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The surface of the syncytium of the human chorionic villus

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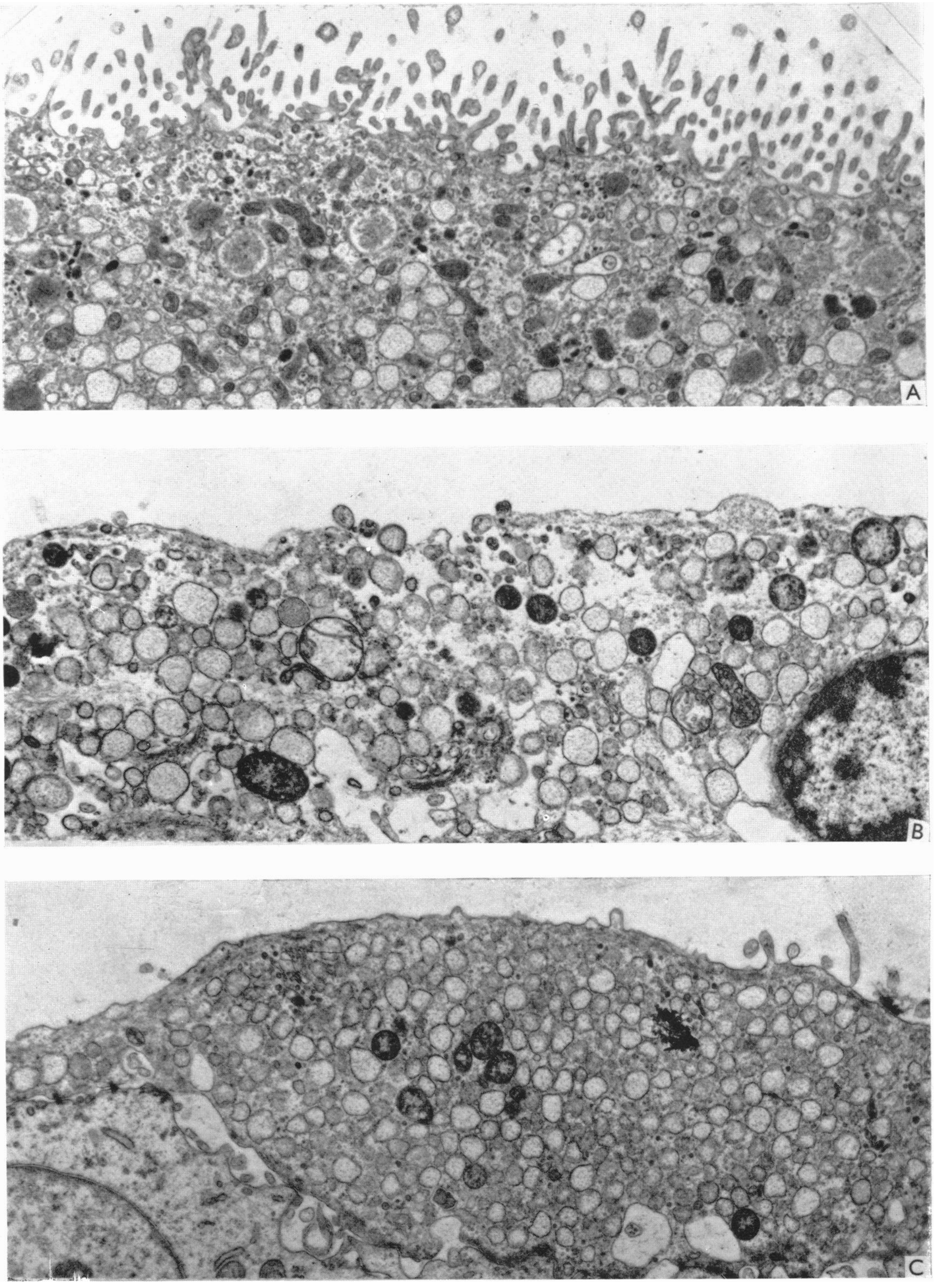
INTRODUCTION

In an account of early human chorionic villi, as observed by electron microscopy Boyd & Hughes (1954) described the microvilli which are the structural basis for the brush border seen with the optical microscope on the surface of the trophoblastic syncytium. Their micrographs showed differences in the distribution and in the degree of the development of these microvilli. These differences were interpreted as resulting from variations, possibly cyclic, in the formation and disappearance of the microvilli. Such an interpretation was believed to be supported by the presence of areas of microvilli showing an intermediate degree of development.

The placental brush border was first described and figured by Kastschenko (1885), who wrote, 'Der freie Rand ist gewöhnlich von Wimpern besetzt'. It was Fellner (1903) who elaborated the description of the striations in the syncytial margin and compared them with those located on the surface of the intestinal and renal epithelium. Schaffer (1927) gave a detailed account of the presence of a brush border in a number of other epithelia including those of the choroid plexus, the hepatic ducts and the gall bladder, the secretory ducts of the sweat glands and the epidermis of cyclostomes. Grosser (1927) indicated that the syncytial brush border could not always be identified in sections of chorionic villi, and that its absence was not necessarily related to the quality of fixation.

In their classic account of the histological structure of the human placenta, Wislocki & Bennett (1943) described the light-microscopic appearances of the syncytial surface of the chorionic villi (for further discussion see Wislocki & Padykula, 1961). These investigators found the brush border to be variable in structure and inconstant in its occurrence and distribution. In some regions, moreover, particularly in sections of younger material, irregular fronds and streamers of the syncytial surface were frequently present. For such reasons Wislocki & Bennett (1943) concluded that, in the living condition, the trophoblastic syncytium showed considerable instability, its surface contours being subject to continuous modification. They further suggested that such surface irregularities were implicated in the processes of absorption of fluid and nutriment from the maternal blood in the intervillous space. Syncytial extensions had earlier been described by a number of workers including Hamilton & Gladstone (1942) and Baker, Hook & Severinghaus (1944).

Boyd & Hughes (1954, 1955) reported regional differences in the fine structure of the syncytioplasm, differences which, it was suggested, might in part be due to the extent and degree of the development of the microvilli. It was considered that larger and more frequent vacuoles were present in syncytioplasm underlying the microvilli than in those areas having a smooth surface, and the presence of the brush border


A
B
C

was presumed to be linked with increased pinocytotic activity. Better fixation and improved electron-microscopic techniques, however, soon enabled Wislocki & Dempsey (1955) to demonstrate that the association suggested by Boyd & Hughes could not readily be substantiated. Since these early contributions an extensive literature relating to the fine structure of the human placenta has been published (Boyd & Hamilton, 1967), but there has been little comment on the variability in microvilli and the size and extent of the brush border. This paper reports further observations on this variability and adds some information on the fine structure of the microvilli.

MATERIAL AND METHODS

A large number of electron micrographs of some forty placentae were available for study. The material was derived from placentae associated with embryos or foetuses which ranged in age from about the 25th day of pregnancy until full term. Fixation was either in buffered osmium tetroxide or in glutaraldehyde followed by post-osmication. The earliest studied material was embedded in methacrylate but Araldite was used for most of it. Sections were cut on a Huxley microtome and doubly stained with uranyl acetate and lead citrate.

DESCRIPTION

From the extensive material available to us only a few electron micrographs, illustrative of the points we wish to make, have been selected for special comment.

In many of our placentae the electron micrographs frequently show that, on one and the same villus, regions with a well-developed brush border can be present close to areas with a smooth surface. The contrast between smooth surface syncytium and that which possesses microvilli as the basis for a brush border is usually striking. Nevertheless, between the smooth- and brush-border regions on such a villus, areas possessing a character intermediate between these two extremes can be identified. The three electron micrographs in Fig. 1 are from closely adjacent regions of the syncytial surface of a chorionic villus of a placenta associated with a 65 mm C.R. length human foetus. In Fig. 1A, microvilli are present and constitute a characteristic placental brush border; Fig. 1B illustrates a smooth area of syncytial surface on the same villus; Fig. 1C is a micrograph of a transitional region between the smooth and microvillous area of the chorionic villus from which Fig. 1A and B were derived. Measurements in a montage of the three electron micrographs in this figure show that in this particular chorionic villus the transition from a brush border to smooth syncytium was 40 μm

Figure 2 is an electron micrograph of the trophoblast of a chorionic villus of a placenta associated with a 28 mm embryo. The syncytial surface of this specimen possesses an obvious abundance of microvilli. The surface of the syncytium fre-

Fig. 1. Electron micrographs of three closely adjoining regions of the syncytial surface of a chorionic villus associated with a 65 mm C.R. length human foetus (Cambridge, H. 1074). A Well-developed microvilli constituting a brush border. B, Smooth area of syncytial surface which shows greater dilatation of the cisternae. C, Transitional region between smooth and microvillous areas of the chorionic villus from which micrographs 1A and 1B were photographed. The diminution in size and the disappearance of the microvilli is clearly shown. × 12000.

quently has depressions and elevations to which, as Fig. 3 shows, the microvilli are attached. In material cut vertically to the surface such regions present a scalloped effect whereas in tangential sections the scallops indicate an orientation of the depressions in parallel sulci (Fig. 4).

The syncytial projections bounding the scallops carry the microvilli and possibly correspond to the fronds that can be identified in light-microscopic sections on the surface of chorionic villi with a brush border. The attachment of microvilli to such projections is illustrated in Fig. 3.

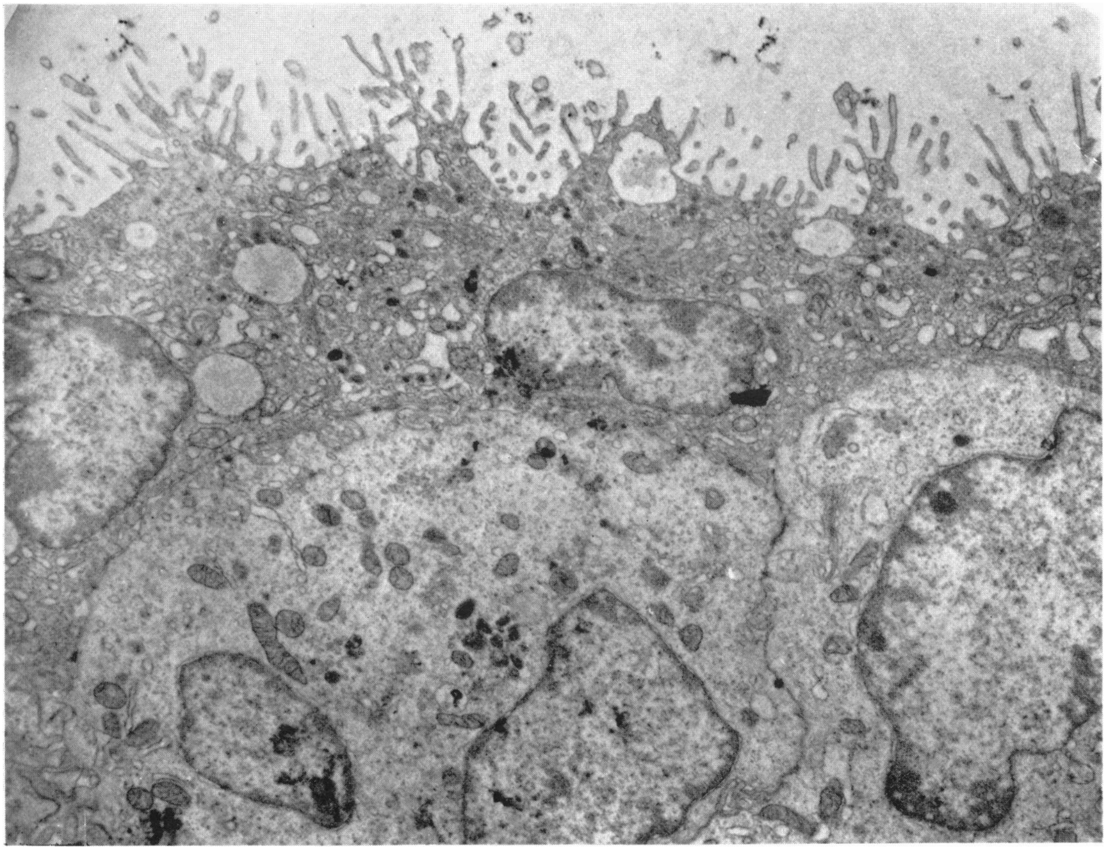


Fig. 2. Electron micrograph of trophoblast of a chorionic villus in a placenta associated with a 28 mm human embryo (Cambridge, H. 1034). Note the brush border and projections on the syncytial surface and the scalloping of this surface. The thin syncytium, with two nuclei and several large vesicles, overlies two Langhans cells, one with a lobed nucleus. × 8100.

Figure 5 is an electron micrograph at a higher magnification of the transitional region illustrated in Fig. 1C. In addition to showing in greater detail the transitional alteration in the surface structure, microfilaments can now be identified in the syncytioplasm deep to the surface plasma membrane. Some of these peripheral microfilaments parallel to the surface can be found in close association so that a banded appearance is produced; this arrangement may correspond to the terminal web found at the bases of the microvilli in other epithelial brush borders.

Figure 6 is an electron micrograph of a section tangential to the trophoblastic surface of a villus and passes through the depths of several syncytial scallops. All of these depressions possess surface microvilli and in the apparent cavity which represents the largest of the scallops sectioned a maternal red blood cell can be identified. The arrangement of the scallops in this electron micrograph is a further indication of an orientation of the microvilli on elevated ridges rather than on circumscribed conical projections of the syncytial surface (cf. Fig. 4).

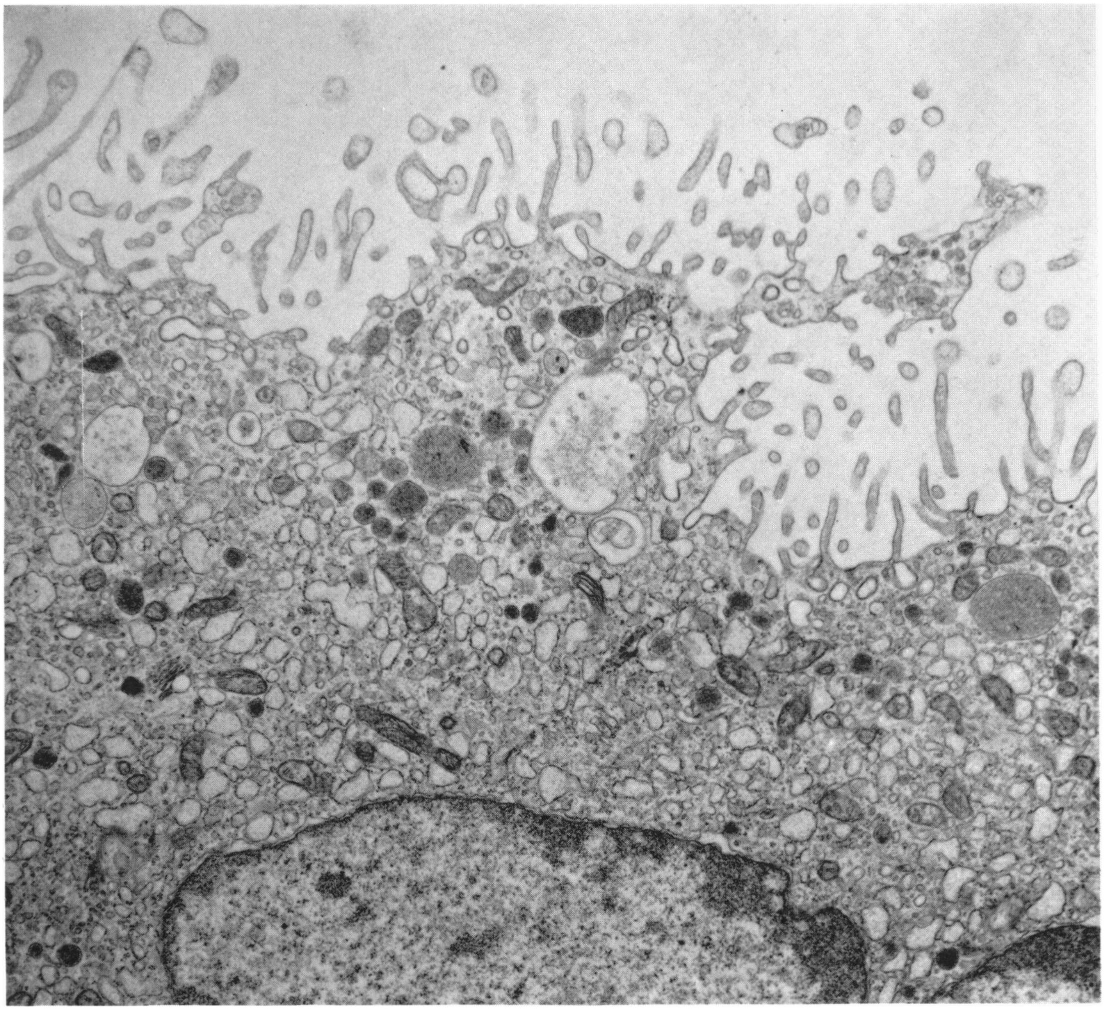


Fig. 3. Electron micrograph of the syncytial surface of a chorionic villus of a placenta associated with a 49 mm C.R. length human foetus (Cambridge, H. 1087). Note varieties of microvilli and the attachment of some of them to syncytial projections. Small, intermediate and large cisternae are present in the syncytioplasm; some of these contribute to a canalicular system. × 15000.

Owing to the variable degree of their development, such as indicated by the descriptions and illustrations that have just been presented, it is not surprising that there is considerable difference in the height of the syncytial microvilli; even on a

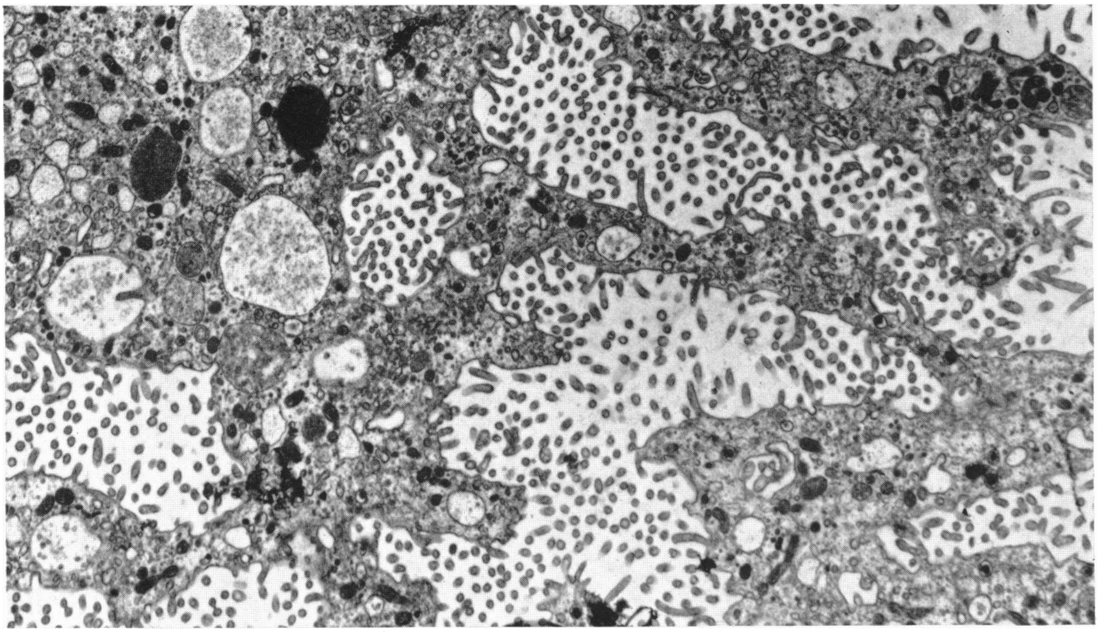


Fig. 4. Electron micrograph of a tangential section through the surface of the syncytium of a chorionic villus associated with a 65 mm human foetus (Cambridge, H. 1074). Note the tendency to parallel orientation of the scallops of grooves. ×9000.

Fig. 5. Electron micrograph at a greater power of magnification of the transitional region between smooth and microvillous syncytial surface illustrated in Fig. 1C. Note the microfilaments in the syncytioplasm deep to the plasma membrane. ×36000.

single villus they can vary up to 5 μm in height. The average height in different well-established brush borders, however, is about 2·5 μm, but in full term placentae obtained at Caesarean section it is rare to find the microvilli of a greater height than 2 μm. The average transverse diameter of the microvilli is much less variable than their height. Microvilli which are attached to depressions on the surface of the syncytium are cylindrical in shape, except at their tips where they taper. Characteristically when the microvilli are not attached to projections or ridges of the syncytial

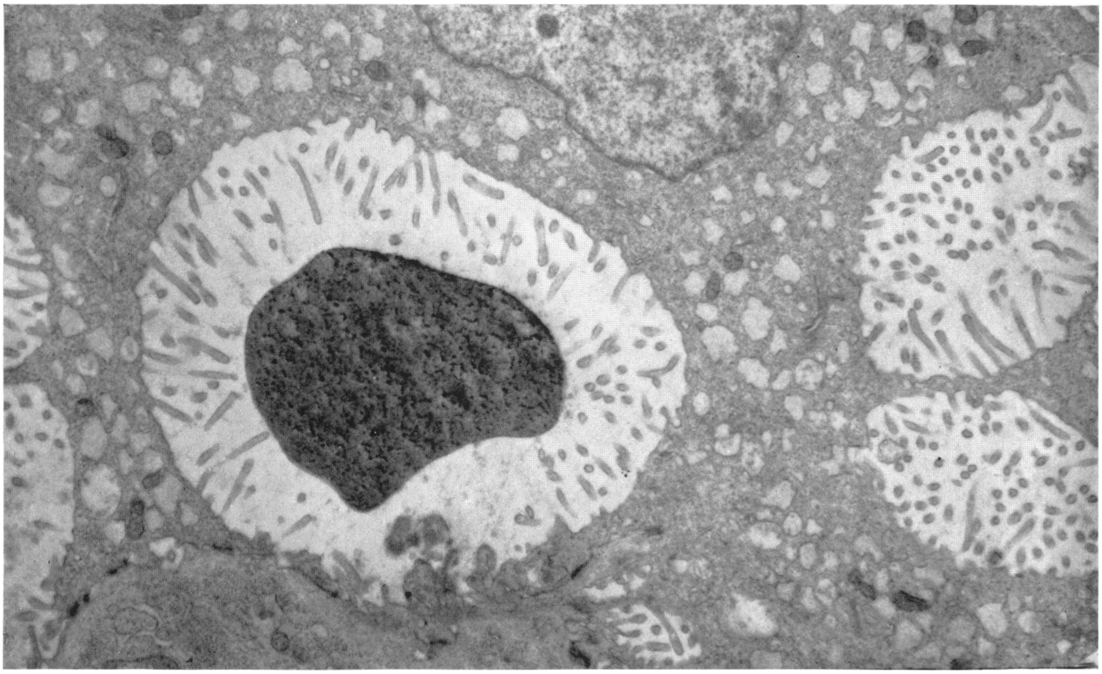


Fig. 6. Electron micrograph of a section through the chorionic syncytial surface of a placenta associated with a 73 mm C.R. length human foetus (Cambridge, H. 1040). The section, tangential to the syncytial surface, passes through the depths of several scallops. All of these possess surface microvilli and in the largest of them is a sectioned maternal blood cell. × 9000.

surface they average 65–75 mμ in diameter. Not all of the microvilli are cylindrical; some of them, the so-called claviform or clavate microvilli, may terminate in bulbous or club-shaped dilatations. Other microvilli vary in transverse diameter along their length, showing successive enlargements and constrictions, thus giving a nodose effect; yet other microvilli may be ramified.

The plasma membranes of the microvilli are continuous at their bases with that on the surface of the syncytium. Even at high powers of magnification, apart from finely stippled densities arranged in a linear manner parallel to the surface, little specific fine structure can be identified in the microvilli. They seem to be composed of an amorphous cytoplasmic substance in which vesicles, containing an electron-dense material, may be present. Larger vesicles are seen only in ramifying microvilli. Occasionally, however, longitudinal and transverse sections of the microvilli do suggest the possession by them of an internal structure (Figs. 7, 8). The microfilaments of the peripheral syncytioplasm do not extend into the microvilli. Caveolae and other obvious morphological indications of surface transport are only present between the bases of adjacent microvilli (Figs. 7, 8).

As has been described above, the free margin of the syncytial trophoblast is often characterized by the presence of cytoplasmic 'digitations' which, in part at least, are

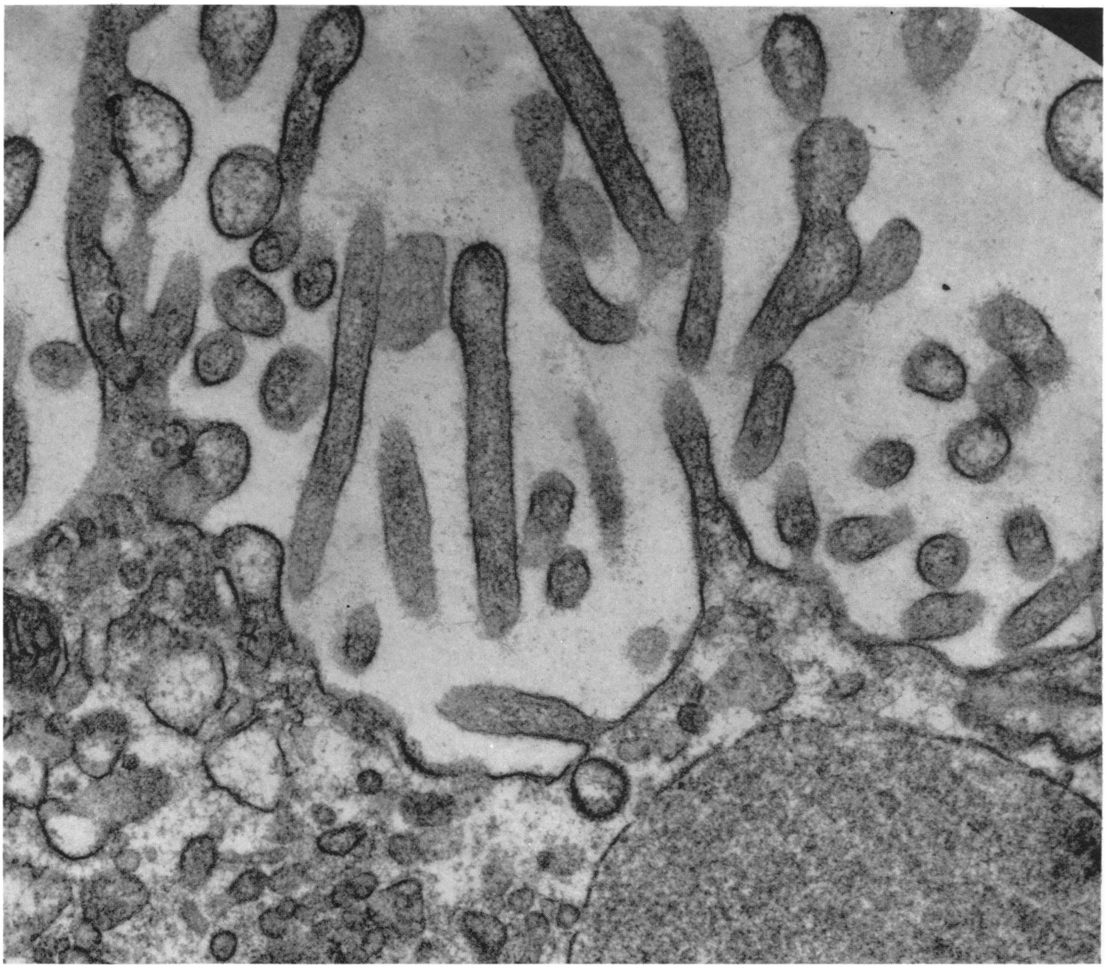


Fig. 7. Electron micrograph of the syncytium of a chorionic villus of a placenta associated with a 65 mm C.R. length human foetus (Cambridge, H. 1074) to show the texture of the microvilli. In this section microfilaments are not apparent in the syncytioplasm. × 72000.

transverse sections of syncytial ridges. Such ridges are variable in height, the average projections being about 6 μm. Their diameters vary from 3 to 4 μm at a maximum, down to a more usual measurement of about 1 μm. In regions where they are high the ridges are separated from each other with a regularity which is almost periodic, the median distance between their centres of successive elevations being 5–7·5 μm.

DISCUSSION

Our electron micrographs of chorionic villi, and those of a number of other investigators (Sermann & Rigano, 1962; and see Boyd & Hamilton, 1967), illustrate very clearly the variability shown by the microvilli which are the structural basis for the syncytial brush border. The arrangement, the structure and connexions of the microvilli in this situation are obviously different from those found in other epithelia possessing brush borders—for example, those of the intestine and the renal tubules.

Fig. 8. Electron micrograph of a longitudinal section through syncytial microvilli of a placenta associated with a 65 mm C.R. length human foetus (Cambridge, H. 1074). The appearance suggests the presence of a glycocalyx on the surface of the microvilli. Note indications of structure in the microvilli. × 120000.

Nevertheless, in histological sections from early stages of gestation, the placental microvilli when aggregated together can present the appearance of an impressive brush border. Whether, in a given region, such a brush border varies at undetermined intervals of time during the life of the villus possessing it cannot at present be established. Moreover, if such temporal changes in the syncytial surface morphology do occur, the possibility of a possession by them of a functional significance also remains as another unanswered question.

It is tempting, of course, to suggest that the presence of the microvilli is to be associated with local functional activity of the syncytium, and that perhaps this activity waxes and wanes in a periodic fashion at different places on the syncytial surface. The suggestion is, of course, that the activity is reflected in, and indeed conditioned by, the associated development, temporary or otherwise, of the microvilli. It must, however, again be emphasized that there is no actual evidence, one way or the other, indicating that the different regions of the syncytial surface can show intermittent development and retrogression of the microvilli, or indeed localized variation in functional activity. The situation may, for example, be that, during their recruitment into the syncytium, some of the cytotrophoblastic cells may possess and retain the power to produce microvilli and that this potential is later manifested locally in the regions of their incorporation, whereas other cytotrophoblastic cells lacking this potential are recruited to syncytium which subsequently cannot form microvilli. Or, again, it is possible that the surface of the syncytium is responsive to endocrine stimulation and that, thus, maternal oestrogens or progesterone might be responsible for the presence or absence of the microvilli. The scattered development of a brush border on the chorionic villi at any given stage of pregnancy, however, is hardly indicative of the presence of the microvilli being highly influenced by maternal endocrinal environment.

It should be noted here that microvilli are not only found on the maternal surface of the syncytium but also in the extracellular space at the syncytio-Langhans cell junction, and also between the syncytium and the villous basement membranes. Variations in these syncytial microvilli during pregnancy have not yet received any attempt at analysis.

The suggestion made by Boyd & Hughes (1954) that chorionic microvilli were specifically associated with underlying syncytial regions containing large numbers of vacuoles and particularly involved in fluid transfer does not fit in with subsequent findings. Indeed, the appearances presented in electron micrographs are often such as to be directly opposed to the suggested association. The vacuoles and vesicles observed by us in ramifying microvilli were also found by Yoshida (1964); he considers them to be concerned with the secretion, possibly, of gonadotrophins into the intervillous space.

Finally, it must be stressed that the pattern of arrangement of the chorionic microvilli is much less systematic and possesses, it would seem, morphologically less stability than is found in the epithelia of such regions as the intestine or the renal tubules. Tempting as it is to group the brush borders of different epithelia together, it seems to us that a caveat is necessary in relation to that of the placental syncytium. Nevertheless, the microvilli of the placental brush border obviously enormously increase the syncytial surface in contact with maternal blood in the intervillous space. Further, the possession by many of the microvilli of a 'fuzzy' surface layer, seen in electron micrographs at high powers of magnification with good resolution (Figs. 7, 8), probably indicates the presence outside the plasma membrane of a specialized carbohydrate cell coat, the 'glycocalyx' of Bennett (1963). Detailed accounts of this coat and a survey of the relevant literature are given by Rambourg, Neutra & Leblond (1966) and Rambourg & Leblond (1967). Extremely fine filaments, which can only be seen at greater powers of magnification, often join adjacent microvilli. The presence of a reddish halo on the surface of the syncytial brush border after treatment with diastase and PAS staining possibly indicates that the radially arranged fine filaments are constituted by a mucopolysaccharide complex.

SUMMARY

Observations are recorded on the arrangement and structure of brush border microvilli found on the syncytium of human chorionic villi at different times during pregnancy.

Particular attention is drawn to variations in the distribution of the microvilli. Data on their size, shape and attachment are also presented and discussed. Attention is drawn to the apparent presence of a glycocalyx on these microvilli.

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