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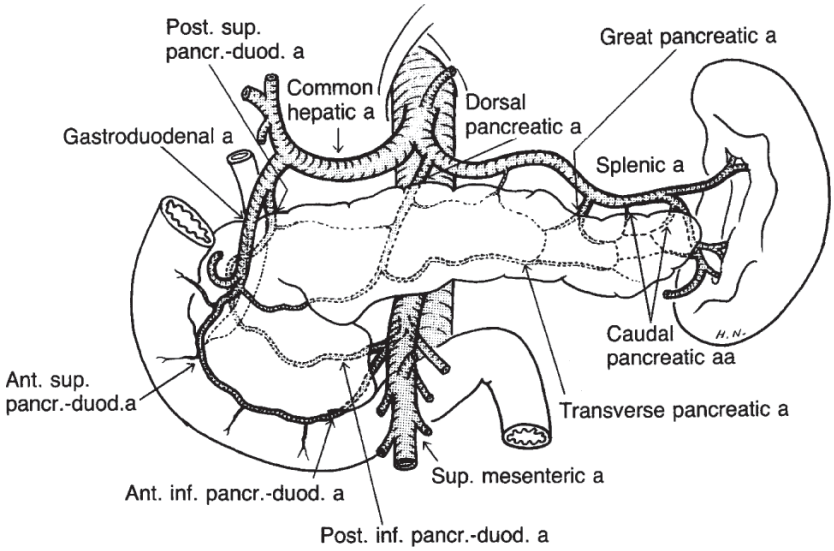
Surgical Vascular Anatomy and Histology

Gross anatomy

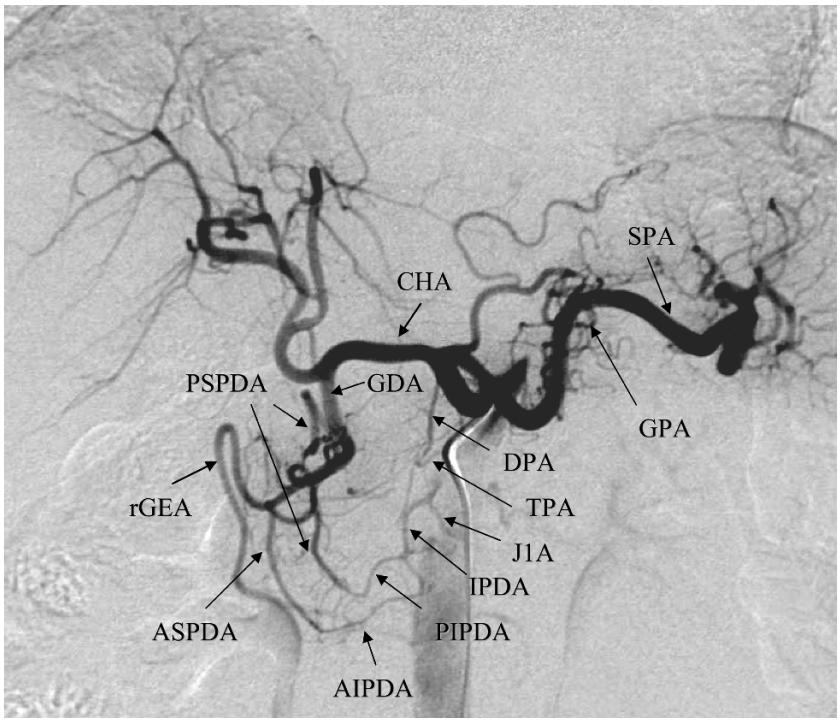
Arterial Anatomy

The pancreas receives its blood supply from branches of the celiac artery (CEA) and the superior mesenteric artery (SMA; Fig. 3.1) [1,2]. The gastroduodenal artery (GDA) generally departs from the common hepatic artery (CHA) and first gives off the posterior superior pancreaticoduodenal artery (PSPDA) near the upper border of the pancreas (Fig. 3.2). The GDA then gives off the right gastroepiploic artery (rGEA) and turns into the anterior posterior pancreaticoduodenal artery (ASPDA). The ASPDA descends on the anterior surface of the head of the pancreas to join the anterior posterior pancreaticoduodenal artery (AIPDA). The PSPDA runs in front of the common bile duct from left to right and descends on along the right side of the common bile duct on the posterior aspect of the pancreas. The PSPDA then runs behind the common bile duct from right to left to join the posterior inferior pancreaticoduodenal artery (PIPDA). The superior and inferior pancreaticoduodenal arteries (ASPDA, PSPDA, AIPDA, and PIPDA) form the anterior and posterior arterial arcades in the head of the pancreas. The ASPDA and PSPDA are consistent in origin, while the AIPDA and PIPDA arise separately or have a common trunk as the inferior pancreatoduodenal artery (IPDA) from the SMA. The IPDA also has variations, arising independently from the right side of the SMA or having a common artery composed of the IPDA and the first jejunal artery (J1A), which arises from the left side of the SMA. After branching off the J1A, the IPDA runs behind the SMA toward the right side and divides into the AIPDA and the PIPDA. These variations in the IPDA have been described in detail by Murakami and coworkers (Fig. 3.3) [3]. The IPDA was found in 80% of 125 autopsy subjects, a common artery composed of the IPDA and the J1A in 56%, and the IPDA arose in-



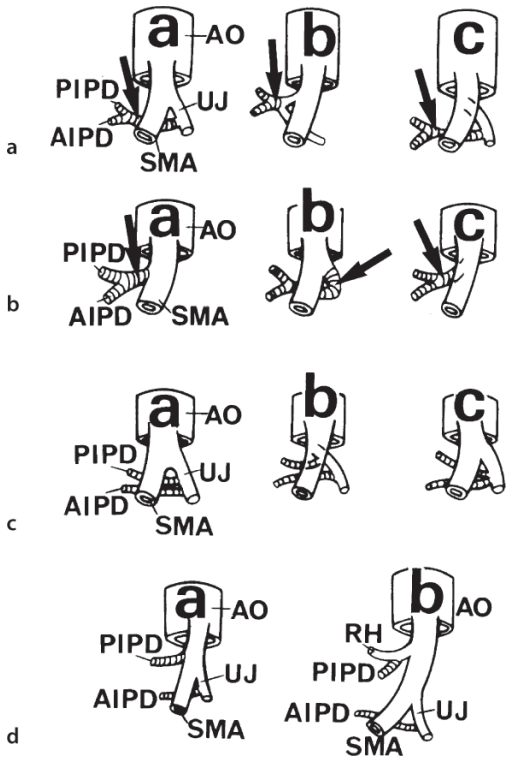
Figurge 3.1

Pancreatic arterial anatomy (with permission [6]). *a* Artery, *ant* anterior, *sup* superior, *post* posterior, *inf* inferior, *pancr.-duod a* pancreatoduodenal artery



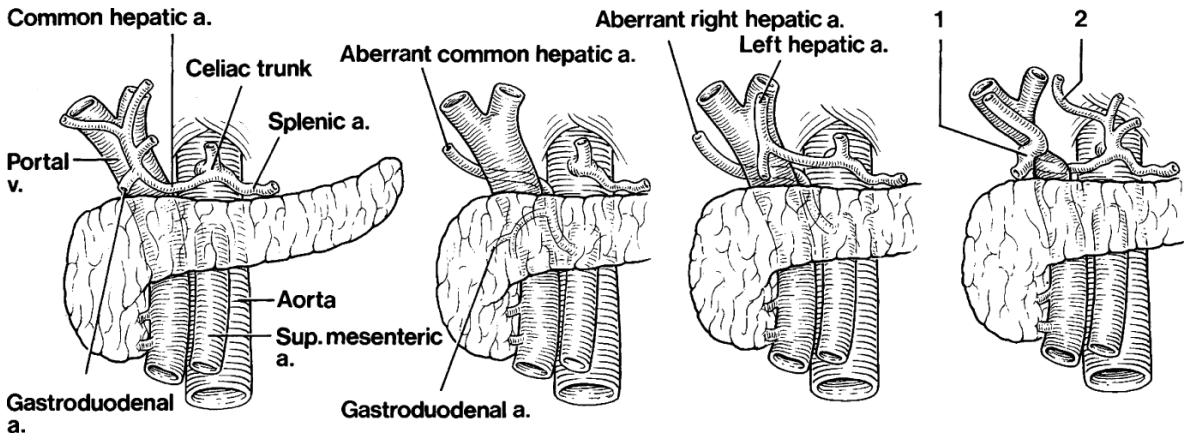
Figurge 3.2

Selective celiac arteriogram (with permission [2]). *SPA* splenic artery, *GDA* gastroduodenal artery, *CHA* common hepatic artery, *PSPDA* posterior superior pancreaticoduodenal artery, *rGEA* right gastroepiploic artery, *ASPDA* anterior posterior pancreaticoduodenal artery, *AIPDA* anterior posterior pancreaticoduodenal artery, *PIPDA* posterior inferior pancreaticoduodenal artery, *IPDA* inferior pancreatoduodenal artery, *J1A* first jejunal artery, *DPA* dorsal pancreatic artery, *TPA* transverse pancreatic artery, *GPA* great pancreatic artery



Figurge 3.3

Variations in the topographical relationships of the origin of the inferior pancreaticoduodenal arteries (with permission [3]). Anterior aspects. Four types (**a, b, c,** and **d**) and 11 subtypes (a, b, and c) were classified in 125 specimens examined. Every incidence described below was estimated in the total specimens. Type A (55.6%) has the inferior pancreaticoduodenal artery (*IPD*, *arrow*) arising from (and forms a common trunk with) the upper jejunal artery (*UJ*). Subtypes a (48.4%), b (6.4%), and c (0.8%) (a + b + c = A) of type A represent differences in the topographical relationships of arteries. Type B (24.2%) is a typical pattern seen in many textbooks, in which the IPD arises directly from the superior mesenteric artery (*SMA*). This type is also divided into three subtypes; a (17.8%), b (4.8%), and c (1.6%) (a + b + c = B). The AIPDA and PIPDA originate from the SMA independently in type C (3.3%) and its subtypes a (1.6%), b (0.9%), and c (0.8%) (a + b+ c = C). Type D (16.9%) consists of other patterns. In type D a (11.3%), the SMA issues the PIPDA, whereas the AIPDA arises from (and forms a common trunk with) the UJ. In type D b (5.6%), the PIPDA issues from the right (accessory) hepatic artery (*RH*) arising from the SMA. This type of RH was seen in 12.7% of the specimens examined; 44.1% of an specimens with an RH showed the type D *AO,* Aorta



Figurge 3.4

Some variations of the hepatic arteries in relation to the pancreas (with permission [7]. **a** Normal configuration. **b** Aberrant common hepatic artery. **c** Aberrant right hepatic artery. **d**, Common hepatic artery (*1*) looping around the portal vein from behind (causing compression of the vein); aberrant left hepatic artery (*2*) arising from left gastric artery

dependently from the SMA in 24% of the subjects. The posterior arcade passes behind the common bile duct, and is farther from the duodenum and in a more cephalad position than is the anterior arcade. The head of the pancreas and duodenum are supplied with blood mainly from these arcades.

The dorsal pancreatic artery (DPA) lies behind the neck of the pancreas, arising from the splenic artery (SPA), the CEA, the CHA, or the SMA. The GDA and the DPA give off branches and form the arcade along the superior margin of the pancreas. The branch from the GDA is called the superior pancreatic branch and the branch from the DPA is called the suprapancreatic branch [4]. The DPA then runs downward to the lower border of the pancreas and divides into the left and right branches. The DPA provides the main blood supply to the neck and body of the pancreas.

The transverse pancreatic artery (TPA) has the left branch of the DPA in 90% of the cases [5], and it departs from the GDA near the point where the GDA divides into the rGEA and the ASPDA. The TPA runs along the inferior margin of the pancreas to anastomose with the great pancreatic artery (GPA) and the caudal pancreatic arteries (CPAs) to form the arcade. This arcade is called the prepancreatic arcade.

The GPA is the greatest artery among the branches of the SPA that course along the superior margin of the body and tail of the pancreas. It usually arises around the border between the body and tail of the pancreas and divides into the left and right branches to anastomoses with the TPA, the DPA, and the CPAs.

The CPAs are small branches of the SPA or the left gastroepiploic artery (lGEP). The TPA, the GPA, and the CPAs supply blood to the body and tail of the pancreas [6].

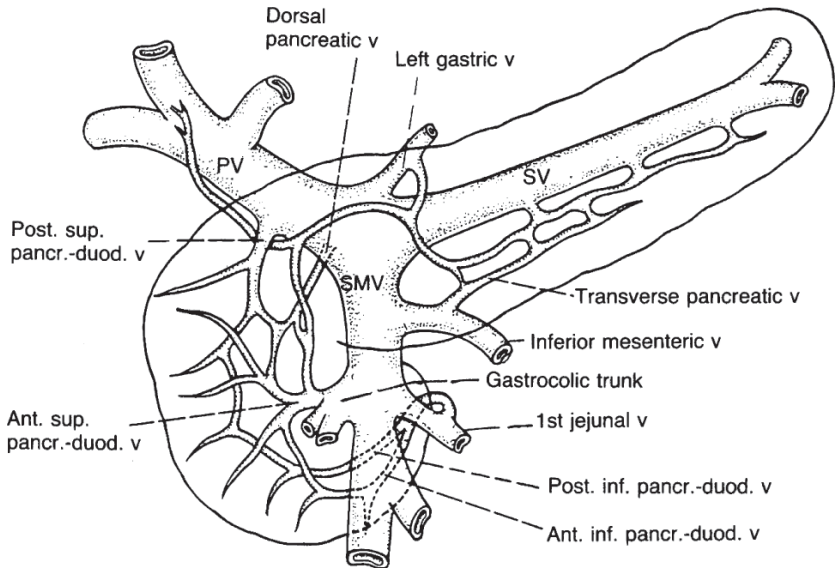
In relation to the arterial anatomy of the pancreas, it is important to understand the variations of the CHA. The CHA sometimes departs from the SMA and divides into the left and right branches in the hilus of the liver, and the right hepatic artery sometimes departs from the SMA. The CHA has other variations, as shown in Fig. 3.4 [7].

Venous Anatomy

The venous blood of the pancreas drains into the portal system around the pancreas; the splenic vein (SPV), the superior mesenteric vein (SMV), the inferior mesenteric vein (IMV), and the portal vein (PV) (Fig. 3.5). In general, the pancreatic veins run parallel to the arteries and lie superficial to them.

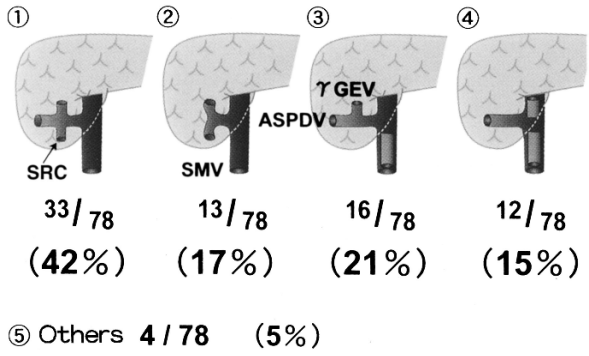
The SPV runs inferior to the splenic artery along the posterior aspect of the pancreas to join the SMV, which passes anterior to the inferomedial aspect of the uncinate process to form the PV behind the neck of the pancreas [6].

The anterior superior pancreaticoduodenal vein (ASPDV) generally terminates in the SMV via the gastrocolic trunk. The gastrocolic trunk is called the gastrocolic trunk of Henle or Henle's trunk, because Henle reported a common trunk of the superior right colic vein (SRCV) and the right gastroepiploic vein



Figurge 3.5

Pancreatic venous anatomy (with permission [6]. *PV* Portal vein, *SMV* superior mesenteric vein, *SPV* splenic vein



Figurge 3.6

Variations and their incidence in the gastrocolic trunk of Henle (with permission [1]). *SRC* Superior right colic vein, *GEV* gastroepiploic vein, *ASPDV* anterior superior pancreaticoduodenal vein

(rGEV) in 1868 [8]. Gillot et al. and Kimura et al. reported that a gastrocolic trunk was found in about 60% of 78 subjects (Fig. 3.6) [9].

The anterior superior pancreaticoduodenal vein (AIPDV) drains into the first jejunal vein or the SMV. The posterior superior pancreaticoduodenal vein (PSPDV) terminates in the right posterior wall of the PV. The ASPDV and the anterior inferior pancreaticoduodenal vein (AIPDV) form an arcade on the anterior surface of the pancreas. However, Takamuro et al. reported that the PSPDV and the posterior inferior pancreaticoduodenal artery (PIPDV) sometimes form arcades and at other times do not [10]. The PIPDV enters the first jejunal vein, frequently to form a common trunk with the AIPDV.

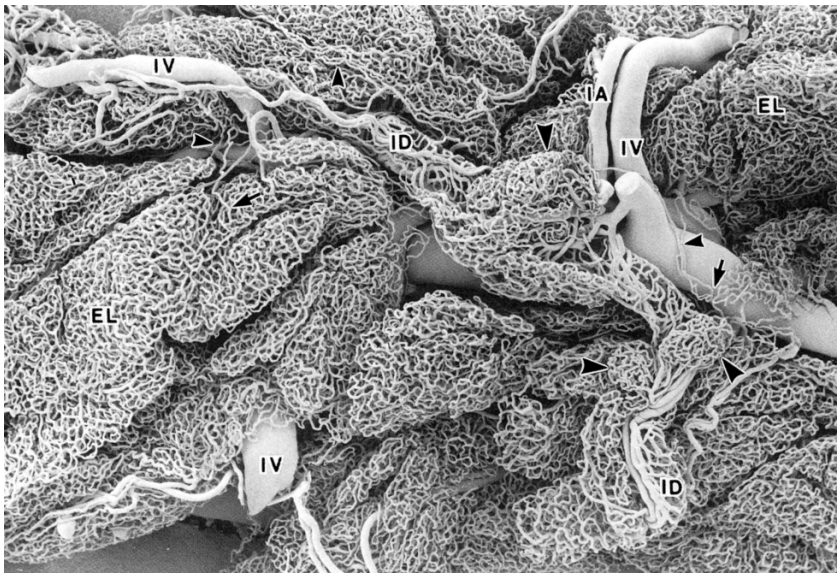
A large vein is sometimes observed running from the posterior aspect of the pancreas to the junction of the SMV and the PV; this vein is called the dorsal pancreatic vein (DPV).

The transverse pancreatic vein (TPV) branches off the small veins together with the DPV and terminates in the SMV, the IMV, or occasionally the SPV or the gastrocolic trunk. The SPV receives some short pancreatic venous branches and these branches anastomose with the TPV and drain the blood from the body and tail of the pancreas.

In relation to the venous anatomy of the pancreas, it is important to understand the variations in the IMV, SPV, and SMV. Kimura reported that the IMV joined the SV in 34% of 38 autopsy patients, the SMV in 42%, and the confluence of the SPV and the SMV in 24% [1].

Microcirculation of the pancreas

In this section, the microcirculation system of the pancreas is explained by showing the results of electron microscopic observations of vascular casts of human pancreas. These results are illustrated schematically in Fig. 3.7 [11].

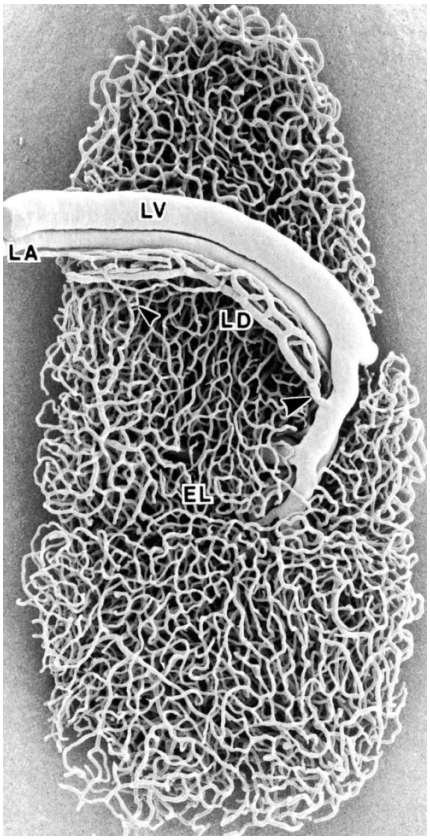


Figurge 3.7

Diagram of the vascular arrangements of the human pancreas (with permission [11]). From the top to the bottom are shown a lobule containing an islet, an extralobular (periductal) islet, and a lobule lacking in an islet. An interlobular duct is illustrated on the right side. *EI* extralobular endocrine islet (islet of Langerhans) or its vascular plexus, *EL* exocrine lobule or its vascular plexus, *IA* interlobular artery, *ID* interlobular duct or its vascular bed, *II* interlobular endocrine islet or its vascular plexus, *IV* interlobular vein, *LA* lobular artery, *LD* lobular duct or its vascular bed, *LV* lobular vein, *PA* periductal artery, *PV* periductal vein, *a* afferent vessel of the islet, *e* efferent vessel of the islet, *s* surface capillary network of the extralobular islet, *v* venous efferent vessel (emissary vein) of the extralobular islet, *la* branch of the lobular artery, *lv* branch of the lobular vein

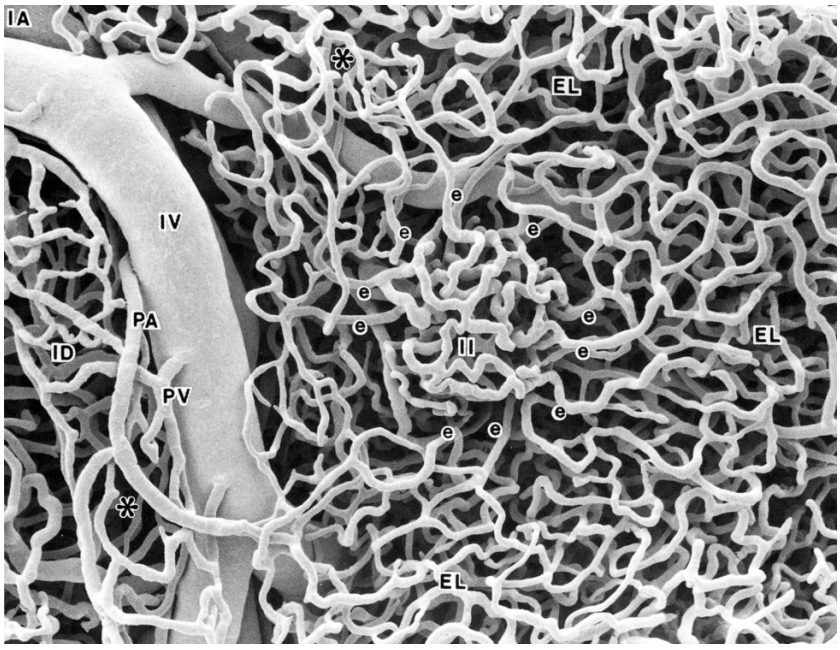
Figurge 3.8

Overview of a replicated blood vascular bed of the human pancreas (a caudal segment exposed by dissection, 25-year-old woman with permission [11]). Note that the blood vascular plexuses of the exocrine lobules (*EL*) and secretory ducts (interlobular ducts, *ID*) are thoroughly reproduced together with their connecting interlobular arteries (*IA*) and veins (*IV*), and that the exocrine lobules (*large arrowheads*) closely associated with the ducts are smaller than the other lobules. The *small arrowheads* indicate the interlobular blood vascular plexuses, some capillaries of which continue into the lobular capillaries (*arrows*). Magnification, ×40



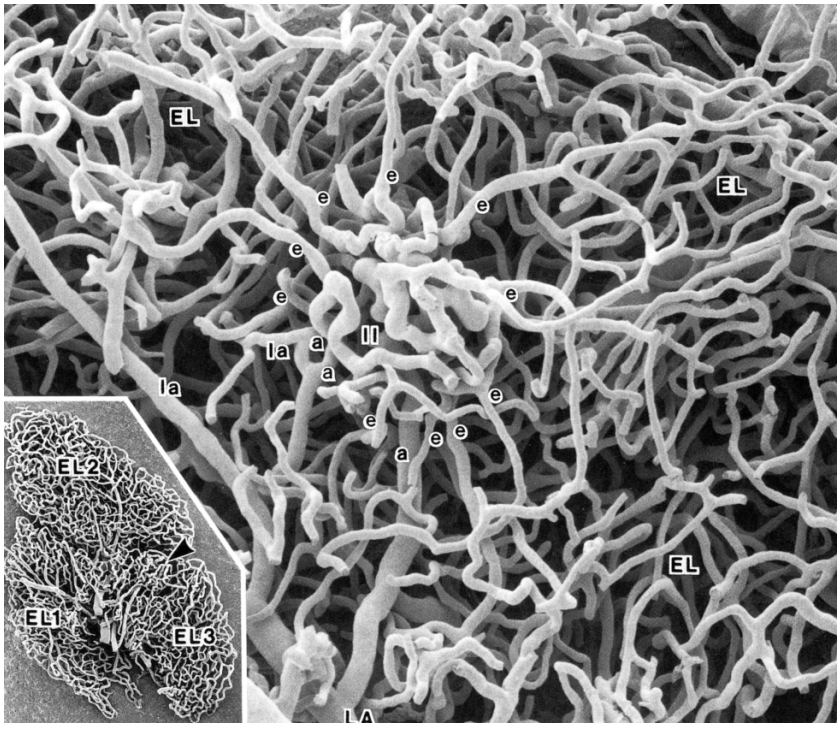
Lobular Vascular Bed

The vascular bed of the exocrine lobules (lobular plexus) consists of fine capillaries (Fig.. 3.7), which receive one or more afferent vessels (lobular arteries) from the interlobular arteries and issue one or more efferent vessels (lobular veins) continuous with the interlobular veins (Figs. 3.8 and 3.9). The lobular plexus occasionally possess insignificant fine connections with the interlobular or periductal plexus (Figs. 3.7 and 3.8).



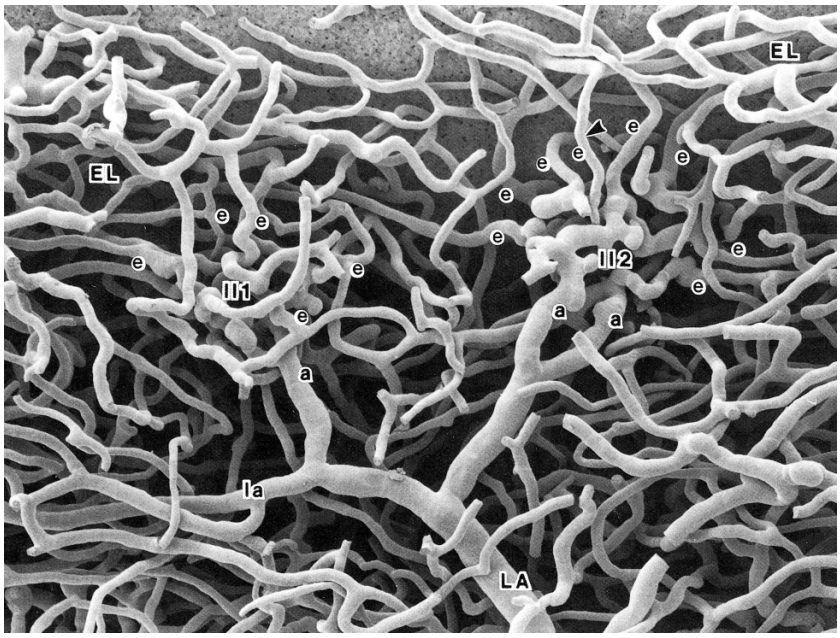
Figurge 3.9

A lobular blood vascular plexus isolated together with its connecting lobular artery, lobular vein, and ductal plexus (with permission [11]). Note that the lobule is fairly independent. The ductal plexus drains at the hilus of the lobule into a branch of the lobular vein (*large arrowhead*). The *small arrowhead* indicates a rare fine capillary connection between the lobular and ductal plexuses. Magnification, ×80



Figurge 3.10

An intralobular islet (*II*) exposed in the lobular surface (with permission [11]). Note that the islet emits marked efferent vessels (*e*), which continue, as the insuloacinar portal vessels, into adjacent lobular capillaries (*EL*). The *asterisk* indicates injection defects. Magnification, ×200



Figurge 3.11

An intralobular islet (*II*) with three afferent vessels (*a*) (with permission [11]). The afferent vessels on the left run from the superficial aspect into the insular capillaries, while that on the right runs deep into the islet. This islet also emits many insuloacinar portal vessels (*e*) continuous with the adjacent lobular capillaries (*EL*). The *inset* shows an isolated cluster of three lobules (*EL1–EL3*). Note in this inset that only the *EL3* lobule contains an islet (*arrowhead*). Magnification, ×250; inset, ×40

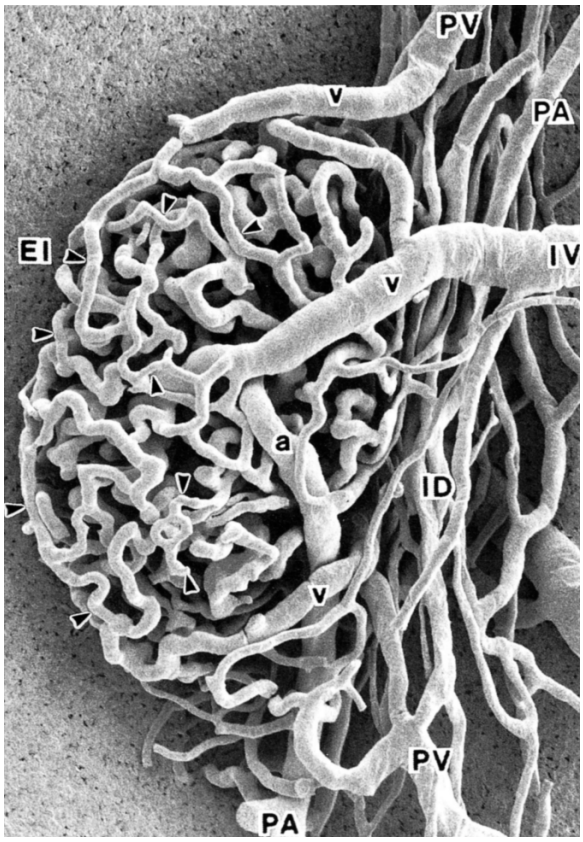
The size of the lobular plexus also varies widely. Large lobules measuring more than 0.5 mm in length contain numerous fine capillaries (lobular capillaries), while small ones, 500 μm or less in length, contain a small number of lobular capillaries. Large lobules are typically located in the superficial layers of the pancreas, whereas smaller ones are typically found in the deeper layers of the organ or in close association with the interlobular ducts (Fig. 3.7).

Intralobular Islets and their Blood Vessels

The vascular network in the islets of Langerhans (insular plexus) consists of thicker (sinusoidal) capillaries conglomerated into a globular mass, measuring 30–250 μm (usually, 100–150 μm) in diameter (Figs. 3.9–3.11). The peripheral or cortical capillaries of the intralobular islets issue numerous efferent vessels that radiate into the capillary network in the surrounding exocrine tissues (Figs. 3.9–3.11). These efferent vessels of the intralobular islets are relatively long, straight, or gently winding capillaries. However, as these vessels connect the intralobular islets and the lobular capillaries covering the exocrine acini and intralobular ducts, they should therefore be described as insuloacinar portal vessels [12–14]. Some portal vessels arise deep in the islets (Fig. 3.11), others more superficially. In human, the intralobular islets issue no efferent vessels directly draining into the veins. The portal vessels are characteristically slender, being never thicker than the capillaries in the islets and as thick as or slightly thicker than the lobular capillaries (Figs. 3.9–3.11).

The number of the portal vessels varies widely among islets. In general, larger islets possess a larger number of portal vessels. Larger islets exceeding 200 μm in diameter issue 30 or more portal vessels, whereas a small islets consisting of only a few capillary loops issue 3–7 portal vessels. Usually, a part of the lobular capillary network is supplied with the portal vessels of the islets, while the remaining parts receive lobular arteries directly; both portions of the lobular capillaries are drained by the lobular veins. On rare occasions, the entire extent of the lobular capillary network is supplied by the portal vessels. In these latter cases, the lobular artery or arteries take the exclusive role as the afferent vessels of the islets.

The islets identified by this characteristic feature in the vascular casts are usually located intralobularly (Figs. 3.9–3.11), embedded in the general capillary network of the exocrine tissue (Fig. 11). Only rarely



Figurge 3.12

Two intralobular islets (*II1, II2*) as found in the same lobule (with permission [11]). The *II2* islet receives two afferent vessels (*a*), and one of its efferent vessels (*arrowhead*) arises deep in the islet. Even in these islets, all of the efferent vessels (*e*) (including that indicated by the *arrowhead*) continue, as the insuloacinar portal vessels, into the adjacent lobular capillaries (*EL*). Magnification, ×280

does an intralobular islet expose its body to the lobular surface (Figs. 3.9 and 3.10).

By surveying many lobules with a light microscope, a clearly definable insular plexus is able to be found in one among seven lobules (Fig. 3.10, Inset). When a lobule reveals an islet, it is usually single, but occasionally several islets can be found in a lobule (Fig. 3.12). Thicker lobules probably possess their islets more consistently. Nevertheless, it is reasonable to say that a considerable number of lobules in the human pancreas are devoid of any islets. Moreover, the range of the portal vessels is limited and rarely cover the entire exocrine lobules. It is thus suggested that in humans, insular control over the exocrine pancreas is generally valid in restricted areas of the lobule.

In humans, it is rare for an islet to be located interlobularly (extralobularly) or periductally (i.e., between the lobules or along the interlobular duct; Fig. 3.12). Species differences in this regard are conspicuous. In the mouse and rat, many islets are located interlobularly along the excretory ducts, and are drained via their surface network of fine capillaries into the interlobular or periductal veins [15,16].

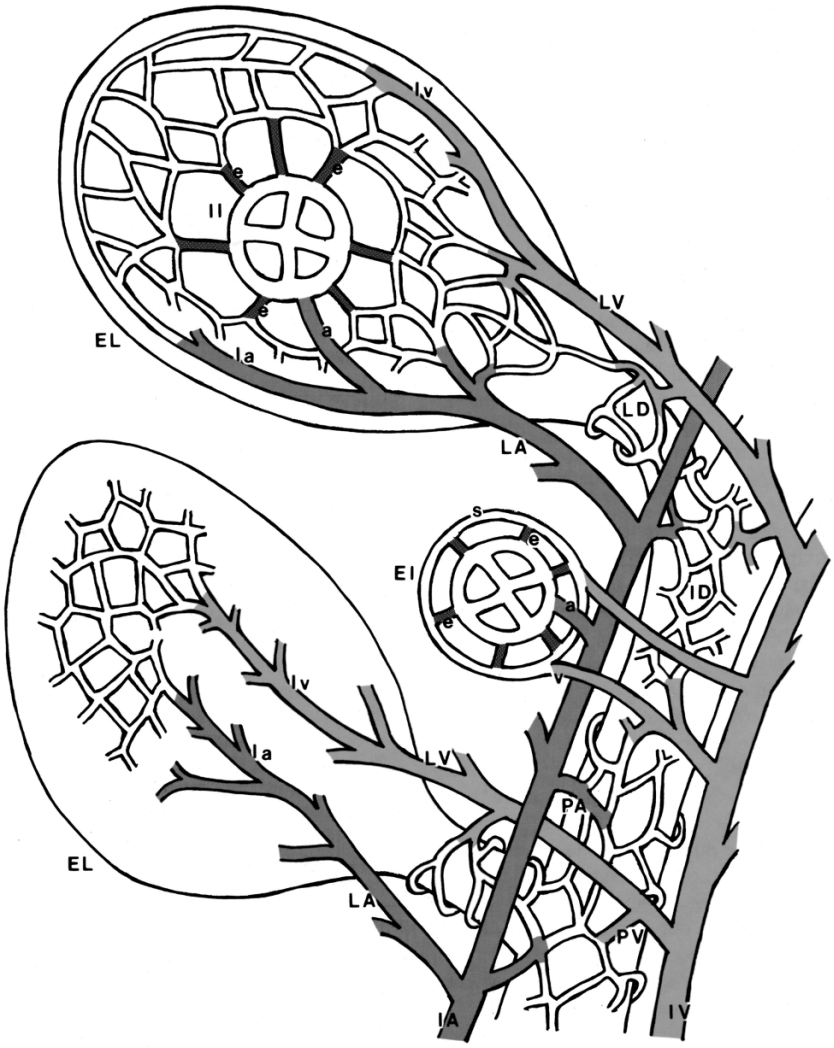
The intralobular islet receives one to three afferent vessels (insular arterioles) from the lobular artery (Figs. 3.9–3.11). These afferent vessels enter deep into the islet and form a conglomeration of sinusoidal capillaries. In some other islets, the afferent vessels divide superficially on one pole of the islet and continue into the sinusoidal capillaries. In typical cases, the afferent vessels break up into superficial and deep branches, which supply the islets both from the superficial and deep aspects, respectively. When the islet receives two or more afferent vessels, one often runs deep into the insular plexus and the other splits into its superficial aspects (Fig. 3.10). In certain animal species, the pattern of insular microcirculation is known to be regular [12,13,17,18]. However, in human islets, no rule can be found as to whether afferent vessels are primarily connected to the deep or superficial portion of the islet, and A, B, and D cells are rather irregularly intermingled within the islets.

Interlobular Islets and their Vascular Connections

The human pancreas only occasionally reveals islets located in the interlobular connective tissue. The interlobular (extralobular) islets receive one or more afferent vessels from the interlobular or periductal arteries (Fig. 3.12). The afferent arterioles penetrate deep into the islets to form a conglomeration of sinusoidal capillaries. This deep capillary plexus is surrounded and drained by a thin network of fine capillaries (the outer capillary meshwork; Fig. 3.12). This marginal network, in turn, issues efferent vessels that are directly continuous with the interlobular or periductal veins (Fig. 3.12).

Periductal Vascular Plexus

The vascular networks surrounding the interlobular and lobular ducts (periductal plexuses) are supplied with periductal arteries and veins that are derived from the interlobular arteries and veins, respectively (Figs. 3.7–3.9). The terminal segments of the periductal plexus (ductal plexus surrounding the lobular ducts) consist of several capillaries that drain into the



Figurge 3.13

An extralobular islet (with permission [11]). Note that this islet is provided with a set of fine capillaries (*arrowheads*), which receives the sinusoidal capillaries of the islet and confluence into the emissary veins (*v*), which are finally continuous with the PV or IV. Magnification, ×250

lobular veins in or outside the lobular plexus (Fig. 3.8). Few capillary connections can be recognized between the lobular and ductal plexuses (Fig. 3.8). This indicates that the capillary plexuses of the exocrine lobules and extralobular secretory ducts are independent of each other in terms of the blood supply. By contrast, within the lobule the exocrine acini and their connecting intercalated and intralobular secretory ducts are commonly supplied.

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