THE GROSS ANATOMY OF THE PANCREAS AND HISTOLOGICAL INVESTIGATIONS OF THE ISLETS OF LANGERHANS OF THE ONE HUMPED CAMEL CAMELUS DROMEDARIUS

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This thesis was prepared under the supervision of the chairman of the candidate's supervisory committee and has been approved by all members of the examination committee. It was submitted to the Dean of Faculty of Science, to the Graduate Council, and to the Library of the University of Jordan.

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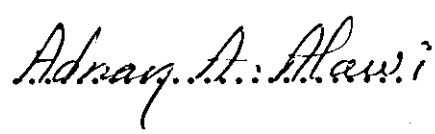

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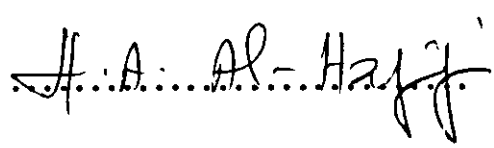

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ABSTRACT

THE GROSS ANATOMY OF THE PANCREAS AND
HISTOLOGICAL INVESTIGATIONS OF THE ISLETS
OF LANGERHANS OF THE ONE HUMPED CAMEL
CAMELUS DROMEDARIUS

The morphology of camel pancreas was studied in situ and after its removal from the animal. The pancreas of ten camels of various ages (1 - 9 years) and of both sexes were investigated. The blood supply of the pancreas was found to come from the celiac and the superior mesentric arteries.

The caudal region of the pancreas was found to be the richest in the islets of Langerhans. Light microscopic investigations showed that the islets of Langerhans were composed of four fundamental types of cells: A, B, D, and C. Two additional types of cells were revealed by ultrastructural study. Neither of these cell types had been reported before in the studied mammal. Argyrophilic (D) cells were demonstrated using ammoniacal silver nitrate method. B and A cells were differentiated after the application of the following methods: combined Gomori, and chrome alum Gomori hematoxylin. The cytoplasm of C cells is clear and did not pick up any of the stains applied. The particular localization of A and B cells in the islets of Langerhans was determined. While A cells are segregated at the periphery of the islets of Langerhans, B cells are located centrally. D cells are intermingled with A cells or with A and B cells. C cells and the

newly reported cells, M and O are randomly distributed. The ratio of A: B: D: C cells is 21: 72: 6: 1, respectively.

The outer coat of the pancreatic ducts contained extensive vascular plexuses. The histology of the duct system was studied and the inter and intralobular ducts were demonstrated. Microscopic examination of camel pancreases injected with India ink led to the following conclusion: the blood runs through four vascular exchange beds, in the following sequence before entering the liver: 1) islet of Langerhans. 2) acinar capillaries. 3) ductal plexuses. 4) hepatic sinusoids. An insulo-acinar portal circulation was observed. The blood which flows through the islets of Langerhans is arterial, while that which drains the acinar part is venous.

To study the course of degenerating nerve elements, specimens from camel pancreas were stained with ammoniacal silver nitrate.

The ultrastructural study of the islets of Langerhans showed the four known cell types: A, B, D and C. The distinct topographical distribution of these cells, as well as their number, size and structure were reported.

Two types of cells are reported here for the first time in the camel. Both types of cells were characterized by their secretory granules. The main characteristic features of M cells are: regular profiles, with ultralucent cytoplasm containing polymorphic secretory granules and an aggregation of polymorphic mitochondria. O cells are characterized by having octopodian shape, coarse textured cytoplasm with oval or round-shaped secretory granules.

دراسة التشريح العلم لغدة البنكرياس وهستولوجية جزر لانجرهانز في الجمل ذى السنام الواحد "كامبلاس دروميداريوس"

فاتنة بكر الحنبلي

المشرف الدكتور أحمد محمد الديسي

الخلاصة

اهتم هذا البحث بدراسة التركيب الشكلي لبنكرياس الجمل وهو في وضعه الطبيعي في داخل الحيوان وبعد فصله من الحيوان ودراسته خارج الجسم . كما درس التركيب النسيجي لعشر عينات من جمال مختلفة الأعمار (١-٩ سنوات) ، وذلك باستخدام طرق صبغ مختلفة للتمييز بين الخلايا المتباينة في جزر لانجرهانز وهي الفا (A) وبيتا (B) وسي (C) ودلتا (D) ، بالاضافة الى نوعين من الخلايا لم يتم تميزهما في بادئ الأمر بواسطة الطرق المتوفرة للمجهر الضوئي وانما ميّزت بواسطة المجهر الالكتروني النفاذ (Transmission Electron Microscope) ، وباستعمال طريقة مبسطة لنترات الفضة تم الكشف عن خلايا محبات الفضة وهي خلايا من النوع (D) . أما الخلايا من النوعين (A and B) فقد تم التمييز بينهما باستعمال طريقتين للصبغ النوعي وهما :

١- طريقة جوموري المركبة Combined Gomori Method .

٢- طريقة جوموري لكرومات الشب والهيماتوكسلين

Chrome alum Gomori hematoxylin

أما بالنسبة لخلايا (C) فقد ميّزت عن طريق سائلها الخلوي الشفاف وعدم التقاطها لأي من الصبغات المستعملة .

بينت هذه الدراسة توزيع الخلايا المختلفة بالنسبة لموقعها في داخل جزر لانجرهانز والخلايا من نوع A تكون تجمعات على محيط هذه الجزر ، بينما الخلايا من النوع B تحتل مراكزها ،وأما بالنسبة للخلايا من نوع D فقد وجد أنها تتداخل ما بين الخلايا من النوع A أو حتى ما بين الخلايا من النوعين A و B . هذا وقد وجدت كل من الخلايا من النوع C وخلايا لم تكن معروفة من قبل منتشرة بأعداد لا بأس بها ،وبشكل عشوائي في داخل جزر لانجرهانز.وهذه الخلايا الأخيرة وجدت أيضا بين خلايا الأجزاء القنوية من البنكرياس (ذات الافراز الخارجي) .

لقد تم حساب النسب ما بين الخلايا الأولية من النوع D و C و B و A ووجدت أنها تساوى تقريبا (A) ٢١٪ ، (B) ٧٢٪ ، (C) ١٪ ، (D) ٦٪ . هذا ولم يؤخذ بالحسبان النوعان الجديدان اللذان تمت دراسة تركيبهما التشريحي الدقيق . هذا كما درس توزيع جزر لانجرهانز في مناطق البنكرياس المختلفة ،ووجد أن الجزء الخلفي من الغدة هو أغناها بجزر لانجرهانز .

وتمت دراسة التركيب التشريحي للقنوات البنكرياسية فوجد أن الغلاف الخارجي لهذه القناة غني بالأوعية الدموية كما درس التركيب التشريحي للقنوات البين فصية والذي تميز بوجود الخلايا الطلائية العمادية والقنوات الداخلة في الفصوص والتي تتميز بالخلايا الطلائية المكعبة .

باستعمال طريقة الحقن بالحبر الصيني ، تمت دراسة الأوعية الدموية ويمكن تلخيص النتائج في وجود أربع مساكب دموية تبدأ بجزر لانجرهانز وتنتهي بالكبد قبل عودتها الى الوريد الأجوف الخلفي وهذه المساكب هي :

مسكب شعري في جزر لانجرهانز ← مسكب شعري في الجزء الغدي ذي الافراز الخارجي ← مسكب في القنوات البنكرياسية ← جيب دموي كبدي .

وبينت هذه الدراسة وجود الدورة الدموية البابية (insulo-acinar portal system) في البنكرياس والتي تربط عادة ما بين جزر لانجرهانز والكبد . والدم الداخل الى جزر لانجرهانز والخارج منها يكون عادة دم شرياني ، أما الدم الذى ينساب من الجزء الغدي ذي الافراز الخارجي فهو من النوع الوريدي .

لقد درس مسرب الأعصاب ومسارها عن طريق تفسيخها وصبغها بواسطة نترات الفضة النشادرية .

هناك أربعة أنواع رئيسية من الخلايا في الجزء الأصم من البنكرياس تمت دراستها بواسطة المجهر الالكتروني وفقا للأسس التالية :

١- عددها . ٢- حجمها . ٣- تركيبها الدقيق وتركيب حبيباتها الافرازية من حيث الشكل والعدد والوضوح .

كما أجريت دراسة كمية للفروقات بين الخلايا المختلفة . وقد تطابقت هذه الدراسة مع الدراسة بالمجهر الضوئي .

بالاعتماد على الصفات الشكلية للحبيبات الافرازية تم التعرف على نوعين جديدين من الخلايا وسميا حسب الترتيب الهجائي (O و M) . حيث تميزت الخلية من النوع M باحتوائها حبيبات افرازية مختلفة الأشكال والحجوم وبالاضافة الى وجود ميتوكوندريونات (Mitochondria) متعددة الأشكال والحجوم ومتجمعة ما بين النواة والحبيبات الافرازية . هذا وقد تم التعرف على النوع O من الخلايا بالاعتماد على شكل حبيباتها الافرازية والتي تتميز بشكلها البيضاوي والدائري وكذلك ما يبدو عليه السائل الخلوي من قوام خشن وعتومة . كما شوهدت الشعيرات الدموية في التركيب الدقيق في داخل الجزر ودرس التركيب التشريحي لها .

كذلك شوهدت علامات لنشاط الخلايا المتمركزة على الشعيرات الدموية مثل B و A حيث شوهدت فيها بروزات بين الخلايا أو بين الخلية والشعيرة الدموية المجاورة .

لقد تم تفسير ومناقشة النتائج على نحو ما ورد في الدراسات السابقة والتي أجريت على بنكرياس الانسان والحيوانات المخبرية .

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LITERATURE REVIEW

In spite of the voluminous literature on the morphology of the pancreas in various animals, there is still lack in our knowledge about this organ in the one humped camel Camelus dromedarius.

Comparison of the structure of cell types in the islets of Langerhans (i.L)* of the pancreas of different species was done by light and electron microscopic studies of vertebrates.

1. Islets of Langerhans morphology and duct system:

The islets of Langerhans were discovered in 1869, by Langerhans; he suggested that these structures were an end-apparatus of nerve fibers. Renaut (1879) considred them lymph structures. Others suggested that the i.L. were temporarily exhausted acini (Lewaschew, 1886). Revell (1902) studied the pancreatic duct of the dog, and indicated that the ductus pancreaticus is the main duct, in the adult animals, whether simple or compound in origin. Moreover, Dale (1905) had reviewed Lewashew's theory and indicated that the acinar and i.L. cells might undergo reciprocal transformation. Furthermore, Mann (1920) revealed the relation of the common bile duct to the pancreatic duct in common domestic and laboratory animals (dog, guinea pig, mouse, monkey, man, rat, goat, ox, horse, cat, bear, striped and pocket gophers). In addition, Korovitsky (1923) studied the pancreatic duct of the cat in relation to pancreatic secretion as the duct is

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* i.L. stands for islets of Langerhans.

able to constrict and relax, allowing the secretion to pass through. Pinherio et al. (1981) studied the histological structure of the pancreatic duct of Brasilian sloth Bradypus tridactylus. After that, Sakhawy and Moussa (1983) revealed the absence of goblet cells in the duct of the one humped camel Camelus dromedarius. Moreover, Prasad and Sinha (1984) reported the presence of goblet cells in the pancreatic duct of buffalo.

Lane (1907) studied the histology of i.L. in guinea pig, and he classified the i.L. into two groups according to the solubility of their granules, the cells which are preserved by alcohol as A cells, while those which are preserved by aqueous chrome sublimate as B cells. The current classification of i.L. cells stemmed from the extensive studies of Bensely (1911) who defined two cell types of the pancreatic i.L. in guinea pig. These cells were termed A and B cells; while the unstained cells were termed as C cells. In 1931, Bloom named the fourth cell type of man in alphabetical sequence as D cell. Later on, Thomas (1937) studied the cytology of i.L. cells in fourty one different species of mammals, including the camel Camelus dromedarius. He was in full agreement with the description of both Bensly's and Bloom's, in having four different types of cells: A, B, D and C cells.

A comparison of the structure of different cell types in the islets of Langerhans, in different animals was studied: Bensley (1911) and Gomori (1941) differentiated between the characteristics of A and B cells, in guinea pig. Moreover, Scott (1952) differentiated the B cells by a rapid staining method of mouse pancreas. Edwin et al.

(1954) used combined Gomori's method in differentiating between A and B cells, in the i.L. of mice and man. Furthermore, Bjorkman et al. (1966) and Boquist (1967) identified the pancreatic i.L. cells of both human and Chinese hamster. They revealed that both include a granular cell type in addition to the three i.L. cell types A, B and D. Abrahamsohn et al. (1981) found only one type of i.L. cells in the pancreas of the toed sloth Bradypus tridactylus, which was related to A cells.

The islets of Langerhans in marine lizard fish Saurida tumbil were described by Shyamasundari (1982). Four types of endocrine cells A, B, D and PP cells were identified in the i.L. of stomachless teleost fish, Barbus conchonius, (Rombout and Thiele, 1982). In the lung fish Neoceratodus forsteri, Rafn and Wingstrand (1981) found numerous islets of Langerhans similar to those of tetrapods. These investigators observed B cells which were predominantly A and D cells. Petersson (1970) revealed the presence of three types of cells A_1, A_2 and B cells in guinea pig's i.L.

The relative distribution of the various islets cell types were studied in different vertebrates. Thus, centric A cells were observed in sheep pancreatic i.L. (Alm and Hellman, 1964) and horse (Fujita, 1973, Hellman et al., 1962), while centric B cells were demonstrated in hamster (Alm and Hellman, 1964), marine lizard fish (Shyamasundari, 1982), stomachless teleost fish, Barbus conchonius (Rombout and Thiele,1982), and the golden hamster (Petkov et al., 1968).

Hellman and Hellerstrom (1960) identified the argyrophilic cells in the i.L. of ducks and chickens, and they indicated that the islets showed positive reaction with silver nitrate. Falkmer and Hellman (1961) stated that there was no real argyrophilia in the i.L of the marine teleosts Cottus scorpius . However , Hellerström and Hellman (1961) classified A cells into silver positive A_1 cells and silver-negative A_2 cells. In the i.L. of dogs, Hellman et al. (1962) had revealed the presence of an argyrophilic population of islets cells. Moreover, they had characterized these cells as a type of A cells, and named them as A_1 cell. In the human pancreas, Grimelius (1968) indicated that argyrophilic reaction appeared in A_2 cells of some i.L. and in some A_1 in others,but never in B cells. In addition, Grimelius and Wilander (1981) studied the endocrine cells impregnated by silver in man. Hellerström and Hellman (1961) distinguished between A_1 and A_2 cells as the glucagon producing cells. Further investigation by Pinherio et al. (1981) on the histochemistry and the histology of the Brasilian sloth Bradypus tridactylus pancreas, revealed a negative reaction with aldehyde fuchsin (for B cells) as well as with phosphotungstic acid hematoxylin (PTAH for A cells); the great majority of islets cells were impregnated by silver.

The distribution of A_1 and A_2 cells was studied in the sheep, hamster, pig, rat, guinea pig and monkey. Their percentages were analysed with regard to the i.L. size. The distribution patterns obtained proved to be similar for the body and caudal regions of the pancreas in all animals studied (Alm and Hellman, 1964). On the other hand, Petersson et al. (1962) studied some characteristics of the two types of A cells

in the islets of Langerhans of guinea pig. Petkov et al. (1970) showed that the pancreatic i.L. of cattle Bos taurus were smaller than those of guinea pig, rat or man. Further, Henderson and Daniel (1979) indicated that the i.L. in the mouse were eccentrical and partially isolated from the exocrine pancreas, while in the cat and baboon the i.L. were centric; in the rat they were somewhat at the peripheral portion in the pancreatic lobule.

Further investigation was carried out by Hellerström and Hellman (1959) who distinguished between A_1 and A_2 cells in the i.L. of the rat and regarded the A_2 cells as the source of glucagon. Hellman et al. (1962) identified the horse central i.L. cells as A cells which produce glucagon. Moreover, Petersson et al. (1962) revealed the characteristics of A cells in guinea pig.

The ratios of A, B and D cells in the islets of human fetus were 20: 40: 40, respectively, in early stages of development (Björkman et al., 1966). In addition, A to B cell ratio in Bos taurus was 1 to 4, while D to A cell, was 1 to 3. Besides, A cells were interlaced between B cells (Petkov et al., 1970). Kramltnger et al. (1979) measured the rabbits islets average volume and found that they were 5.8×10^{-7} ml, and the average i.L. diameter was 0.3 mm. The average volume of the i.L. was 2.4×10^{-4} per gm tissue.

2. Microcirculation of the islets of Langerhans:

The blood supply of the pancreas of mouse, rat and man was studied by Beck and Berg (1931). Björkman et al. (1966) described the capillary course in relation to the i.L. of human fetus. Grimelius (1968) pointed out the presence of D cells along the capillaries. In the pancreatic i.L. of baboon, cat, mouse and rat, much of the blood leaves the islets via capillaries which pass into the exocrine pancreas rather than forming a single vein (Daniel and Henderson, 1978).

The insulo-acinar portal system was described by many authors in mouse, rat and man (Wharton, 1932), monkey and horse (Fujita, 1973); baboon, cat, rat, mouse and rabbit (Henderson and Daniel, 1978), rabbit (Lifson et al., 1980; Fraser, 1980; Lifson et al., 1980); cat (Syed, 1982), and rabbit (Lifson and Lassa, 1981). In addition, Schiller and Anderson (1975), studied the microcirculation in canine and illustrated the blood flow from the i.L. to the acini. Moreover, the insulo-acinar circulation was studied in baboon, rat, mouse, and rabbit (Daniel and Henderson, 1978). The latter authors proposed the presence of three capillary beds: in the islets, in the exocrine pancreas and in the liver before returning to the heart. Further, Lifson and Lassa (1981) described the passage of blood through three capillary beds: in the i.L., in the acini, and in the ducts. More work was done by Fujita (1973) who described the arrangement of blood capillaries which were flowed from A cells to B cells.

3. Pancreatic innervation with special reference to the islets of Langerhans.

Richins (1945) revealed that the nerves of the cat's pancreas passed through the celiac plexus and reached the pancreas via the blood vessels which supplied it. Honjin (1956) studied the nervous pathways and general distribution of nerve plexus in the pancreas of the mouse which is supplied with nerve branches issued from the vagus and the mesenteric nerve plexuses. Meyling (1953) investigated the peripheral extension of the autonomic nervous system, and indicated the presence of autonomic interstitial cells of Cajal (a.i.c.), in all organs and tissues investigated of rat, rabbit, horse, cow, and sheep. In addition, Coupland (1958) studied the innervation of the pancreas of the rat, cat,and rabbit. He indicated the presence of a general nerve net which pervaded the acinar tissue, and the nerve fibers were associated with occasional interstitial cells; Also, discrete nerve endings were described. In cat pancreas, Fujita (1979) demonstrated the Pacinian corpuscles. He also found islands which were composed of insular cells and nerve fibers in some pancreases of adult dogs. Yamamoto (1960) revealed that in monkeys, the pancreas was relatively rich in sensory terminations. These terminations were found in the interlobular spaces and in the islets of Langerhans. But in macaque,no Pacinian lamellar bodies were found. Hoessels (1966) studied the terminal innervations of the pancreas in mouse, cavia, cat, rabbit, dog, pig, goat, ox, camel, dromedary, horse, elephant,and monkey, and noticed the presence of post ganglionic nerve fibers, peri-acinary, peri-capillary, peri-insulary and autonomic interstitial Cajal cells.

Furthermore, Honjin (1956) stated that there were three kinds of innervations, in the mouse pancreas, according to their location: the peri-vascular, peri-insular, and peri-acinar. However, the peri-insular plexus was formed from a few medullated fibers, and a large number of non medullated fibers.

4. Ultrastructure of the islets of Langerhans.

Comparative studies were carried out by many workers concerning the ultrastructure of the i.L. cells in many vertebrate species. Sato et. al. (1966) studied the i.L. cells of the pig, turkey, salamander, newt, and congo eel and showed the ultrastructural variations among the various types of cells A, B and D or clear cell in these animals. Moreover, four types of different cells were indicated in the i.L. of guinea pig (Lacy 1957 a and b; Bencosme and Pease 1958).

Three different types of cells A, B and D which were characterized by their specific secretory granules in rat islets were described (Lacy, 1957 a,b; Stöeckenius and Kracht, 1958; Nordmann and Wolf 1960; Caramia, 1963). In this connection, the ultrastructure of various cell types in dog islets were illustrated by Lacy (1957 a,b , 1961) Lazarus and Volk (1962) and variations were shown in A, B and D cell structure with respect to their secretory granules.

Comparative studies were done on dog, rabbit and opossum i.L. differentiating among various cell types, and showing that in opossum there were E and F cells,besides A, B and D cells, which were present in dog and rabbit . Also,F cells were found in the uncinate process of

dog pancreas, with regard to the ultrastructure of their secretory granules, (Munger et al. 1965).

A comparative study of the pancreatic islets of Langerhans was done for salamander, newt, rat, guinea pig, pig, chicken, turkey, cat,and dog, for electron microscopy, in which, alpha, beta, delta and clear cells were identified by Sato et al. (1966).

Beta cell cytoplasm was highly variable, some cells were filled with secretory granules and contained little ER, Golgi, ribosomes, and mitochondria, while others contained few secretory granules and an abundance of other organelles. However, beta granules of some species such as the dog, congo eel, and the salamander appeared crystalline.

The pancreatic i.L. cells in rabbit, dog, guinea pig and horse have shown that A and B cells differ mainly in the appearance of their secretory granules (Lacy 1957, 1959, 1961; Bjorkman et al., 1963). On the other hand, the ultrastructure and enzyme histochemistry of the pancreatic i.L. of the horse has been analysed with special reference to the A_2 cells. They pointed out that the main characteristic of the central cells was the presence of dense granules in the cytoplasm and that they measured about 0.4 μm.

Kobayashi and Fujita (1969) tabulated the fine structure of the pancreatic islets D cell secretory granules of many authors. Indistinct secretory granules with almost completely lost limiting membrane were demonstrated in guinea pig (Lacy 1957) and rabbit

(Munger, 1962). Semi opaque secretory granules were reported in the guinea pig (Caramia et al., 1965). Vacuole-like but partly solid core were found in cat (Bencosme and Pease, 1958), while empty vesicles limited with interrupted but distinct membrane were encountered in monkey (Winborn, 1965). Diffuse and obscure secretory granules with an interrupted or fragmentary limiting membrane were described in guinea pig and dog (Sato et al., 1966).

The Golgi apparatus was found to be more prominent in B cells than in A cells of dog, cat, rabbit, guinea pig, and rat (Lacy 1957; Bencosme and Pease, 1958). In addition,the islets of Langerhans in adult normal mice have been studied in some detail by Bjorkman, et al. (1963), who showed that Golgi complex in B cells, which occupied a central position in the i.L., taking up a relatively large area.

In the chinese hamster, four types of cells A_1, A_2, B and agranular cells were identified with special reference to their secretory granules: A_2 showed electron opaque cores, A_1 were variable density in their electron opacity, and B cores were moderately electron dense with wide haloes. All the cell types contained lysosome-like organelles. The nature of the agranular cell type was also described. Moreover, Boquist and Falkmer (1970) demostrated cilia in B cells of nondiabetic Chinese hamster.

In cattle Bos taurus L., Galabova and Petkov (1975) described the ultrastructure of four cell types A, B, D and C cells (agranular cells), which were identified on the basis of size, and structure of their secretory granules.

Caramia et al. (1965) identified three types of A cell in the guineal pig islet as A_a, A_b and A_c, according to the size of their granules. However, Kern (1969) revealed that in the guinea pig, rat and dog most A cells contain a small fraction of less electron dense granules, but intermediate stages of condensation were lacking in these species. In human A cells, granules were described with a strong osmiophilic central part surrounded by a rim of less electron dense material (Like, 1967). Furthermore, Kern (1969) described the vacuoles in the cytoplasm of A cells coming from an enlargment of the cisternae of the endoplasmic reticulum. Orci et al. (1970) demonstrated lytic bodies, dense bodies containing granules, which were considered as a possible mode of granulolysis in A cells of diabetic spiny mice. In addition, Lazarus and Volk (1970) revealed the presence of secretory granules in rabbit B cell, diffusely distributed with cytoplasmic vacuoles which were partly translucent and partly filled with pale granules.

Meyer and Bencosme (1965) and Lazarus et al. (1966) observed two types of granules, in rabbit one contained a central dense body separated from the limiting membrane by electron lucent spaces (dense granules), and another one which was partly filled with low density material (pale granules). Furthermore, Lazarus and Volk (1965) and Lazarus et al. (1966, 1967) showed the origin of both types of beta granules from rough endoplasmic reticulum and stated that both contained insulin in different physical or chemical states. They also found that lysosomal bodies were not involved in secretory granule formation or release. In addition, Lacy (1970) described the basic mechanism of B cell

secretion by emiocytosis, and proposed the hypothesis of the intracellular transport of its granules, which involved the microtubular system.

Munger et al. (1965) described F cells in opossum i.L. which resembled A cells of the uncinate process in the dog pancreas. Furthermore, Rhoten (1982) studied the pancreatic i.L. tissue of fetal and adult lizard (green anolis) and reported the presence of F cells which contain pancreatic polypeptide (PP), and characterized by their small secretory granules. These cells were rarely seen in the adult lizard pancreas. Rhoten and Hall (1981) described the PP cells and regarded them as F cells. In their words "this previously unidentified cell type", was named the "F" cell, in keeping with the localization of PP to the original F cell of the canine pancreas. They also described the F cell granules as similar in appearance to those described in F cell of canine uncinate process by Munger et al. (1965); while, they differ from those described by Pelletier (1977) in human PP cells; as anolian F cell granules were larger. Greider et al. (1970) described the human pancreatic i.L. cells and showed the irregular profile of D cell secretory granules, where the mitochondria were spread among these granules. Munger (1968) described D cells in guinea pig as stellate cell, and possessing an autonomic innervation. E cells were described by Munger et al. (1965) in opossum i.L. They have a large size and moderately electron opaque secretory granules; Also, they were found at the periphery of the i.L. Furthermore, Petkov (1973) revealed that in most cases the core of B cell granules were round, as in golden hamster, while in rodents and ruminants they were more rarely

bar shaped, rectangular, hexagonal or crystalloid. These differences in B granule structure were considred as an expression of the different molecular structure of the insulin they contain (Grodsky and Forshman, 1966).

The active sector in B cells of rat, rabbit, and guinea pig was shown by Petkov and Donev (1973a). Furthermore, Sorenson et al. (1970, quoted by Petkov and Donev 1973a) confirmed that the conversion of proinsulin into insulin occurred precisely in the B granules.

Lacy (1957) reported that it had not been possible to differentiate A and B cells in the mouse; while Munger (1958) studied the electron microscopic appearance of the changes in structure of mouse pancreatic i.L.

In human pancreatic islets, the multivesicular cytoplasmic inclusions resembeled lytic bodies were conspicuous in most B cells (like, 1967). Moreover, Petkov et al. (1970) reported the presence of cilia, which could rarely be seen in B cells of hamster.

Galabova and Petkov (1975) showed the presence of elongated or branched or even half moon mitochondria in cattle (cow). In their interesting observation in the horse i.L., Björkman et al. (1963) observed the shrunken mitochondria in B cells.

MATERIALS AND METHODS

The pancreases of ten healthy one-humped camels Camelus dromedarius of both sexes and various ages were collected from Sahab Slaughter House (Table 1, Appendix 1). The camels were sacrificed by slaughtering. Immediately after slaughtering, injection with the vital stain dithizone was done, two milliliters of this solution (Appendix II), were injected slowly intra-venously. This dye chelates zinc in the i.L. cells, and colors them red. The color appears within 10 - 20 seconds after injection, and fades away slowly (Fraser and Henderson, 1980). Small pieces from head, body and tail regions of the pancreas were taken and preserved in 10% buffered formalin, 10% formalin saline, Bouin's, and in Helly's, fixatives (Appendix II). The preserved tissue was washed and dehydrated (Table I, Appendix II); then embedded in paraffin wax or in paraplast. Five micrometers thick sections were prepared by using a rotary microtome (type: Lipshaw 45). Mayer's haematoxylin and eosin-phloxine solutions were used for identifying the islets of Langerhans (Appendix II), (Sheehan and Hrapchak,1980). The combined Gomori method was used to differentiate between A and B cells (Edwin, and Haskell, 1954). Differentiation of A, B and D cell types was achieved according to the chrome alum Gomori method (Raphael,1976). Ammoniacal silver nitrate (Land, 1970) was used to study the degenerated nerves of the islets of Langerhans, and the argyrophilic cells, (Appendix II).

In ultrastructural studies, 5% glutaraldehyde and 1% osmic acid were used as fixatives (Appendix II), and uranyl acetate and

lead citrate were used as stains (Appendix II).

The following staining methods were used in light microscopical studies:

I. Haematoxylin and Eosin (Al-Hussaini and Demian, 1973):

Five micrometers thick sections were deparaffinized by xylene, and hydrated with a descending sequence of ethanol down to 30% (3 minutes each). Then the tissue was washed with hot tap water before transferring it into haematoxylin (10-15 minutes) and subsequently washing it with tap water for two minutes.

Dehydration in ethanol sequence (30 to 70%) was carried out before staining with eosin-phloxine solution, then the tissue was transferred to an ascending sequence of ethanol up to 100% (2 minutes each). After that, clearing and mounting the tissues was done.

II. Combined Gomori methods for demonstration of pancreatic alpha and beta cells (Edwin and Haskell, 1954):

Sections (5 μm) were dewaxed in xylene, then hydrated in a descending sequence of ethanol down to distilled water (3 minutes each), then immersed in 0.5% iodine in 0.5% ethanol. The tissue was rinsed in tap water and later with 0.5% sodium thiosulfite, and finally with tap water followed with 80% ethanol solution.

The sections were stained for one hour in Gomori's aldehyde fuchsin (Appendix II) and were then rinsed in 2 changes of 80% ethanol as well as in tap water. Thereafter, sections were stained in 0.5%

phloxine B (5 minutes), which was followed by rinsing in tap water. They were differentiated in 5% aquaous phosphotungstic acid (1 minute); followed by washing in tap water for 5 minutes. If the sections were too red, the tissues were quickly rinsed in 80% ethanol (20 seconds). Finally, the sections were dehydrated, cleared, and mounted in Canada balsam, then they were examined and photographed. Kodak films 100 and Sakura films 100 were used.

III. Chrome alum Gomori Stain (Raphael, 1976):

The sections were dewaxed and hydrated as mentioned above; then, treated with acid permanganate (1-2 minutes), after which they were bleached in 4% sodium sulfite and washed in tap water.

After the sections were stained in chrome alum haematoxylin (15 minutes), they were transferred to acid alcohol (1% HCl + 70% ethanol) for 1-2 minutes, then washed in running tap water (clear blue sections).

The sections were transferred to 0.5% aqueous phosphotungstic acid (1 minute), and washed in tap water (red color sections), then dehydrated in ascending ethanol sequence of 95%, and 100%. Later on they were cleared and mounted.

IV. Ammoniacal silver nitrate method (Land, 1970):

Thick frozen sections(30 µm)were spread on slides and preserved in 10% buffered formalin (pH.7), (Appendix II), with sucrose 30% (5 - 9 days). They then were dehydrated in an ethanol sequence,

cleared in xylene, infiltrated and embedded in paraffin; thereafter, 5 um thick sections were cut from the previous material and were stained as follows:

The sections were dewaxed and hydrated then rinsed in distilled water and transferred to 2.5% uranyl nitrate for 5 minutes, they were rinsed in distilled water and stained with ammoniacal silver nitrate 10 - 15 minutes (Appendix II), after which they were transferred into the reducer for 2 - 5 minutes (Appendix II), and rinsed in distilled water.

These sections were transferred into a 0.5% solution of 0.5% sodium thiosulfate for 2 minutes and rinsed in distilled water, then bleached in 1% potassium ferricyanide for 15 seconds. After counter staining with 1% cresyl violet for 1 minute, the sections were dehydrated in 95% and 100% ethanol and finally cleared and mounted.

V. India ink (Fujita 1973):

Fresh pancreas was injected with India ink through the cut ends of some of the arteries and veins or through the celiac and the superior mesenteric arteries, and the hepatic vein until the ink drained through the opposite ends of the cut arteries and veins.

The whole pancreas was fixed in 10% formalin saline (Appendix II), for two weeks at least. Then from the well injected areas, 1 mm thin slices were cut with a razor blade, dehydrated through an ethanol sequence and cleared in methyl salicylate for more than four hours. The tissue was examined and photographed.

VI. The external morphology, macro and microcirculation of the pancreas:

The dorsal aorta was ligated anterior to the diaphragm; Another ligation was made at the site of the emergence of the renal artery, posterior to the superior mesenteric artery. Then the viscera were pulled out, in order to determine the location of the pancreas, and its connections with the surrounding organs.

The abomasum was ligated 5 cm before its pyloric fundus, and the duodenum was ligated at its distal end. The posterior vena cava was ligated anterior to the renal veins posteriorly, and at its entrance into the thoracic cavity anteriorly. Later both the dorsal and ventral lobes were identified.

Cuts were made at the ligation sites. Pancreas, dorsal aorta, posterior vena cava, duodenum, and parts of the liver were taken out and spread, in order to study the detailed morphological structures of the pancreas and its blood supply, then adipose tissue and fleshy parts attached to the blood vessels were removed, and with the aid of a probe the pathway of various blood vessels in relation to the pancreas was followed.

VII. Ultrastructural studies of the islets of Langerhans:

Tissues from various regions, head, body and tail of the pancreas were cut into blocks with sizes of 0.5 - 1 mm and fixed with 5% glutaraldehyde in 0.1 M phosphate buffer, pH 7.4 (Appendix II) for two hours. Then they were washed overnight several times in

phosphate buffer to which sucrose (0.68 gm sucrose / 5 ml of buffer) was added. The tissue was post fixed with 1% osmic acid for 30 minutes, and washed several times with phosphate buffer for 1 - 2 hours.

In an ascending acetone sequence up to 100%, the tissue was dehydrated , for 15 minutes each, then infiltrated in an acetone-plastic mixture sequence (from 10% to absolute plastic) 30 minutes each. Thereafter, it was left overnight in Spurr Epon (Dawes 1973) (Appendix II). Later on, the tissues were embedded in plastic and left for 2 days in the oven at 60°C.

Silvery sections 70 nm thick were cut using the ultramicrotome (Sorval MT 2-B, Porter-Blum). Glass knives were cut using the knife maker 7800 B (LKB - PRODUKTER AB, S-161 25 BROMA 1, SWEDEN); then copper grids of meshes 300 were used for mounting the sections which were examined in Zeiss electron microscope (Model, EM 10 B), after being stained by uranyl acetate and lead citrate (Appendix II).

Kodak electron microscope films No. 4489, $3\frac{1}{4}$ x 4 in., were used. Finally, the electron microscope films were developed and printed using Agfa prints.

RESULTS

I. Morphology

In the camel, the pancreas is an elongated gland, pinkish in color, lobulated and sandwitched between two layers of areolar connective tissue. The pancreas is located in the dorsal abdominal cavity, caudal to the liver. The average weight of the pancreas of six adult healthy camels was 0.458 $\pm$ 0.02 kg, the average body weight was 458 $\pm$ 28.62 kg (Table 1, Appendix I). The ratio of the pancreas weight to the body weight was found to be 0.001 $\pm$ 0.0001 kg.

The pancreas is basically divided into two lobes: 1) a large ventral lobe and 2) a short wide dorsal lobe (Fig. 1). The two lobes are united at the pancreatic angle and posterior to the liver. Moreover, lymphoid tissue is intermingled with the pancreas at the pancreatic angle. Measurements of the ventral and dorsal lobes are illustrated in Tables 4 and 5 (Appendix I). The ventral lobe which is located in the mesoduodenum is flattened and divided into, head, body, and tail regions.

In juvenile camels the pancreas is separated from the duodenum by a mesentery of a distance of about seven centimeters. This distance may reach 12 cm in adult camels. The mesentery is highly rich in adipose and limphoid tissues. These tissues increase in size and number of cells with age.

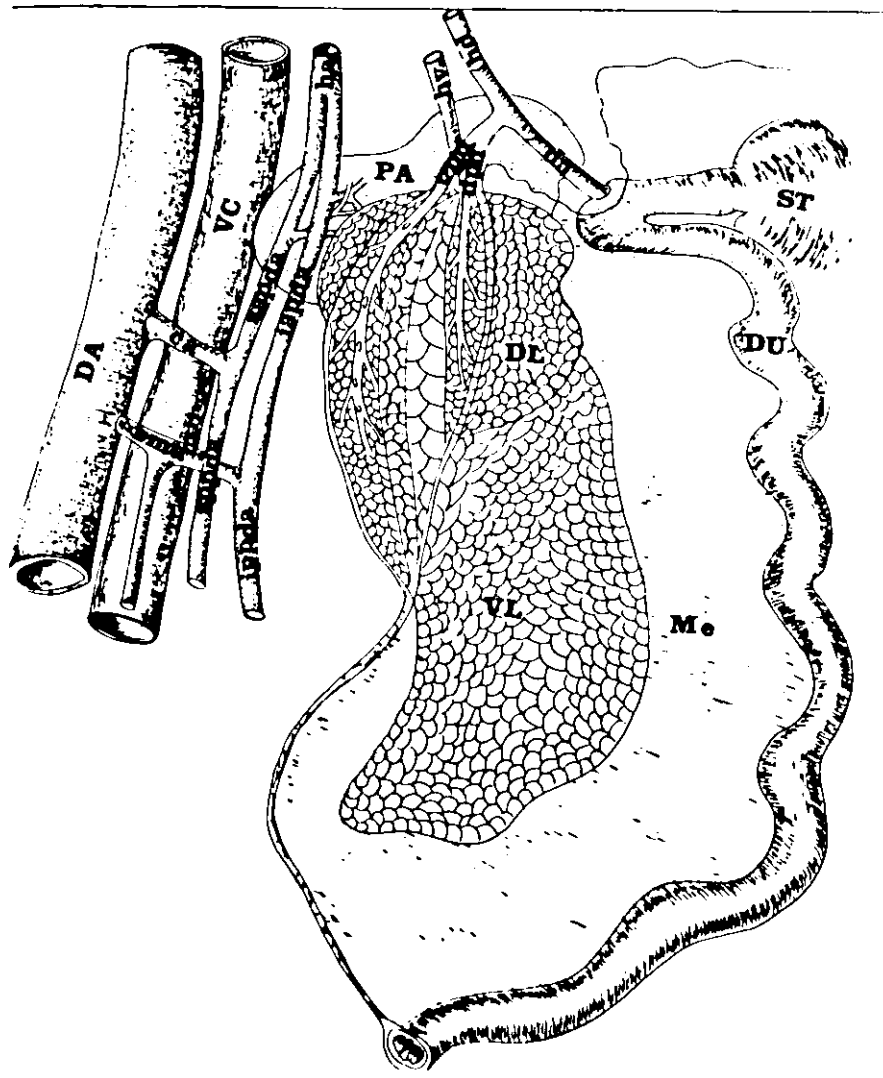

Fig. 1. Scheme of the pancreas, pancreatic ducts, and blood vessels. (ca)coeliac artery; (DA) dorsal aorta; (DL) dorsal lobe of pancreas; (dpd) dorsal pancreatic duct; (DU) duodenum; (iapda) inferior anterior pancreatic duodenal artery; (ippda) inferior posterior pancreaticoduodenal artery; (Me) mesentery; (PA) pancreatic angle; (sapda) superior anterior pancreaticoduodenal artery; (sma) superior mesenteric artery; (sppda) superior-posterior pancreaticoduodenal artery; (ST) stomach; (VC) vena cava; (VL) ventral lobe of pancreas; (vpd) ventral pancreatic duct.

The head of the ventral lobe runs obliquely and anteriorly toward the pylorus. The body and tail of this lobe which run in the duodenal loop are narrow in width and dorsoventrally flattened. The tail region molds with the distal part of the duodenum. The caudal part of the ventral lobe is ventral to the kidney. The inferior surface of the ventral lobe is related ventrocranially to the dorsal wall of the stomach. The dorsal lobe lies in the dorsal region of the mesoduodenum superimposing the ventral lobe. It lies posterodorsaly to the pancreatic angle and measures 11.25 $\pm$ 0.29 cm (Table 5, Appendix I). The dorsal lobe has a palmate shape, and is shorter than the ventral lobe. The anterior margin of this lobe is connected to the pancreatic angle and is posterior to the liver. The dorsal surface of this lobe is related to the kidney.

The pancreatic angle unites the two lobes and attains a thickness of about 1.5 cm. It extends anteriorly and attaches to the closer portion of the pyloric region, and lies posterior to the liver. Several structures: hepatic duct, portal vein, gastropancreatic artery, and the gastroduodenal vein, pass through the pancreatic angle.

II. Ducts of the pancreas:

The pancreatic duct unites with the hepatic duct at a point 2 cm before the latter enters the duodenum. Each lobe of the pancreas has its own duct, which travels along the blood vessels in the interlobular septa. Both major ducts of the two lobes penetrate the pancreatic angle and give one pancreatic duct which joins the hepatic duct at a point 2 cm before the latter enters the ampulla duodeni.

The ampulla duodeni lies 10 - 12 cm distal to the pylorus, (Fig. 1 and Fig. 3).

III. Pancreatic circulation:

The pancreas receives its major blood supply from the coeliac trunk and the superior mesenteric artery. The branches of both blood vessels anastomose in two distinct arcades, anterior and posterior to the pancreas. The principal arteries that run from the coeliac trunk to both of pancreas and duodenum are branches of the following arteries: gastroduodenal artery, the anterior superior pancreaticoduodenal artery, and the posterior pancreaticoduodenal artery. The superior mesenteric artery gives off two branches, which are the anterior inferior panareaticoduodenal and the posterior inferior pancreaticoduodenal arteries. The anterior blood vessels of both sets (Coeliac and superior mesenteric arteries) anastomose with one another and the posterior vessels do likewise. The anterior arcades cross the mesentery to the pancreatic angle through the head region and give branches to both structures in a tree-like manner. The posterior superior pancreaticoduodenal artery supplies the dorsal lobe and the duodenum with blood. It gives many branches which cross the mesentery to the pancreatic lobe and to the surrounding duodenal loops. The posterior inferior pancreaticoduodenal artery provides both the ventral lobe and the duodenum. The branches of both the superior and the inferior posterior pancreaticoduodenal arteries anastomose in the duodenal wall. The arterioles which supply the pancreatic lobes provide them with blood and give many branches which terminate in the

Fig. 2. The pancreas, and neighboring structures.
(D) duodenum; (K) kidney; (L) liver; (P) pancreas; (S) stomach.

Fig. 3. The pancreas, pancreatic duct and neighboring structures.
(D) duodenum; (d) duct of dorsal lobe; (h) hepatic duct; (P) common pancreatic duct; (S) stomach; (V) duct of ventral lobe.

pancreatic lobule and cross the pancreatic inter- and intralobular septa. The anterior superior pancreaticoduodenal arteries unite in the liver forming the common hepatic artery (Fig. 1).

The veins of the duodenum and the pancreas correspond with the arteries and usually lie superfacial to them. Each of the anterior and posterior venous arcades end in two superior pancreaticoduodenal veins and in two inferior pancreaticoduodenal veins. These veins were named as the surrounding arteries. The superior pancreaticoduodenal veins unite in the body of the ventral lobe. The united veins from the dorsal and the ventral lobes join each other in the pancreatic angle, and empty directly in the portal vein. Many venules which travel through the mesentery come from the duodenum, penetrating the pancreas, which drains in larger vessels.

The anterior inferior pancreaticoduodenal and the posterior inferior pancreaticoduodenal veins are tributaries, either singly or as a common trunk of the superior mesenteric vein. The posterior vena cava lies to the left of the aorta penetrating the liver and receiving the drainage of hepatic veins.

IV. Pancreatic microcirculation:

This part of the study deals with the intrapancreatic circulation. The islets of Langerhans have a very rich vascular supply. After injection with India ink a network structure with black spots was observed indicating the positions of the islets of Langerhans.

The pancreas is lobulated and the lobules separated by interlobular septa. The arteries run in the interlobular and intralobular septa, attaining straight or arcuate courses issuing short branches. These branches branch in turn either singly or in a dicotomous fashion. The arterial branches are uniformly thick, and each branch (arteriole) ends in a capillary glomerulus of the islet of Langerhans. In general, arteries do not issue direct branches to the acinar tissue. It is the arterioles that issue one or a few thin twigs to the islets of Langerhans. The arterial branches or vasa afferents enter into the capillary glomerulus of the islet of Langerhans at its periphery. The afferent arteriole breaks up abruptly at its end into twisted and thin capillaries, which anastomose with each other and radiate to the center of the islet of Langerhans (Figs. 4 and 5).

Upon entering the pancreas, the branches of the arteries divide and course along the interlobular septa forming an interlobular arterial plexus, from which branches arise to enter the pancreatic lobules and are called interlobular arteries. The intralobular arteriole entering each lobule has a thin wall with an insignificant muscular coat. The arteriole divides to end in a glomerular like arrangement among the cells of the islets of Langerhans.

The vessels which enter the islets of Langerhans become immediately of wider lumen, are lined by a single layer of endothelial cells which are surrounded by a thin layer of delicate connective tissue (Fig. 9).

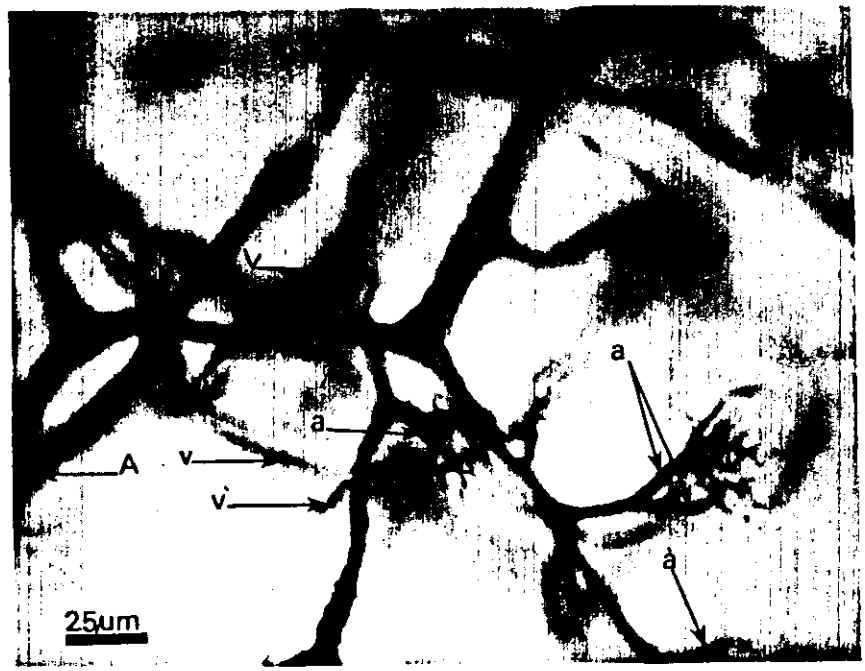

Fig. 4. Blood supply of part of lobule in camel pancreas, showing the circulatory pattern of an island of Langerhans and its relationship to the acinar vessels.
(A) intralobular artery; (a) afferent arteriole; (a') small artery supplying acinar tissue; (I.L.) islets of Langerhans; (V) intralobular vein; (v) efferent vessel; (v) efferent acinar vessel (vein). (India ink, 100x).

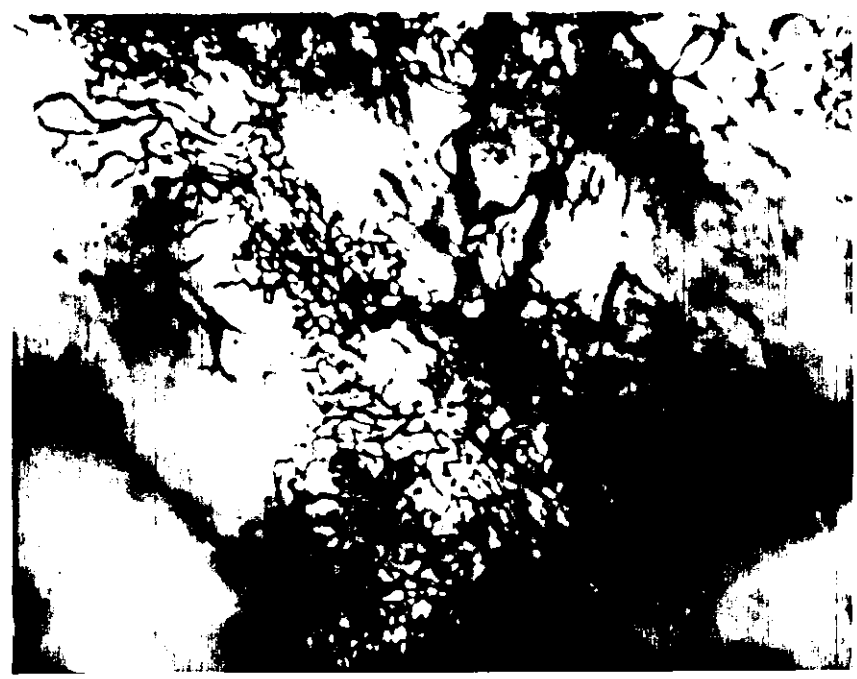

Fig. 5. Arrangement of capillaries in island of Langerhans. Anastomoses of capillaries forming glomerulus. (India ink,100x).

From the center of the capillary glomerulus relatively straight vessels emerge to supply the exocrine pancreas. These vessels were found to be varied in diameter when the pancreas was injected with India ink. Sometimes they divide dichotomously and then communicate with the capillary network surrounding each acinus of the pancreas. The acinar capillaries are usually thinner than those of the islets capillaries.

A zone of exocrine tissue which immediately surrounds the islets of Langerhans, looks clearer than the other exocrine parts, and contains only relatively few thin efferent vessels and their branches. This periinsular clear zone is visible especially when the vascular injection is sufficient. In such a case, the arterial branches and islets of Langerhans capillaries were filled with a large amount of India ink, while the capillary bed in the exocrine tissue, a certain distance from the islets contained only a small amount of India ink or even none (Fig. 6).

The interacinar capillary network is drained by venules which have no arterial partners to accompany. They gather the blood of the lobular capillaries with arborized, short roots, and rapidly increase in diameter and thickness in contrast to the uniformly thick arteries, forming interlobular veins, which usually accompany an interlobular artery.

It was noticed that the blood supply of the islets of Langerhans depends upon the size of the islets. For descriptive purposes, it is convenient to divide the islets of Langerhans roughly into three

Fig. 6. Pancreatic islets in part of lobule showing their numerous communications with the vessels of the surrounding exocrine tissue. Note the avascular halo surrounding the islets.(40x).

Fig. 7. Pancreatic tissue of camel after injection of India ink. Note the area is highly vascularized and numerous glomeruli are observed. (40x).

groups according to their sizes (After Beck and Berg, 1931):

Group I: This group includes the largest islets of Langerhans which measure 0.35 mm in diameter and are supplied by more than one arteriole. These are the least numerous of the studied groups.

Group II: This group is the most dominant, its islets measure 0.17 mm to 0.35 mm and are supplied by one or more arteriole each.

Group III: This comprises randomly distributed, irregular islets , in which both afferent and efferent blood vessels are rarely seen.

Rich anastomoses were found to exist between the capillaries of the islets of Langerhans and those in the interacinar rete. It is not hard to distinguish the two types of vessels because the former is shaped in the form of loops, while the latter has a pattern which confirms to the outlines of the acini.

Two to four branches of the intralobular artery enter the same islets to form a glomerular structure. The relatively large afferent vessel enters the islet of Langerhans and becomes a wide convoluted sinusoid within the islet (Figs. 8 and 9).
In summary, the intralobular arteriole gives branches to the islets, penetrating it from the periphery to the center, where the efferent vessels travel to the interacinar tissue.

In studying serial sections stained with hematoxylin and eosin, numerous scattered areas filled with red blood corpuscles were noticed which correspond to the islets of Langerhans (Fig. 10).

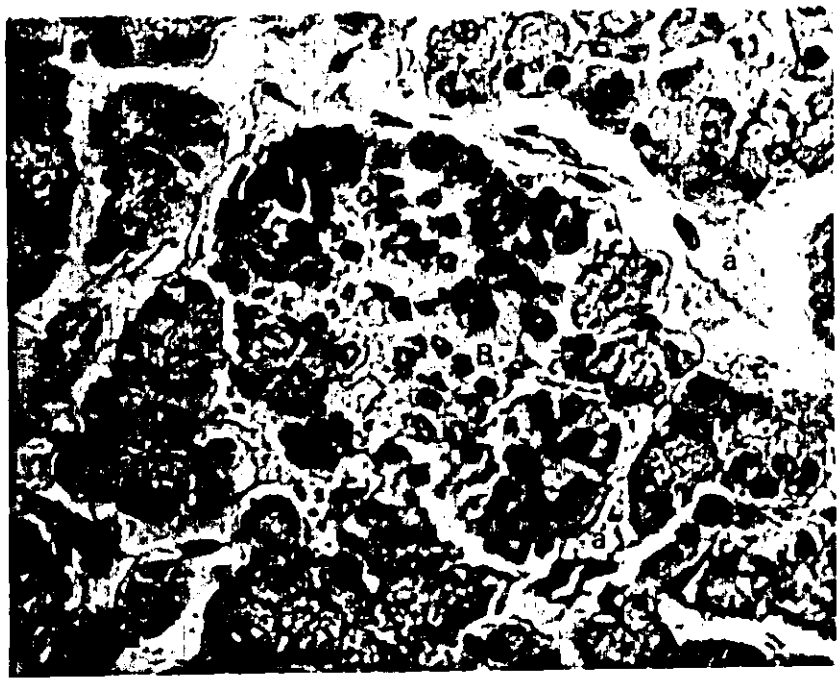

Fig. 8. Arrangement of capillaries in an islet of Langerhans. (A) alpha cell; (a) afferent sinusoid; (a) intralobular peri-insular sinusoid; (B) beta cell; (D) delta cell. (e) efferent sinusoid. (Bouin, Chrome alum Gomori) .

Fig. 9. Arrangement of sinusoids in the islet of Langerhans. (a) afferent; (e) efferent sinusoids. (Formaline, chrom alum Gomori).

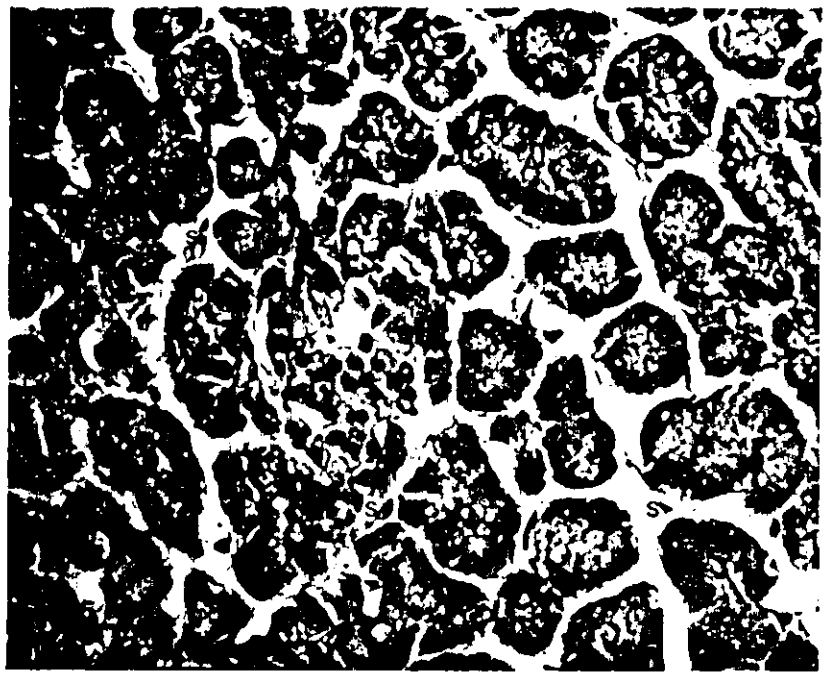

Fig. 10. Islet of Langerhans surrounded by acinar tissue stained with hematoxyling eosin.
(Ac) acini; (I.L.) islet of Langerhans; (s) sinusoids.
(5 μm).

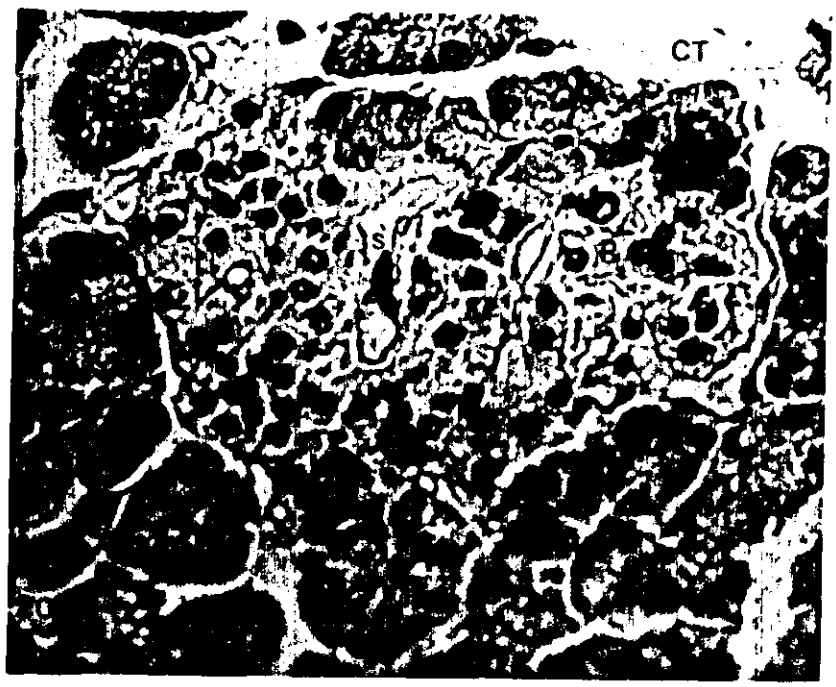

Fig. 11. Islet of Langerhans stained with chrome alum Gomori.
(A) alpha cell; (B) beta cell; (C) C cell; (CT) areolar connective tissue; (D) delta cell; (S) sinusoids. (5 μm).

In addition, small inter acinar vessels appear near these islets of Langerhans. The acinar tissue is found to be enclosed by the vascular sinusoid. Thus the small efferent vessels travel from the center of the islets of Langerhans to the acinar tissue. Figure 11 shows a section stained with chrome alum Gomori and fixed in formalin. The intralobular arteries are observed and the insular vessels or sinusoids are lined by a single layer of endothelial cells supported by a few fibers of delicate connective tissue.

V. Panreatic degenerated nerve fibers and their terminals:

In the present study the degenerated nerve fibers and their terminals were studied by using the ammoniacal silver nitrate method (Land et al., 1970). The pancreatic nerve plexuses are grouped according to their location in the pancreas as follows:

1. Peri-vascular plexus.
2. Peri-acinous plexus.
3. Peri-insular plexus.

The three plexuses are not separated, but they anastomose with one another along their course. The nerve bundle runs from one kind of plexus to another. The distribution of the nerve bundles and nerve terminals is seen within the pancreas (Figs. 12 and 13).

Degenerating nerves are noted in the connective tissue around the ducts as well as the blood vessels. Moreover, anastomoses of degenerating nerve endings are also observed in the walls of blood vessels. In addition, the degenerating nerves are also visible in

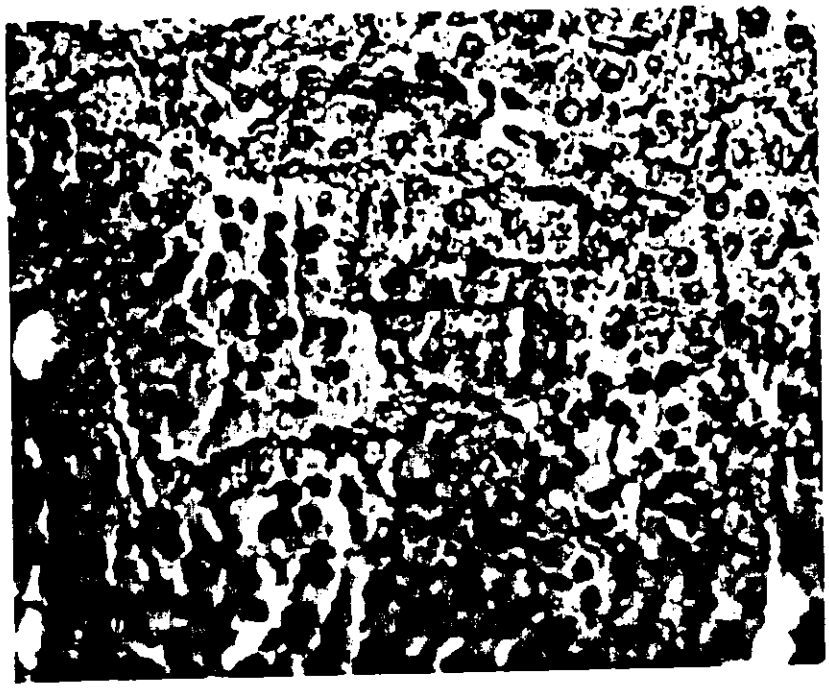

Fig. 12. Degenerated nerve fibers and endings showing its pathway (P.A.) Peri-acinus; (P.I.) Peri-insular. (Ammoniacal silver nitrate, 5 µm).

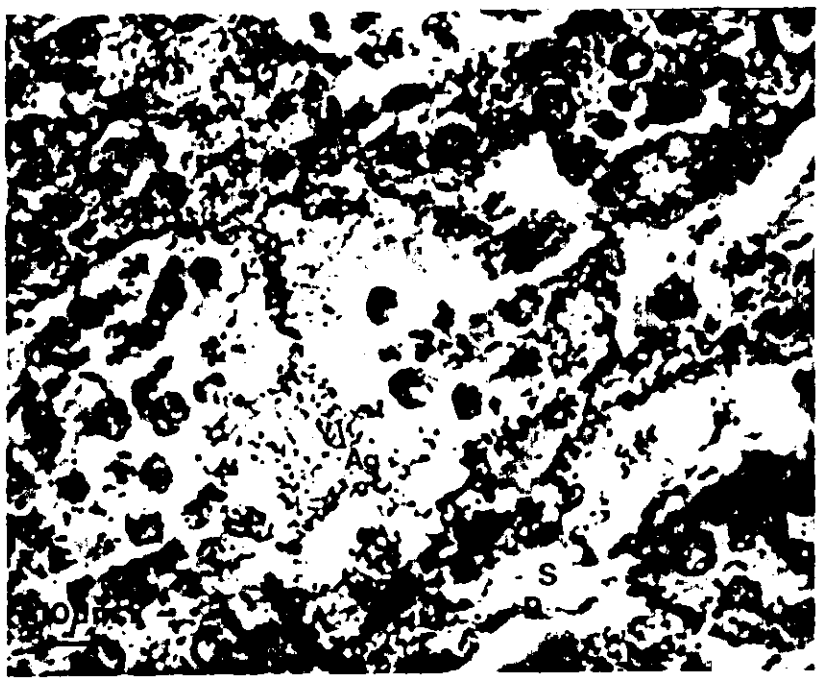

Fig. 13. Degenerated nerve fibers and endings.
(Ag) argyrophilic cells; (I.I.) Intra-insular plexus; (P.I.) peri insular plexus; (P.V.) perivascular. (S) sinusoid. (Ammoniacal silver nitrate, 5 µm).

the interstitial connective tissues of both the inter and intralobular septa. A large number of degenerating nerve fibers and terminals, are demonstrated in the peri-acinar spaces. Some of the peri-acinar nerve branches form the peri-insular nerve plexuses which lie between the islets of Langerhans and the acini. The degenerating nerves situated around the islets of Langerhans are relatively more numerous than those in the interlobular connective tissue and among the acini. Divisions and even subdivisions of degenerating nerve fibers emerge along their course and anastomose with other branches forming a neural plexus.

Degenerated nerve fibers and terminals located in the peri-insular connective tissue are shown in Figure 14. Many branches are also observed as single separate dark brown or black dots. Usually the nerves accompany blood sinusoids within the islets of Langerhans. The degenerating nerve fibers and nerve terminals are peri-vascular as well as intrainsular. As mentioned above, the nerve bundles situated in the interlobular connective tissue proceed into the glandular parenchyma, following up the branching of the blood vessels. In their course they are divided into many nerve branches. Some of them reach the walls of blood vessels where they form the peri-vascular plexus which is mainly composed of non medullated fibers (Figs. 13, 14 and 15). Large and medium sized arteries have a heavy plexus which orginates from nerve fibers which in their turn depart individually or in fine bundles of two or more fibers parallel to the vessels. The end branches of these fibers are connected with the neural terminal nets that lie in the walls of the blood vessels

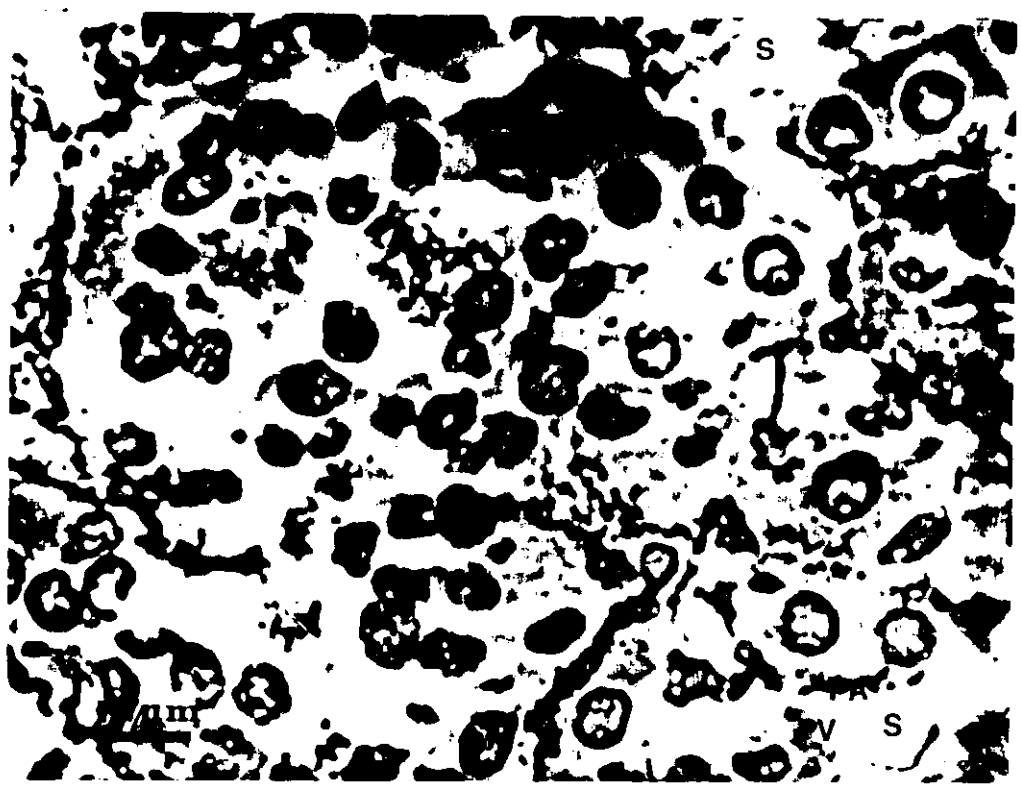

Fig. 14. The arrangement of degenerated nerve fibers and endings. (Ag) argyrophilic cells; (P.A.) periacinus; (P.I.) peri insular plexus; (P.V.) perivascular; (S) sinusoids, (Ammoniacal silver nitrate).

(Figs. 13 and 15).

The network of the terminal branches in large arteries are mainly parallel to the axes of the smooth muscle cells. These branches penetrate deeply into the wall forming the terminal neural net under the endothelium. In small arteries the peri-vascular plexus is less extensive than that in large arteries, but the terminal net of the small arteries is still relatively rich.

In general, the walls of the veins receive less nerve supply than those of the arteries.

The neural terminals anastomose with one another to form a neural terminal net which envelops the capillaries. This net is intimately connected with that of the neighboring tissues, namely; the interlobular connective tissue. In the wall of large vessels and in the pancreatic parenchyma, the neural terminal net forms a large net, which extends into various parts of the pancreas. The neural terminal net, also occurs among the acini.

The terminal net usually passes among the acini and their capillaries innervating both simultaneously (Figs. 13 and 15). The varicosities lying in the course of the terminal net show a neuro-fibrillar structure and are often seen in contact with the outer surface of the pancreatic acinous cells (Figs. 15 and 16). The course of the degenerated nerves, fibers and terminals, among the acini is tortuous. Furthermore, the neural terminal net is continuous throughout the whole lobules. Moreover, the excretory duct of the pancreas

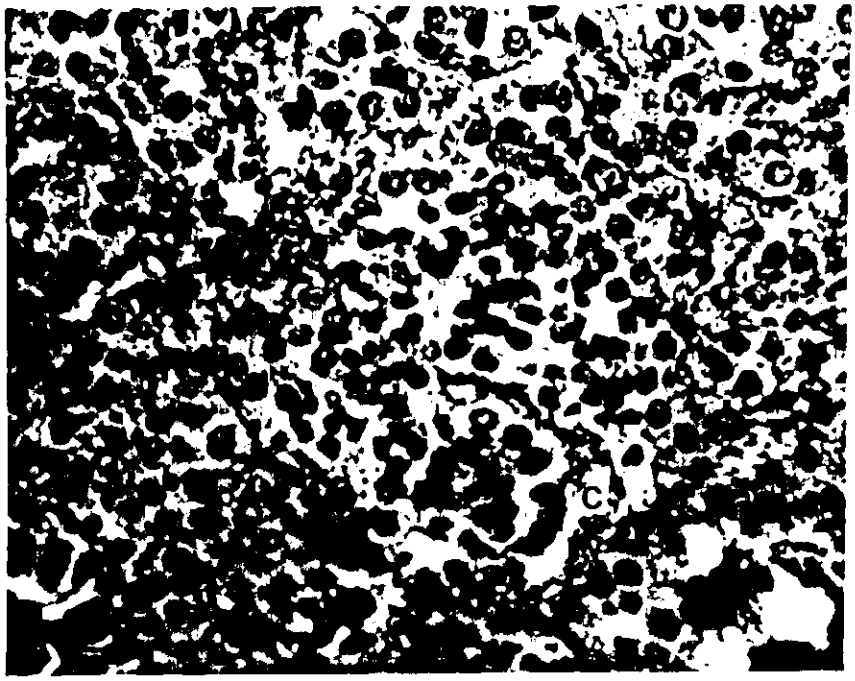

Fig. 15. Arrangement of degenerated nerve fibers and endings. (C) capillary; (I.I.) intrainsular plexus; (P.A.) peri-acinus plexus; (P.I.) peri-insular plexus; (P.V.) peri-vascular plexus. (Ammoniacal silver nitrate) .

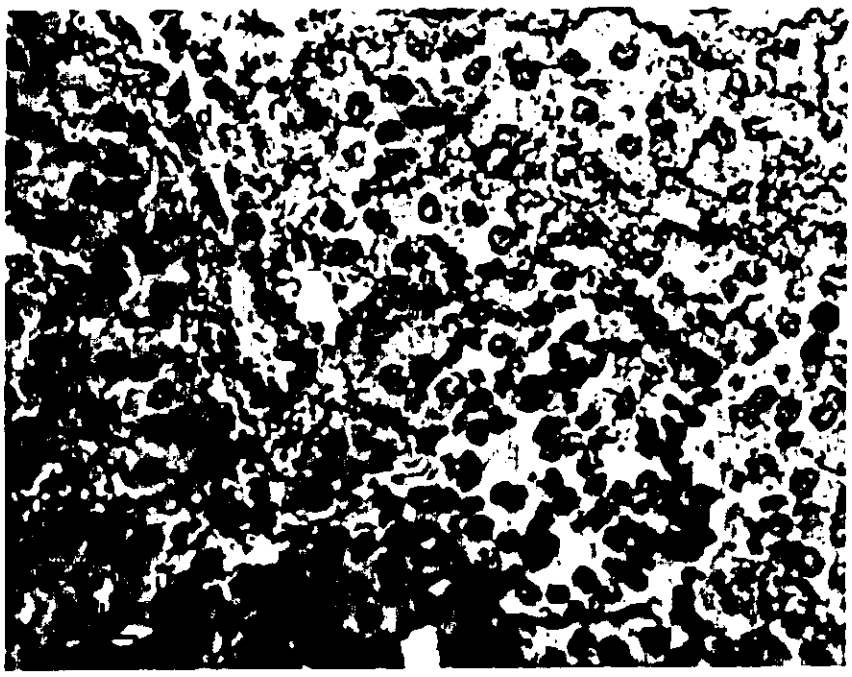

Fig. 16. Distribution of degenerated nerve pathways. (d) duct; (P.A.) peri-acinus plexus; (P.d.) peri-ductus plexus; (P.I.) peri-insular plexus. (Ammoniacal silver nitrate) .

is innervated by the neural terminal net (Fig. 16).

The islets of Langerhans are characterized by numerous innervations, which are composed of nerve bundles that terminate and form the peri-insular plexuses. These plexses are larger than the other two plexuses, peri-acinar and peri-vascular. The peri-insular plexuses are composed mainly of non-medullated fibers and to a lesser degree of medullated ones. The latter are surrounded by halo zones.

The degenerated nerves which are situated in the islets parenchyma or in the insular connective tissue correspond to the neural terminals as they are often found on the inner surface of the islets. The degenerated nerve bundles show branches which run over the islets of Langerhans and take a course on their outer surface . Usually the peri-insular plexus envelops the islets, while the others penetrate the islets parenchyma.

Some of the nerve fibers of the peri-insular plexus do not enter the islets of Langerhans but run to the exocrine acini either as single fibers or as nerve bundles. The intra-insular innervation is usually peri-sinusoid as shown in Figures 13 and 15.

VI. Micromorphology of the islets of Langerhans:

The camel pancreas is covered by a relatively thin capsule of connective tissue, rich in fibroblasts, collagen and reticular fibers. These fibers also surround the islets of Langerhans but do not penetrate them.

The exocrine secretory units are tubular and consist of pyramidal cells. The apexes of the acini are mostly vacuolated as a result of the release of secretory granules (Figs. 17 and 18). At the base of the acini, round nuclei are found. The pancreas is penetrated by septa, dividing it into a number of lobules. Each lobule contains a number of acini packed together with connective tissue rich in collagen fibers.

The islets of Langerhans appear as groups of small cells separated from the exocrine tissue by a capsule of connective tissue which is sometimes hard to differentiate.

All fixatives used gave satisfactory preservation of the islets of Langerhans, but upon applying the differential granule staining procedures, the best results were often obtained with Bouin's fluid. In this connection, Gomori's chrome alum stain was the best differential one.

The pancreatic tissue of unsuckling camels (1 - 9 years) can be stained with aldehyde fuchsin (combined Gomori method), or chrome alum Gomori, to demonstrate the arrangement of the alpha and beta cells. Beta cells are mosly confined to the center of the islets; while alpha cells are distributed around their periphery (Figs. 19 and 22). By using the chrome alum hematoxylin phloxine stain, and some other techniques, the various types of islet cells can be differentiated as follows:

Beta cells are steel gray and aldehyde fuchsin-positive; alpha cells are bright red, phloxine-positive, and phosphotungstic

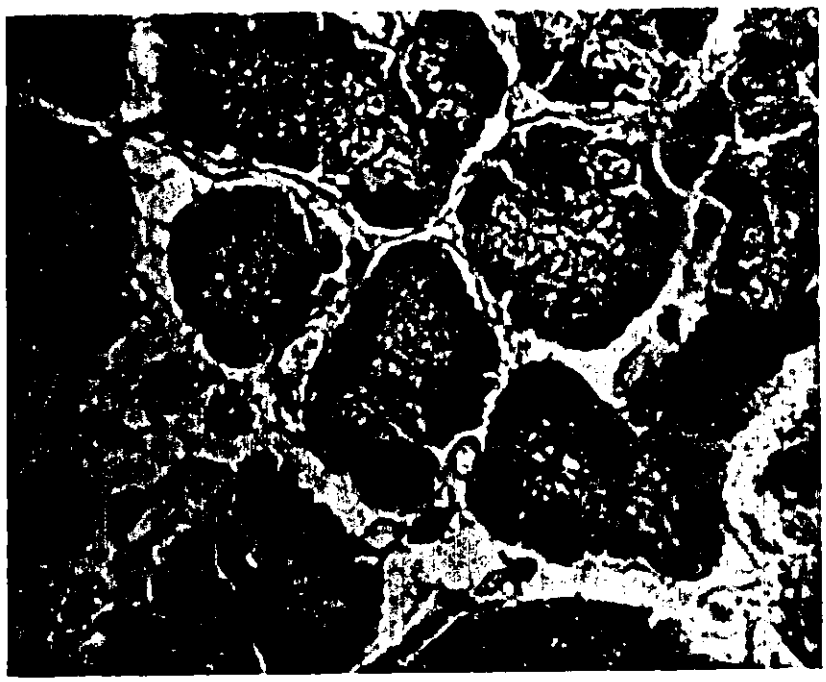

Fig. 17. Acinar tissue. (Ac) acinus cells; (C.T.) connective tissue; (rbc) red blood corpuscles. (chrome alum Gomori).

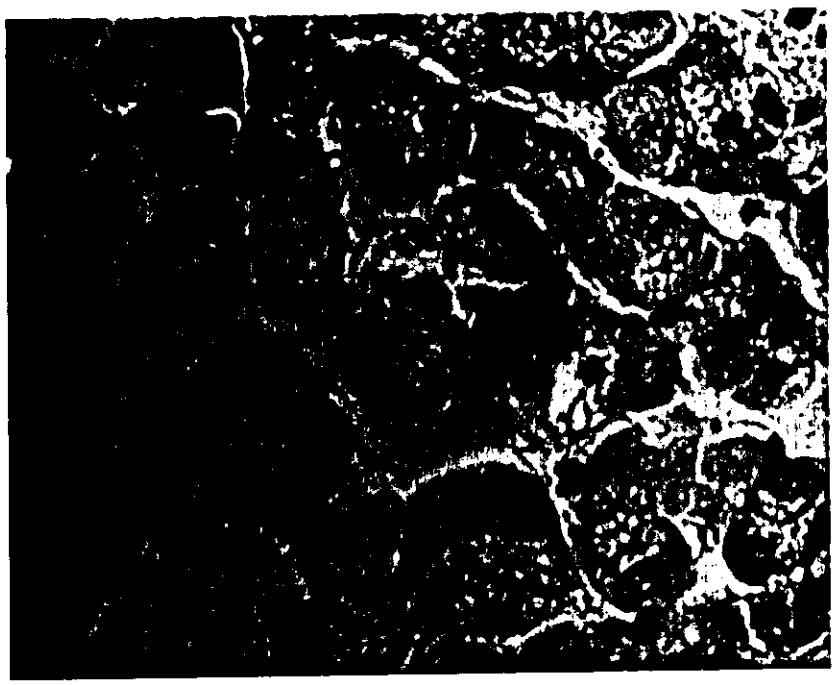

Fig. 18. Arrangement of exocrine tissue and A cells (endocrine). (A) alpha cells; (Ac) acinus cells. (Chrome alum Gomori).

acid hematoxylin (PTAH) positive (Fig. 19); delta cells are stained red by the phloxine stain, show positive argyrophillic reaction, tend to occur singly and occupy an intermediate zone between alpha and beta cells (Figs. 19 and 22). They may exist in the peripheral portion of the islets. The C cells show unstained cytoplasm indicating the absence of secretory granules. C cells tend to occur singly and occupy an intermediate zone between the alpha cells at the periphery of the islets or they may be found inside the islets. Beta cells are the most numerous of all types of islets cells. They are smaller than the alpha type and are crowded together in a less orderly fashion. The delta cells and C cells are the least numerous of all the islet cell types (Fig. 22). The delta cells are larger than the beta cells but are about the same size as the alpha cells. The shape and size of the nucleus vary among the various cell types. The C cells rarely occur in groups of more than two cells. The distal portions of alpha cells are packed with small secretory granules. Their nuclei vary in shape, are oval or round in outline, and have smooth margins or irregular ones. They are rich in chromatin. When the sections were treated by silver nitrate impregnation method, only the delta cells gave a positive reaction.

1. General structure of the islets of Langerhans:

The islets of Langerhans are round, oval, or mostly irregularly and diffusely sacttered in the exocrine pancreatic tissue. The islet tissue has a rich vascular supply as indicated by India ink injections (Fig. 7). Moreover, degenerated nerves are observed in the surrounding

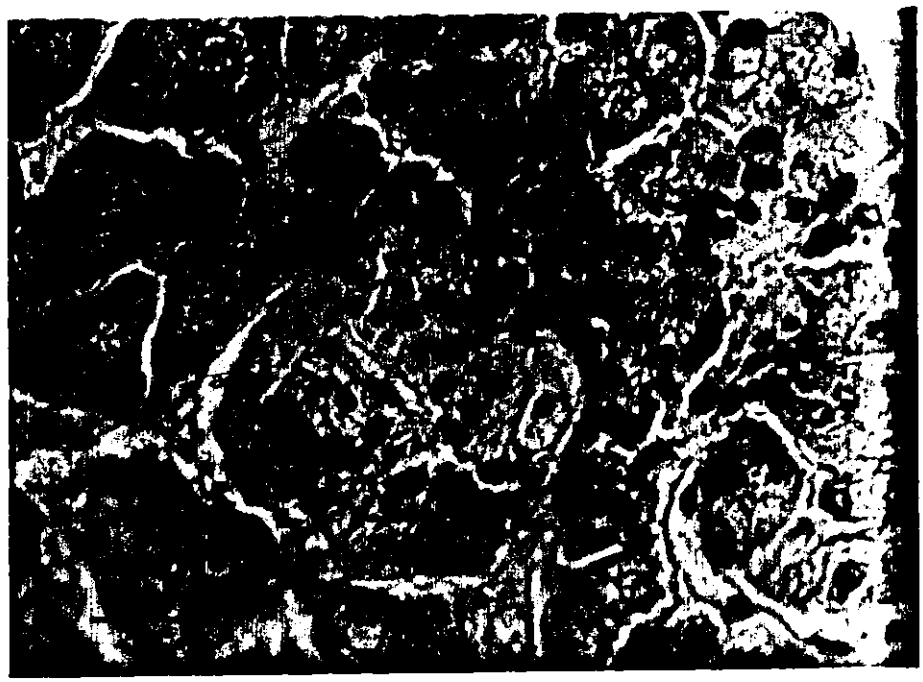

Fig. 19. Pancreatic islet, (A) alpha cell; (a) afferent sinusoid; (Ac) acinar cell; (B) beta cell; (D) delta cell; (e) efferent sinusoid; (i) unidentified cell; (s) sinusoid.

capsule of areolar connective tissue, after applying the ammoniacal silver nitrate method. The diameter of the islets of Langerhans varies from 0.17 to 0.35 mm. The distribution of islets varies in the various regions of the pancreas. The largest number of the islets of Langerhans is in the caudal region. In the body of the pancreas the number of islets amounted to 51.2/cm^2 for adults and 51.25/cm^2 for juveniles. In the head region of the pancreas, on the other hand, the corresponding figures were 6.7 and 6.0 respectively.

In most cases, the islets of Langerhans are crowded at the capillary endings or(nearby). In some islets, beta cells form together strand-like configurations like those of hepatic strands (Fig. 20). The surrounding capsule of the islets is well developed, as in (Fig. 21). However, in some cases the capsule penetrates the islets, dividing it into two lobes and forming intra-insular septa, which consist of areolar connective tissue rich in collagen fibers. Blood vessels run through the septa. In the studied sections, some islets of Langerhans showed random distribution of their cells while in other islets empty areas were seen (Fig. 21).

2. Beta cells:

Beta cells occur in the central region of the islets of Langerhans. After the combined Gomori method, the sections acquire a greyish steel color and beta cell secretion granules pick up the aldehyde fuchsin stain (Fig. 19). The beta cells proved to be non-argyrophilic. They are polygonal and show slight variations in size as they measure 10.8 $\pm$ 0.556 µm (Table 8, Appendix IV). The nuclei of B cells are

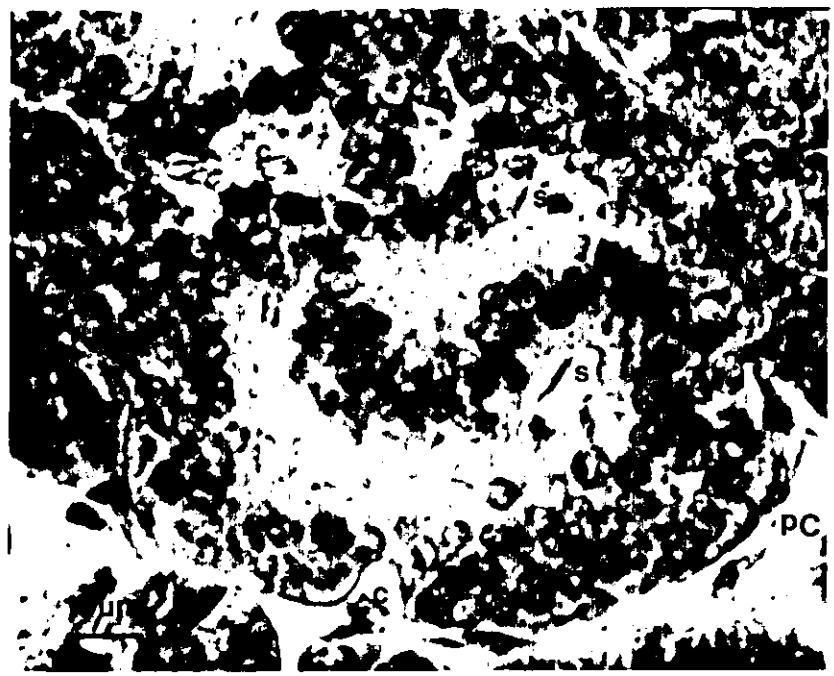

Fig. 20. Arrangement of islet cells in strand like manner involving sinusoids among them.
(C) capillary; (PC) peri-insular capsule; (S) sinusoids. (combined Gomori).

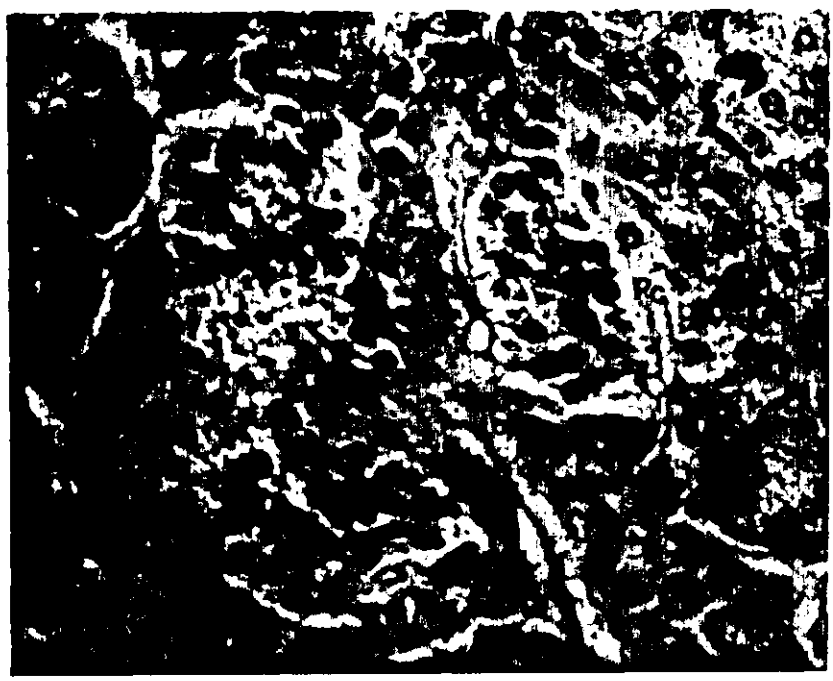

Fig. 21. Islets of Langerhans surrounded by peri-insular capsule of connective tissue (PC).
(c) empty area; (I.C.) intra-insular septa of connective tissue. (Hematoxylin).

round or oval and have moderate amounts of somewhat unevenly dispersed chromatin and their nucleoli are mostly indistinct. The nucleus measures 5.35 ± 0.17 µm (Table 8, Appendix IV). The amount of cytoplasm is moderate and the cytoplasmic borders are poorly demarcated. The nucleus is mostly eccentric as it lies in one pole of the cell, while in the other pole, near to the capillaries the granules are found. These granules are stained a greyish color, after chrome alum Gomori method, and the granular density was found to vary somewhat in different cells of the same islet .

3. Alpha cells:

Alpha cells are mainly found in aggregations in the peripheral parts of the islets of Langerhans. By chrome alum Gomori staining procedures, the alpha cells are stained red, and are thus known as phloxinophil cells. After staining with silver nitrate, the alpha cells are "negative"; they are also "negative" to aldehyde fuchsin. The alpha cells are polygonal and measure 11.25 ± 0.55 µm in diameter (Table 9, Appendix IV). There are slight variations in the size of the individual cells. The nucleus is round in shape but mostly irregular with an indistinct nucleolus, and moderate chromatin density. The nucleus of these cells is eccentric and measures 6.26 ± 0.169 µm (Table 9, Appendix IV). The secretory granules are found in the cytoplasm of the other pole of the cell. The cellular membrane is hardly distinguishable. These cells also could be encountered between the acini as they stain bright red, while the acinar cells appear pinkish in color (Figs. 19 and 22).

4. Delta cells:

By the silver impregnation procedure, argyrophilic cells are found mainly in the peripheral part of the islets of Langerhans between the alpha cells. Using the chrome alum Gomori method, they are stained a reddish color and are hardly recognized from alpha cells as their nuclei are indistinct.

Like the alpha and beta cells, the delta cells are polygonal, and of about the same size as alpha cells, with a slight variation in size . The cytoplasm is granulated, and when stained with phloxin B, attains a red color. The cellular membrane is indistinct. After the silver technique the argyrophilic reaction occurs in the form of brown to black granules in the cytoplasm. The silver granules are diffusely distributed through the cytoplasm or they are more or less concentrated at the capillary pole of the cell. Thus, the highly vascularized islets of Langerhans often exhibit larger numbers of argyrophilic cells.

5. C cells or agranular cells:

The main feature exhibited by these cells is their negative reaction to the light microscopic techniques applied in the present study. Their cytoplasm is clear and devoid of granules. They are present in small numbers and show random distribution.

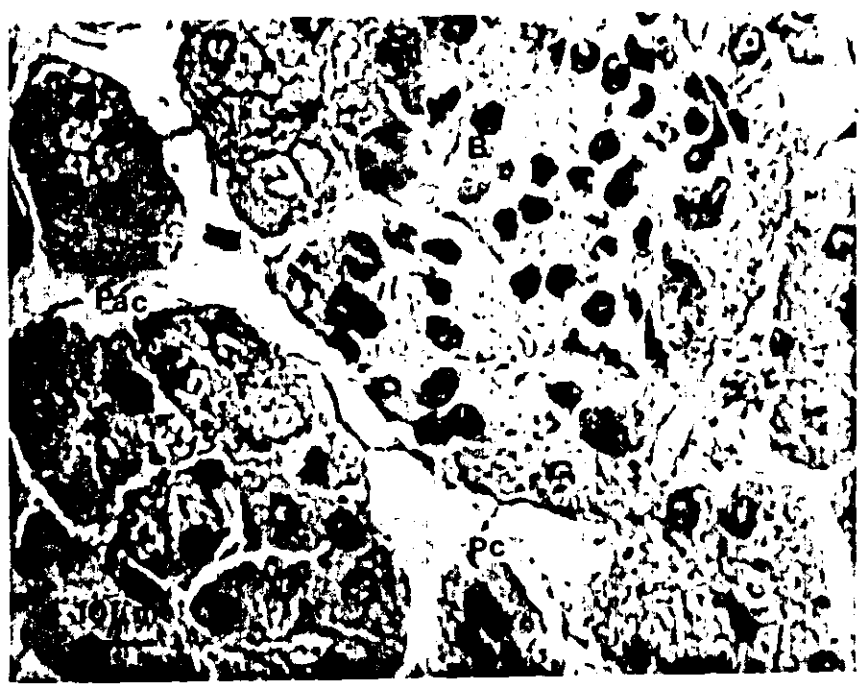

Fig. 22. Pancreatic islets of Langerhans in camel after staining with chrome alum Gomori.
(A) alpha cells; (Ac) acinar cells; (B) beta cells; (C) C cells; (Ca) capillary; (D) delta cells; (Pac) peri-acinar capsule; (Pc) peri-insular capsule; (S) sinusoid; (R) red blood corpuscle.
(5 µm thick, Sakura).

VII. Histology of duct system:

The duct system extends in the connective tissue septa , which are rich in fibroblasts and reticular fibers,and subdivide the pancreas into small lobules. The main secretory duct of the pancreas (the pancreatic duct), extends in the pancreatic angle for a distance of about two centimeters, and gives rise to two main branches. The first one extends the entire length of the ventral lobe, while the second passes in the dorsal lobe, giving off short lateral branches, to each lobule. The interlobular and main ducts are lined with a simple high columnar epithelium that rests on a basement membrane, surrounded by connective tissue of various thickness proportional to the size of the duct (Fig. 23). The epithelium is devoid of goblet cells. Similar results were obtained by Sakhawy and Moussa (1983). As the ducts enter the lobules, they decrease in size, and the epithelium becomes low cuboidal. The interlobular ducts possess columnar epithelial cells and exist between the lobules in the interlobular septa. The intralobular ducts are lined by cuboidal cells with clear cytoplasm and nuclei of irregular profiles (Fig. 24). The duct system gives further branches known as small tubules formed of a low flattened cuboidal epithelium.

The lamina propria consists of collagen and reticular fibers embedded in loose connective tissue. The duct system ends in the lumina of the acini. Within the lumina of many acini, one or more small epithelial cells, lie in contact with the apices of the secreting cells: these are the centroacinar cells. Near the termination of the

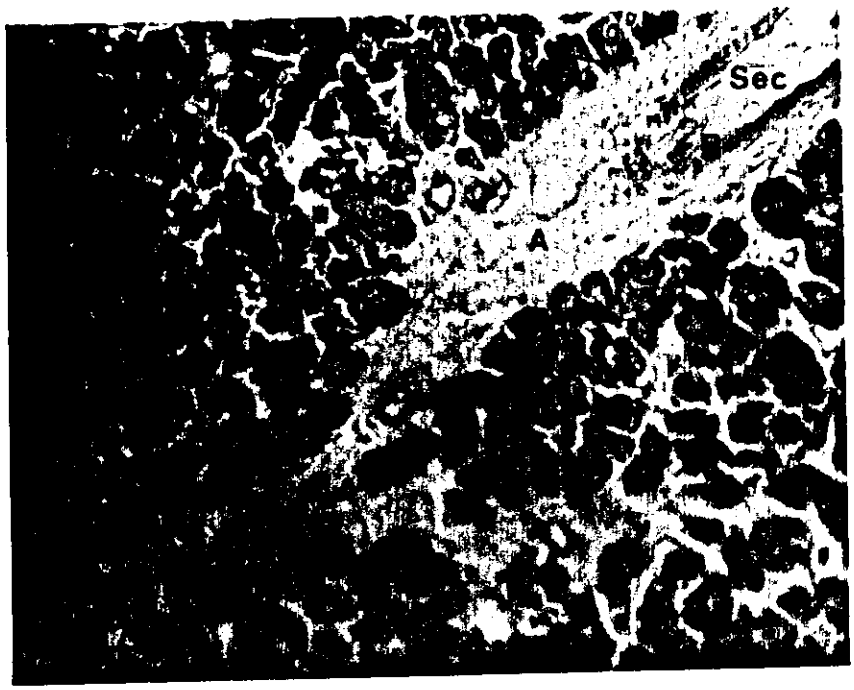

Fig. 23. Inter-lobular duct. (A) lamina propria; (a) artery; (Ac) Acinus cells; (B) lining cells; (sec) secretions; (v) vein. (hematoxylin eosin).

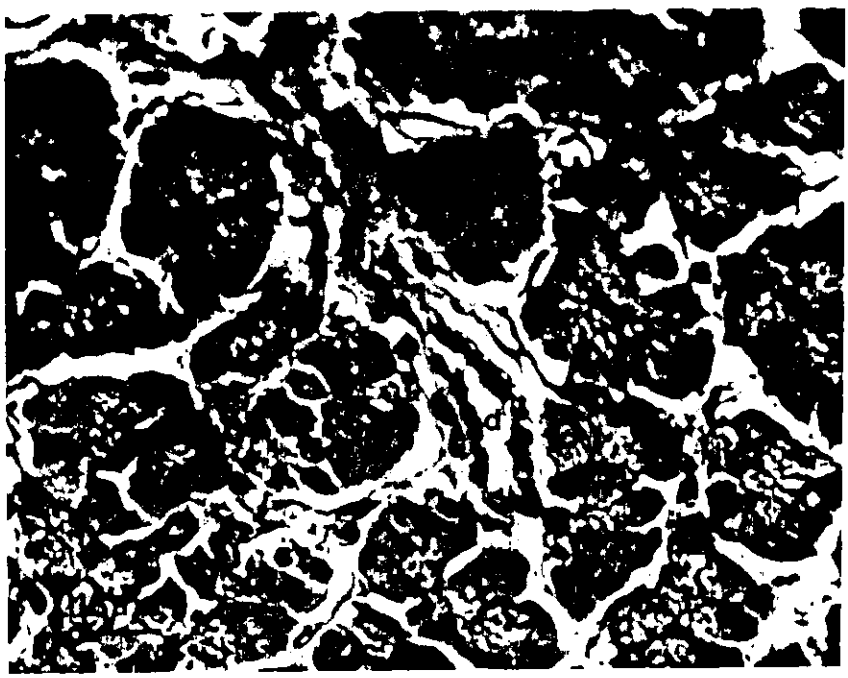

Fig. 24. Intra-lobular duct (d). (combined Gomori).

duct system, part of the wall may be made up of centroacinar cells and part by acinar cells (Fig. 25).

VIII. Islet cells, ratios and sizes:

The mean values ± st.d. of the cellular size of the alpha and beta cells are 11.25 ± 0.55 μm, and 10.8 ± 0.556 μm, respectively.

The nuclear sizes of alpha and beta cells are 6.26 ± 0.189 μm, and 5.35 ± 0.17 μm respectively.

The cell ratios of alpha, beta, delta and C cells are found in, a 5 years old adult male camel, to be 0.21 : 0.725 : 0.063 : 0.011, and in 8 years female they are 0.21 : 0.725 : 0.055 : 0.01, while in a male of 2 years of age they are 0.21 : 0.72 : 0.06 : 0.01 and in a female 1.5 years of age they are 0.2 : 0.73 : 0.06 : 0.01.

The above ratios indicate that there are no major differences among the camels studied irrespective of their sex or age.

The ratio of A : B and D : A cells are 0.29 (1 : 3.5), 0.28 (1 : 3.6) respectively.

IX. Ultrastructure of the islets of Langerhans:

The islets of Langerhans of the camel Camelus dromedarius are easily distinguished from the exorine tissue by being more diffuse and having finer granules (Fig. 26). However the limits between the islets of Langerhans and the acinar tissue are not always clear-cut.

Fig. 25. Electron micrograph of a terminal segment of the duct system of camel pancreas showing the lumen bounded on one side by acinar (Ac); and on the other by centro-acinar cells (C.C.); (z) zymogen granules.

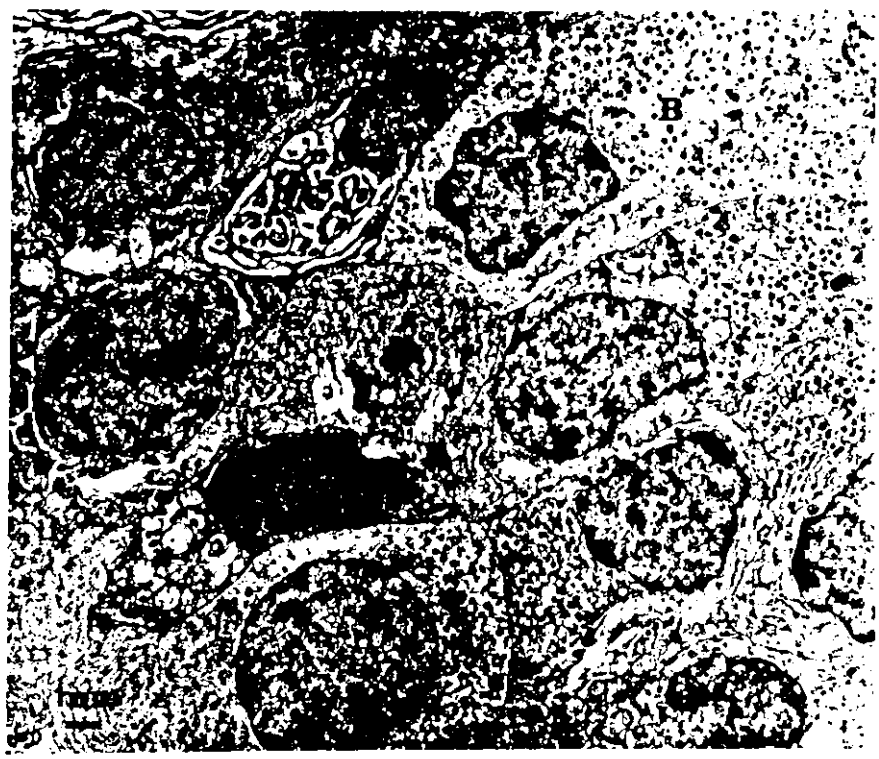

Fig. 26. Part of islets of Langerhans of a camel.
(A) A cell; (Ac) acinar cell; (B) B-cell; (N) nucleus;
Arrows indicate cellular membrane .

The islet cells are always separated from the lumen of the capillaries by a double basement membrane, of which one component belongs to the endothelium and the other to the islet cells, (Figs. 27 and 32). In the inter membranous space there are small numbers of collagen fibers.

In the islets of Langerhans, six types of cells were identified on the basis of their ultrastructural characteristics. Differences in morphology suggest that they differ in function as well.

1- Beta cells:

The beta cells have a round oval, irregular or crescentic indented nucleus. The nuclear membrane is distinct (Fig. 29). The beta cell nucleus has abundant euchromatin (E), and relatively little heterochromatin (H) (Fig. 28). The heterochromatin is mostly aggregated peripherally around the inner aspect of the nuclear envelope. The blocks of heterochromatin are separated by euchromatin channels leading to the nuclear pores. The surrounding envelope, consists of outer and inner membranes with an intervening cavity, the peri-nuclear cisterna. A nuclear pore is a gap in this cisterna, but it is not a simple hole, and it is bridged by a diaphragm. External to the pore a difuse collar of faint density extends out into the cytoplasm (Fig. 30). The nucleolus is indistinct in most cases. Deep identations of the nuclear envelope are also observed (Fig. 29).

The cytoplasm of the beta cell displays many of the main cytoplasmic components. The cellular membrane, shows sparse distinct desmosomes (Figs. 28 and 31). The beta cells are smooth in outline

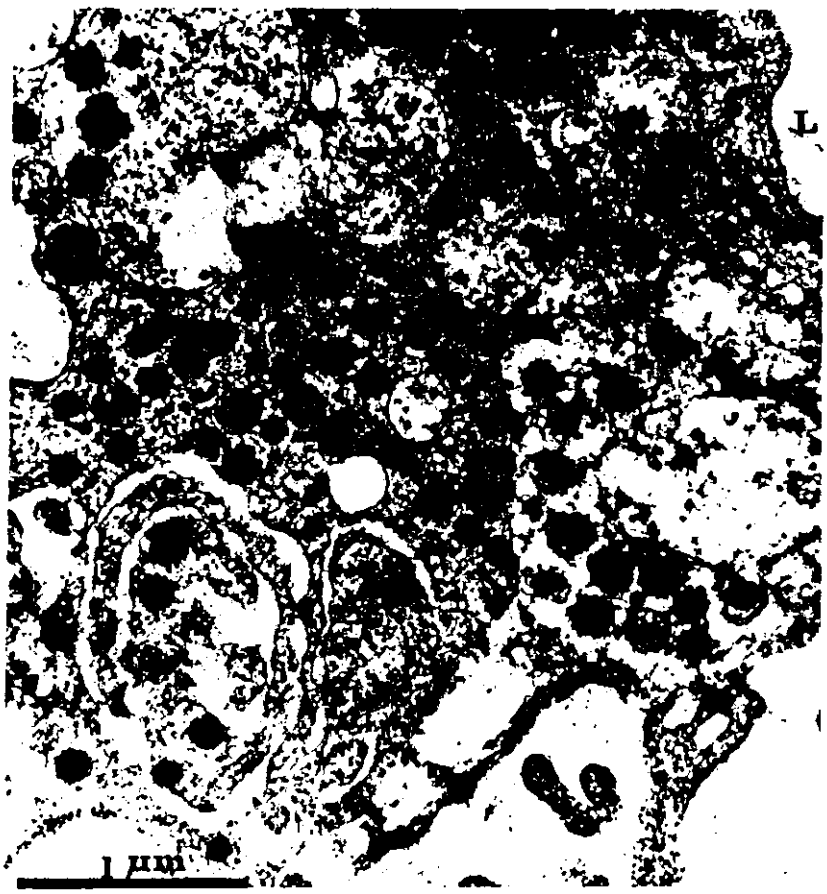

Fig. 27. Part of a typical A-cell. The granules are spherical; electron dense; and of variable size. The empty space between the granule and its membrane is characterized by a narrow halo; (L) lumen of capillary; (se) sub-endothelial area.

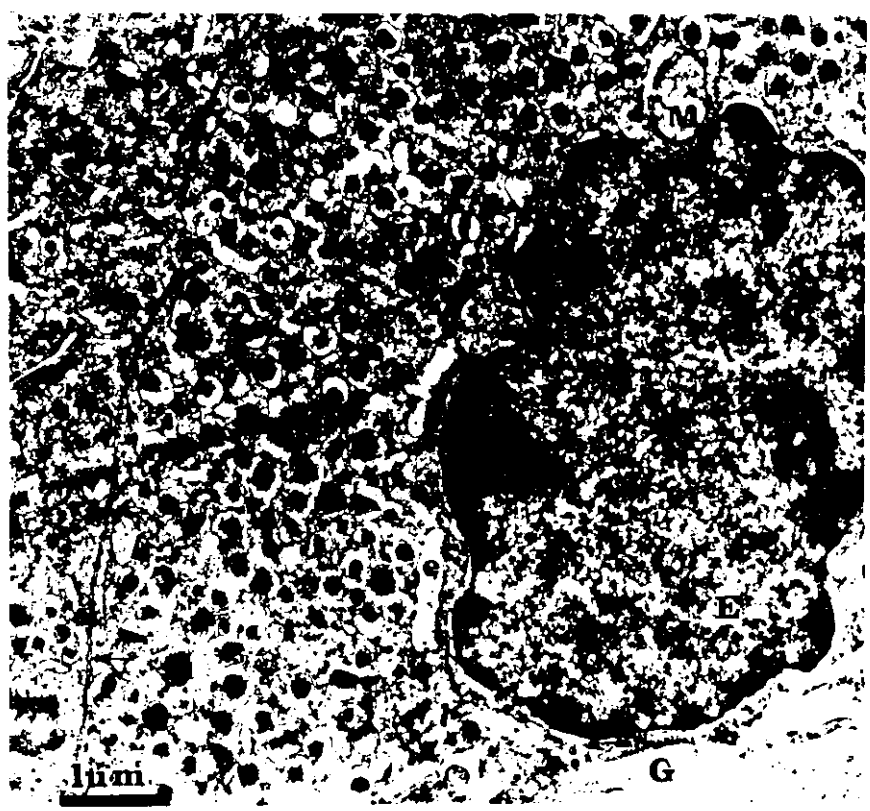

Fig. 28. Electron micrograph of part of beta cell. (E) secretory granules; (e) cisterna of endoplasmic reticulum; (G) Golgi apparatus; Arrow indicates cellular membrane; (M) mitochondrion;(N) nucleus.

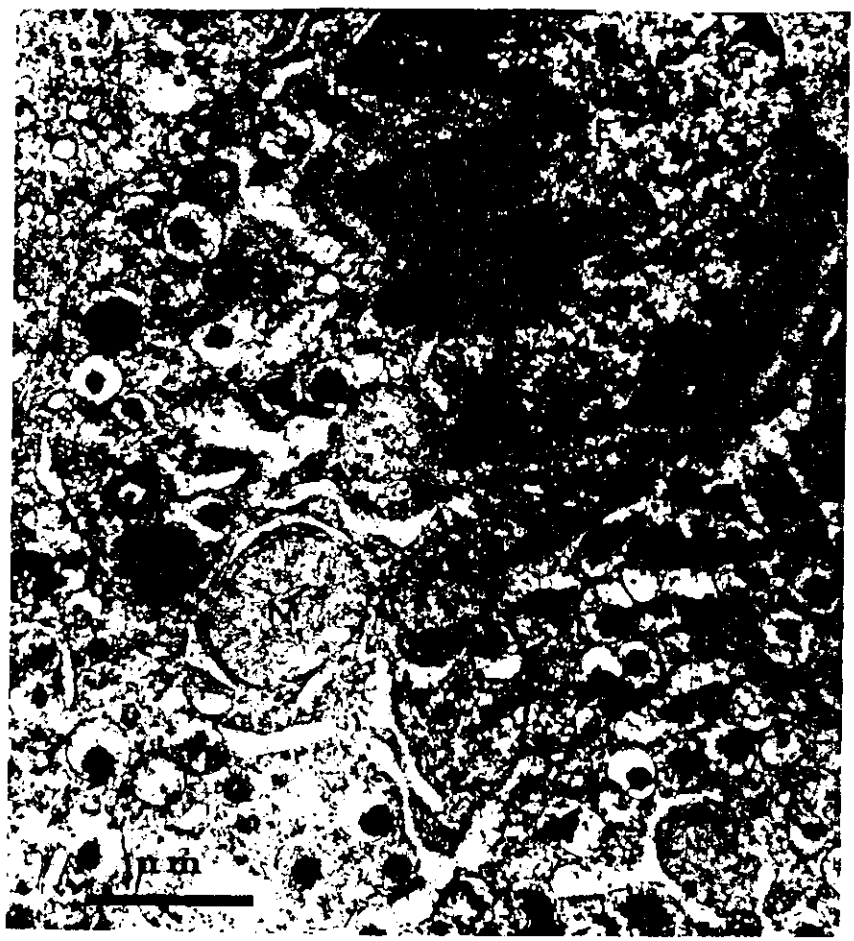

Fig. 29. Part of beta cell. The granule core is spherical shaped of variable size and surround by membranous sac with large halo. (H) hetero-chromatin; (E) euchromatin; (M) mitochondrion; (N) nucleus with nuclear pores; (P) Note nuclear deep indentation. Arrow indicates nuclear pore.

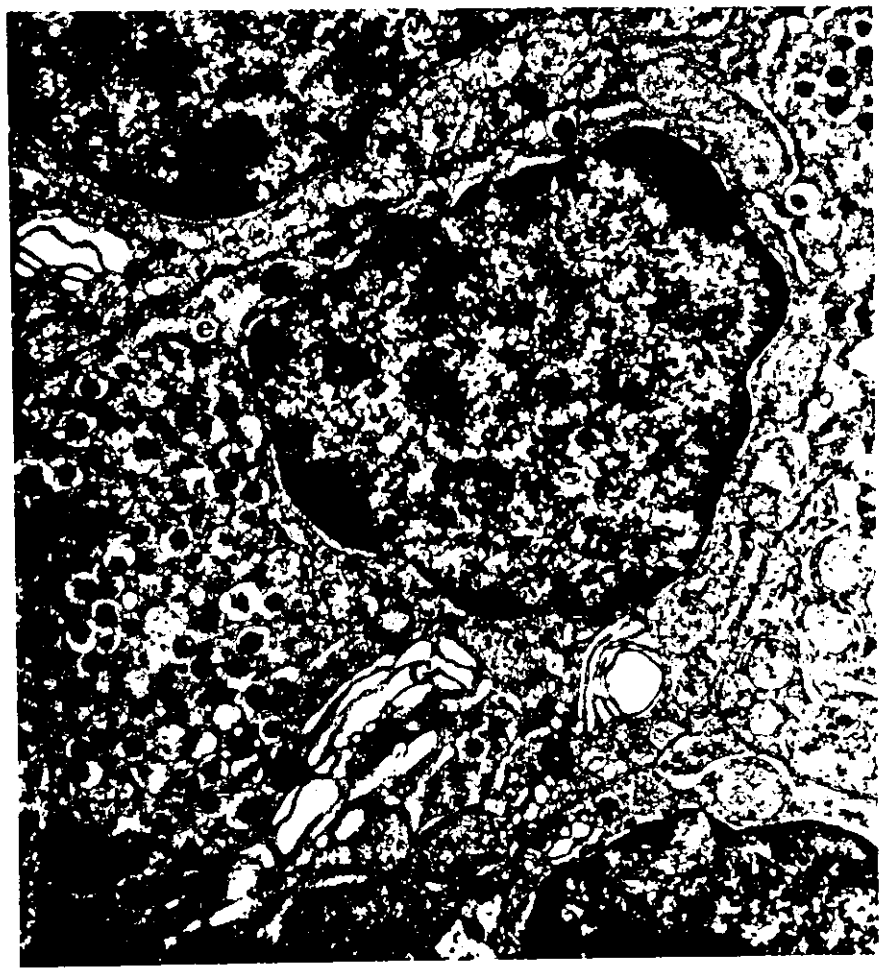

Fig. 30. Electron micrograph of part of beta cell (B); (E) euochromatin; (e) cisterna of endoplasmic reticulum; (H) heterochromatin; (G) Golgi apparatus. Arrows indicate nuclear membrane; (N) nucleus.

and are closely apposed with a narrow intervening intercellular space (Figs. 28, 30 and 31). The pericapillary beta cells are not much different. They show some cytoplasmic vacuolation with embedded secretory granules of various sizes. Also, small islands of cytoplasm containing secretory granules are observed (Fig. 32). Thin interdigitating cytoplasmic processes criss-cross overlapping each other in the inter cellular clefts (Fig. 32). The basal lamina is separated from the endothelial cells of the neighbouring capillary by a thick layer of collagen fibers (Fig. 32).

The mitochondria of the beta cells are varied is shape: round, oval, elongated filamentous and triangular, with tubular cristae. They occupy a considerable part of the cellular volume. They are found near the nucleus and are also scattered between the secretory granules, (Fig . 29).

The Golgi apparatus is clearly seen. The parallel membrane-limited sacs or cisternae are dilated in places to form vacuoles and numerous small Golgi vesicles, which lie around the apparatus (Fig. 30).

In beta cells the rough endoplasmic reticulum is sparse and cisternae of the granular reticulum reveal that the membranes are studded on their external surfaces with numerous ribosomes, (Fig. 30) . The profiles of the rough endoplasmic reticulum could be found either throughout the cytoplasm of one pole of the cell or peri-nuclear, and they are relatively sparse (Figs. 28, 30 and 31).

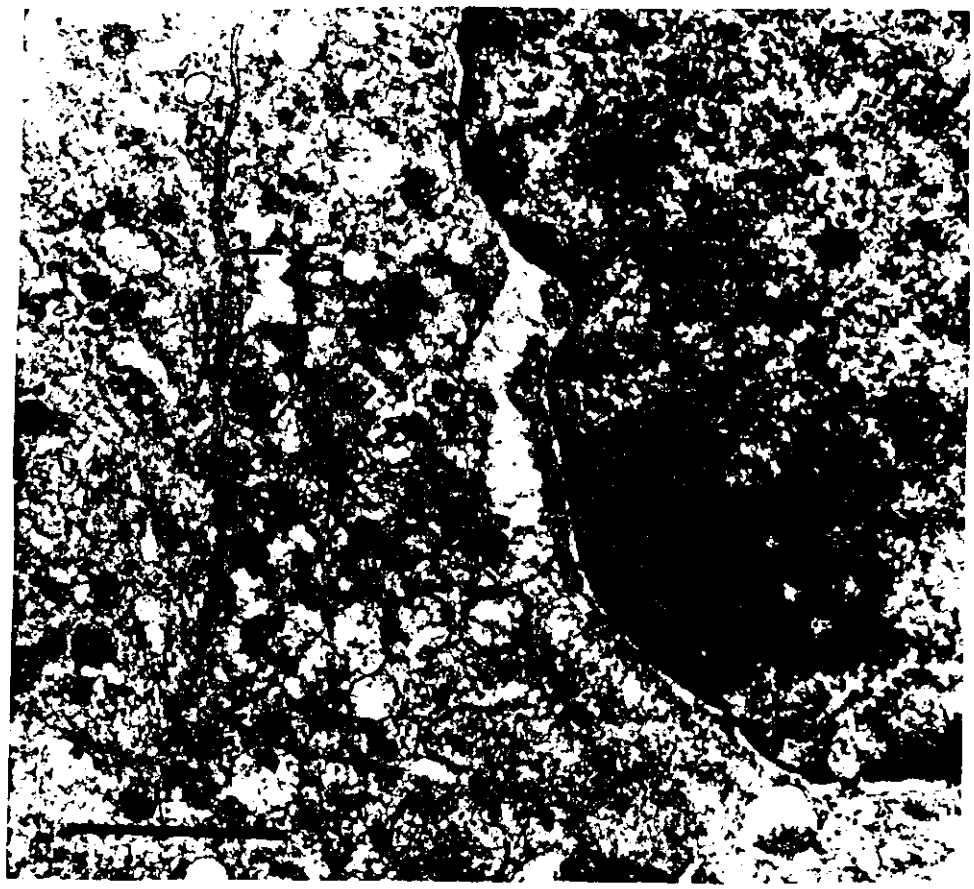

Fig. 31. Electromicrograph of beta cell showing the cellular membrane (arrows).
(d) desmosome; (N) nucleus; (s) secretory granule.

Fig. 32. Electron micrograph of part of beta cell at capillary. (b) basal lamina; (C) collagen fibers; (en) endothelium; (P) interdigitating cytoplasmic processes; (rbc) red blood corpuscle; (V) cytoplasmic vacuolation. Arrows indicate active sector.

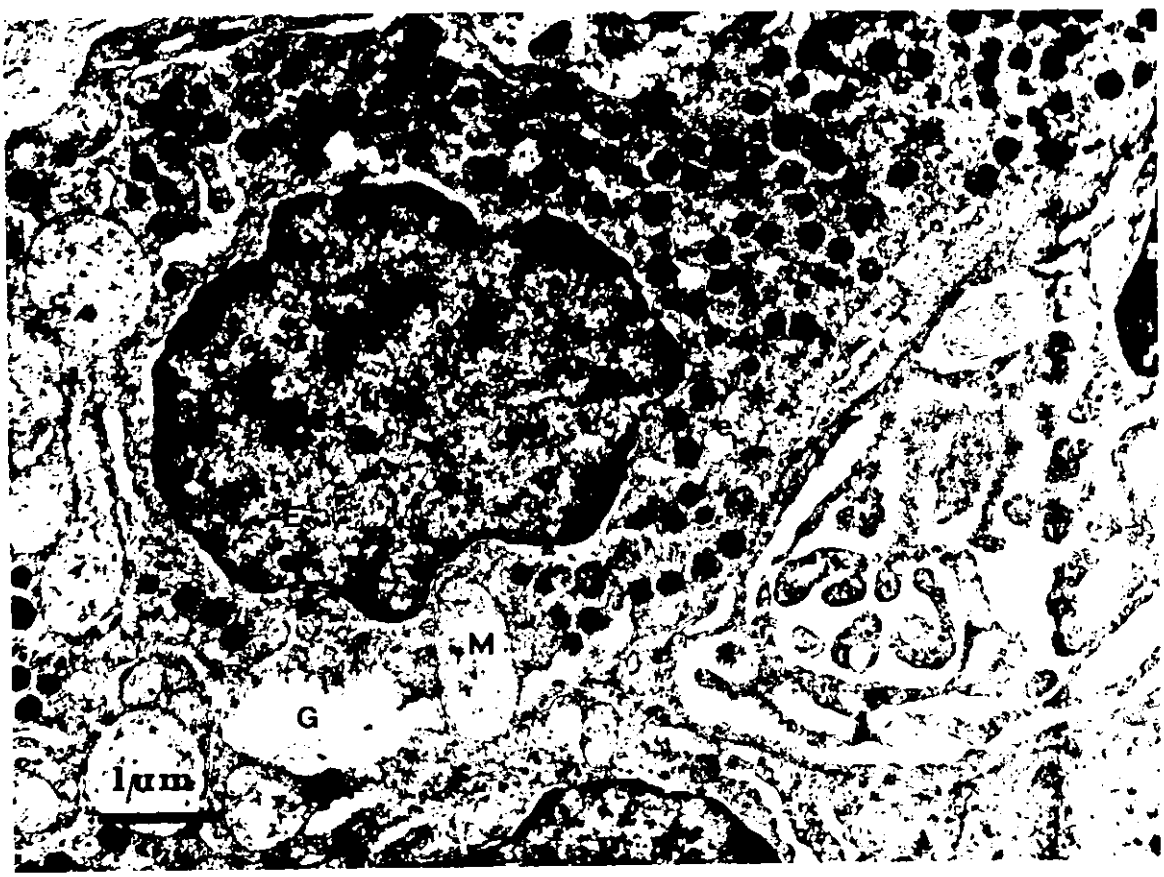

Fig. 33. Electron micrograph of part of alpha cell. Spherical secretory granule with narrow halo.
(E) euchromatin; (e) rough endoplasmic reticulum;
(G) Golgi apparatus; (H) heterochromatin; (M) mitochondrion;
(N) nucleus; (s) secretory granule.
Arrows indicate cellular membrane.

matrix of these membranous sacs are ultralucent and have a small number of free ribosomes. The intercellular spaces are occupied by complex flap-like cytoplasmic projections which interdigitate with each other forming an elaborate labyrinth (Figs. 34 and 35). There are also fuzzy spheroidal bodies of unknown nature. The rough endoplasmic reticulum is more abundant in alpha cells and its elements are located near the capillaries (Figs. 33, 34 and 42). Also, dense bodies and clusters of glycogen, are rarely encountered, while fat globules are completely absent (Figs. 33, 34 and 35).

The nucleus is located at one pole of the cell, while the secretory granules occupy the other pole. However, when the cell is close to a capillary, abundant alpha granules are usually found in the cytoplasmic portion adjacent to the capillary. Few mitochondria are observed in such areas of granule aggregation. Also, unattached ribosomes, or endoplasmic reticulum are sparse (Fig. 34). However, these organelles are more numerous in other peri-capillary cells (Fig.43). In areas which lack secretory granules, there are large amounts of rough endoplasmic reticulum which appear lamellar or vesiculated. There are also more unattached ribosomes and mitochondria (Fig. 42). The Golgi apparatus consists of several lamellated and vesicular elements.

The alpha cell membrane is smooth and tortuous. It consists of two layers separated by a clear zone or ultralucent area (Fig. 33). Desmosomes are seen, while intercellular digitations are rarely observed.

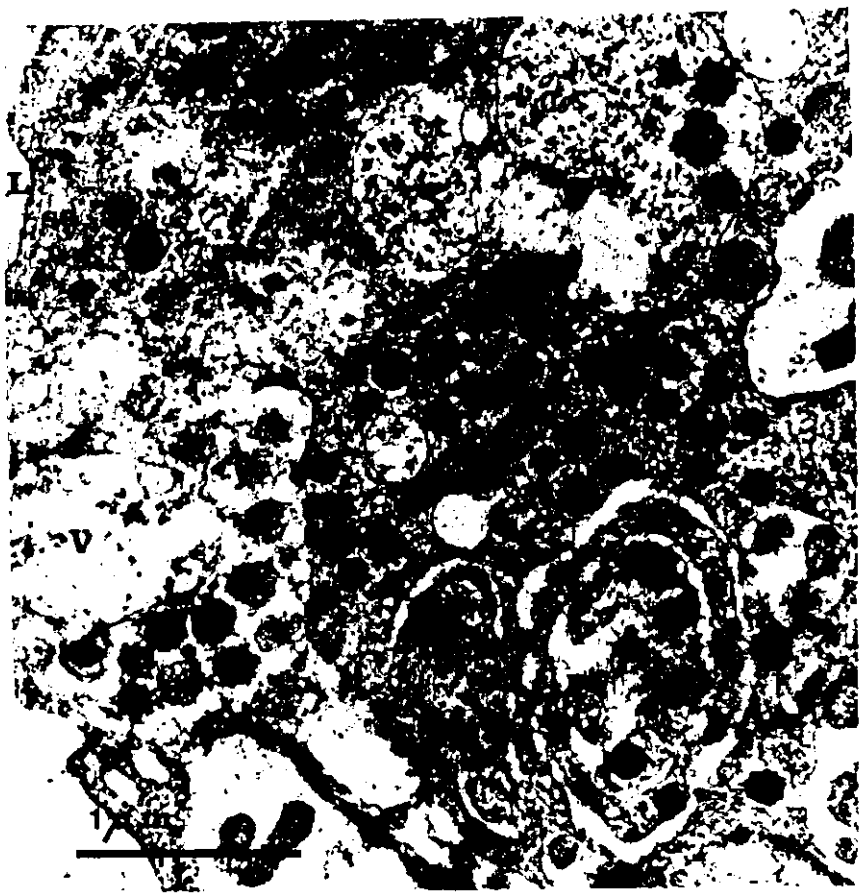

Fig. 35. Electron micrograph of part of alpha cell. Dense spherical secretory granule.
(L) lumen of capillary; (P) interdigitating cytoplasmic processes;(s) secretory granule; (V) cytoplasmic vacuolation.
Note the coarse cytoplasmic matrix.

The secretory granules of the alpha cells have a characteristic appearance. As in beta cells, they are often concentrated towards the capillary pole of the cell. The granules are exhibited as round electron dense cores. The alpha cell granules are identical in shape and vary in density and homogenity. They are surrounded by a halo enclosed in either smooth membrane or irregular or serrated membranous sacs. The granule core measures 267 ± 9 nm (Table 11, Appendix IV).

3- Delta cells:

The delta cells are found in small numbers. They could be present at the periphery of the islets of Langerhans, between alpha cells, between alpha and beta cells, or between alpha and C cells. Delta cells seem to be of the same size as alpha cells. They are irregular in shape, but are mostly polygonal, with inter-cellular digitations (Fig. 36). The D cell nucleus is similar to that of the beta cell nucleus. The mitochondria of delta cells are round or oval as in alpha cells with distinct mitochondrial cristae. They are mostly distributed at the periphery of the cell, and near the nucleus and the Golgi apparatus. The latter organelle consists of dilated lamellae forming vacuoles and a moderate number of vesicles. These wide sacs extend for relatively long distances in the pancreatic delta cell cytoplasm (Fig. 36).

A rough endoplasmic reticulum is observed near the nucleus in small amounts. It is also found surrounding the mitochondria. The latter are located in one pole of the cell and the secretory granules are accumulated at the other pole. Some times the Golgi apparatus

Fig. 36. Electron micrograph of delta cell.
(C) part of C cell; (D) delta cell; (e) cisterna of endoplasmic reticulum; (G) Golgi apparatus; (Ip) interdigiting cellular membrane; (M) mitochonrion; (N) Nucleus; (s) secretory granule.
Arrows indicate nuclear pores.

might contain sparse dense granules or ultralucent microvesicles which measure approximately 80 nm. (Fig. 36). The secretory granules are located at the vascular pole of the cell. The size of the granules is intermediate between that of the beta and that of the alpha cell granules at 222 nm (Table 12, Appendix IV). The granules vary in their electron density. Dense bodies are rarely found in this type of cells.

4- C cells:

This type of cells is rare. It may be found between the other three types of cells (alpha, beta, and delta cells). In addition, C cells are also seen between two other types of cells, which contain secretory granules that resemble those of the enterochromaffin cells and the enterochromaffin like cells (EC and ECL cells) in the human gastric mucosa (Pearse, 1974; Solcia et al., 1973; Alison and Polak, 1981). C cells are the smallest in size in comparison with all other types (Figs. 37 and 38). The granules are either present in small numbers or completely lacking. This is why such cells are called clear cells. C cells have irregular shape and are bounded by a smooth tortuous cellular membrane. In some C cells the cytoplasmic components, as unattached ribosomes, small amounts of rough endoplasmic reticulum, many vesicles, numerous vacuoles and few cytoplasmic bodies are observed (Fig. 37).

Few mitochondria are encountered, while the Golgi apparatus, may appear in some of these cells. The granules of these cells resemble those of the beta cells (Figs. 37 and 38).

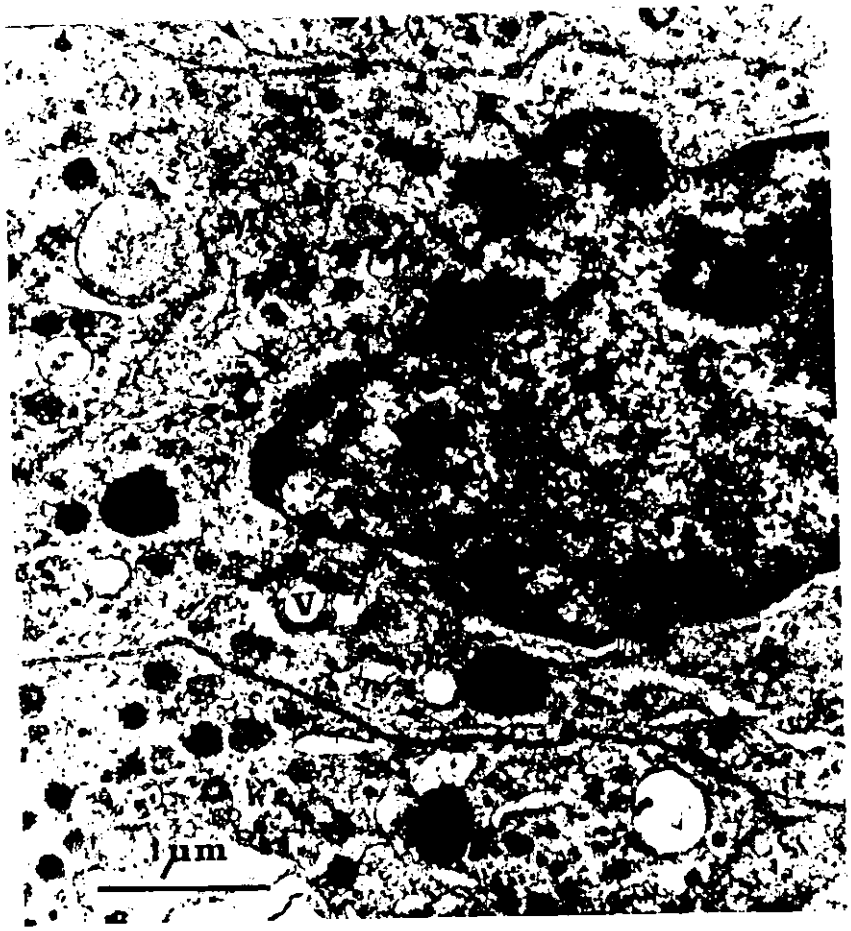

Fig. 37. Electron micrograph of part of C cell.
(C) channel; (D) dense body; (E) euchromatin; (e) cisterna of granular endoplasmic reticulum; (H) hetero-chromatin; (M) mitochondrion; (N) nucleus; (Nu) nucleolus; (s) secretory granule; (V) vacuole.
Arrows indicate nuclear pore.

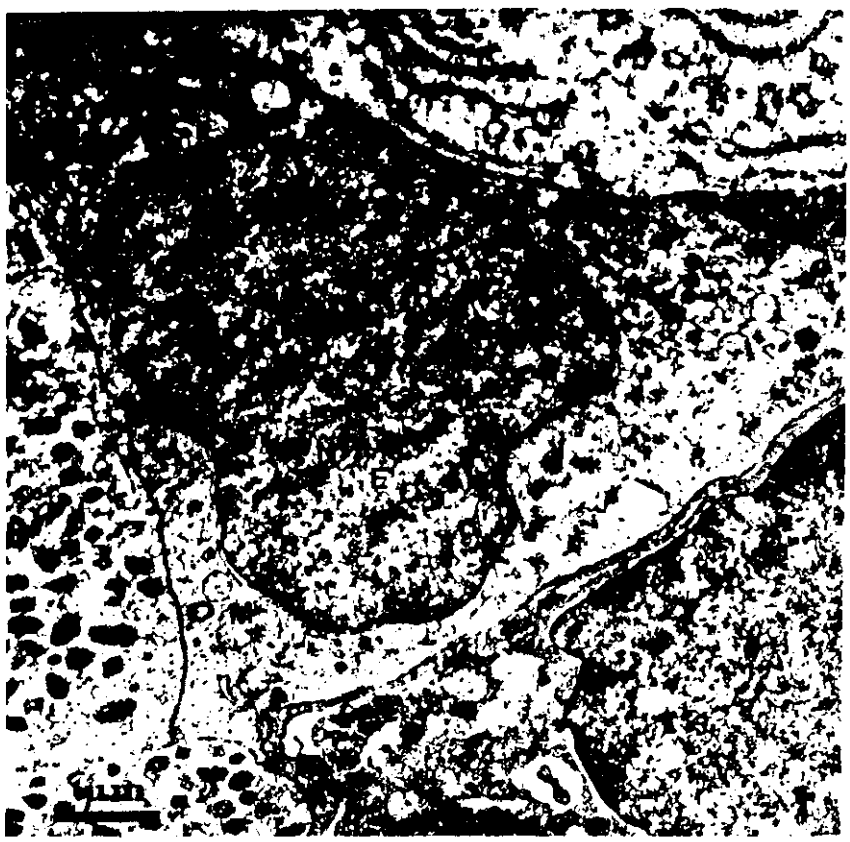

Fig. 38. C cell.
(E) euochromatin; (H) heterochromatin; (M) mitochondrion;
(N) nucleus; (s) secretory granule.
Arrow head indicates cisterna of rough endoplasmic reticulum .

5- M cells:

Previous investigations had not revealed the existence of this type of cells in any of the animals studied.

This type of cell is characterized by its polymorphic granulation. Also, it is bounded by a smooth cellular membrane. The cell is mostly regular in shape, and measures about 10.8 μm in diameter. The nucleus is rounded with sparse heterochromatin and abundant euchromatin. The nuclear membrane is distinctly smooth. The nucleolus is indistinct.

A Golgi apparatus is shown in Fig. 39,and the rough endoplasmic reticulum elements are poorly developed, and located in the perinuclear zone. The dominant character in these cells is the accumulation of mitochondria between the nucleus and the secretory granules. These mitochondria are polymorphic in shape (oval, round, filamentus, irregular and triangular) and of various sizes (Fig. 40). The cristae are of variable packing either scanty or packed in the same or different mitochondria. The cytoplasm of these cells is mostly ultralucent and rarely contains multi-vesicular cytoplasmic vacuoles . A small number of free ribosomes are scattered throughout the cytoplasm.

The secretory granules of these cells resemble EC cell granules of human gastric mucosa as revealed by Solcia et al.(1973)and Pearse (1974). They are polymorphic in shape (round, ovoid, oblonge, pear-shaped, triangular or kidney-shaped, etc.). The sizes of the secretory granules is variable (103 - 482 nm, Fig. 41). The granules are heterogenous with a core of greater or lesser osmsphilic density

Fig. 39. Electron micrograph of part of islets of Langerhans.
(B) beta cell; (C) C cell; (G) Golgi apparatus; (M) M cell;
(Mt) mitochondrion of M cell; (N) nucleus of M cell; (O)
O cell; (V) vacuole.
Note the polymorphic M secretory granule .

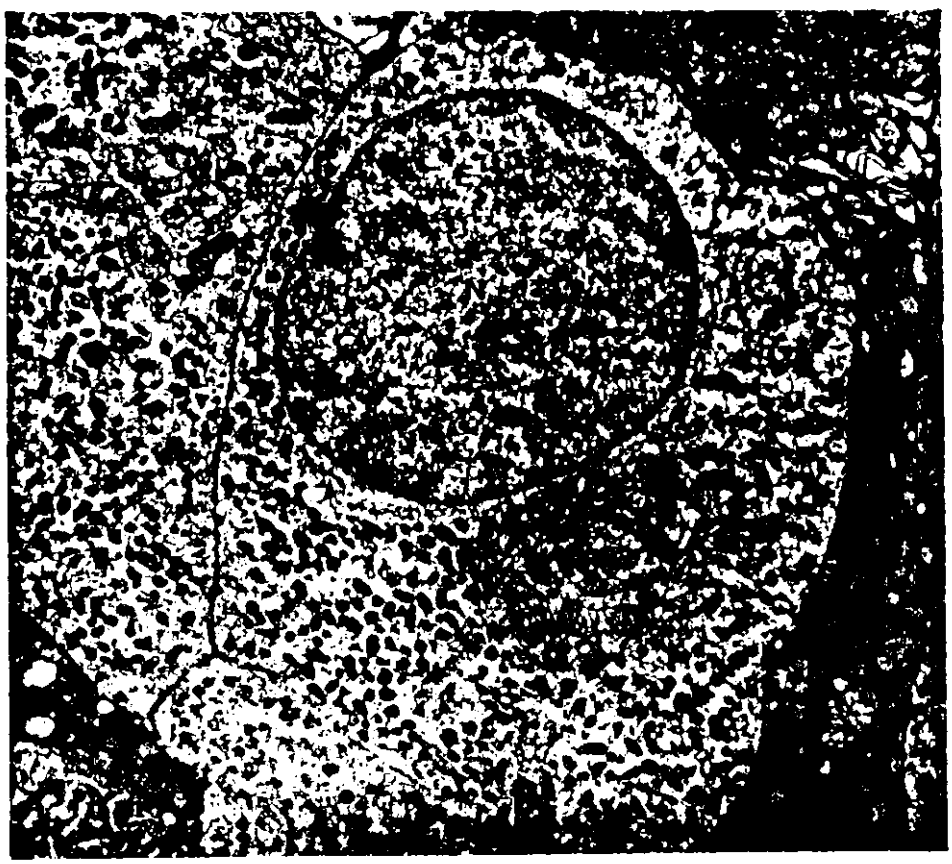

Fig. 40. Electron micrograph showing M cell.
(E) euchromatin; (H) heterochromatin; (M) mitochondrion; (N) nucleus; (O) vacuole in O cell; (s) secretory granules. Arrow head indicates cisterna of rough endoplasmic reticulum.

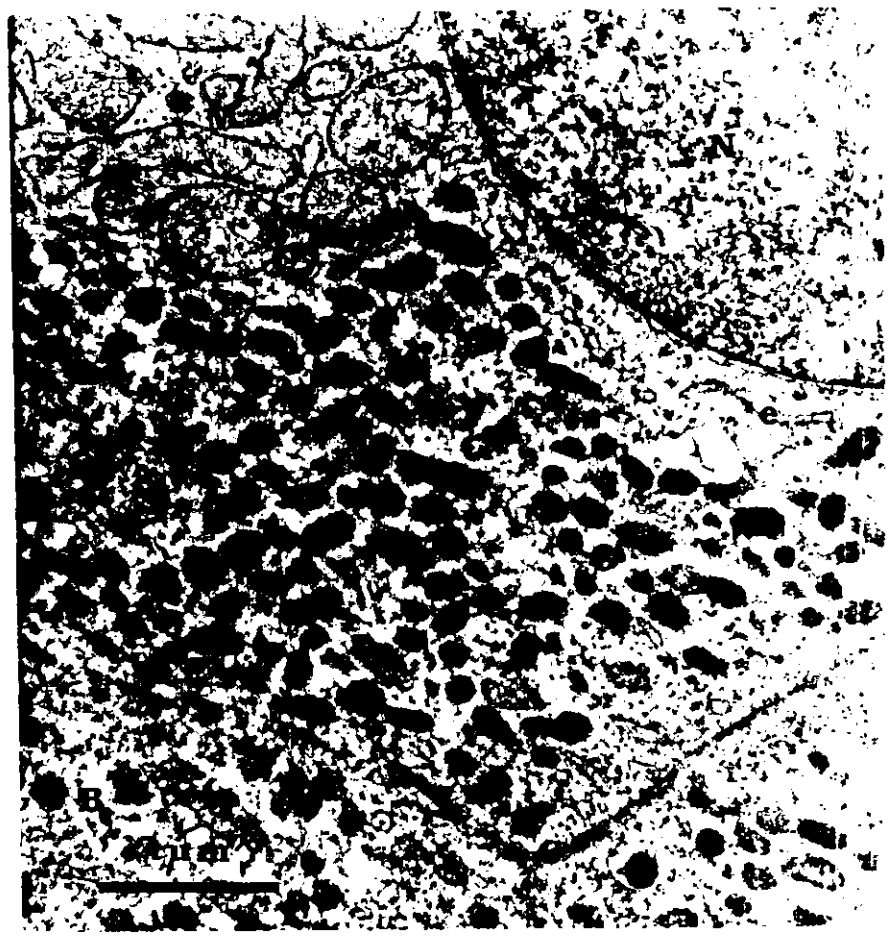

Fig. 41. Electron micrograph of part of M cell.
(B) part of beta cell; (C) cellular membrane; (e) granular endoplasmic reticulum; (i) indistinct cellular membrane; (M) mitochondrion (polymorph); (N) nucleus with visible nuclear envelope; (s) polymorphic secretory granule.

These granules are enveloped by membranes which adhere closely to them (Fig. 40).

6- O cells:

Previous studies had not shown this type of cells. These cells resemble A cells in their coarse cytoplasm. They are irregular and have an octopodan shape. Their nuclei are located in the body and the arms extend between the surrounding cells. The nuclei are irregular and contain larger amounts of heterochromatin than the case in M cells. The nucleolus is indistinct (Fig. 39).

The mitochondria are round or oval with moderatly packed cristae which are of medium size in comparison with those of the M cells. These mitochondria are distributed randomly in the cell.

The cytoplasm of these cells is coarse in its texture due to the abundance of free ribosomes (Fig. 42). Inter-cellular spaces with inter-digitating cell processes crossing it are observed. There is also cytoplasmic vacuolation, and dense bodies in the cytoplasm.

The secretory granules are characteristically round or oval. The diameter of these granules ranges between 107 - 321 nm . These granules show mostly high electron dense cores. The surrounding membrane adheres tightly to this core (Fig. 41).

X. Ultrastructure of capillaries:

Endothelial cells line the capillaries. There are two basement membranes between the capillaries and the islet cells (Fig. 43) .

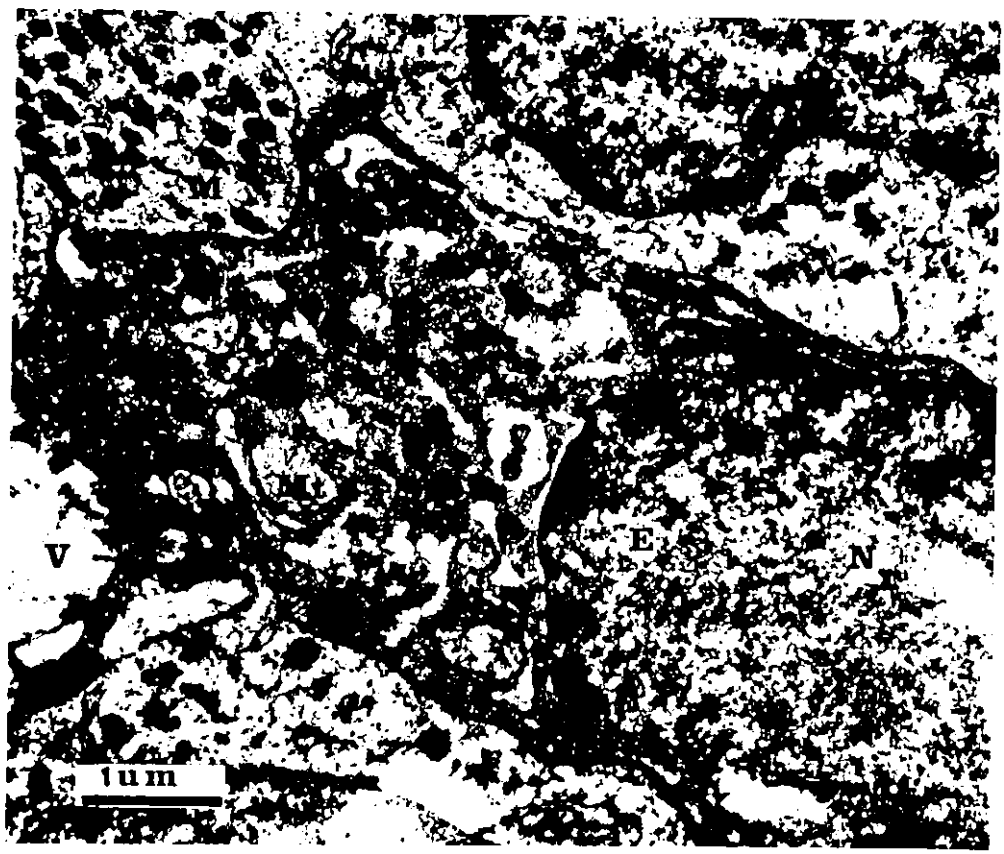

Fig. 42. Electron micrograph showing O cell.
(E) euchromatin; (H) heterochromatin; (M) part of M cell; (Mt) mitochondrion; (N) nucleus of O cell; (s) secretory granule; (V) cytoplasmic vacuole.
Arrow's head indicate nuclear pores .

Fig. 43. Electron micrograph showing peri-insular capillary. (A) A cell; (Ac) acinar cells; (b) basal lamina; (C) collagen fibers; (e) rough endoplasmic reticulum; (G) Golgi apparatus; (L) lumen of capillary; (M) mitochondrion; (N) nucleus of capillary endothelial cell; (P) interdigitating process (microvilli); (RBC) red blood corpuscle .

An amorphous material is present adherent to the plasma membranes of the endothelial cells and between them. A space is usually present between these two basement membranes, although in some instances they appear continuous. The connective tissue around the vessel (capillary) contains scattered collagen fibrils with a well developed basal lamina applied closely to the endothelial cell (Figs. 34 and 44). An endothelial cell junction is seen with associated marginal folds (Figs. 44 and 45), which project into the lumen of the capillary. Red blood corpuscles are seen in the lumen of the capillary (Figs. 43, 44 and 45).

Fig. 44. Electron micrograph showing efferent sinusoid. (B) beta cell; (b) basal lamina; (C) collagen fiber; (e) endothelial cell; (L) lumen of capillary; (RBC) red blood corpuscle.

Fig. 45. Electron micrograph showing capillary between the exocrine and the endocrine cells.
(Ac) part of acinar cell; (b) basal Lamina; (d) dense body; (e) endothelial cell; (g) microglobule of secretory granule; (M) part of M cell; (Mt) mitochondrion; (RBC) red blood corpuscle.

DISCUSSION AND CONCLUSIONS

1. Morphology: This part of the present investigation deals with the camel's pancreas. It is tongue shaped, similar to dog's pancreas (Revell, 1902), in contrast to the human pancreas which is long and irregularly prismatic in shape (Woodburne, 1954). The camel's pancreas consists of two superimposed lobes, while the dog pancreas is bent acutely on itself near its middle, giving an inverted V-shape. The present study shows that the pancreatic mesentery surrounds the pancreas for a considerable distance from the duodenal loop. The dog pancreatic mesentery attains relatively lesser width (Revell, 1902); while the human pancreatic mesentery is the least in width (Woodburne, 1954).

The pancreatic duct of the camel consists of two major ducts. These two ducts usually join each other within the gland at the pancreatic angle forming a common excretory duct that opens in the ampulla. Similar description of the dog pancreatic duct was reported by Revell (1902). In rare cases, the two pancreatic ducts in the dog do not join within the glands and open separately in the duodenum (Revell, 1902). The common pancreatic duct of the camel enters the duodenum with a single opening in the ampulla duodeni. According to Bottin (1934)* the two pancreatic ducts open separately into the duodenum. A similar description was reported by Mann (1920) in ox, pig, rabbit, guinea pig and striped gopher. Each of these animals has two separate ducts entering the duodenum. Mann (Loc. cit.) also

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* Quoted by Miller, 1962.

reported in monkey, dog, cat, and man the presence of an accessory duct which opens separately in the duodenum. On the other hand, he found two ducts (ventral and dorsal) with a common entrance to the duodenum in the pancreas of the horse, monkey, dog, cat and man. The duct empties directly into the common bile duct, usually at quite a distrance from the opening of the latter into the duodenum, as in goat, sheep, deer, mouse, rat, and pocket gopher.

2. Micromorphology of the islets of Langerhans.

The highly vascularized areas of the pancreas, such as the caudal region, are the richest in islets of Langerhans. The present study, shows that the islets are round, oval, and mostly irregular. The camel's islets of Langerhans are of various sizes. Similar results have been reported by Petkov et al. (1968) in hamster islets.

The camel islets are partially or completely isolated from the exocrine tissue by areolar connective tissue. Similar results were reported for mouse islets (Henderson and Daniel, 1979).

Centrally located B cells and peripheral A cells are observed in the camel's islets. The present description of A and B cell types arrangement is similar to that given for the rat islets (Hellerstrom and Hellman, 1960); for hamster and pig islets (Alm and Hellman, 1964); for hamster and rat islets (Petkov et al., 1968). However, in the horse pancreas the A cells are located in the center of the islet (Hellman et al., 1962). Result similar to the latter was observed by Alm and Hellman (1964) in the sheep pancreatic islets.

The peripheral localization of the A cells is established by staining with phloxin B. B cells are positive with aldehyde fuchsin and with chrome alum hematoxylin. The D cells are hardly recognizable from A cells after the application of the chrome alum hematoxylin method. However, D cells show positive argyrophilic reaction with the ammoniacal silver nitrate method, contrary to A and B cells of the camel islets. Hamster islet cells show the same results as those of the camel in argyrophilic reaction (Petkov et al., 1968). However, in brasilian sloth pancreas after phloxine B staining, the islets appeared as groups of small cells separated from the exocrine tissue by an obvious thin capsule of connective tissue. No aldehyde fuchsin granules are observed in the islet cells (Pinherio et al., 1981). D cell could be demonstrated in sloth pancreatic islets, when the tissue was impregnated with silver (Grimelius method).

In the present study the ratio of D cells to A cells proved to be about 0.28, and the ratio of A cells to B cells is 0.29. In this connection, Petkov et al. (1970) described the presence of A and B cells interwoven one with the other in the cattle Bos taurus, and D cells account for about one third of the total number of the A cells. However, Hellman and Hellerström (1960) found that in the duck islets, silver positive cells constitute about one fifth of the total cell content, and are characterized by their location along the capillary walls.

The islets of Langerhans are more abundant in the tail of the camel pancreas than in its head. A similar description was reported by Copenhaver et al.(1971) in human pancreas. The ratios of the various

types of cells of both sexes in camels show that, in adult female they are 0.2 (A): 0.725 (B): 0.055 (D): 0.01 (C); while in adult male they are 0.21 (A): 0.711 (B): 0.063 (D): 0.011 (C). The above results show that the ratios of various types of cells are approximately the same in both sexes. The same ratios apply also for juvenile camels.

The combined Gomori method was used to differentiate A and B cells of camel pancreas. B cells are stained purple, while A cells take a red color. Such results confirm the findings of Edwin et al. (1954) who applied the same method in staining the islet cells of man, dog, and rat.

Petkov et al. (1968) described the argyrophilic cells as located between A and B cells, but the difference in form and size of the islets, as well as in the localization of its cells in relation to sex, are not detected in the Golden hamster.

Argyrophilic cells are found between A cells and B cells at the periphery of the islets in the camel. Such results are based on previous studies of the argyrophilic islets cells which are considered to be equivalent to the D cells defined by electron microscope. The present investigation confirms Caramia's study (1963) on guinea pig, and Munger's et al. (1965) reported that in the rabbit, D cells are found between the zones of the islets containing A and B cells. In this connection, D cells are the common cells found in the tail region and in the uncinate process of the dog (Hellman et al., 1962). D cells are also found sandwiched between acinar cells of the dog (Munger et al., 1965). Munger et al. (1965) reported the presence of D cells in the

opossum islets contrary to what had been mentioned by Thomas (1937). The argyrophilic cells cannot be considered as equivalent to C cells as they are devoid of cytoplasmic granules (Thomas, 1937 and Bensely, 1911).

Silver impregnation is a valuable method for identification of the D cells in the endocrine pancreatic tissue of several species because of its high specificity for certain kinds of A cells. Camel D cells are argyrophilic and so are the D cells of man (Grimelius, 1968). Following silver impregnation, these cells show a distinct blackening of the background. Grimelius (1968) indicated that human pancreatic tissue shows argyrophilic reaction in A_2 cells in some islets, while in other islets, the reaction occurs in A_1 cells. But this reaction is negative in B cells. Hellerström and Hellman (1960) used the silver nitrate method for impregnating nerves. They found argyrophilic cells in the rat pancreas. But, they did not find any correlation between the argyrophilic reaction in the dark islet cells and their content of S-H and S-S groups or tryptophane; a correlation that could be established in the chicken pancreas.

From the above, it is clear that camel pancreatic islets are located in the highly vascularized areas especially in the caudal region. The islet's B cells react positively to aldehyde fuchsin (combined Gomori; chrome alum Gomori hematoxylin). Also positive results were obtained with phosphotungstic acid hematoxylin (PTAH) for A cells, and with ammoniacal silver nitrate for D cells. The camel islets of Langerhans contain all 3 types of cells named A, B and D. These were

demonstrated by the previous by mentioned techniques. In the present study, unstained C cells (agranular cytoplasm) were observed. In addition,a relatively large cell, not reported previously, is detected in this study, through light microscopic study, and is confirmed by the electron microscope.

C. Circulation:

The present investigation revealed that the camel pancreas receives its major blood supply from the celiac and the superior mensenteric arteries and is similar in this concern to what is found in man, dog, and rabbit (Woodburne, 1969; Miller et al., 1964; Lifson and Lassa 1981). The main branches of the two major arteries (superior anterior, superior inferior pancreatico duodenal arteries) are the same as in man and dog (Woodburne, 1969 and Miller, 1962). In the camel,these branches cross the mesentery and the pancreatic angle; then smaller branches penetrate the pancreas as in the dog (Miller, 1962). However, in man the branches of the celiac axis directly run down behind the head of the pancreas and then divide into two branches supplying the pancreas (Wyburn, 1972).

The present study indicates that essentially all the arterial blood to the pancreatic parenchyma, enters the islets of Langerhans through the lobular arteries and their branches. The arteriole supplies the islets of Langerhans, and is never found to issue a branch to the exocrine tissue. However, an arterial branch is recognized to supply the exocrine zone free of islets of Langerhans. Results of injection with India ink show that the intralobular artery divides to

end in a glomerular like structure (Figs. 4 and 7). The blood forms two serial capillary beds when passing first through the capillaries of an islet and then through those surrounding the adjacent exocrine cells (Fig. 46) known as continuous portal system. The present results are in full agreement with previous studies. Fujita (1973) called the insulo-acinar, in the horse, circulation as portal system. Moreover, Henderson and Daniel (1978) showed that the exocrine pancreas derives its blood supply from the islet capillaries. Besides, it also receives blood supply directly from the arterioles. Then the blood goes to the islets and passes through no less than three serial capillary beds, which belong to : the islets, the exocrine pancreas, and the liver, before returning to the heart. Similar observations were made in the camel pancreas (Fig. 47). In this connection, Lifson et al. (1980). proved that all the islets efferent vessels go to the acinar capillaries before leaving the pancreas. They concluded that the flow to the islets is large enough to permit significant local actions of the islet hormones on the exocrine pancreas. This confirms the existence of an insulo-acinar portal system in rabbit pancreas. Moreover, Daniel and Handersön (1978) proved by arterial and venous injections that blood flowing in rat, mouse, cat and baboon pancreases runs predominantly from islets to exocrine tissue.

In the camel pancreas, the ductus portal system is not recognizable due to the transparency of the examined specimen upon treatment with methyl salicylate after India ink injection, in spite of the fact that intra-arterial and intra-venous injections are done at the same

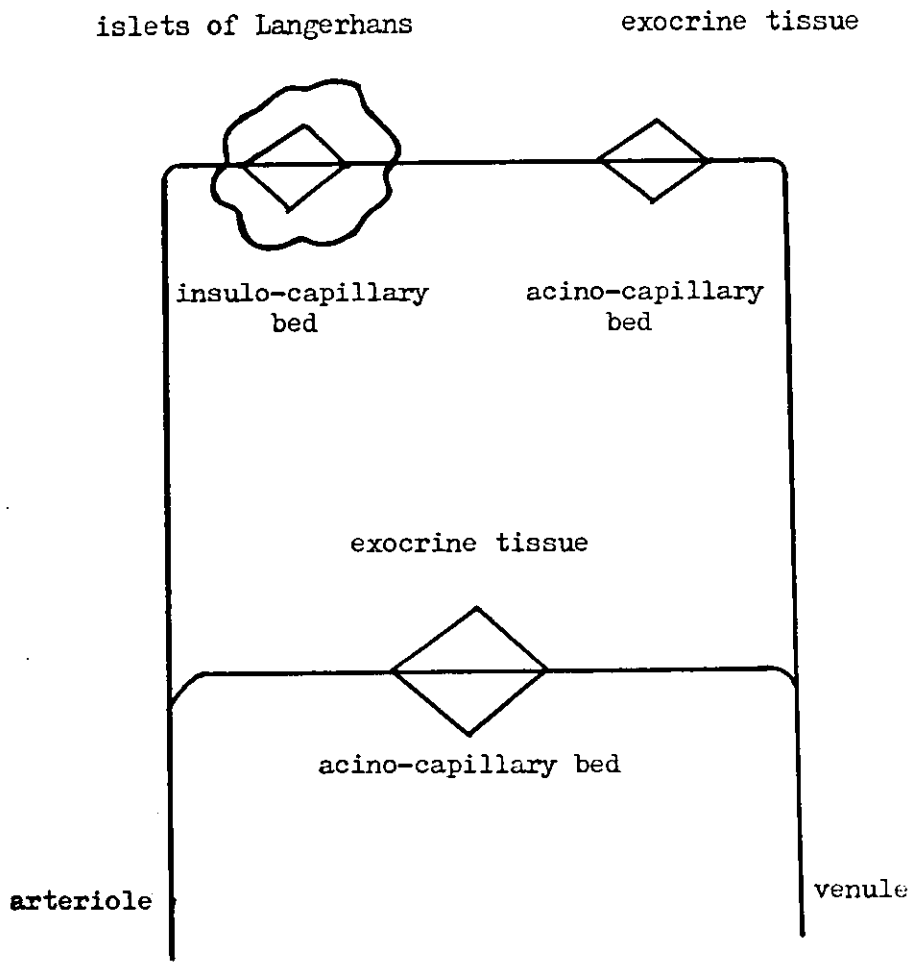

Fig. 46. The arrangement of blood vessels through the pancreatic tissue, showing the insulo-acinar portal system (modified from Henderson and Daniel, 1978).

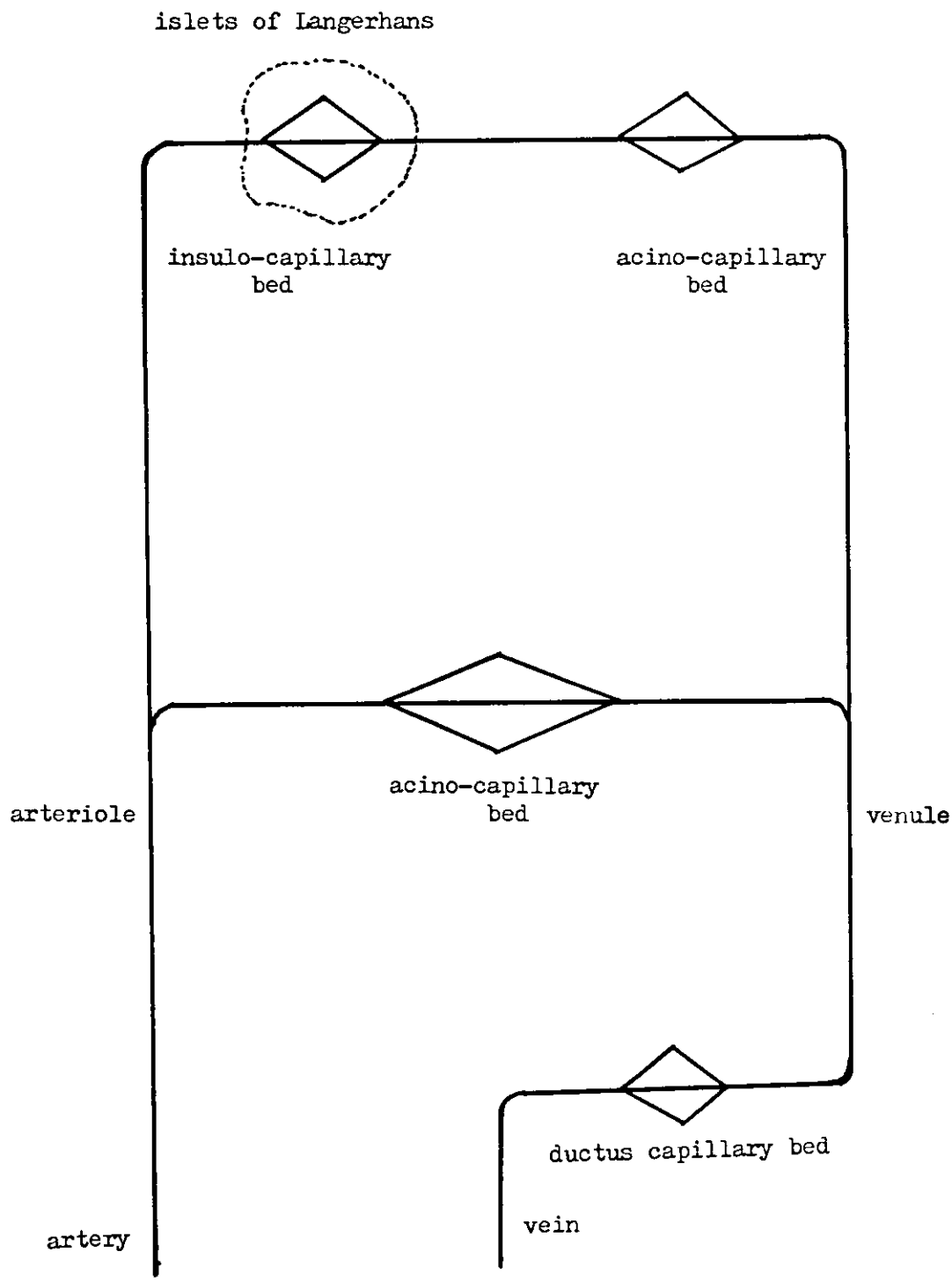

Fig. 47. The insulo-acinar ductal portal system, and the presence of 4 capillary beds.

time. However, hematoxylin eosin stained cross sections show the acino ductal blood vessels (Fig. 23). Lifson and Lassa (1981) attributed the failure of intra-arterial hematoxylin injection to stain the ductal vessels, to the venous nature of the plexus. Moreover, the passage of blood through three capillary beds (islets ⟶ acini ⟶ ducts) before leaving the pancreas to the liver in rabbit was described by Lifson and Lassa (1981). Thiel (1954)* described the pancreas of the dog, rabbit, guinea pig, and horse, after arterial injection with India ink, and showed the intra-lobular arteries which branch both to the islets and to the exocrine tissue. She also indicated that each islet usually receives one arteriole. Moreover, Schiller and Anderson (1975) studied the interlobular vessels in normal canine pancreas, and found that the intralobular vessels form a fine reticular pattern throughout the clear lobules. Their findings are confirmed by the present study (Fig. 7). As proved by intravascular injection of the camel pancreas with India ink, the present study revealed results similar to those obtained by using other dyes (burline blue, hematoxylin and methylene blue) in other animals, followed by the examination of histological sections of human (Wharton, 1936), rat, mouse, rabbit and baboon (Daniel and Hendersön, 1978), and horse pancreases (Fujita, 1973).

In the camel pancreas it was found that the arterial capillaries are shorter than the acinar capillaries (Figs. 6 and 7). This shortness allows for a level of blood pressure in the islet higher than that in the acinar arterial capillaries. Furthermore, it is

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* Quoted by Fujita (1973).

a well known fact that, venous blood vessels show low blood pressure, and the pressure in the short arterioles to the islets would be sufficient to overcome the high resistance in the venous system. Similar observations were made by Beck and Berg (1931) in mouse pancreas. Moreover, scanning electronmicroscopy of monkey's pancreas was studied by Fujita and Murakami (1973) who stated that the vas afferent terminates at the center of the islets in relation to the central position of A cells. From the periphery of the islets of Langerhans numerous vasa efferentia radiate into the exocrine tissue. Their capillaries are referred to as insulo-acinar portal vessels. The results of the present study agree with the findings of Fujita and Murakami (1973) but disagree with Syed's (1982) suggestion that a direct venous drainage of the islets may occur in the cat pancreas.

This study also disagrees with Henderson's (1969) findings which showed that the venous drainage of the islets is often via capillaries and venules into exocrine tissue, and that it is rare to find direct connections between islets capillaries and veins. Fujita (1973) noticed only capillaries as efferent vessels of the islets of the horse, dog and rabbit. He termed this type of circulation insulo-acinar portal system, which attracted attention to the significance of the insulo-acinar hormonal axis.

The present study reveals that blood flows from the periphery of the islets where A cells are found, toward the center of the islet where B cells are located. The vascular design in the camel and the rabbit islets is opposite to that of the horse. The afferent capillaries

penetrate the camel islets from the periphery to the center. In the horse, the opposite was demonstrated by Fujita (1973). Fraser and Hendersön (1980), showed the inhibitory effect of glucagon and somatostatin on exocrine secretion. From the previous studies and the main features of the microanatomy of the islets of Langerhans in the camel, it is obvious that glucagon and somatostatin affect insulin secretion, as glucagon activates the pancreatic B cells, while they inhibit exocrine secretion (Fujita 1973; Fraser and Hendersön 1980). Hendersön (1969), had previously proposed that high concentrations of hormones from the islets reaching the exocrine pancreas play an important role in the function of the pancreas.

4. Pancreas innervation:

The present study shows that the intralobular nerve fiber gives off many dividing branches. Some of these branches innervate the acini, capillaries, insulae, and ducts, forming peri-acinar, peri-vascular, peri-insular, and peri-ductus plexuses. Hoessels(1966) revealed the presence of large ganglia situated in the connective tissue, and around the acini as well as around the insulae. These ganglion cells are either round or have star-shaped prolongations.

In the camel, there are three fundamental plexuses named according to their location: peri-vascular, peri-acinar, and peri-insular plexuses. The nerve fibers of these three plexuses are, however, not entirely separated from each other. A similar observation was made by Honjin (1956) concentrating on the crossing over of nerve fibers from one plexus to another in the mouse pancreas. In mouse,

the peri-acinar plexus is composed of a large number of non-medullated fibers and a few medullated ones. The former have communication with the neural terminal net, while the latter form the afferent endings among the acini. The peri-insular plexus is made of a few medullated fibers and a large number of non-medullated ones. The medullated fibers are preganglionic fibers of the peri-insular ganglion and afferent fibers (Honjin, 1956). Honjin (Loc. cit.) also illustrated that the afferent fibers are not related to the islets innervation, but are running through this plexus. The nonmedullated fibers are apparently efferent, having syncytial connections with the neural terminal net in the islets.

Cholinergic and adrenergic nerves endings were described in various mammals by light microscopic techniques (Hoessels, 1966). It was found that in most mammals the pancreas is highly cholinergically innervated, as in horse, goat, camel, dromedary, and elephant. Major bundles which are extended from the interlobular connective tissue are stained by the cholinergic reaction. Also delicate periacinary fibers are found. However, ganglion cells are not found, and the islets of Langerhans show no positive reaction with choline esterase. But in monkey, higher innervation of this type was observed. Furthermore, in the rat, the rabbit and the cat, high cholinergic innervation was observed in both the exocrine and endocrine parts, as well as in the ducts (Hoessels, 1966). In the dog, peri-acinary cholinergic innervation is evident, but little or even no nerve elements can be seen in the peri-vascular, peri-insular, and peri-ductus plexuses (Hoessels, 1966). On the other hand, adrenergic innervation shows various intensity in

different animals. The least intensity is in the elephant, then dromedary, followed by the dog. The group which is highly adrenergically innervated, includes rat, mouse, cavia, rabbit, goat, camel, horse and monkey; while extraordinarily high innvervation is found in pig and cat. Hoessels (1966), from the above mentioned description , it clearly appears that the pathway of adrenergic nerve fibers and endings in the camel can be related to cholinergic and adrenergic innervation in the peri-acinary plexuses, while adrenergic nerves fibers are related to peri-insular and peri-vascular plexuses.

In the region of the islets of Langerhans in most animals including the camel,nerve fibers may be traced from the acinar nerve net and from discrete nerve bundles to the peri-insular region, where they form a plexus. From this plexus, fine fibers penetrate the islets passing between the cells. Intra-insular fibers which are closely associated with the blood vessels in camel pancreas form a very fine peri-vascular plexus along these capillaries. Such description applies to the rat; while in the cat and rabbit this is not the case (Coupland, 1958). Moreover, Coupland (Loc. cit.) concluded that the sympathetic system has no direct effect on the islets.

Yamamoto (1960), found small ganglia of sympathetic nature frequently present in the interlobular connective tissue of Formosan macaque pancreas, while no peri-insular nerve plexus containing ganglion cells were found. No lamellar Pacinian body can be found in the macaque pancreas. However, monkey pancreas is rich in sensory terminations which are found in the islets of Langerhans, besides the

interlobular and interacinar tissue. Purwar (1975) revealed the presence of ganglia in the periphery of the islets in black rat, and the peri-vascular plexus is made up of myelinated nerve fibers contrary to Honjin's (1956) findings in the mouse. Moreover, most of the ganglionic nerves are cholinesterase positive.

In summary, the pancreas of the camel is innervated by both sympathetic and para-sympathetic nervous system. The present study reveals the presence of peri-insular and intra-insular plexuses, besides the presence of peri-vascular, peri-acinar, and peri-ductus plexuses. However, according to Hoessels'(1966) study, the peri-insular plexus is adrenergically rather than cholinergically positive, which means that the islets are supplied by the sympathetic nervous system. The rest of the pancreas is innervated by both the sympathetic and parasympathetic nervous systems. Moreover, as the insular plexuses are of relatively lesser number than in other animals, according to Coupland (1958) there is no direct effect of the sympathetic nervous system on the islets.

5. Islets of Langerhans ultrastructure.

Numerous ultrastructural investigations were carried out on the normal pancreatic islets tissue in various species. Previous electron microscopic studies of the pancreatic islets cells in different species have shown that A and B cells differ mainly in the appearance of the secretory granules.

The main characteristic feature of the camel islets of Langerhans is the localization of the A cells at the periphery, B cells in the center, with D are cells intermingled with both types of cells at the periphery (Fig. 26). Similar observations were made in the hamster and rat (Alm and Hellman, 1964). In sheep , A cells are located in the center and B and D cells at the periphery, (Alm and Hellman, 1964); and horse (Fujita, 1973; Hellman et al., 1962; and Björkman et al., 1963).

The four types of cells (A, B, D and C) are differentiated on the basis of their secretory granules. Some of these types of cells were studied by various authors in different animals (Table 13, Appendix IV).

Under the electron microscope the A cell has opaque secretory granules with a granular limiting membranes relatively closely applied to the granule core. This cell is present in all species studied till now. The structure of the alpha cell graules in the camel is similar to the granules described in other mammals (Lacy, 1957; Bencosme and Pease, 1958; Sato et al., 1965; Boquist, 1967; and Petkov et al., 1970). They have large, round dense cores with relatively small halos separating them from the membranous sacs. On rare occasions in the dog, a few granules were seen surrounded by a network of finely interlaced fibrils similar to those seen in some beta granules (Lacy, 1957b; Munger et al., 1965). Alpha granule core varies in diameter among various species. In the camel the diameter of alpha cell granules is 267 $\pm$ 9 nm. The diameter of A cells granules of various animals is

indicated in table 13 (Appendix IV). The variation in the size of the cores is probably due to glucagon quantity.

The Golgi apparatus is prominent in the camel alpha cells as well as in the previously reported mammals. Furthermore, in these cells, the endoplasmic reticulum is sparse.

The camel B cells can be readily distinguished from the A cells by the morphology of their granules (Fig. 27). Beta granule morphology seems be characteristic for most species. The present observations are similar to those made by Lacy (1957 a, b; 1961), who suggested that such morphologic variations may reflect differences in the molecular structure of either insulin or its associated binding protein. The camel beta granule core is spherical, but rarely crystalloid (Fig. 28). These granules are usually spherical except for some species such as the dog (Sato et al., 1966). The latter authors suggested that the polymerization of secretory product confers on it a crystalline configuration. Munger et al. (1965) have confirmed the results of Sato and his coworkers in their study of the dog beta granules. In addition, Petkov (1973) recorded that in most cases the core of B cell granules is round, or more rarely barshaped, rectangular, hexagonal or crystalloid (dog, cat, guinea pig, hamster, rat, mouse, lamb, rabbit and pig).

The majority of B granule cores is highly electron opaque, especially at their center. A significant decrease of core has been observed in the camel (Fig. 32), as well as in the guinea pig (Lacy, 1957b; Sato et al., 1966). In this case, the core has a ring like or

crescentric profile. Granules containing oval cores are observed in B cells of rat, mouse, hamster, guinea pig, rabbit, lamb and hedgehog (Grodsky, 1966)*. Granules with bar-shaped or rhomboid cores are rarely observed in these mammals, but are seen in beta cells of dog and cat (Sato, et al., 1966). In the camel, the electron opaque material in the peripheral part of the core often seems to disperse in the form of a cloud of a lower electron opacity (Fig. 29). Sometimes, globular or bar-shaped structures may be observed in granules of lower electron opacity. The width of the clear halo varies and is dependent on the shape and size of the core which varies among various species. In the present study, beta granule cores measure 164 ± 6 nm. The core measurements of B cell secretory granules are illustrted in Table 13 .

Both A and B cells of the camel showed active sectors which were described by Petkov and Donev (1973a), who made an attempt to explain the process of insulin secretion by pancreatic B cells. Generally, pericapillary secretory cells show the presence of interdigitating cellular processes and a well-visible basal lamina at which the active sectors are demonstrated. The present study reveals the presence of the active sector in both A and B pericapillary cells as well as in M pericapillary cells. These active sectors were indicated in B cells of ruminants and rodents by Petkov and Donev (1973b). The active sectors are single and small in the camel, and this coincides with Petkov's findings, in which he reported that in conditions of normal hormone release, the active sectors increase and fuse, whereas the membrane loses its distinct structure when insulin is stimulated.

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* Quoted by Petkov 1973.

On the basal lamina of A, B and M cells (Fig. 32,34, and 45), microglobules of the core seem to be the carrying structure of their specific hormones up to its releasing locus of the cell membrane,which is termed the active sector by Petkov and Donev (1973a) in guinea pig, rat ,mouse and rabbit . They also found that disintegration of the B granules occurs in the stimulated B cells . Such phenomenon was observed in the present study in pericapillary cells (Fig. 32) . Besides , the destruction of the sac and cores was evident ; the core being disrupted into microglobules .

The fine structural characteristcs of D cell granules were generally known to previous electron microscopists (Lacy,1957; Bencosme and Pease,1958;Munger,1968;Sato et. al.,1966),who described their granules to be of low electron density with coarse or granular texture. In the present investigation, the electron opacity of D cell granules was always less than that in A cells and the limiting membrane is more closely applied to the granule core . Similar results were obtained in sevsral earlier investigations (Lacy, 1957 and Bencosme and Pease ,1958). D cell, contains secretory granules that are similar to A granules but less electron opaque, and measure about 222 ± 7 nm . Some authors (Caramia et. al., 1965; Boquist,1967 and Petkov et. al., 1970) considered D cell to be a type of A cell , contrary to Munger et. al., (1965) who classify D cells as a separate type , since the A cell has unique characteristic features . In the camel islets of Langerhans , it was found that the ultrastructures of D and A cells

differ in their cytoplasmic texture, opacity and size of their secretory granules. This may suggest that D cells differ from A cells which would agree with Munger's opinion. It was found that the D cell granules measure 222 ± 7 nm. These granules presented different measurements in the studied species as illustrated in Table 13 (Appendix IV).

Munger (1968) indicated that D cells were responsible for the production of a hormone bearing some similarity to that identified as gastrin. This is contrary to the findings of Alison and Polak (1981) who stated that somatostatin is the hormone secreted by D cells either in the pancreas or in gastric mucosa of man.

Cells of the agranular type or the C cells, of the camel occur more seldom than the other types, and are situated either in the central or in the peripheral regions of the islets. Similar results were obtained in different species like guinea pig (Lacy, 1957a; Hato et al., 1966) and cattle Bos taurus L. (Galabova and Petkov, 1975). The present investigation shows that C cells contain a small number of secretory granules resembling beta granules in shape and size (Figs. 28, 37 and 38). This finding may indicate that the C cells constitute an independent cellular type. On the other hand, it may also indicate that they are B-cells in the phase of discharge of their specific granules. Similar results were obtained by Galabova and Petkov (1975), who stated that C cells are probably A cell, or most likely B cell.

The present study demonstrates the presence of two cell types that had not previously been described. These cells are named in alphabetical sequence, they are described according to their secretory granules and the distribution of other cellular organelles (mitochondria, Golgi apparatus etc...). There are the M cells, in which the secretory granules are similar to EC cells of the gastric mucosa of man (Alison and Polak, 1981). M cells mitochondria are of interest as they are polymorphic, juxtanuclear, present in large numbers, and exhibit wide variations in their cristal arrangement. However, the mitochondria in other cell types of the islets of Langerhans in the camel are of round or oval shape showing transverse cristae. None of the cell types observed in the present study possessed shrunken mitochondria. This is contrary to what Björkman et al. (1963), who reported about the mitochondria of beta cells of the horse pancreas and in mice, especially hyperglycemic ones. In the cattle pancreas, ring-shaped, half moon, branched and large mitochondria of A cells were demonstrated by Galabova and Petkov (1975). The Golgi apparatus is prominent in all studied cells of the camel pancreas, except for the M cell. This organelle was found to be better developed in B cells than in A cells of the dog, cat, rabbit, guinea pig and rat (Lacy, 1957, 1959; Bencosme and Pease, 1958). Stöckenius and Kracht (1958) reported this difference to be insignificant in the rat pancreas.

The O cell is characterized by its opaque cytoplasm and its secretory granules, which are morphologically distinct and appear oval or round with an adherent membranous sac (Fig. 41).

The D cells of the camel pancreas are characterized by the presence of granules in the Golgi apparatus which measure about 80 nm. in diameter. Similar results were obtained by Björkman et al. (1963) in the horse A cell.

The present investigation shows that there are interdigitations which maintain contact between the cells across the gap separating them, and thus establishes the labyrinthine nature of the intercellular space. This configuration of the cell surface is believed to be important in enhancing the transport of fluids and hormones during cellular activity. The same phenomenon was demonstrated in the fetal rat pancreas between A and B cells (Lambert et al., 1970).

Dense bodies were rarely seen by the present writer in the camel pancreatic cells. Similar observations were recorded for the horse islet cells (Gusek and Kracht, 1959).

The results obtained here by the electron microscope concerning the rich insular vascular supply support the results obtained by light microscopy (Figs. 11, 43 and 45). The mechanism by which the secretory granules are released from the islets cells to the blood stream is illustrated by many phenomena. A fusion between the membrane of the granule and the plasma membrane with ejection of the contents have been described by Lacy (1961). This process by which the ejection occurred has been termed emiocytosis (Lacy, 1961; Lacy and Howell, 1970). They stated that the B granules encompassed by their smooth membranous sacs move to the cell surface. In the present investigation, the sacs are seen fused with the plasma membrane,

opened, and the granules liberated into the extracellular space where they undergo dissolution (Fig. 45). Moreover, numerous cytoplasmic processes or microvilli are observed on the surface of the B cell when B granules are rapidly released by emiocytosis.

The endothelial lining of the capillaries was demonstrated to possess microvesicles (Fig. 32). This finding agrees with the results of Björkman et al. (1963), and Koboyashi and Fujita (1969).

SUMMARY

The present study illustrates the morphology of the pancreas of the camel, Camelus dramedarius, as well as the macro and micro-circulation. Detailed description of the various islets of Langerhans cell-types was reported.

1. Pancreases of ten healthy camels of both sexes with a range of age between 1 - 9 years were studied. The tongue shaped pancreas is located posterior to the liver. It lies in the duodenal loop and is packed between the stomach ventrally and the kidnies dorsally.

2. The pancreas receives its major blood supply from the superior mesenteric and the celiac arteries.

3. Glomerulus-like structure of islets of Langerhans blood vessels was observed after India ink injection. Affarent and efferent islets capillaries were recognized.

4. In sections of Langerhans which were identified using hematoxylin eosin stain. Counting of the islets of Langerhans in 1 cm^2 area shows that the caudal region of that gland is the richest in islets.

5. Four fundamental cell types (A, B, D and C) were differentiated by chrome alum Gomori's hematoxylin method. Besides, two previously undescribed types of cells were noticed.

6. Differential counts on the four types of cells (A, B, D and C) gives the ratios between these types as 72% (A); 21% (B); 6% (D) and 1% (C).

7. Ammoniacal silver nitrate method was used to illustrate the pathway of the degenerated nerve fibers and their endings. Three nerve plexuses were identified: 1) peri-insular plexus; 2) peri-vascular plexus; and 3) peri-acinar plexus. Argyrophilic cells were observed by this method.

8. The ultrastructure of six different types of cells was described in detail. These cells are A, B, C, D, M and O.

M and O are being described for the first time here and are termed in alphabetical sequence.

9. Ultrastructural investigations of M cell show polymorphic secretory granules with adherent membranes. Mitochondria are polymorphic forming juxta-nuclear aggregation.

10. O cell secretory granules are round or oval surrounded with adherent course textured membrane. The cytoplasm is opaque and rich in free ribosomes.

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APPENDIX I

Analysis of Variance

The following method was used to analyze the variation of the, cell size, nuclear diameter, granule size and the pancreatic-body weight ratio.

The method could be summarized in the following steps; the pancreatic body weight ratio was taken as model.

Table 1: The ratio of pancreatic weight to body weight

Sex	Age/ Year	Pancreatic Weight X	Body Weight Y	X/Y (Z)	$Z^{*}-Z^{-**}$	$(Z-Z^{-})^{2}$
Female	1.5	0.14 kg	125 kg	0.00113	-0.000105	1.1025×10^{-8}
Female	2.0	0.13 kg	120 kg	0.00110	-0.000075	5.6250×10^{-9}
Male	1.0	0.12 kg	120 kg	0.00100	0.000025	6.2500×10^{-10}
Male	2.0	0.12 kg	120 kg	0.00100	0.000025	6.2500×10^{-10}
Female	8.0	0.45 kg	460 kg	0.00095	0.000045	2.0250×10^{-9}
Male	4.0	0.40 kg	400 kg	0.00100	0.000025	6.2500×10^{-10}
Male	5.0	0.40 kg	420 kg	0.00095	0.000075	5.6250×10^{-9}
Male	6.0	0.55 kg	550 kg	0.00100	0.000025	6.2500×10^{-10}
Male	7.0	0.45 kg	400 kg	0.00113	-0.000105	1.1025×10^{-8}
Male	9.0	0.50 kg	520 kg	0.00096	0.000065	4.2250×10^{-9}

* Ratio of pancreatic-body weight.

** Mean ratio of pancreatic-body weight.

$$Z = 0.01025$$

$$\bar{Z} = \frac{Z}{10} = 0.01025/10$$

$$\sum (Z-\bar{Z})^2 = 1.29 \times 10^{-8}$$

$$\text{St.d.} = \frac{\sqrt{1.29 \times 10^{-8}}}{10 - 1}, \quad \text{St.d.} = \frac{\sqrt{(X - \bar{X})^2}}{n - 1}$$

$$= \pm 0.0001$$

$\therefore$ The pancreatic-body weight ratio = 0.001025 $\pm$ 0.0001. That means one gram pancreatic weight per one kg body weight.

Table 2: The relations between pancreatic weight, and body weight in adult camels.

Sex	Age	Pancreatic Weight Kg (X)	Body weight Kg (Y)	Panc.wt./ Body wt. X/Y (Z)	$(Z^{*}-Z^{-**})^{2}$
Female	8.0	0.45	460	0.00095	2.3329×10^{-9}
Male	4.0	0.40	400	0.00100	2.8900×10^{-12}
Male	5.0	0.40	420	0.00095	2.3329×10^{-9}
Male	6.0	0.55	550	0.00100	2.8900×10^{-12}
Male	7.0	0.45	400	0.00113	1.7345×10^{-8}
Male	9.0	0.50	520	0.00096	1.4669×10^{-9}
	Mean			0.0009983	

The ratio of the pancreatic weight to body weight is $9.983\times10^{-4} \pm 9.692\times10^{-5}$, $(0.0009983 \pm 0.00009692)$.

Then pancreatic weight per body weight is 0.0009983 ± 0.00009692, in adult camels, which means 1 g. of pancreatic weight per 1 kg. body weight.

* Ratio of pancreatic-body weight.

** Mean ratio of pancreatic-body weight.

Table 3: The average pancreatic and body weights.

Sex	Age Year	Pancreatic weight (X)	$(X-\bar{X})^2$	Body wt. (Y)	$(Y-\bar{Y})^2$
Female	8.0	0.45 kg	0.0000064	460 kg	2.89
Male	4.0	0.40 kg	0.0000336	400 kg	3398.89
Male	5.0	0.40 kg	0.0000336	420 kg	1466.89
Male	6.0	0.55 kg	0.008464	550 kg	3408.89
Male	6.0	0.45 kg	0.000064	400 kg	3398.89
Male	9.0	0.50 kg	0.001764	520 kg	3806.89
Mean		0.458	Mean	458.3	

Average pancreatic weight = 0.458 ± 0.02 kg.

Average body weight = 458.3 ± 28.62 kg.

Table 4: The measurement of the ventral and the dorsal lobes of the pancreas.

Juvenile Camels

Sex	Age/ Year	T.L.V.	C.W.V.	H.W.V.	B.W.V.	L.D.	W.D.
FF	1.50	18.50	3.50	4.00	2.50	9.00	7.00
M	2.00	22.00	4.00	5.00	3.00	9.00	7.00
Mean		20.25	3.75	4.50	2.75	9.00	7.00

T.L.V. = Total length of ventral lobe.

C.W.F. = Caudal width of ventral lobe.

H.W.V. = Head width of ventral lobe.

B.W.V. = Body width of ventral lobe.

L.D. = Length of dorsal lobe.

W.D. = Width of dorsal lobe.

Adult Camels

Sex	Age/ Year	T.L.V.	C.W.V.	H.W.V.	B.W.V.	L.D.	W.D.
Female	8.00	35.00	8.00	10.00	5.000	11.00	10.00
Male	5.00	34.00	7.00	9.00	4.500	11.00	10.00
Male	6.00	34.00	8.00	9.00	5.000	11.00	10.00
Male	9.00	36.00	8.00	10.00	5.000	12.00	11.00
Mean		34.75	7.75	9.75	4.875	11.25	10.25

In all of the above studied animals the thickness of the head region measured 0.8-1 cm, while in the caudal region measured 0.3 - 0.5 cm.

Table 5: The relation between the age, sex, and the total length of both ventral and the dorsal lobes of adult camels pancreas.

Sex	Age/Year	T^{*}.L.V.	$(T^{**}-T.L.V.)^2$	$(T^{**}-T.L.V.)^2$	L.D.	L^{-}L.D.	$(L^{-}-L.D.)^2$
Female	8.00	35.00	-0.25	0.0625	11.00	0.25	0.0625
Male	5.00	34.00	0.75	0.5625	11.00	0.25	0.0625
Male	6.00	34.00	0.75	0.5625	11.00	0.25	0.0625
Male	9.00	36.00	-1.25	1.5625	12.00	-0.75	0.5625
Mean		34.75	Mean		11.25		

* Total length of ventral lobe.

** Mean of total length of ventral lobe,

L.L. Length of dorsal lobe.

L^{-} Mean of the length of dorsal lobe.

The total length of the ventral lobe of the adult camel pancreas was 34.75 ± 0.55 cm, while the length of the dorsal lobe was 11.25 ± 0.29 cm.

APPENDIX II

Table 1. The procedures used with different fixatives

a. Light microscopy preparations.

Fixative	Time	Washing	Time	Dehydration	Time	Clearing	Time	Infiltration	Time
10% N.F.*	2 hrs	Tap Water	2 hrs	Ethanol 30-100%	1-2 hrs each	Xylene	1-2 hrs.	Mix. Paraffin + Xylene	2 hrs
10% F.S.**	2 hrs	Tap Water	2 hrs	Ethanol 30-100%	1-2 hrs each	Xylene	1-2 hrs.	Mix. Paraffin + Xylene	2 hrs
Bouin's	48 hrs	70% EtOH	2-10 hrs	Ethanol 70-100%	1-2 hrs each	Xylene	1-2 hrs.	Mix. Paraffin + Xylene	2 hrs
Holley	15 hrs	Tap Water	Over-night	Ethanol 30-100%	1-2 hrs each	Xylene	1-2 hrs,	Mix. Paraffin + Xylene	2 hrs

* Buffered formaline; ** Formaline saline *** ethanol alcohol

Table 1

b. Electron microscopy preparations

Fixative	Time	Washing	Time	Dehydration	Time	Clearing	Time	Infiltration	Time
5% Glutaraldehyde	2 hrs	Phosphate Buffer + Sucrose	Overnight	Acetone Seq. 30-100%	15 min.	Mix of Plastic + acetone	30 min each over-night in 100% Plastic	In Spurr Plastic	1 - 2 days
OSO_4*	½ hr	Phosphate Buffer + Sucrose	1-2 hrs						

* Osmic acid

Table 2: Special-stains fixation results recommended for the islet of Langerhans.

Fixative(s)	Stain(s)	Sections thickness	Results
10% F.S.	Mayer haematoxylin and eosin	5 µm	Differentiates islets of Langerhans from the surrounding tissue.
10% B F	Chrome alum Gomori	5 µm	Colours the red blood corpuscles.
10% BF	Silver nitrate (ammonical	5 µm	1. Shows the degenerated nerves of the islet of Langerhans. 2. Stains the argyrophilic cells.
Bouins	1. Haematoxylin Erlich and Eosin.	5 µm	Differentiate islets of Langerhans.
	2. Combined Gomori method	5 µm	Differentiates A and B cells.
	3. Chrome alum Gomori	5 µm	Differentiates A, B and D cells & newly discovered cells.
Helleys	Chrom alum Gomori	5 µm	Differentiates A B and D cells & newly discovered type of cells.
Glutaraldehyde 5% and OSO_4	Uranyl acetate and Lead citrate.	5 µm	Differentiates the ultrastructure of A , B, D, C and X-type of cells and newly disocvered ones

APPENDIX III

This section, includes various types of preparations and techniques of the used solution.

1. Preparation of fixatives.

a- Formalin saline solution 10% FS

9 Grams of sodium chloride were dissolved in 900 ml of distilled water, then 100 ml 40% Formalin were added. (Drury et al. 1967, Bradbury, S.P. 1973).

b- Buffered formalin 10% (BF)

4 gm of sodium phosphate monobasic, monohydrate were dissolved in 900 ml of distilled water, the solution was heated gently to speed the dissolution of the salt, then 6.5 gms of sodium phosphate, dibasic anhydrous were added, 100 ml of 40%, formalin were mixed with the above mixture. (Drury et al. 1967).

c- Bouin's fluid

25 ml of 40% formalin were mixed with 75 ml of saturated picric acid, then 5 ml of glacial acetic acid were added.

d- Helley's fluid

A stock solution was prepared of 50 gm mercuric chloride, 25 gms potassium dichromate and 10 gms of sodium sulphate, which were dissolved in 1 liter of distilled water. Five ml of 40% Formalin were added to 95 ml of the previous stock. (Drury et al., 1967).

iii. Working solution of eosin-phloxine

100 ml of stock eosin was mixed with 10 ml of stock phloxine, 780 ml of 95% ethanol was added, then 4 ml of glacial acetic acid was mixed with the previous mixture (Sheehan, and Hrapchak, 1980).

c- Gomori's aldehyde fuchsin

1 ml of paraldehyde, 1 ml of concentrated HCl, and basic fuchsin 0.5 gm, were dissolved in 65% ethanol alcohol and left to stand for 24 hours before use (Edwin and Haskell, 1954).

d- Gomori chrome alum

50 ml of 1% aqoueous haematoxylin, 5 ml of 3% aqueous chrome alum, 2 ml of 5% aqueous potassium dichromate and 2 ml of 0.5N H_2SO_4, were mixed.

e- Ammoniacal silver nitrate

40 ml of 1.5% silver nitrate, 24 ml of 95% ethyl alcohol, 4 ml of ammonium hydroxide, and 3.6 ml of 2.5% sodium hydroxide, were mixed.

f- Uranyl acetate

0.1 gm of uranyl acetate was dissolved in a mixture of 5 ml of 70% ethanol and 5 ml of 25% methanol (Dawes, 1973).

g- Lead citrate

0.4 gm of lead citrate was dissolved in 10 ml of cooled boiled double distilled water, 10N NaOH, 0.1 ml was added (Dawes, 1976).

h- Dithizone

120 mg diphenylthiocarbazone was dissolved in 1.5 ml of 96% ethanol, 2 drops of ammonia solution (S.G. 0.88) were added, then the solution continued to 20 ml with distilled water.

3. Preparation of solutions

a- 0.2 M phosphate buffer

23 ml of 0.2 M sodium dihydrogen phosphate was mixed with 77 ml of 0.2 M disodium hydrogen phosphate.

b- Reducer

810 ml distilled water, 90 ml of 100% ethanol, 27 ml of 10% Formalin, and 27 ml of 1% citric acid, were mixed throughly.

c- Acid permanganate:

0.5 gms were dissolved in 100 ml distilled water added to 0.5N H_2SO_4 (0.30 ml), then preserved in dark bottles.

APPENDIX IV

DIFFERENTIAL COUNTS

Differential counts were carried out under a binocular microscope with a mechanical stage and a magnification of X 1000 (immersion lens). The sections were examined and the differential count was carried out of the islets, using the transect method. The cells with nuclei or with nuclear fragments were counted. (Lars Grimelius, 1968). Two 5 µm thick Bouin-fixed sections, chrome alum Gomori-stained, were differentially counted. At least 1500 islet cells were counted per section.

The ratios of different cell types in the islets of Langerhans, were carried out, then the mean ratio of each was calculated. Sections of the pancreases of two males (2 years, and 5 years old), and two females (1.5 years, and seven years old), were studied.

Table 1: The ratios between the pancreatic islet of Langerhans cells (A, B, D and C cells), Male 2 years

A	B	D	C	A : B : D : C
9	32	2	0	0.2093 : 0.7442 : 0.0465 : 0.0000
13	83	3	1	0.1300 : 0.8300 : 0.0300 : 0.0100
16	56	6	1	0.2025 : 0.7089 : 0.0759 : 0.0127
18	76	5	1	0.1800 : 0.7600 : 0.0500 : 0.0100
16	59	5	1	0.1980 : 0.7280 : 0.0620 : 0.0120
16	78	6	1	0.1584 : 0.7723 : 0.0594 : 0.0990
19	75	5	1	0.1900 : 0.7500 : 0.0500 : 0.0100
7	36	2	0	0.1556 : 0.8000 : 0.0444 : 0.0000
16	46	2	1	0.2460 : 0.7080 : 0.0310 : 0.0150
13	71	4	0	0.1480 : 0.8070 : 0.0450 : 0.0000
34	97	6	1	0.2463 : 0.7030 : 0.0435 : 0.0072
14	61	5	1	0.1730 : 0.7530 : 0.0620 : 0.0120
23	72	4	1	0.2300 : 0.7200 : 0.0400 : 0.0100
22	54	9	0	0.2590 : 0.6350 : 0.1060 : 0.0000
24	61	12	2	0.2420 : 0.6160 : 0.1213 : 0.0200
8	22	5	0	0.2290 : 0.6290 : 0.1420 : 0.0000
24	55	10	1	0.2667 : 0.6111 : 0.1111 : 0.0111
18	46	4	1	0.2610 : 0.6670 : 0.0580 : 0.0140
23	69	7	1	0.2300 : 0.6900 : 0.0700 : 0.0100
333	1149	102	15	Mean ratio = 0.21 : 0.72 : 0.06 : 0.01 (A : B : D : C)

The total number of cells counted in two sections 5 µm thick of 2 years old male camel pancreas was 1599.

The percentage of A cells = 333 ÷ 1599

= 0.208 i.e 20.8%

or

It can be calculated by calculating the mean of the A ratios 3.9548 ÷ 19 = 0.208

B cells mean ratio = 1149 ÷ 1599

= 0.719

D cells mean ratio = 102 ÷ 1599

= 0.064

C% = 15 ÷ 1599 = 0.009

∴ A : B : D : C were equal to

0.21 : 0.72 : 0.06 : 0.01

Table 2: The ration between various types of islet cells (A : B : D : C), of 1.5 year female

A	B	D	C	A : B : D : C
20	64	4	1	0.2250 : 0.7190 : 0.0450 : 0.0110
16	60	5	1	0.1950 : 0.7320 : 0.0610 : 0.0120
18	80	6	1	0.1710 : 0.7620 : 0.0570 : 0.0095
17	59	4	0	0.2120 : 0.7380 : 0.0500 : 0.0000
30	84	8	2	0.2420 : 0.6770 : 0.0650 : 0.0160
24	75	6	2	0.2240 : 0.7010 : 0.0560 : 0.0190
20	73	6	1	0.2000 : 0.7300 : 0.0600 : 0.0100
18	80	6	1	0.1710 : 0.7620 : 0.0570 : 0.0095
14	65	6	1	0.1630 : 0.7560 : 0.0700 : 0.0110
16	56	6	1	0.2025 : 0.7089 : 0.0759 : 0.0127
20	79	5	1	0.1905 : 0.7520 : 0.0480 : 0.0095
21	69	4	1	0.2210 : 0.7260 : 0.0420 : 0.0110
26	84	4	1	0.2260 : 0.7300 : 0.0350 : 0.0090
15	51	4	2	0.2080 : 0.7080 : 0.0560 : 0.0280
20	77	7	1	0.1900 : 0.7330 : 0.0670 : 0.0100
18	62	4	0	0.2140 : 0.7380 : 0.0480 : 0.0000
19	72	3	1	0.2000 : 0.7580 : 0.0320 : 0.0100
12	35	4	0	0.2350 : 0.6860 : 0.0780 : 0.0000
344	1225	92	18	0.2 : 0.73 : 0.06 : 0.01
Σ	1679			A : B : D : C

Table 3: The ratios of various types of cells of the pancreatic islet, of 5 years old male camel, were recorded.

A	B	D	C	A :	B :	D :	C
26	88	8	1	0.2110:	0.7160 :	0.0650:	0.0081
14	80	5	1	0.1400:	0.8000:	0.0500:	0.0100
9	60	3	1	0.1230:	0.8220:	0.0410:	0.0140
12	34	6	2	0.2220:	0.6300:	0.1110:	0.0370
5	34	1	0	0.1250:	0.8500:	0.0250:	0.0000
7	25	3	0	0.2000:	0.7100:	0.0900:	0.0000
5	25	1	0	0.1600:	0.8100:	0.0300:	0.0000
7	26	1	0	0.2060 :	0.7650:	0.0290:	0.0000
11	28	4	1	0.2500 :	0.6400:	0.0900:	0.0200
17	70	5	2	0.1810 :	0.7450:	0.0530:	0.0210
7	22	3	0	0.2200:	0.6900 :	0.0900:	0.0000
4	16	1	0	0.1900:	0.7600 :	0.0500:	0.0000
8	50	3	1	0.1290:	0.8070:	0.0480:	0.0160
19	61	9	2	0.2090:	0.6700 :	0.0990:	0.0220
8	29	5	1	0.1860:	0.6740:	0.1160:	0.0240
14	28	3	0	0.3110:	0.6270:	0.0670:	0.0000
8	24	4	0	0.2220:	0.6620 :	0.1110:	0.0000
14	60	5	1	0.1800:	0.7500:	0.0600:	0.0100
26	51	4	1	0.3200:	0.6200 :	0.0500 :	0.0100
18	55	2	1	0.2370 :	0.7240:	0.0260 :	0.0130
6	17	3	0	0.2300:	0.6500:	0.1200:	0.0000
16	44	6	1	0.2400:	0.6600:	0.0900:	0.0100

Table 4: 5 years male camel, pancreatic islet of Langerhans cells ratios

A	B	D	C	A : B : D : C
14	66	6	1	0.160 : 0.760 : 0.070 : 0.010
8	11	1	1	0.380 : 0.520 : 0.050 : 0.050
4	26	1	0	0.130 : 0.840 : 0.030 : 0.000
7	20	2	1	0.230 : 0.670 : 0.060 : 0.040
5	17	2	0	0.210 : 0.710 : 0.080 : 0.000
29	33	4	0	0.440 : 0.500 : 0.060 : 0.000
11	45	2	1	0.190 : 0.760 : 0.030 : 0.020
16	61	3	1	0.200 : 0.750 : 0.040 : 0.010
10	43	2	1	0.180 : 0.770 : 0.040 : 0.010
5	14	1	0	0.250 : 0.700 : 0.050 : 0.000
23	70	6	1	0.230 : 0.700 : 0.060 : 0.010
393	1333	115	23	0.21 : 0.711 : 0.063 : 0.011
				Mean ratios
Σ 1864				

From the above table the ratios of A : B : D : C were 0.21 : 0.711 : 0.063 : 0.011

Table 5: The islet of Langerhans cell types ratios A: B : D : C cells, of 8 years female pancreas

A	B	D	C	A : B : D : C
22	70	3	1	0.22920: 0.72920: 0.03130: 0.01030
26	78	6	1	0.23420: 0.70270: 0.05410: 0.00900
11	38	4	0	0.20700: 0.71698: 0.07550: 0.00000
16	58	3	1	0.20513: 0.74358: 0.03846: 0.01280
12	44	3	1	0.20000: 0.73330: 0.05000: 0.01670
7	34	2	0	0.16279: 0.790697:0.04651: 0.00000
19	86	4	2	0.17117: 0.77480: 0.03604: 0.01800
13	45	5	1	0.20300: 0.70300: 0.07800: 0.01600
14	53	5	0	0.19440: 0.73610: 0.06940: 0.00000
17	75	6	1	0.17170: 0.75750: 0.06060: 0.01010
8	34	3	1	0.17400: 0.74000: 0.06500: 0.02100
18	44	6	1	0.26100: 0.63800: 0.08700: 0.01400
11	45	2	1	0.19000: 0.76000: 0.03000: 0.02000
7	26	1	0	0.21000: 0.76000: 0.03000: 0.00000
23	79	6	1	0.21100: 0.72500: 0.05500: 0.00900
12	50	5	1	0.18000: 0.73500: 0.07000: 0.01500
30	58	4	0	0.32600: 0.63000: 0.04400: 0.00000
24	83	6	2	0.20900: 0.72200: 0.05200: 0.01700
290	1000	74	15	0.210 : 0.725 : 0.055 : 0.010
Σ	1379			Mean ratios

Table 6: The number of islets of Langerhans in 1 cm^2 surface area of caudal, body and head regions, of pancreas in adult camels (male + female)

Sex	Age	Caudal region	Body region	Head region
M	6	93.0	52.0	6.0
M	5	95.0	48.0	8.0
F	8	91.0	51.0	7.0
M	4	90.0	50.0	6.0
M	7	93.0	53.0	7.0
M	9	89.0	53.0	6.0
Mean		91.2	51.2	6.7

The number of i.L.* in one cm^2 surface area is equal to 91.2 $\pm$ 1.04 in the caudal region; 51.2 $\pm$ 0.69 i.L. in body region and 6.7 $\pm$ 0.44 i.L. in the head region.

i.L. stands for islet of Langerhans.

Table 7: The number of i.L. per 1 cm^2 surface area of young camels (1 - 2 years, male and female), in caudal, body and head regions.

Sex	Age/Year	Caudal region	Body region	Head region
F	1.50	93.00	52.00	5.00
M	2.00	90.00	53.00	6.00
M	1.00	92.00	49.00	6.00
F	2.00	88.00	51.00	7.00
Mean		90.75	51.25	6.00

The number of i.L. per 1 cm^2 surface area of caudal region was 90.75 $\pm$ 1.28, in body region 51.25 $\pm$ 0.98 and in the head region 6 $\pm$ 0.67 i.L.

Table 8: The diameter of the beta cell and beta nuclei in μm

B cell diameter (X) μm	$(\bar{X} - X)$	$(\bar{X} - X)^2$	B cell nuclei diam. (Y) μm	$(\bar{Y} - Y)$	$(\bar{Y} - Y)^2$
13	-2.2	4.84	5	+0.35	0.1225
8	+2.8	7.84	4	+1.35	1.8225
10	+0.8	0.64	5	+0.35	0.1225
16	-5.2	27.04	7	-1.65	2.7225
10	+0.8	0.64	6	-0.65	0.4225
10	+0.8	0.64	5	+0.35	0.1225
9	+1.8	3.24	6	-0.65	0.4225
15	-4.2	17.64	5	+0.35	0.1225
11	-0.2	0.04	5	+0.35	0.1225
12	-1.2	1.44	6	-0.65	0.4225
12	-1.2	1.44	6	-0.65	0.4225
13	-2.2	4.84	5	+0.35	0.1225
10	+0.8	0.64	6	-0.65	0.4225
13	-2.2	4.84	6	-0.65	0.4225
8	+2.8	7.84	6	-0.65	0.4225
12	-1.2	1.44	5	-0.35	0.1225
10	+0.8	0.64	4	+1.35	1.8225
15	-4.2	17.64	5	+0.35	0.1225
10	+0.8	0.64	5	-0.35	0.1225
8	+2.8	7.84	5	-0.35	0.1225
Σ 216		111.8	107		10.55

The mean of the Beta cell diameter = $\frac{216}{20}$

= 10.8 µm

$St.d._{B.C.} = \frac{111.8}{19}$

$= \pm 0.556$

∴ The mean diameter of the Beta cells ± St.d. equal 10.8 ± 0.556 µm.

The mean of the nuclei of Beta cells = $\frac{107}{20}$

= 5.35 µm

$St.d._{B.W.} = \frac{10.55}{19}$

$= \pm 0.17$

∴ The mean diameter of Beta cell nuclei ± $St.d._{B.N.}$

= 5.35 ± 0.17 µm.

Table 9: Alpha cells diameter, and nuclei diameter in μm.

-cell diameter (X)μm	$(\bar{X} - X)$	$(\bar{X}-X)^2$	-cell nuclei diam. (X)μm	$(\bar{Y} - Y)$	$(\bar{Y} - Y)^2$
13	1.75	3.0625	6	0.26	0.0676
8	+3.25	10.5625	6	0.26	0.0676
10	+1.75	1.5625	6	0.26	0.0676
16	-4.75	22.5625	6	0.26	0.0676
10	+1.25	1.5625	5	1.26	1.5876
10	+1.25	1.5625	6	0.26	0.0676
9	-2.25	5.0625	6	0.26	0.0676
15	+3.75	14.0625	6	0.26	0.0676
11	-0.25	0.0625	5	1.26	1.5876
12	+0.75	0.5625	7	-0.74	0.5476
10	+1.25	1.5625	5	1.26	1.5876
13	+1.75	3.0625	5	1.26	1.5876
8	+3.25	10.5625	5	1.26	1.5876
12	+0.75	0.5625	7	-0.74	0.5476
10	+1.25	01.5625	6	0.26	0.0676
15	+3.75	14.0625	7	-0.74	0.5476
10	+1.25	1.5625	7	-0.74	0.5476
8	+3.25	10.5625	7	-0.74	0.5476
12	+0.75	0.5625	6	0.26	0.0676
13	+1.75	3.0625	5	1.26	1.5876
Σ225		107.75			12.872

The mean of the alpha cell diameter

$$= 225 \div 20$$

$$= 11.25\ \mu m$$

$$St.d._{A.C.} = \frac{107.75}{19}$$

$$= \pm\ 0.546\ \mu m$$

$\therefore$ The mean diameter of alpha cell $\pm$ $St.d._{A.C.}$

$$= 11.25 \pm 0.546\ \mu m.$$

The mean diameter of alpha cells nuclei

$$= \frac{119}{20}$$

$$= 6.26\ \mu m.$$

$$St.d._{A.N.} = \frac{12.872}{19}$$

$$= \pm\ 0.189\ \mu m$$

$\therefore$ The mean diameter of alpha cell nuclei $\pm$

$St.d._{A.N}$ $= 6.26 \pm 0.189\ \mu m.$

Table 10. The beta cell secretory granule core diameter.

x	$x - \bar{x}$	$(x - \bar{x})^2$	x	$x - \bar{x}$	$(x - \bar{x})^2$
0.208	0.044	0.001936	0.125	-0.039	0.005210
0.208	0.044	0.001936	0.125	-0.039	0.005210
0.104	-0.060	0.003600	0.208	0.044	0.001936
0.125	-0.039	0.005210	0.208	0.044	0.001936
0.208	0.044	0.001936	0.125	-0.039	0.005210
0.166	0.002	0.000040	0.083	-0.081	0.006560
0.125	-0.039	0.005210	0.208	0.044	0.001936
0.125	-0.039	0.005210	0.208	0.044	0.001936
0.125	-0.039	0.005210	0.125	-0.039	0.005210
0.125	-0.039	0.005210	0.166	-0.002	0.000040
0.166	0.002	0.000040	0.25	-0.086	0.007396
0.166	0.002	0.000040	0.125	-0.039	0.005210
0.125	-0.039	0.005210	0.125	-0.039	0.005210
0.125	-0.039	0.005210	0.166	0.002	0.000040
0.203	0.044	0.001936	0.166	0.002	0.000040
0.25	0.086	0.007396	0.166	0.002	0.000040
0.125	-0.039	0.005210	0.166	0.002	0.000040
0.166	0.002	0.000040	0.166	0.002	0.000040
0.208	0.044	0.001936	0.125	-0.039	0.005210
0.125	-0.039	0.005210	0.166	+0.002	0.000040
0.083	-0.081	0.006560	0.166	-0.002	0.000040
0.208	0.044	0.001936	0.208	0.044	0.001936

.../

Table 10 Cont'd.

X	$X - \bar{X}$	$(X - \bar{X})^2$	X	$X - \bar{X}$	$(X - \bar{X})^2$
0.208	0.044	0.001936	0.208	0.044	0.001936
0.125	-0.039	0.005210	0.208	0.044	0.001936
0.083	-0.081	0.006561	0.166	-0.002	0.000040
0.166	0.002	0.000040	0.208	0.044	0.001936
0.125	0.039	0.005210	0.208	0.044	0.001936
0.125	0.039	0.005210	0.125	0.039	0.005210
0.166	0.002	0.000040	0.166	0.002	0.000040
0.208	0.044	0.001936	0.208	0.044	0.001936
0.208	0.044	0.001936	0.166	0.002	0.000040
0.166	0.002	0.000040	0.125	-0.039	0.005210
0.125	0.039	0.005210	0.25	0.086	0.007390
0.125	0.039	0.005210	0.208	0.044	0.001936
0.166	0.002	0.000040	0.166	0.002	0.000040
0.208	0.044	0.001936	0.125	0.039	0.005210

Mean of Beta cell secretory granule core

$= 0.164 \pm 0.006\ \mu m$

$= 164 \pm 6\ nm$

Table 11: A cell granule core diameter

X	$X - \bar{X}$	$(X - \bar{X})^2$	X	$X - \bar{X}$	$(X - \bar{X})^2$
0.266	0.001	0.000001	0.266	0.001	0.000001
0.333	0.066	0.004356	0.200	0.067	0.004489
0.200	0.067	0.004489	0.266	0.001	0.000001
0.133	0.134	0.017956	0.333	0.066	0.004356
0.200	0.067	0.004489	0.266	0.001	0.000001
0.200	0.067	0.004489	0.200	0.660	0.004356
0.333	0.066	0.004356	0.133	0.134	0.017956
0.266	0.001	0.000001	0.299	0.032	0.001024
0.333	0.066	0.004356	0.266	0.001	0.000001
0.266	0.001	0.000001	0.333	0.066	0.004356
0.266	0.001	0.000001	0.333	0.066	0.004356
0.333	0.066	0.004356	0.199	0.068	0.004624
0.266	0.001	0.000001	0.199	0.068	0.004620
0.200	0.067	0.004439	0.266	0.001	0.000001
0.200	0.067	0.004489	0.266	0.001	0.000001
0.333	0.066	0.004356	0.200	0.067	0.004489
0.200	0.067	0.004489	0.133	0.134	0.017956
0.333	0.066	0.004356	0.266	0.001	0.000001
0.333	0.066	0.004356	0.266	0.001	0.000001
0.266	0.001	0.000001	0.266	0.001	0.000001
0.266	0.001	0.000001	0.200	0.067	0.004489
0.200	0.087	0.004489	0.266	0.001	0.000001
0.133	0.134	0.017956	0.133	0.134	0.017956
0.333	0.134	0.017956	0.333	0.066	0.004356
0.266	0.001	0.000001	0.266	0.001	0.000001

Mean of alpha granule core $\pm$ St.d is equal to
0.267 $\pm$ 0.009um or 267 $\pm$ 9 nm

Table 12: The diameter of D cell granules

X	X - X	$(X - X)^2$	X	X - X	$(X - X)^2$
0.200	0.022	0.000484	0.200	0.022	0.000484
0.266	0.044	0.001936	0.266	0.044	0.001936
0.133	0.089	0.007921	0.266	0.044	0.001936
0.200	0.022	0.000484	0.200	0.022	0.000484
0.200	0.022	0.000484	0.266	0.044	0.001936
0.200	0.022	0.000484	0.266	0.044	0.001936
0.266	0.044	0.001936	0.266	0.044	0.001936
0.266	0.044	0.001936	0.200	0.022	0.000484
0.133	0.089	0.007921	0.266	0.044	0.001936
0.133	0.089	0.007921	0.266	0.044	0.001936
0.266	0.044	0.001936	0.200	0.022	0.000484
0.266	0.044	0.001936	0.266	0.044	0.001936
0.200	0.022	0.000484	0.266	0.044	0.001936
0.133	0.039	0.007921	0.200	0.022	0.000484
0.133	0.089	0.007921	0.200	0.022	0.000484
0.200	0.022	0.000484	0.266	0.044	0.001936
0.266	0.044	0.001936	0.266	0.044	0.001936
0.200	0.022	0.000484	0.266	0.044	0.001936
0.200	0.022	0.000484	0.266	0.044	0.001936
0.266	0.044	0.001936	0.200	0.022	0.000484
0.266	0.044	0.001936	0.220	0.002	0.000004
0.266	0.044	0.001936	0.200	0.022	0.000484
0.200	0.022	0.000484	0.266	0.044	0.001936
0.200	0.022	0.000484	0.133	0.089	0.007921
0.200	0.022	0.000484	0.133	0.089	0.007921

Mean value $\pm$ St.d. of the Delta cell granule core is 222 + 7 nm.

Table 13: The diameter of A, B and D cells secretory granule cores in various animals as represented by different authors.

Author	Animal	A	B	D
Caramia et al., (1965)	cat	206±31nm	-	-
Lacy (1957 b)	dog	170nm	-	-
Caramia et al., (1965)	dog	243±35nm	-	-
Munger et al., (1965)	dog	300nm	100-500nm	-
Lacy (1957 b)	guinea pig	180-230nm	230nm	-
Caramia et al., (1965)	guinea pig	231±59nm	-	-
Bjorkman et al., (1963)	horse	-	400nm	-
Boquist (1967)	hamster	120-180nm	160-200nm	180-240nm
Petkov et al., (1970)	hamster	130-600nm	130-600nm	200-570nm 80-150nm
Deconinck .,	human (adult)	350-450nm	350-500nm	450-800nm
Munger et al., (1965)	opossum	200nm	220nm	200nm
	Opossum	200nm	220nm	200nm
Lacy (1957b)	rabbit	130-200nm	130nm	-
Munger et al., (1965)	rabbit	200nm	180nm	240nm
Lacy (1957b)	rat	170-180nm	170nm	-
Caramia et al., (1965)	rat	196±43nm	214±50nm	-