ELECTRON MICROSCOPIC OBSERVATIONS ON THE PLACENTA OF THE CAT*

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During the past several years, cytological, histochemical, and electron microscopic studies have been carried out on the placentas of several different species of mammals. In these studies, particular attention has been paid to the so called placental barrier; that is, the regions of the choriallantoic placenta in which the circulating fetal blood most closely approximates the maternal blood. We have also investigated certain other specialized placental structures, such as the yolk sac in rodents, lagomorphs, and the mare, the brown and green borders or paraplacental chorion of the cat and dog, respectively, and the endometrial cups of the placenta of the mare. These various structures are of particular interest since there is evidence that each participates in some particular placental function; the yolk sac of rabbits in the transmission of maternal antibodies to the fetus (Brambell, Rogers, Hemmings, and Henderson, 1951), the paraplacental chorion of carnivores in the transmission of iron to the fetus, and the mare's endometrial cups in the production of the hormone characteristic of pregnant mare serum. The present investigation extends our studies by presenting observations with the electron microscope upon the chorioallantoic placenta and the paraplacental chorion or brown border in a carnivore, the domestic cat.

Material and Methods

The specimens were obtained from five pregnant cats in which the fetuses ranged from 50 to 110 mm. in crown rump length. The animals were anesthetized with ether, the abdomen and uterus opened, and the fetuses delivered through the uterine incision. The zonular placenta was thus exposed, adherent to the inner surface of the uterus. Small pieces, about 1 mm. in each dimension, were immediately excised from the center of the chorioallantoic placental labyrinth and from the paraplacental chorion. These pieces were fixed by immersion in the OsO_4 mixtures recommended either by Palade (1952) or Dalton (1955). Fixation was adequate with either mixture, but our best preparations were obtained after fixing in Dalton's fluid for 1 hour. The fixed blocks were washed, dehydrated through ethanol, infiltrated by and embedded in a mixture of 3 parts butyl- to one part methyl-methacrylate, and sectioned on a

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modified Minot microtome as described by Dempsey and Lansing (1953). The sections were mounted on collodion-coated, copper-mesh grids and examined directly in the electron microscope, RCA model EMU 2E. Photographs were made at initial magnifications of 1000 to 8000 diameters. The micrographs were subsequently enlarged as desired.

RESULTS

The histological structure of the cat's placenta has been reviewed recently by Wislocki and Dempsey, 1946; and by Amoroso (1952). Basically, the placenta consists of a series of more or less parallel trophoblastic plates or lamellae, separated from one another by regions containing fetal connective tissue through which course the slender fetal capillaries. Within the lamellae, surrounded by trophoblast, run the tortuous, sinusoidal maternal capillaries. The trophoblast also encloses "decidual" giant cells, lodged between the maternal capillaries. These cells are derived from fibroblasts of the original uterine mucosa which are transformed into giant cells during the invasion of the endometrium by the fetal trophoblast (Wislocki and Dempsey, 1946). Both the giant cells and the maternal capillaries are surrounded by a variably broad zone of amorphous substance which is best detected after staining with one of the triacid connective tissue stains. Lipide droplets are frequent in the trophoblast, which consists of an outer syncytial and an inner cellular layer.

In the paraplacental regions, invasion of the endometrium by the trophoblast either does not occur or is at best, slight in extent. Consequently, this region consists of chorionic cells, the apices of which face the surfaces of, for the most part, uninterrupted uterine epithelial cells. Within the uterine lumen between these two cell layers are variable numbers of erythrocytes and fragments of desquamated maternal cells. The chorionic cells of the paraplacental borders are apparently phagocytic, since whole and fragmented erythrocytes and the detritus present in the uterine lumen can commonly be observed within them, particularly in their apical portions. The chorionic cells presumably break up and digest the erythrocytes, extracting from them their iron, since histochemical reactions for iron are strong in the layer and the brown color which gives it its name has been ascribed to the presence of bile pigments derived from hemoglobin (Wislocki and Dempsey, 1946; Amoroso, 1952).

The various elements of the placental lamellae are easily recognized in electron micrographs, because of their characteristic topography. In the center of the lamellae, the maternal capillaries are situated. Erythrocytes, smaller than those in the fetal capillaries, are frequently encountered in their lumens. The endothelial walls of the maternal capillaries are characteristically thick and basophilic in carnivore placentas (Amoroso, 1952) and the cat is no exception (Wislocki and Dempsey, 1946). In electron micrographs, the cytoplasm of these thickened, hyperplastic endothelial cells has a lacy appearance, owing to the presence of numerous, irregularly shaped spaces containing a flocculent precipitate (Figs. 1 to 5). These spaces, which on first impression appear vacuolar, communicate openly, in some instances, with the lumen of the capillary so that the flocculent precipitate in them appears to be maternal blood plasma (Fig. 2).

Between the spongy spaces lies the formed cytoplasm of the endothelial cells. It contains a fair number of mitochondria, many of which are greatly swollen. This appearance strongly suggests an artifact of fixation since mitochondria swell readily in tissues not fixed promptly, or when the pH of the fixing fluid is not optimal, or when the tissue is exposed to hypotonic solutions prior to fixation. Yet, mitochondria in the trophoblast and the fetal fibroblasts in the same sections are not swollen, and even in the maternal endothelium not all the mitochondria are enlarged (Fig. 3). As a consequence of this puzzling difference it seems likely that the swollen and vacuolated mitochondria must represent some physiological condition different from that of those which are unswollen.

Besides the spaces containing flocculent precipitate and the swollen, vacuolated mitochondria, many of the endothelial cells also exhibit numerous small, smooth walled vacuoles or tubules, grouped together into a characteristic aggregate which usually lies in the basal part of the cytoplasm (Fig. 5). These groups of vesicles resemble in many respects the Golgi complex of other cells (*cf.* Dalton and Felix, 1954; Dempsey and Wislocki, 1955).

The cytoplasmic ground substance, surrounding the structures described above, contains at least two other organelles distinguishable by means of the electron microscope: the first, small and indistinct granules and the second, somewhat larger and much denser bodies. The latter are similar to the small granules described recently by Palade (1955 *a*) and considered by him to represent an important element of the basophilic component of the cytoplasm. This view accords well with the fact that these endothelial cells are quite markedly basophilic in the light microscope. The dense granules occur throughout the cytoplasm, except in the Golgi zone, and they often appear in linear arrays along the margins of the spongy spaces (Fig. 5). This appearance suggests that the spongy spaces may represent dilated ergastoplasmic sacs. However, the presence of connections between some of these spaces and the vascular lumen, and the frequent occurrence of bits of cytoplasm protruding into the maternal blood plasma, in a fashion similar to the appearance of cells exhibiting pinocytosis, inclines one to the interpretation that the spaces communicate by sponge-like channels with the maternal blood stream so that the vacuoles contain ingested plasma fluid. Indeed, perhaps the attempt to distinguish between extracellular, sponge-like spaces and ergastoplasmic sacs is only academic, since Palade (1955 *b*) suggests that ergastoplasmic sacs are derived from invaginated plasma membranes, to which intracellular granules become attached.

Between the maternal endothelium and the contiguous trophoblast there is a variable amount of ill defined, amorphous substance. In places, this perivascular substance is copiously present, being a few microns thick, in others it thins out to very narrow dimensions, and in still others it is entirely absent so that the plasma membrane of the endothelium and that of the trophoblast are directly contiguous. The endothelial margin of this substance is more or less regular, as is also the basal plasma membrane of the adjacent endothelium. Its opposite margin, however, is irregular and indented by the trophoblast. Previous cytological observations, using the light microscope, led to the conclusion that this substance represented an amorphous connective tissue ground substance derived from the uterine decidual and endothelial cells (Wislocki and Dempsey, 1946). Its electron microscopical appearance agrees well with this concept, since its homogeneity and density are quite similar to those of the amorphous component of basement membranes observed elsewhere. Its indented, trophoblastic margin suggests that it may be eroded by the trophoblast and constantly renewed by the endothelium.

Lying between the maternal capillaries in the center of the lamellae there is a variable number of giant decidual cells. These are sometimes binucleate but usually contain a single large nucleus. The cytoplasm of these cells, observed with the electron microscope, is foamy in appearance because of innumerable rather small vacuoles (Fig. 11). Small mitochondria are interspersed among the vacuoles. In older specimens (110 mm. fetus) the vacuoles have smooth walls whereas in placentas associated with younger fetuses (50 mm.) the vacuoles have indistinctly granular membranes. Whether or not these vacuoles represent dilated ergastoplasmic sacs or are formed from some other structure has not been ascertained. An amorphous substance continuous with and in every respect similar to the basement membrane surrounding the maternal capillaries, separates the giant cells from the trophoblast. (Figs. 1 and 11).

The blood vessels and giant decidual cells described above represent the maternal elements of the lamellae. They are enclosed or bordered on both sides by a sheet of fetal chorion, comprising the trophoblast. The chorion is composed of an outer sheet of syncytium abutting the maternal endothelium and giant cells and of an inner layer of cytotrophoblasts, the number of which diminishes as pregnancy advances. In some places the syncytium abuts the maternal endothelium and giant cells directly without any intervening ground substance. The syncytium and cytotrophoblast are separated from one another only by apposed thin plasma membranes.

The syncytial trophoblast contains rather irregular nuclei with densely organized clumps of chromatin. A moderate number of rather small, ovoid mitochondria are present in the cytoplasm, located mostly near the nuclei. Large vacuoles containing an electron-dense osmophilic material and a somewhat less dense flocculent precipitate are also scattered throughout the cytoplasm (Figs. 1, 2, and 4). The vacuoles presumably represent the large fat droplets observed by light microscopy, but it is noteworthy that their appearance is quite different from that of the lipide inclusions in the cytotrophoblasts (Figs. 1 and 4). In addition to these organelles the cytoplasm contains numerous small, moderately dense granules amongst which some larger, denser granules are interspersed; these elements appear similar to Palade's microgranules or to the ergastoplasmic granules of Weiss (1953).

Perhaps the most noteworthy aspect of the syncytial trophoblast concerns the irregular character of its limiting plasma membranes. Along its fetal margin, in the gaps between the cytotrophoblasts the syncytium sends fairly stout branched processes toward the basement membrane upon which they end in broad, foot-like contacts. Between the plasma membrane of these processes and the basement membrane seemingly empty, extracellular spaces are visible (Figs. 2 and 4). These clear spaces between the syncytial processes present a pattern of interlocking lacunae or sinuses in the basal region of the trophoblast (Fig. 2). The appearance of the foot-like endings and the spaces between them is reminiscent of the way in which the renal epithelial cells are attached to the capsule of the renal glomerulus (Rinehart, Farquhar, Jung, and Abul-Haj, 1953; Pease, 1955).

The cytotrophoblastic cells posess large vesicular nuclei, moderate numbers of mitochondria and numerous small fat droplets (Fig. 4). The granules of the cytoplasm are less dense than are those of the syncytium. The borders of the cytotrophoblasts are rather smooth and even, and do not exhibit the processes and invaginations displayed at the interfaces between the syncytium and the basement membrane.

External to the basement membrane, in the stages we have examined, is the fetal connective tissue. Loosely distributed fetal fibroblasts and reticulum fibers form the basic elements of this layer. Where fetal capillaries occur, the endothelium rests upon a thin, amorphous basement membrane similar to that of the trophoblast. In the regions where a fetal capillary approaches closely or even indents the trophoblast, the two basement membranes remain distinct and do not fuse. They are separated by a narrow connective tissue space in which occasional collagenous fibrils can be seen (Fig. 4). The fetal endothelium does not present any especially noteworthy features. It is narrower and not nearly so dense as that lining the maternal vessels. In some regions, small microvesicles have been observed.

The paraplacental chorion, or brown border, is easily recognized in electron micrographs by the presence of tall columnar chorionic epithelial cells containing large numbers of dense vacuoles and phagocytized aggregates. At their apical surfaces, the epithelial cells exhibit microvilli of varying sizes, some of which are branched (Fig. 6), besides identations or invaginations of the plasma membrane into the cells (Fig. 7). These appearances, together with the presence within the cytoplasm of whole or fragmented erythrocytes and aggregates of uterine secretion and detritus, similar to those found in the uterine lumen, leave little doubt that these cells are actively phagocytic. The largest aggregates and the least altered erythrocytes are located in the apical region of the cells, whereas, toward the interior; the aggregates become smaller and the erythrocytes become shrunken, indicating a fragmentation and gradual digestion of their contents. The mitochondria of these cells are exceptionally dense, a quality which suggests that they are peculiarly modified.

The paraplacental chorionic epithelium rests upon a well defined basement membrane which is moderately dense and homogeneous in appearance. It separates the epithelium from the fetal connective tissues. Fetal fibroblasts, collagenic fibrils, and fetal capillaries constitute this layer. In places, reticulum fibrils can be observed extending toward the basement membrane and becoming embedded in it (Fig. 8). These attachments serve to anchor the basement membrane firmly to the stroma. Reticulum fibrils are frequently seen coursing near the surfaces of fibroblasts and their processes, and in occasional fields, the collagenic fibrils appear to fuse with the plasma membranes of fibroblasts with small dense nodes occurring at the points of fusion (Fig. 8).

The plasma membranes along the lateral margins of the paraplacental cells pursue relatively irregular courses from the apex of the cell to its base. Here and there, a protrusion from one cell fits into a corresponding recess in its neighbor. Such interlocking arrangements are illustrated along the middle of the field shown in Fig. 6. In addition, well developed terminal bars are regularly encountered along the lateral margins of the cells near their apices. These are also illustrated at the arrow in Fig. 6. In these structures, a thickened, osmiophilic substance appears to be applied to the internal margins of the apposed plasma membranes.

Uterine Epithelium.—Facing the paraplacental chorion, and separated from it by the uterine lumen, is the surface epithelium of the uterus. Occasional symplasmic masses, or multinucleate giant cells, are interspersed among the irregular columnar elements of the epithelium. Within the uterine lumen, disintegrating cells and nuclei are mixed with numerous erythrocytes. The latter probably represent extravasations from maternal blood vessels at the placental border which have been eroded as a result of the invasive character of the trophoblast. Besides the signs of epithelial degeneration, noted above, one sees also evidence of regeneration with frequent mitoses. It would appear, therefore, that the uterine mucosa is subject to constant attrition by the trophoblast as well as constant repair by its own regenerative powers.

The cells of the uterine epithelium are extremely variable, when examined with the electron microscope, and they deserve further careful study. In the present investigation we have had occasion to make only incidental observations, but yet would call attention to two outstanding features of the epithelium. First, its apical border is irregular and exhibits numerous short, slender microvilli (Figs. 9 and 10). And, secondly, within the cytoplasm, particularly in the supranuclear region, numerous dilated vacuoles are often present (Fig. 10). The latter are lined by membranes the cytoplasmic margins of which exhibit numerous dense micrograniules. This appearance is consonant with secretory activity, although it might also be construed as indicating a destructive influence of the chorion on the endometrium.

Amniotic Epithelium.—We have encountered occasional sections through the amniotic epithelium. One such field is illustrated in Fig. 12. Short, blunt, and branching microvilli project into the amniotic cavity. Laterally, the cells are bounded by plasma membranes which pursue a tortuous course, interlocking extensively with the neighboring cells. Basally, the cells rest upon a delicate, amorphous basement membrane. A few small, spheroidal mitochondria and occasional vesicular and elongated Golgi elements constitute the formed structures of the cytoplasm.

DISCUSSION

With the availability of improved methods for fixing and sectioning tissues, together with the increased resolution and magnification now possible with the electron microscope, it has become possible to depict cellular organelles and other structures with much greater precision than could be done formerly with the older methods of light microscopy. With the electron microscope, the internal structure of mitochondria, microvillous and microlabyrinthine extensions of the cell membrane, the structure of the ergastoplasm of cells and the appearance of the Golgi complex and other intracellular membranes can now be further visualized. Structures, the size of which lies at or below the limits of resolution by the light microscope, constitute a subject of investigation which is of great interest to cellular biologists. Description of the disposition of such elements in cells having varied physiological functions, and observations on the changes induced in the fine structure of cells subjected to varying physiological loads should do much to further our understanding of the submicroscopic organization of cells.

Placentas are excellent material for the correlation of fine structure with function, particularly with reference to growth, absorptive and phagocytic phenomena. In the cat's placenta, the paraplacental chorion faces the uterine epithelium and is separated from it by the uterine lumen in which glandular secretion, cellular detritus and extravasated maternal erythrocytes are present. The chorionic epithelium is actively phagocytic, as is attested by the presence of whole erythrocytes in the apical cytoplasm and by the accumulation of intravitally injected trypan blue in the supranuclear, mid-portion of the cytoplasm of the tall columnar cells (Wislocki, 1920). In addition, vacuoles, containing granular material similar to that found free in the uterine lumen, are a common feature of the apical part of these cells. The configuration of the free surface of the chorion throws light on the mechanism whereby these vacuoles are formed. In addition to the profuse microvilli, which greatly increase the cell's free surface, a system of canals exists just beneath the apical plasma membrane and, here and there, these canals appear to communicate with the uterine lumen by means of pores. Thus, the absorptive surface of the cells is organized in a fashion comparable to that described in the yolk sac epithelium of the guinea pig (Dempsey, 1953), for which the suggestion was made that absorption vacuoles segregated uterine milk in the cell's interior by means of similar microlabyrinthine canals.

Iron reactions are strongly positive in the paraplacental chorionic epithelium, but usually only in its apical or middle portions and in the basement membrane (Wislocki and Dempsey, 1946). In our present electron micrographs, the supranuclear portion of these cells commonly contains whole red cells or fragments of them. It would appear, therefore, that iron is released from hemoglobin during the fragmentation process. However, the infranuclear portion of these cells frequently contains vacuoles filled with a dense material (Fig. 6) although the iron reactions are negative in this region. These observations can possibly be accounted for by the assumption that the latter, dense osmophilic substance represents the bile pigments or degraded porphyrins resulting from the removal of iron from the hemoglobin. It is in this region particularly that intravitally administered trypan blue accumulates in numerous small particles or masses (Wislocki, 1920). In this region, too, numerous small particles or masses are present which stain intensely with the periodic acid–Schiff reagent (Wislocki, unpublished observation). For the latter reaction some of the shrunken erythrocytes and especially elements derivative from them would appear to be responsible.

The endothelial cells lining the maternal capillaries of the chorioallantoic placenta exhibit several remarkable features. They are extraordinarily thick as compared with endothelium in other organs, they are basophilic and contain many of Palade's (1955 *a*) micr180granules, they contain a large and extensive Golgi apparatus, they have large and vacuolated mitochondria and they possess spaces or lacunae filled with a flocculent precipitate which resembles maternal blood plasma. It seems possible that these lacunae represent vacuoles or invaginations of the cell's surface whereby blood plasma is transferred into the endothelium by a process resembling pinocytosis. Communications between these spaces and the capillary lumen, such as that illustrated in Fig. 2, are not uncommon and lend weight to this suggestion. Furthermore, the swelling and vacuolation of the mitochondria in the vicinity of the lacunae provide some further slight support for this hypothesis, since mitochondria elsewhere are known to be sensitive osmometers (Weiss, 1953) and might well be affected by the introduction into the cell of a fluid such as plasma. These appearances, therefore, can be reconciled with the view that fluid is rapidly traversing the cells.

The remaining specializations of the maternal endothelium are such as to suggest a secretory process. Their basophilia and their content of ergastoplasmic microgranules, coupled with the large Golgi apparatus, are phenomena ordinarily seen in cells which are rapidly forming protein. In this connection it should be recalled that the endothelium first becomes thickened and basophilic at the period of placental development when it is incorporated into the trophoblastic lamellae (Wislocki and Dempsey, 1946) and the basement membrane surrounding the maternal capillaries is becoming greatly thickened. Because of these observations, the suggestion is offered that the thick basement membrane is, in part, elaborated by the maternal endothelial cells and that it may be the secretion of this material which requires some of the cytological specializations adumbrated above. As a further thought, we should like to call attention to the rather smooth and regular apposition of the basement membrane with the endothelial plasma membrane, in contrast to its scalloped and irregular contour facing to the trophoblast. This difference is consonant with the view that the amorphous substance of the basement membrane is elaborated continuously by the endothelial cell, whereas it is being simultaneously eroded and absorbed by the trophoblast. An erosive action is certainly acknowledged to be a property of the trophoblast of the cat's placenta, especially in the junctional zone during the period when the placental labyrinth is being formed.

The views advanced above, concerning the possible formation and destruction of the perivascular basement membrane of the maternal capillaries raise the question of the nature of the similar amorphous substance which surrounds the giant cells of the lamellae. Wislocki and Dempsey (1946) have described previously the manner in which these cells are formed, first as plaques of hypertrophied fibroblasts which are gradually incorporated into lamellae by advancing tongues of trophoblast which surround them and the neighboring capillaries. Thus, these cells appear to be maternal decidual cells which become enclosed in the trophoblastic lamellae in exactly the same fashion as the maternal capillaries. These cells are enveloped by a membranous ground substance which is continuous with the similarly thickened basement membranes of the maternal capillaries. These membranes, therefore, may have dual origin, part being elaborated by the endothelium and part by the giant decidual cell. This view is not unreasonable since both cells are related in that they have a common connective tissue derivation, and the giant cell in its early stages contains a goodly amount of the ergastoplasmic granular sacs which may well be the morphological representation of the cell's synthetic machinery. In this connection it might be pointed out that carnivores, excepting the

Felidae, do not possess giant decidual cells in their placental lamellae. Instead, they contain solely maternal capillaries surrounded by prominent perivascular basement membranes (Amoroso, 1952).

It remains to discuss some of the special features exhibited by the trophoblast. We have referred briefly, in a previous section, to the irregular contours of the amorphous basement membrane which is interposed between the maternal capillaries and the trophoblast, and have suggested that the ragged appearance of the margin which faces the trophoblast is caused by the erosive action of the latter. Such a suggestion is in keeping with other observations on the activity of the cat's trophoblast. In the subplacental junctional zone, Wislocki and Dempsey (1946) have described an erosive or digestive action of the chorion, in that the collagenous fibers of the endometrium lose their argyrophilia, swell, and become transformed into a homogeneous substance which encapsulates the decidual cells. Similarly, in the placental junctional zone the lumens of the uterine glands are occluded by tongues of chorionic tissue, and in this zone the glandular epithelium adjacent to the chorion becomes converted into symplasmic masses which disintegrate and are variously phagocytized and absorbed (Wislocki and Dempsey, 1946; Amoroso, 1952). Thus, there is cytological evidence that the trophoblast can erode and destroy maternal cells and fibers. Our suggestion that the syncytium continues to erode and digest the perivascular basement membranes, and that these continue to be secreted or replaced by the maternal endothelium and giant cells, merely extends a known action of the trophoblast to a time later and a location other than those which have been noted previously.

Another feature of the syncytial trophoblast which deserves mention is the specialization of its margin which faces the fetal stroma. Separating the chorion from the connective tissue is a thin and well defined basement membrane which is relatively smooth. The cytotrophoblastic cells abutting this membrane also are quite smooth, exhibiting a simple plasma membrane which is closely applied to the basement membrane with a narrow interstitial space separating the two. However, in the course of gestation, as the cytotrophoblasts disappear and the syncytium survives, the latter sends cell process or pseudopodia between the cytotrophoblasts down to the basement membrane. These pseudopodia are surrounded by anastomosing extracellular space. The pseudopodia of the syncytium, extending across this space and ending upon the basement membrane, resemble the podocytes exhibited by the visceral epithelium of Bowman's capsule (Hall, Roth, and Johnson '53; Rinehart, Farquhar, Jung, and Abul-Haj, 1953; Pease, 1955, Dempsey and Wislocki, 1955).

The basal plasma membrane in renal tubules exhibits a modification similar in some respects to those mentioned above. Sjöstrand and Rhodin (1953), Rhodin (1954) and Palade (1955) have described basal invaginations of the plasma membranes into the substance of the cell, thus creating real or potential extracellular spaces or channels and Pease (1955) has shown that these spaces, in the renal tubules, become greatly dilated during water diuresis. We have encountered similar spaces in incidental observations on kidneys, and have observed that the tubular basement membrane, identified by intravitally deposited silver, is not apparently reflected into the clefts created by the ingrown cell membranes (Dempsey and Wislocki, 1955). Another situation in which we have seen such basally situated, extracellular spaces created by foot processes attached to a basement membrane, is in the acinar cells in the mouse's mammary gland (Dempsey, unpublished observation).

The sum of these observations suggests that the basal feet of epithelia, which create extracellular compartments such as those described and illustrated here in the cat's syncytial trophoblast, are encountered in regions in which there is an active fluid transfer. Such an hypothesis would account for their occurrence in the glomerulus, in cases in which the formation of the glomerular filtrate is thought to constitute a rapid and extensive flow. The enlargement of the spaces in renal tubules during hydration (Pease, 1955) and the presence of the spaces in mammary glands are also in accord with the hypothesis. Such reasoning suggests a rapid fluid transport across the cat's placenta, and, by analogy with the other locations, permits the speculation that the direction of flow is here predominantly from the fetal to the maternal tissues.

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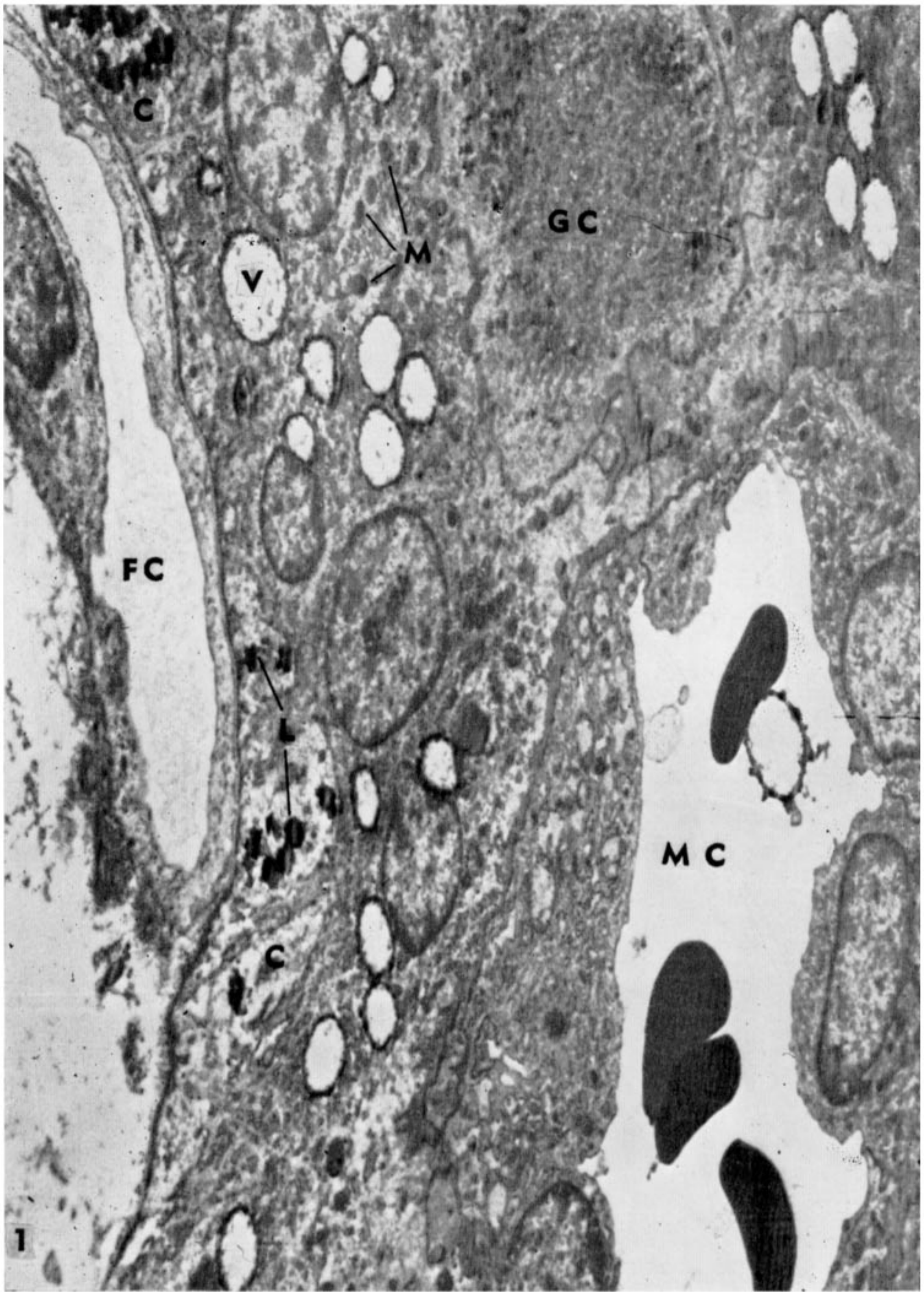
EXPLANATION OF PLATES

PLATE 192

FIG. 1. Section through a typical placental lamella from a cat during mid-gestation (70 mm. fetuses). The section illustrates the topographic relationships of the various placental elements. A maternal capillary (*MC*) containing four erythrocytes is shown at the lower right. Its thickened endothelial wall contains numerous vacuoles or spaces, and rests upon an irregular membrane of homogeneous material. A similar membrane surrounds the maternal giant cell (*GC*) visible at the upper right center. To the left of these structures lies the fetal syncytial trophoblast. Numerous mitochondria (*M*) and dark-rimmed vacuoles (*V*) appear within it. The latter presumably represent the lipide of the syncytial trophoblast; compare with Fig. 4. The cytotrophoblasts (*C*) are located marginally in the lamellae, contain cytoplasm less dense than that of the syncytium, and exhibit clusters of small lipide inclusions (*L*). The trophoblast rests upon a basement membrane lateral to which is the fetal connective tissue and a fetal capillary (*FC*). Palade's fixation. × 6,000.

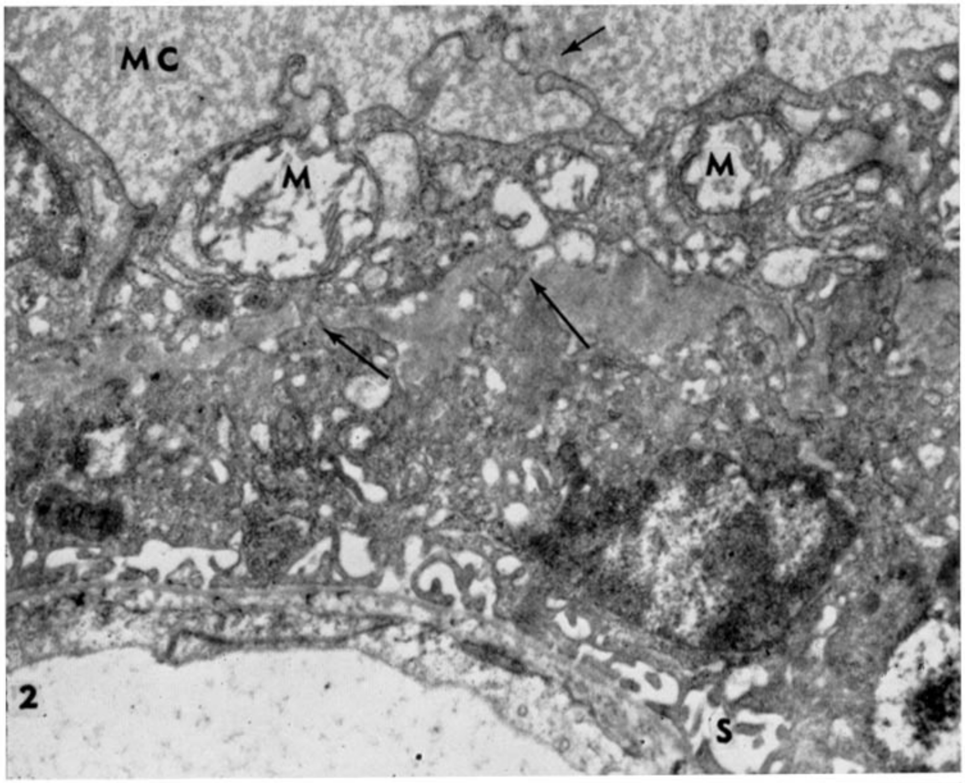


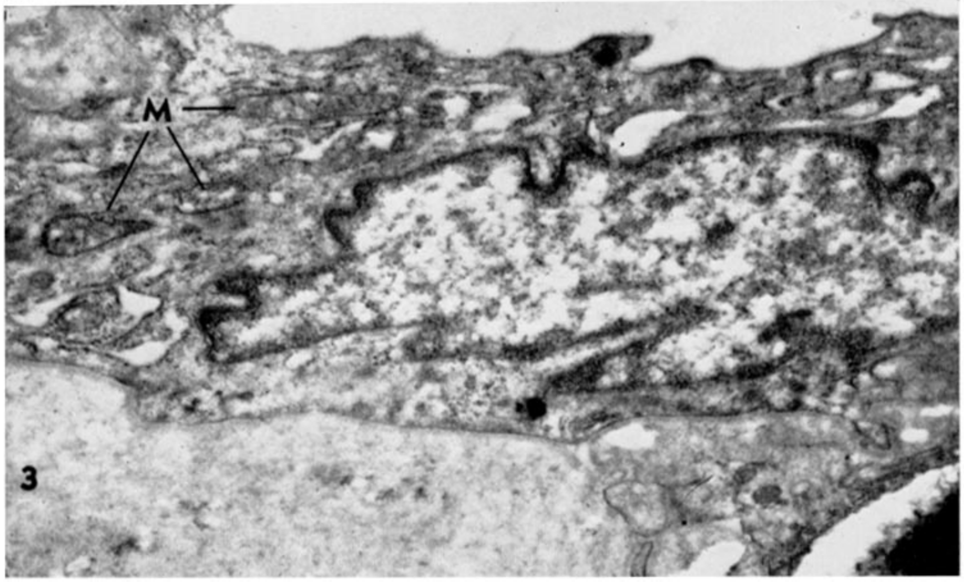
(Dempsey and Wislocki: Electron microscope studies on placenta)

PLATE 193

FIG. 2. Section through a typical placental lamella from a cat late in pregnancy (110 mm. fetuses). The maternal capillary (*MC*) containing a flocculent precipitate of plasma is shown at the top of the figure. The thickened maternal endothelium has a lacy appearance caused by spaces or vacuoles filled with a flocculent precipitate similar to that in the capillary lumen (see arrow). Swollen mitochondria (*M*) can be seen. The surface of the endothelium is irregular; projections extend into the lumen in fashions suggesting the enclosure of plasma into vacuoles by pinocytosis. Beneath the endothelium lies the thick, maternal basement membrane. Its irregularity and actual discontinuity are illustrated at the arrows, where the endothelium and syncytium are contiguous. At the base of the syncytium, foot-like processes rest upon the fetal basement membrane. Between them lie extracellular spaces (*S*) which extend upward for considerable distances into the trophoblast. The fetal capillary is illustrated at the bottom of the figure. Palade's fixation. × 15,000.

FIG. 3. Another area of the preceding section. The endothelial cell shown here contains fewer of the spongy cavities, and the mitochondria (M) are not swollen as they are in the neighborhood of the cytoplasmic vacuoles. Along the lower margin of the figure there is a relatively broad field of the amorphous substance comprising the basement membrane of the endothelium. A small portion of a lipide droplet is seen in the trophoblastic syncytium at the extreme lower right. Palade's fixation. × 20,000.

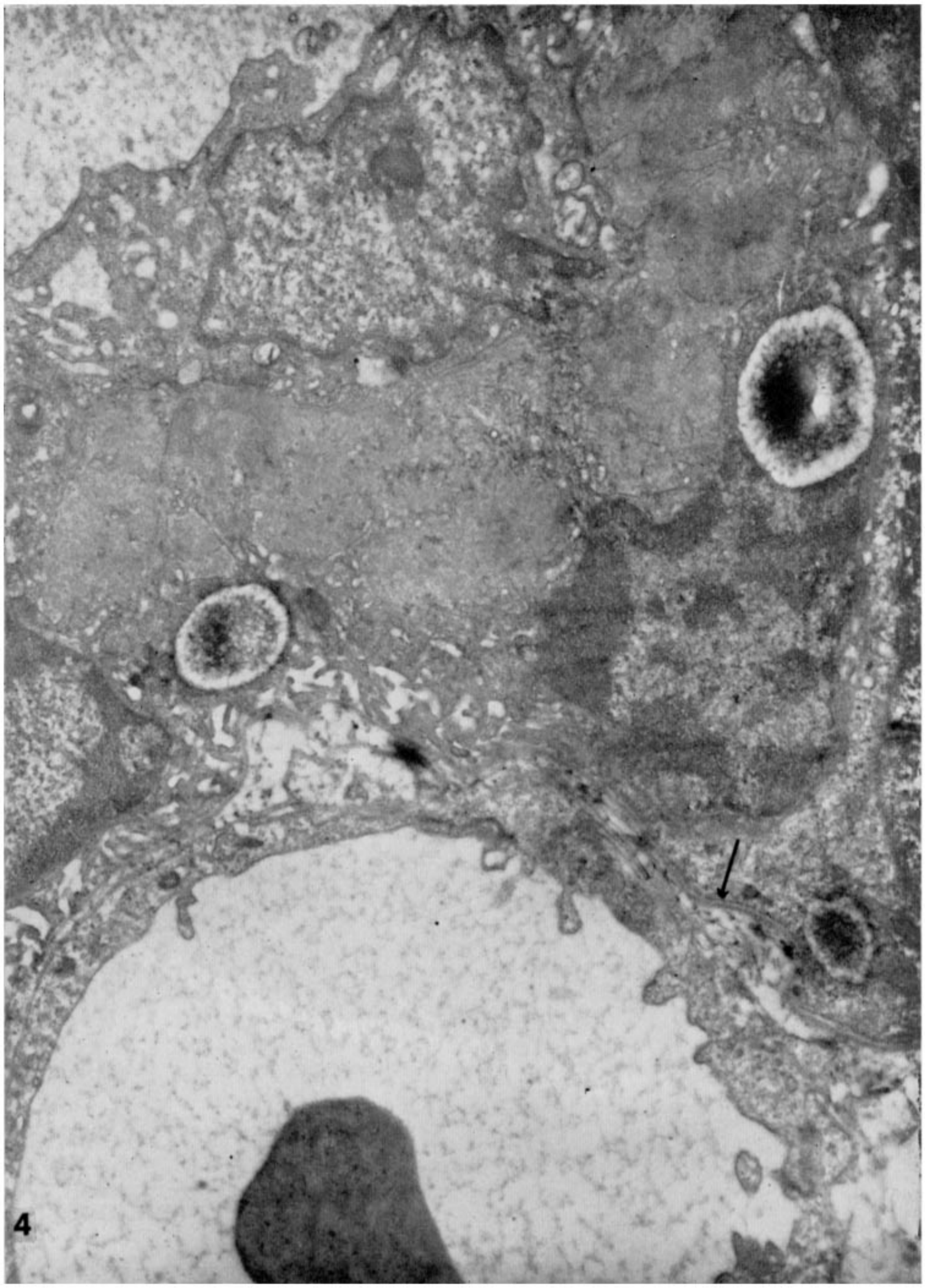




(Dempsey and Wislocki: Electron microscope studies on placenta)

PLATE 194

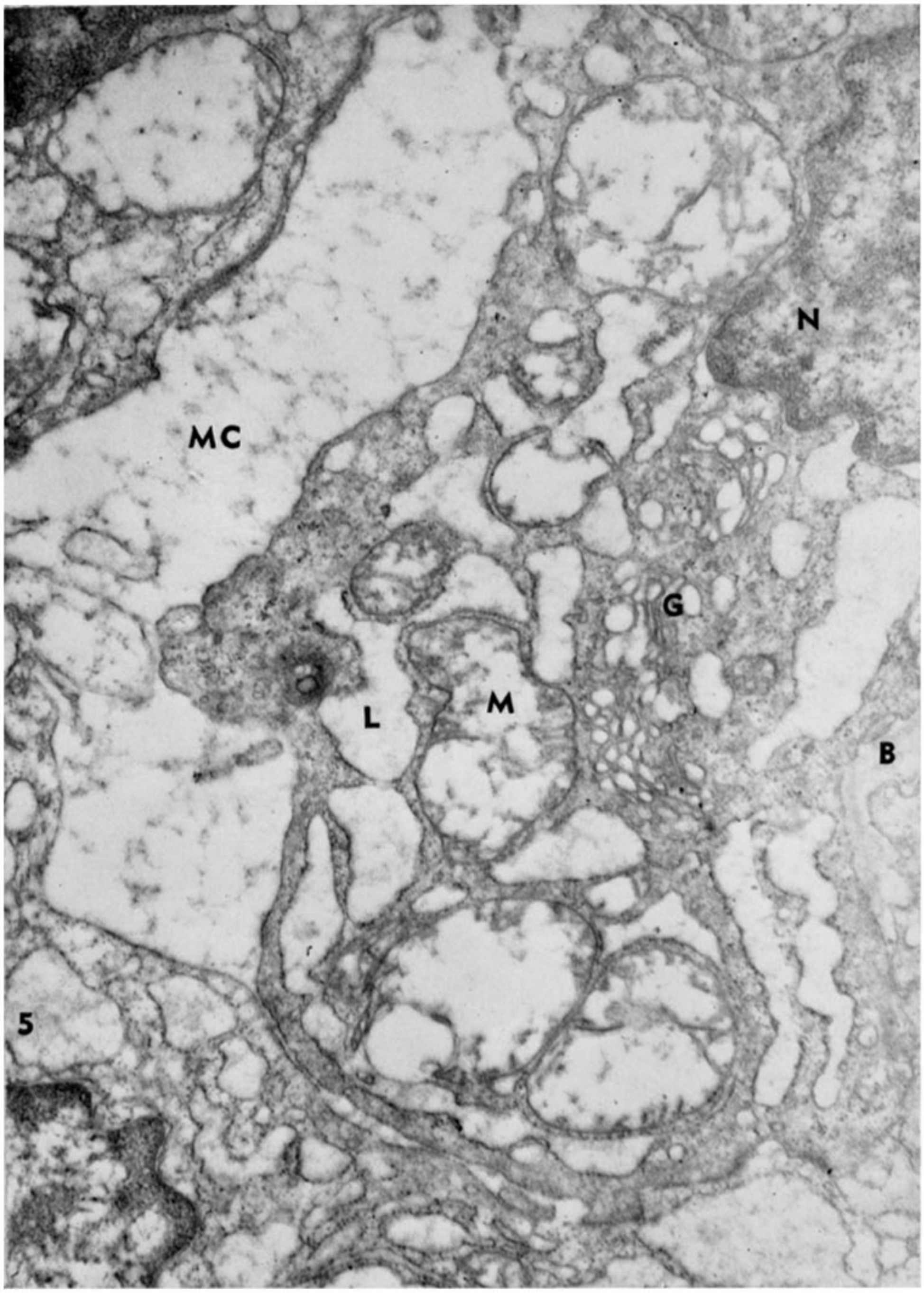
FIG. 4. Many of the phenomena illustrated in the previous pictures are also shown here to good advantage. These include the spongy texture and dilated mitochondria of the maternal endothelium, the irregular border of the amorphous, encapsulating maternal basement membrane, the lipide inclusions in the trophoblastic syncytium and the foot processes. Part of a cytotrophoblast is shown along the right hand border of the picture. Unlike the syncytium, the cytotrophoblast lacks foot processes; instead its plasma membrane rests continuously upon a basement membrane (arrow). A small lipide inclusion is present in the cytotrophoblast. The endothelium lining the fetal capillary has occasional pseudopodial extensions, and within the cells several microvesicles can be seen. Dalton's fixation. × 15,000.



(Dempsey and Wislocki: Electron microscope studies on placenta)

PLATE 195

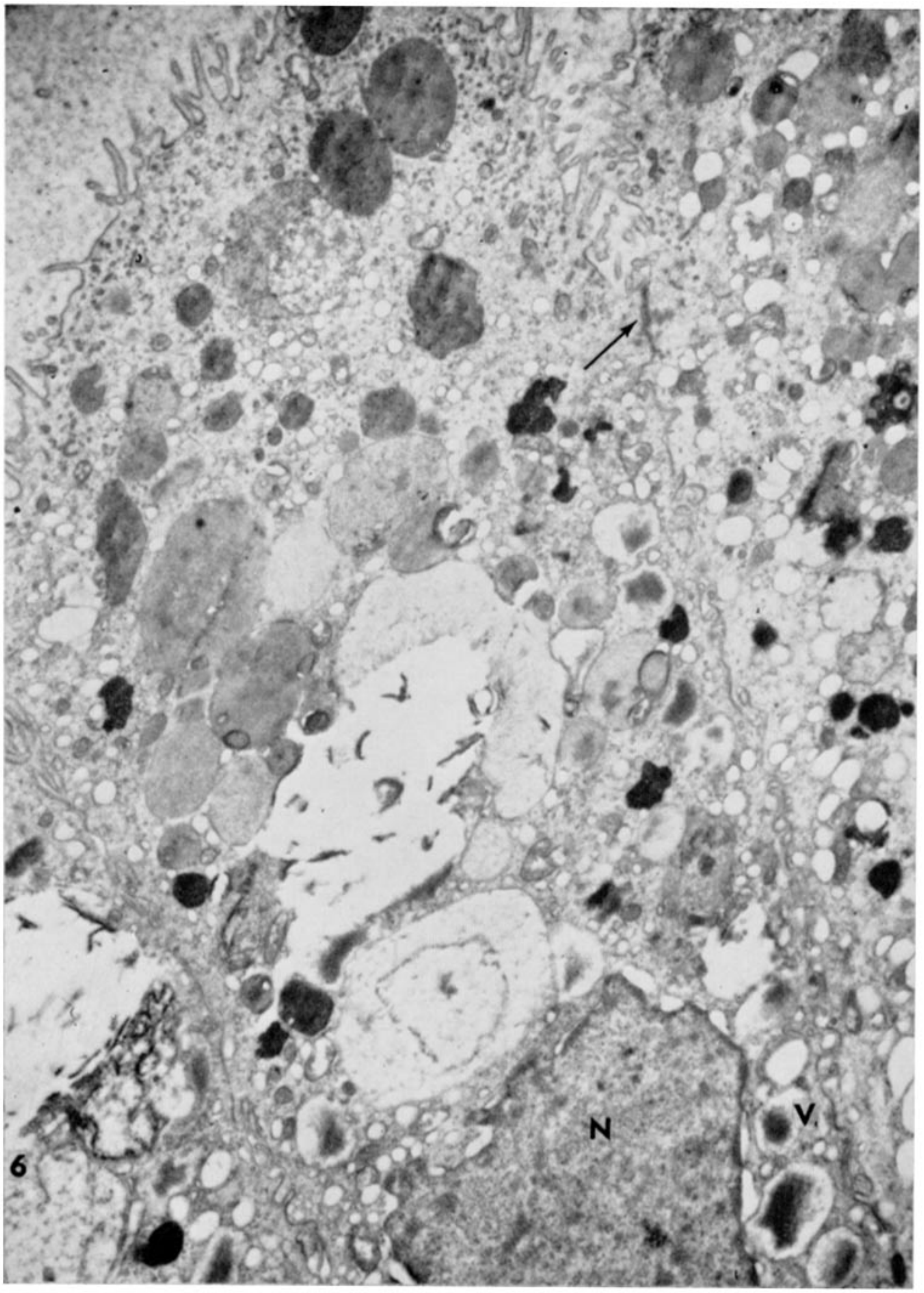
FIG. 5. Another area of the preceding section showing details of the wall of a maternal capillary at higher magnification. Swollen mitochondria (*M*) and cytoplasmic lacunae (*L*) are apparent. The endothelial cytoplasm contains many compact, dense microgranules; these represent presumably ergastoplasmic granules and are the equivalent in the electron microscope of the basophilic substance of the cytoplasm of light microscopy. They appear often to be lined up along the walls of the lacunae. An extensive series of tubules and vacuoles occupies the right center of the picture (*G*), an appearance which agrees with that exhibited by the Golgi region of other cells. At the extreme right a bit of the perivascular basement membrane is illustrated (*B*). Maternal capillary (*MC*). Nucelus of endothelium (*N*). Dalton's fixation. × 25,000.



(Dempsey and Wislocki: Electron microscope studies on placenta)

PLATE 196

FIG. 6. Section through the apical and supranuclear portions of three chorionic epithelial cells from the paraplacental, brown border of a cat late in gestation (110 mm. fetuses). Well developed and branched microvilli project into the uterine lumen, shown at the top left. Beneath the plasma membrane are numerous small circular and ellipsoidal profiles which represent a system of microlabyrinthine canals communicating with the uterine lumen. Whole and fragmented dark erythrocytes, as well as vacuoles containing granular material, are present in cytoplasm (compare with Fig. 7). Toward the bottom of the figure, another type of vacuole (*V*) containing a dense material can be seen; these correspond in location to the bile pigments which confer the brown color upon this region. The arrow points to a terminal bar. Dalton's fixation. Nucleus (*N*). × 15,000.

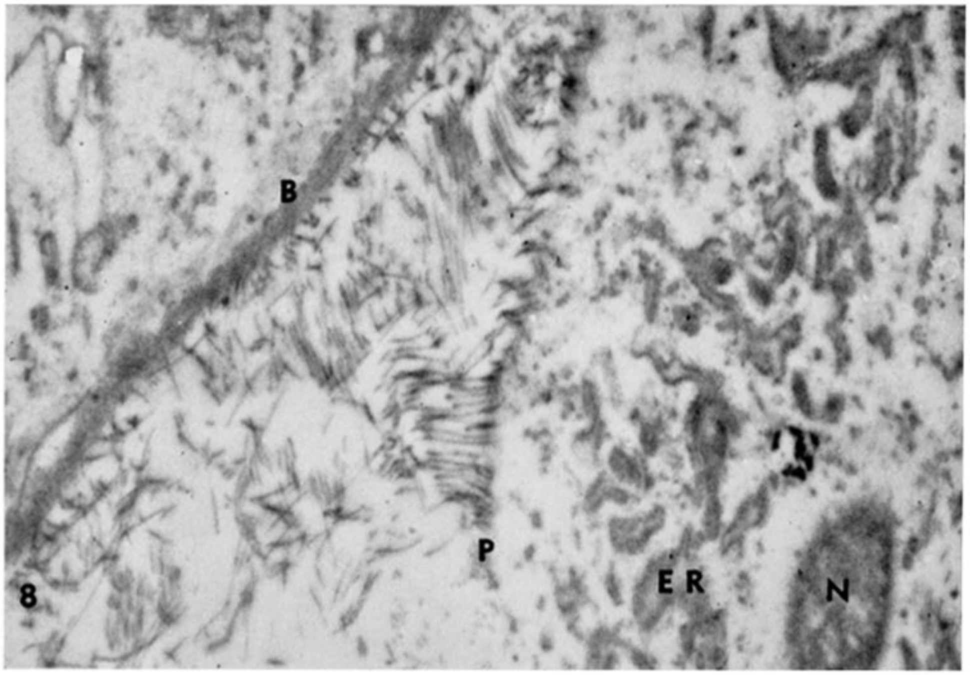


(Dempsey and Wislocki: Electron microscope studies on placenta)

PLATE 197

FIG. 7. The apical portions of two chorionic epithelial cells from the brown border of the preceding specimen. The microvillous and microlabyrinthine character of the free surface is illustrated. The large black objects in the cytoplasm represent whole, ingested erythrocytes. Palade's fixation. × 15,000.

FIG. 8. Section through the base of the paraplacental chorion and the subjacent connective tissue from a cat in mid-gestation (50 mm. fetuses). The edge of a chorionic epithelial cell is shown at the upper left. Beneath it, the basement membrane (*B*) runs diagonally across the figure. Numerous collagenous fibrils course through the connective tissue space beneath the basement membrane, and many of them appear to insert into the basement membrane. At the right is shown part of a fibroblast. The nucleus (*N*), ergastoplasm (*ER*), and plasma membrane (*P*) are depicted. Collagenous fibrils appear to be attached directly to the fibroblast's plasma membrane. At the attachment, a darkened enlargement can be observed. Palade's fixation. × 20,000.

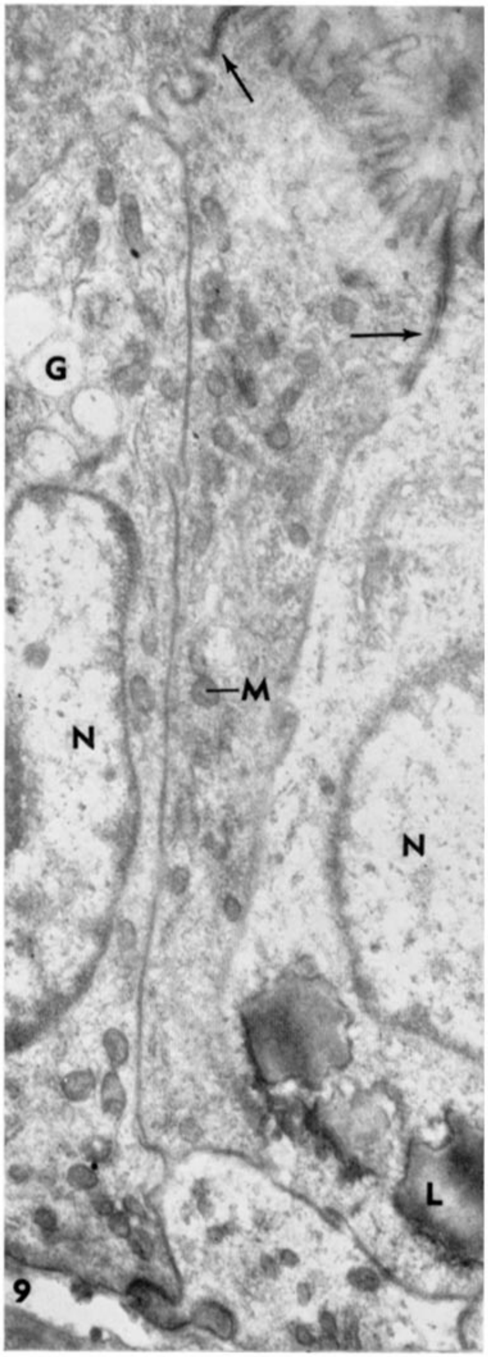


(Dempsey and Wislocki: Electron microscope studies on placenta)

PLATE 198

FIG. 9. Section through the epithelium of a uterine gland from a cat late in pregnancy (110 mm. fetuses). Microvilli project into the glandular lumen (at top of picture). The plasma membranes separating contiguous cells pursue rather straight courses from apex to base of the cells. Near the apices of the cells several thickened dense areas of the plasma membrane are apparent (arrows). These resemble modifications of the plasma membranes such as those which occur at the locations of terminal bars and intercellular bridges, and presumably represent points of reinforced attachment. Small mitochondria (*M*), Golgi vacuoles (*G*), nuclei (*N*), and basal lipide inclusions (*L*) are seen. Dalton's fixation. × 15,000.

FIG. 10. A field of uterine epithelium facing the paraplacental chorion of the preceding specimen. Microvilli, microgranules, and dilated vacuoles are illustrated. The vacuolar appearance here might be correlated with the destructive activity of the chorion, or, on the other hand, with secretory activity. Dalton's fixation. × 15,000.


G
M
N
N
L
9

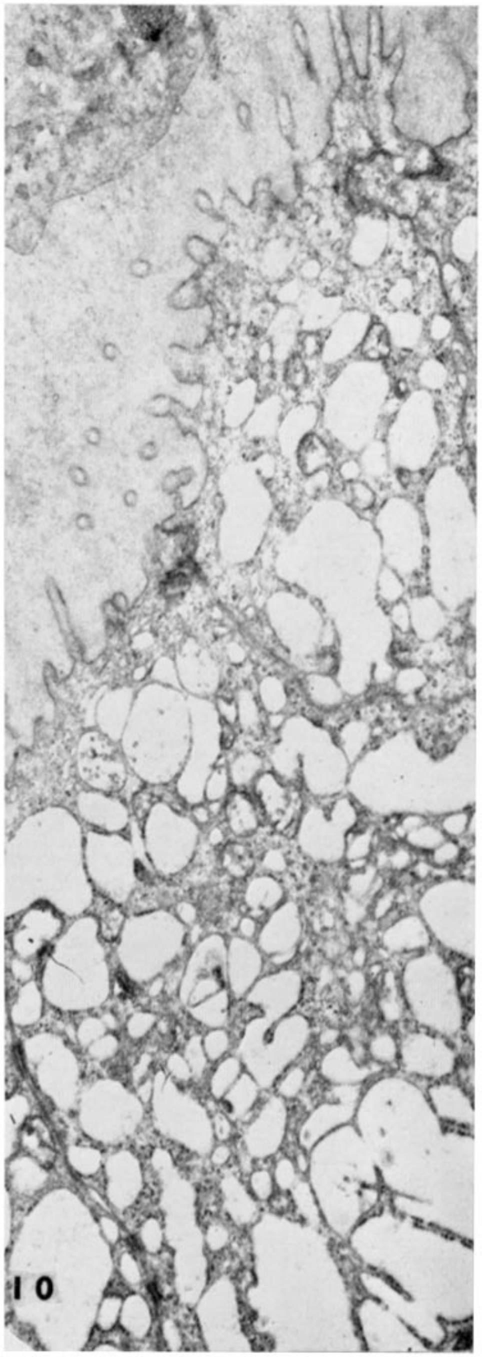

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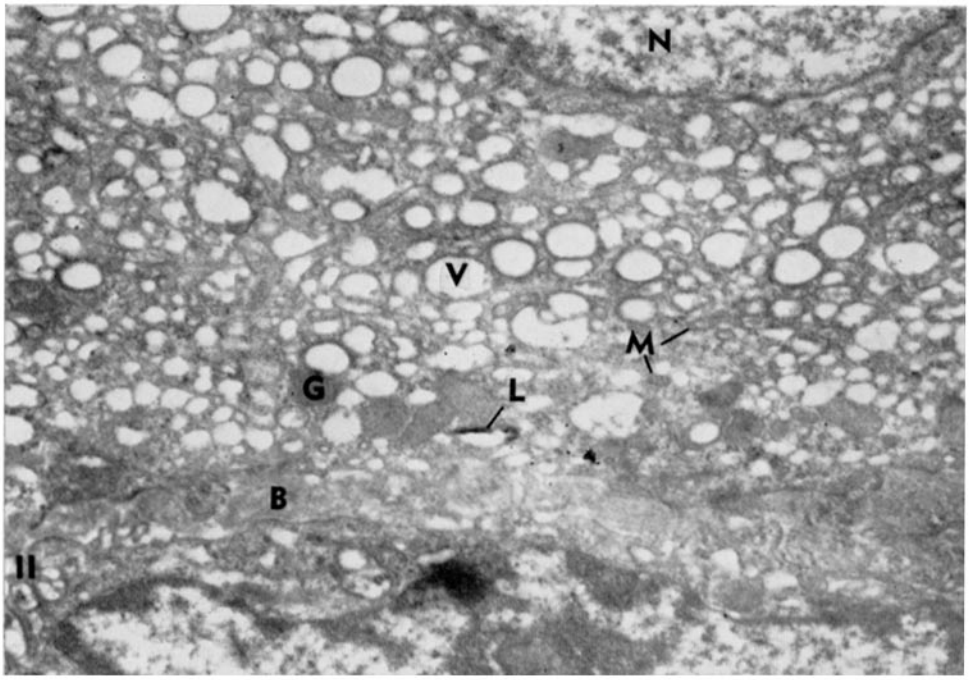
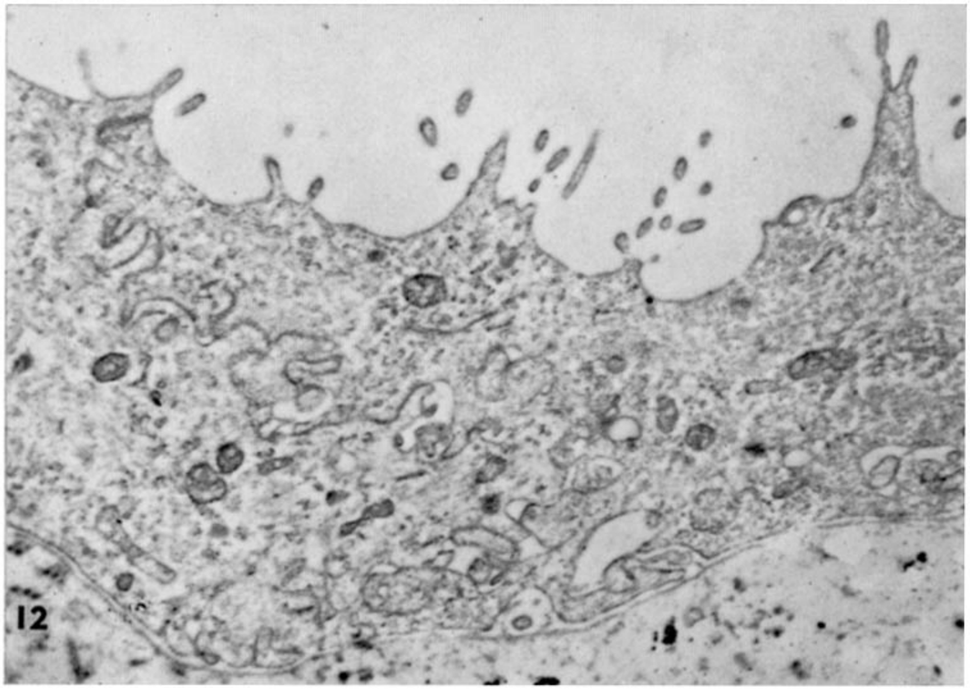
PLATE 199

FIG. 11. Section through a maternal giant decidual cell located in a placental lamella of the preceding specimen. The giant cell nucleus (*N*) is shown at the top of the figure; whereas at the bottom is a nucleus in the syncytial trophoblast. The surrounding ground substance or basement membrane (*B*) of the giant cell separates it from the trophoblast. Vacuoles (*V*), granules (*G*), mitochondria (*M*), and small lipide droplets (*L*) are present in the giant cell cytoplasm. Dalton's fixation. × 15,000.

FIG. 12. Section through the amnion from the paraplacental margin in a cat late in pregnancy (110 mm. fetuses). The interlocking extensions and recesses of contiguous amniotic epithelial cells are shown. Pseudopods and microvilli project from the free surface. Basally, the epithelium rests upon an extremely delicate basement membrane. Dalton's fixation. × 15,000.





(Dempsey and Wislocki: Electron microscope studies on placenta)