The External Secretion of the Pancreas

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A well documented and clearly illustrated monograph on the Morphology; Experimental Methods; Pancreatic Juice; Functions of External Secretion; Stimuli for the Pancreas; Secretion and Pancreogymin; Functional Innervation; Mechanism of Pancreatic Secretion.

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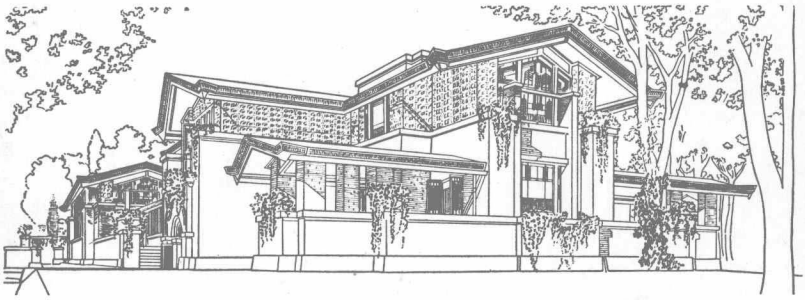

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PREFACE

If I had been writing a monograph for physicians some twenty years ago I should have felt obliged to confine myself to the so called practical aspects of the subject; at the present time I feel no such compulsion. It is my observation that modern physicians are about as much interested in the sciences that are basic to their practice as are those who spend their whole time in teaching and research. It is unfortunate that this interest is often frustrated through lack of the time required to consult original sources. If this discussion helps in a small way to improve that situation it will have served one of its purposes. Another objective has been to provide a convenient guide to source material for students and teachers of physiology.

In a work of this length it is, of course, impossible to cite all the literature or even a major part of it. References have been selected for their historical significance, their usefulness, and, too often perhaps, their availability. Articles that have been published in more than one language have been cited, by preference, in the language most likely to be familiar to the reader. This applies particularly to articles originally published in the Russian language and later reviewed or published in translation in French or German journals.

Through the kindness of several colleagues I have been able to include in the text some observations and opinions that have not yet found their way into the published literature. I take this occasion to express my gratitude to Drs. Horace W. Davenport, M. H. F. Friedman, E. S. Nasset, I. J. Pincus, V. Brown Scott, and Wm. J. Snape for permission to use their unpublished contributions. I am also indebted to Drs. N. A. Michels and A. J. Ramsay for their indispensable help in writing the chapter on Morphology and to Dr. M. H. F. Friedman for his assistance in preparing the section on Secretin and for reading and correcting the entire manuscript. Acknowledgement is also due to Dr. S. A. Kornarov for many valuable criticisms and suggestions.

Prof. B. P. Babkin has been kind enough to read and criticize several of the chapters and has made many helpful suggestions. His interest in our work has been a constant source of stimulation and encouragement. I am further indebted to Prof. Babkin, as every writer in this field must be, in that his publications have served as guides to the early literature and as sources for much of the subject matter.

J. E. T.

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THE EXTERNAL SECRETION OF THE PANCREAS

Chapter I

MORPHOLOGY

THE pancreas is an elongated gland which extends from the duodenum obliquely upward behind the stomach across the posterior abdominal wall to the spleen, at the level of the first and second lumbar vertebrae. For descriptive purposes it is divided into a head, body and tail. The parts are not separated by any well-defined markings but form a continuous retroperitoneal mass firmly attached to the posterior abdominal wall. The most massive portion of the gland is the head. It is flattened dorsoventrally and lies within the concavity of the duodenum, to which it is attached by numerous blood vessels, the pancreatic ducts and loose connective tissue. The uncinate process is a hook-like medial projection of the lower part of the head. The body of the pancreas makes up the major portion of the remainder of the gland. It is somewhat prismatic in shape and presents an anterior, a posterior and an inferior surface. The tail is the pointed, tongue-like left end of the gland which lies in contact with the spleen.

The terms used to describe the human pancreas are applicable also to the pancreas of the dog and cat. The principal difference from the human is the greater mobility of the pancreas in these animals, particularly in the region of the head which lies within the duodenal mesentery. The uncinate process is well developed and parallels the descending portion of the duodenum. In the rabbit and other rodents the pancreas is rather diffusely distributed in the mesentery of the upper intestine.

The following anomalies of the pancreas have been described (1) as of rather frequent occurrence: 1. The uncinate process may develop as a separate structure which then becomes a "lesser pancreas." 2. Glandular tissue from the head of the pancreas may completely surround the descending duodenum forming an "annular pancreas." 3. Pancreatic tissue may develop in unusual locations, chiefly in the wall of the stomach or the jejunum, resulting in an "accessory pancreas."

THE PANCREATIC DUCTS

Embryology: The peculiarities of the duct system of the pancreas are intelligible only when considered in relation to the embryologic development. The gland develops from two outgrowths of the primitive gut, one arising from the ventral and the other from the dorsal wall immediately below the primitive stomach. The ventral rudiment (at times double) appears to develop in common with the embryonic liver bud whereas the dorsal rudiment develops directly from the gut as a single outpocketing. As a result of rotation of the gut and its mesenteries and the growth of the rudiments themselves the two portions of the pancreas come into contact at the left of the duodenum and eventually fuse (Fig. 1, B). The dorsal pancreatic bud grows more rapidly than the ventral, producing some of the head of the gland, its body, and its tail; the main portion of the head is contributed by the ventral bud. The duct of the ventral pancreas joins the ducts of the dorsal portion somewhere along the course of the latter, usually near its origin, and the two subsequently form a continuous channel which constitutes the major pancreatic duct (ductus pancreaticus, or duct of Wirsung).

In keeping with the fact that the proximal portion of this duct (ventral bud) was developed in conjunction

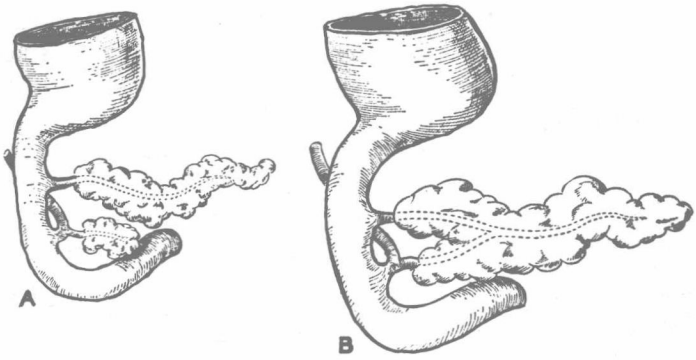

Figure 1

Pancreas of the human embryo. A. Fifth week. B. Seventh week. (From Reinhoff and Pickrell (2): Archives of Surgery.)

with the liver bud, the duct of Wirsung in the adult enters the duodenum in close association with the common bile duct. That portion of the duct of the dorsal rudiment which lies between the duodenum and the point of anastomosis with the ventral duct is normally retarded in its subsequent development and becomes the accessory duct (ductus pancreaticus accessorius or duct of Santorini).

The duodenal end of the accessory duct was found not to be patent in 24 per cent of 250 cases examined by Reinhoff and Pickrell (2). Probably in a majority of instances, according to their findings, it drains into the major duct rather than into the duodenum. These authors give the following frequency of other anomalies of the pancreatic ducts: failure of the ducts to anastomose within the pancreas, 15 per cent; accessory duct larger than the "principal" duct, 6.61 per cent; no accessory duct 0.737 per cent. In calculating their percentages they included with their data

the results of previous studies by Opie (3) and others. The problem was also studied by Simkins (4). The most frequent arrangement of the ducts as found by Reinhoff and Pickrell is illustrated in Fig. 2 A.

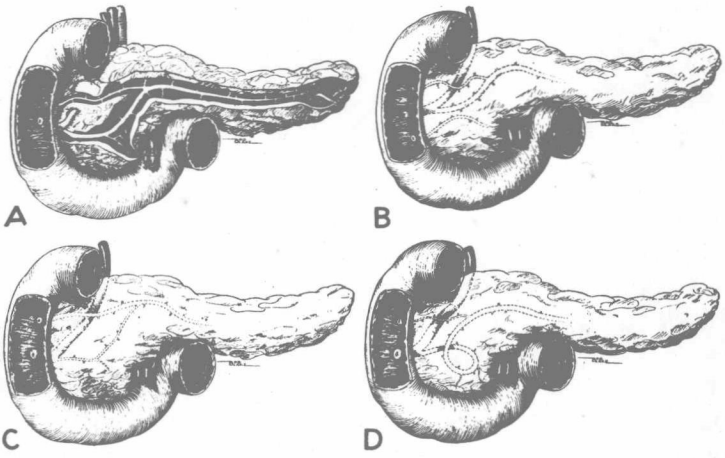

Figure 2

A. The most frequent arrangement of the pancreatic ducts. B. Specimen with three papillae. C. Dissected specimen of an adult pancreas showing an embryonic type of duct system in which the accessory duct carries most of the secretion. D. Dissected specimen of an adult pancreas showing an unusual loop configuration of the main pancreatic duct. (From Reinhoff and Pickrell (2): Archives of Surgery.)

A matter of considerable clinical interest is the relation of the pancreatic duct to the common bile duct at the point of their common entrance into the duodenum. They may enter separately or form a conjoined bile and pancreatic duct which, as it passes through the duodenum, dilates to form the ampulla of

Vater which opens into the duodenal papilla. In the series studied by Reinhoff and Pickrell (2) an ampulla was present in only 81 of their 250 cases. Combining their data with those previously published they arrived at a figure of 46 per cent for all cases reported. In the remaining 53 per cent the ducts entered the duodenum separately or were separated by a septum which extended to within 2 mm. of the common orifice. The point is of interest largely because of the commonly held belief that a stone at the common orifice which would close the ampulla would cause bile to enter the pancreatic ducts and possibly cause acute pancreatitis. The theory is improbable for several reasons. The necessary anatomical relations are relatively infrequent, the secretory pressure of bile is insufficient to force a significant amount of bile into the pancreas (5, 6), (see also Chap. VIII, Secretory Pressure) and bile when injected into the pancreatic ducts experimentally has failed to cause pancreatitis unless enough force is used to rupture the ducts. (Archibald, also Nordman, quoted by Reinhoff and Pickrell (2).)*

It seems much more probable that when acute pancreatitis follows occlusion of the common orifice the damage is caused by activation of the pancreatic enzymes in the mixture of bile and pancreatic juice in the ampulla, as pointed out by Popper (20). The process of activation may then spread through the juice in the pancreatic ducts by autocatalysis (see under "Trypsin and trypsinogen," Chap. III).

The arrangement of the ducts in the dog follows the same general plan as in the human except that the duct of the dorsal rudiment which, in the human, arises between the stomach and the liver bud, in the dog apparently arises caudad to the point of origin of the liver; at least it occupies this position in the adult in which it becomes the major pancreatic duct; the duct

*See also Tejerina-Fotheringham, Gastroenterology, 10: 687 (1948).

associated with the common bile duct becomes the accessory duct. The accessory duct is a relatively important channel in the dog since, according to Bottin (7), it is patent and anastomoses with the principal duct in all cases. Bottin found a third duct in 20 to 25 per cent of his animals which enters the duodenum midway between the biliary papilla and the opening of the major duct; it communicates with the other ducts but is very small. Additional anomalous ducts have been described (8). In the cat the development more nearly follows the human pattern, the pancreatic duct being closely associated with the common bile duct.

Continued growth and division of the smaller intralobular branches of the pancreatic ducts produce the definitive secretory portions of the gland, acini and islets of Langerhans.

BLOOD SUPPLY

The blood supply of the pancreas has been investigated by numerous workers, the more recent being Pierson (9), Ziegler (10), Kirk (11), and Michels (12). According to the latter, the arteries that supply the pancreas are substantially as follows (references are to Fig. 3).

1. Anterior and posterior pancreaticoduodenal arcades about the head of the pancreas. The anterior arcade is formed by the anterior superior pancreaticoduodenal (ASPD), a branch of the gastroduodenal. The posterior arcade is formed by the textually unlisted retroduodenal (RD), or posterior superior pancreaticoduodenal (PSPD), the upper, nearly invariable, first branch of the gastroduodenal. The arcades may end in the superior mesenteric via a common inferior pancreaticoduodenal in which case the anterior pancreaticoduodenal artery sends a dorsal branch to pick up the retroduodenal arcade;

or each arcade may end in the superior mesenteric via its own inferior pancreaticoduodenal artery (IPD) as shown in Fig. 3.

2. Dorsal pancreatic (DP)* is an unlisted artery of variable size (1-4 mm) distributed to the dorsal surface of the pancreas near the junction of the head and body where the splenic vein joins the superior mesenteric vein to form the portal vein. The dorsal pancreatic has a varied origin, from the celiac or aorta, from the first part of the hepatic or splenic, or from the superior mesenteric.

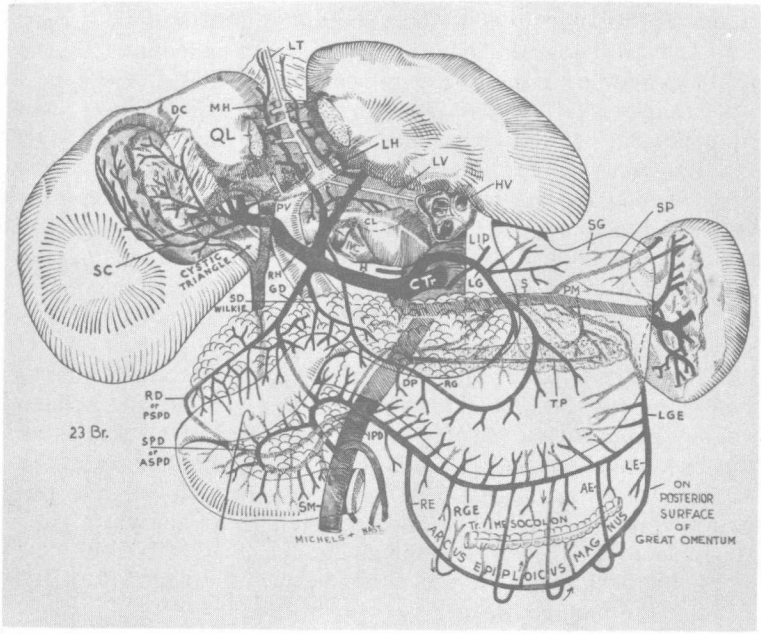

Figure 3

Relations of the pancreas to the regional blood vessels and organs according to Michels based on dissection of 200

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*Superior pancreatic of Pierson (9).