstract: The pancreatic islets of Langerhans represent highly specialized endocrine microstructures responsible for maintaining glucose homeostasis and coordinating metabolic regulation. Their histological organization, cellular heterogeneity, vascular architecture, and ultrastructural characteristics are closely associated with the synthesis, storage, and secretion of pancreatic hormones. This article examines the histological and ultrastructural organization of pancreatic islets, emphasizing the morphological and functional characteristics of beta, alpha, delta, pancreatic polypeptide-producing, and epsilon cells. Particular attention is devoted to the relationship between endocrine cell distribution, secretory granules, mitochondrial activity, capillary networks, and intercellular communication. The study is designed as a narrative review using descriptive, comparative, and morphological-functional approaches. The analysis demonstrates that pancreatic endocrine regulation depends on the coordinated activity of structurally specialized cell populations and their interactions with vascular, neural, and extracellular matrix components. Alterations in islet architecture and cellular ultrastructure are also considered in relation to pancreatic endocrine dysfunction, particularly diabetes mellitus. Understanding these histological mechanisms is essential for interpreting normal endocrine physiology and the morphological basis of metabolic disorders.

Keywords: pancreatic islets, histology, ultrastructure, beta cells, alpha cells, insulin, glucagon, endocrine pancreas, secretory granules, glucose homeostasis.

Introduction

The pancreas is a multifunctional gland consisting of exocrine and endocrine components that differ in their structural organization and physiological functions. The exocrine portion occupies most of the pancreatic parenchyma and consists primarily of serous acini and a ductal system involved in digestive enzyme secretion. The endocrine component is represented predominantly by the pancreatic islets of Langerhans, which are distributed throughout the gland and participate in the hormonal regulation of carbohydrate, lipid, and protein metabolism.

Although pancreatic islets constitute only a small proportion of the total pancreatic tissue, their physiological importance is considerable. They contain several populations of endocrine cells that synthesize and release hormones directly into the circulation. Among these hormones, insulin and glucagon play central roles in maintaining blood glucose concentrations, while somatostatin and

HSR (LONDON),
HOUGHTON STREET REVIEW JOURNAL
ISSN: 2058-5519|Impact factor-15.9
http://houghtonstreetreview.com/index.php/hsr

pancreatic polypeptide contribute to the regulation of endocrine secretion and gastrointestinal functions.

The structural organization of pancreatic islets is closely related to their physiological activity. Endocrine cells are arranged in association with an extensive capillary network, allowing rapid detection of circulating nutrients and efficient delivery of secreted hormones into the bloodstream. The ultrastructural characteristics of these cells, including secretory granules, mitochondria, endoplasmic reticulum, and Golgi complexes, reflect their specialized secretory functions.

Recent developments in microscopy, immunohistochemistry, and three-dimensional tissue analysis have improved understanding of pancreatic islet architecture. These approaches have demonstrated that human islets possess complex cellular arrangements that cannot always be adequately represented by simplified models derived from rodents.

The relationship between pancreatic islet structure and function is particularly important in diabetes mellitus. Type 1 diabetes is characterized by immune-mediated destruction of pancreatic beta cells, whereas type 2 diabetes involves complex interactions between insulin resistance, beta-cell dysfunction, and changes in endocrine tissue organization.

The aim of this article is to examine the histological and ultrastructural characteristics of pancreatic islets and analyze their relationship with endocrine regulation under physiological and pathological conditions.

Materials and Methods

The present article was prepared as a narrative literature review focusing on the histological, ultrastructural, and functional organization of pancreatic islets. Scientific publications addressing human pancreatic morphology, endocrine cell composition, immunohistochemical characteristics, electron microscopy, and islet microcirculation were examined.

The methodological framework included descriptive histological analysis, comparative morphological interpretation, and functional correlation of cellular structures with endocrine activity. Particular emphasis was placed on studies employing hematoxylin and eosin staining, immunohistochemical identification of pancreatic hormones, fluorescence microscopy, and transmission electron microscopy.

Comparative analysis was used to distinguish characteristic features of human pancreatic islets from those described in experimental animals. The relationship between endocrine cell ultrastructure and hormonal secretion was evaluated using established findings from cellular physiology and pancreatic histology.

No original human tissue samples, experimental animals, histological preparations, or laboratory measurements were used in this article. Consequently, the Results section presents a structured synthesis of previously published morphological findings rather than original experimental observations.

HSR (LONDON),
HOUGHTON STREET REVIEW JOURNAL
ISSN: 2058-5519|Impact factor-15.9
http://houghtonstreetreview.com/index.php/hsr

Results

General histological organization of pancreatic islets

The pancreatic islets of Langerhans are microscopic endocrine cell aggregates embedded within the exocrine pancreatic parenchyma. In routine hematoxylin and eosin preparations, islets usually appear as relatively pale-staining cellular regions surrounded by darker exocrine acini. Their cells are commonly arranged in irregular cords or clusters separated by a network of capillaries and delicate connective tissue components.

Human pancreatic islets vary considerably in size, shape, cellular composition, and spatial organization. A comprehensive review in Endocrine Reviews describes human islets as highly vascularized multicellular structures containing endocrine cells together with endothelial cells, pericytes, neural elements, resident immune cells, and stromal components. This organization supports rapid communication between circulating nutrients and hormone-producing cells.

Oxford Academic+1

The endocrine cells of pancreatic islets are not uniformly distributed. Earlier descriptions frequently emphasized a central beta-cell population surrounded by alpha and delta cells. However, studies of human pancreatic tissue demonstrate a more complex organization, particularly in larger islets, where different endocrine cell populations may be closely associated with penetrating capillaries.

Bosco and colleagues demonstrated that small human islets may retain a recognizable central beta-cell arrangement, whereas larger islets exhibit a more elaborate architecture involving folded cellular plates and extensive vascular relationships. These findings suggest that endocrine cell distribution is related to islet size and internal vascular organization.

PubMed

Cellular composition and histological characteristics

Pancreatic islets contain several specialized endocrine cell populations distinguished by their hormonal products, cytoplasmic characteristics, and ultrastructural features.

Endocrine cell	Principal hormone	Main physiological function
Beta cells (β)	Insulin	Promotes glucose utilization and storage
Alpha cells (α)	Glucagon	Supports hepatic glucose production
Delta cells (δ)	Somatostatin	Inhibits local endocrine secretion
PP/gamma cells (γ)	Pancreatic polypeptide	Modulates pancreatic and gastrointestinal functions
Epsilon cells (ε)	Ghrelin	Participates in metabolic and endocrine signaling

HSR (LONDON),
HOUGHTON STREET REVIEW JOURNAL
ISSN: 2058-5519|Impact factor-15.9
http://houghtonstreetreview.com/index.php/hsr

Beta cells constitute the predominant endocrine population in most human pancreatic islets, although their relative proportion varies considerably among individuals and anatomical regions. Alpha cells represent another major population, while delta, PP, and epsilon cells are less abundant. These differences should be interpreted with caution because reported percentages depend on tissue sampling and the methods used to count or measure cells.

PMC

Ultrastructural characteristics of pancreatic beta cells

Beta cells are specialized for the synthesis, processing, storage, and regulated secretion of insulin. Their cytoplasm contains rough endoplasmic reticulum, a developed Golgi apparatus, mitochondria, and numerous membrane-bound secretory granules.

The rough endoplasmic reticulum participates in the synthesis of preproinsulin, which undergoes intracellular processing to form proinsulin. Subsequent processing within the secretory pathway produces insulin and C-peptide.

Transmission electron microscopy reveals characteristic insulin-containing granules, many of which possess a dense central core surrounded by a relatively electron-lucent halo. This appearance reflects the organization of stored insulin within the granule.

Mitochondria are particularly important in beta-cell physiology because glucose-stimulated insulin secretion depends on metabolic signaling. Increased glucose metabolism alters the intracellular ATP-to-ADP ratio, initiating electrical and calcium-dependent mechanisms that promote insulin granule exocytosis.

Recent ultrastructural research has emphasized that electron microscopy remains valuable for investigating secretory granule maturation, organelle organization, and structural alterations associated with beta-cell dysfunction.

Springer Nature Link

Histological and ultrastructural features of alpha cells

Alpha cells synthesize and secrete glucagon, a peptide hormone that plays an important role in maintaining glucose availability during fasting and hypoglycemia.

At the ultrastructural level, alpha cells contain membrane-bound secretory granules with relatively homogeneous electron-dense cores. Their secretory apparatus includes rough endoplasmic reticulum, Golgi complexes, and mitochondria, reflecting the requirements of peptide hormone synthesis and secretion.

Glucagon acts primarily on the liver, stimulating glycogenolysis and supporting gluconeogenesis. Its secretion is influenced by glucose availability, amino acids, autonomic signaling, and local interactions with other pancreatic endocrine cells.

The close anatomical relationship between alpha and beta cells facilitates intra-islet communication. Insulin and other locally released substances may influence alpha-cell activity, while glucagon can contribute to the regulation of beta-cell function.

HSR (LONDON),
HOUGHTON STREET REVIEW JOURNAL
ISSN: 2058-5519|Impact factor-15.9
http://houghtonstreetreview.com/index.php/hsr

Delta cells and paracrine regulation

Delta cells secrete somatostatin, which serves as an important local regulator of pancreatic endocrine activity. These cells are less abundant than beta and alpha cells but possess significant functional importance.

Histologically, delta cells may exhibit elongated cellular processes extending toward neighboring endocrine cells. Their secretory granules differ from those of beta and alpha cells in size and electron density.

Somatostatin acts through specific receptors to suppress insulin and glucagon secretion, contributing to the fine regulation of intra-islet hormonal activity.

The anatomical distribution of delta cells and their close relationship with capillaries and neighboring endocrine populations support their role in local paracrine communication.

Oxford Academic

Microvascular organization of pancreatic islets

Pancreatic islets possess a rich capillary network that supports the rapid exchange of nutrients, signaling molecules, and hormones. Islet capillaries are characterized by specialized endothelial structures that facilitate communication between circulating blood and endocrine cells.

The close association between endocrine cells and capillaries is essential for efficient hormonal regulation. Glucose and other circulating nutrients must reach endocrine cells, while secreted hormones must enter the circulation rapidly to produce systemic metabolic effects.

The extracellular matrix surrounding capillaries also contributes to the structural stability and functional organization of pancreatic islets. Interactions between endocrine cells, endothelial cells, and extracellular matrix proteins influence cell survival, differentiation, and secretory activity.

These relationships demonstrate that pancreatic islets should be regarded as integrated microorgans rather than simple collections of hormone-producing cells.

Histological alterations in diabetes mellitus

Structural abnormalities of pancreatic islets are closely associated with endocrine dysfunction.

In type 1 diabetes mellitus, autoimmune destruction of pancreatic beta cells leads to severe insulin deficiency. Histological findings may include inflammatory infiltration of islets during active disease and substantial reduction of insulin-producing cells.

In type 2 diabetes mellitus, morphological changes are more heterogeneous. Beta-cell dysfunction, altered beta-cell mass, islet amyloid deposition, and disturbances in endocrine cell organization may be observed.

HSR (LONDON),
HOUGHTON STREET REVIEW JOURNAL
ISSN: 2058-5519|Impact factor-15.9
http://houghtonstreetreview.com/index.php/hsr

Islet amyloid is associated with the aggregation of islet amyloid polypeptide, also known as amylin, which is normally cosecreted with insulin. Its accumulation may contribute to beta-cell stress and dysfunction.

Nevertheless, pancreatic histological findings vary according to disease duration, metabolic conditions, individual characteristics, and the methods used to examine tissue.

These observations emphasize the importance of interpreting morphological changes together with physiological and clinical information.

Discussion

The reviewed evidence demonstrates that pancreatic endocrine regulation is closely related to the structural specialization of islet cells and their organization within a highly vascularized microenvironment.

Beta-cell secretory granules, mitochondria, and intracellular membrane systems provide the morphological foundation for regulated insulin production and release. Alpha-cell secretory structures support glucagon synthesis and secretion, while delta cells contribute to local hormonal coordination through somatostatin.

One of the important findings of contemporary histological research is that human pancreatic islets exhibit substantial structural heterogeneity. Differences in cell distribution, islet size, and vascular architecture indicate that simplified descriptions based exclusively on experimental animals cannot fully represent human endocrine pancreatic organization.

Bonner-Weir and colleagues demonstrated that human islets possess organized cellular arrangements, although their composition and architecture vary considerably. This finding supports the importance of examining human tissue directly when investigating pancreatic endocrine morphology.

Sage Journals

The relationship between cellular ultrastructure and endocrine function also has clinical significance. Changes in mitochondrial integrity, endoplasmic reticulum function, secretory granule formation, and cellular interactions may accompany pancreatic endocrine dysfunction.

However, structural abnormalities do not always establish a direct causal relationship with metabolic disease. Histological findings should therefore be interpreted alongside molecular, biochemical, and clinical evidence.

The limitations of the present article include its narrative review design and the absence of original morphometric measurements. Future investigations combining immunohistochemistry, electron microscopy, three-dimensional imaging, and molecular analysis may provide a more comprehensive understanding of pancreatic islet organization in normal and pathological conditions.

Conclusion

The pancreatic islets of Langerhans represent structurally specialized endocrine microorgans that play a central role in maintaining metabolic homeostasis. Their functional activity depends on the

HSR (LONDON),
HOUGHTON STREET REVIEW JOURNAL
ISSN: 2058-5519|Impact factor-15.9
http://houghtonstreetreview.com/index.php/hsr

coordinated interaction of beta, alpha, delta, PP, and epsilon cells within a complex vascular and extracellular environment.

The ultrastructural organization of endocrine cells reflects their hormonal functions. Secretory granules, mitochondria, rough endoplasmic reticulum, and Golgi complexes participate in the synthesis, processing, and release of pancreatic hormones.

Human pancreatic islets exhibit considerable variation in cellular composition and spatial architecture, emphasizing the importance of species-specific histological investigation.

The morphological relationship between endocrine cells, capillaries, and local signaling mechanisms contributes to the precise regulation of insulin and glucagon secretion.

Understanding these histological and ultrastructural characteristics is essential for explaining the physiological mechanisms of endocrine pancreatic activity and the structural changes associated with diabetes mellitus.

Further studies integrating modern microscopic techniques with molecular and functional investigations may contribute to improved understanding of pancreatic endocrine disorders and the development of regenerative therapeutic strategies.

References

1. Brissova, M., Fowler, M. J., Nicholson, W. E., et al. (2005). Assessment of human pancreatic islet architecture and composition by laser scanning confocal microscopy. Journal of Histochemistry & Cytochemistry, 53(9), 1087–1097.
2. Cabrera, O., Berman, D. M., Kenyon, N. S., Ricordi, C., Berggren, P.-O., & Caicedo, A. (2006). The unique cytoarchitecture of human pancreatic islets has implications for islet cell function. Proceedings of the National Academy of Sciences, 103(7), 2334–2339.
3. Bosco, D., Armanet, M., Morel, P., et al. (2010). Unique arrangement of alpha- and beta-cells in human islets of Langerhans. Diabetes, 59(5), 1202–1210.
4. Bonner-Weir, S., Sullivan, B. A., & Weir, G. C. (2015). Human islet morphology revisited: Human and rodent islets are not so different after all. Journal of Histochemistry & Cytochemistry, 63(8), 604–612.
5. Röder, P. V., Wu, B., Liu, Y., & Han, W. (2016). Pancreatic regulation of glucose homeostasis. Experimental & Molecular Medicine, 48, e219.
6. Campbell, J. E., & Newgard, C. B. (2021). Mechanisms controlling pancreatic islet cell function in insulin secretion. Nature Reviews Molecular Cell Biology, 22, 142–158.
7. Hall, J. E., & Hall, M. E. (2021). Guyton and Hall Textbook of Medical Physiology (14th ed.). Elsevier.
8. Mescher, A. L. (2021). Junqueira's Basic Histology: Text and Atlas (16th ed.). McGraw Hill.
9. Ross, M. H., & Pawlina, W. (2020). Histology: A Text and Atlas (8th ed.). Wolters Kluwer.

HSR (LONDON),
HOUGHTON STREET REVIEW JOURNAL
ISSN: 2058-5519|Impact factor-15.9
http://houghtonstreetreview.com/index.php/hsr

10. Melmed, S., Auchus, R. J., Goldfine, A. B., Koenig, R. J., & Rosen, C. J. (Eds.). (2020). Williams Textbook of Endocrinology (14th ed.). Elsevier.