

ELECTRON MICROSCOPIC STUDY OF LEPROMATOUS CHANGES IN THE IRIS¹

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Ultrastructural details of *M. leprae*, and skin and peripheral nerve lesions of lepromatous and tuberculoid types of leprosy, have been studied since the introduction of electron microscopic technics in the pathologic study of leprosy (7, 8, 11, 16, 17, 18, 30).

In the field of ophthalmology, anatomic details of various normal tissues of the eye have been studied by electron microscopy, and many problems that could not be understood clearly by light microscopic studies are now being elucidated (9, 19, 24, 25, 27, 28, 29). However, few reports at the ultra-structural level are available on pathologic changes in the eye except in trachoma and sympathetic ophthalmia (5, 6, 7, 14, 15), and no reports are available yet on ophthalmologic changes in leprosy at the electron optic level.

In the present article, we shall describe the electron microscopic details of lepromatous changes of the iris. In the study here reported we shall elucidate the details of lepromatous changes in smooth muscle cells that could not be seen clearly with a light microscope. In addition the problem of the origin of lepra cells in the iris stroma on which there have been many different opinions, will be discussed on the basis of electron microscopic features.

MATERIALS AND METHODS

Five specimens of iris obtained from 5 lepromatous patients in the Aisei-en Leprosarium were used in this study. These specimens were secured by optical iridectomy or by iridectomy before extirpation of the lens. The iris in each case was fixed immediately in 1% osmium tetroxide (pH 7.2-7.4) in phosphate buffer, and left in a refrigerator for 3 hours. After the fixation, the specimens were dehydrated in ethyl alcohol (70%, 90% and 100%) and embedded in a 7:3 mixture of n-butyl- and methyl-methacrylate.

Ultrathin sections were made with the JCM-3 ultramicrotome (Japan Electron Optics Laboratory Co. Ltd.) with glass knives. The electron microscope used in this study was the Akashi Tronscope 50 of the Leprosy Research Laboratory, Kyoto University. Pictures were taken at direct magnifications of 1,000 to 15,000.

ELECTRON MICROSCOPIC OBSERVATION

For the orientation of leprosy lesions in the whole structure of the iris, wide field composite pictures of the iris are more useful than numbers of single separate pictures. For this reason we have made composite pictures of serial fields (from several to 30 serial pictures) in order to cover the whole area of the iris. Figures 1 and 2 represent such composite pictures.

Histopathologic studies of the lepromatous iris by light microscope examination have been reported by many authors (3, 4, 12, 13, 21, 22, 23).

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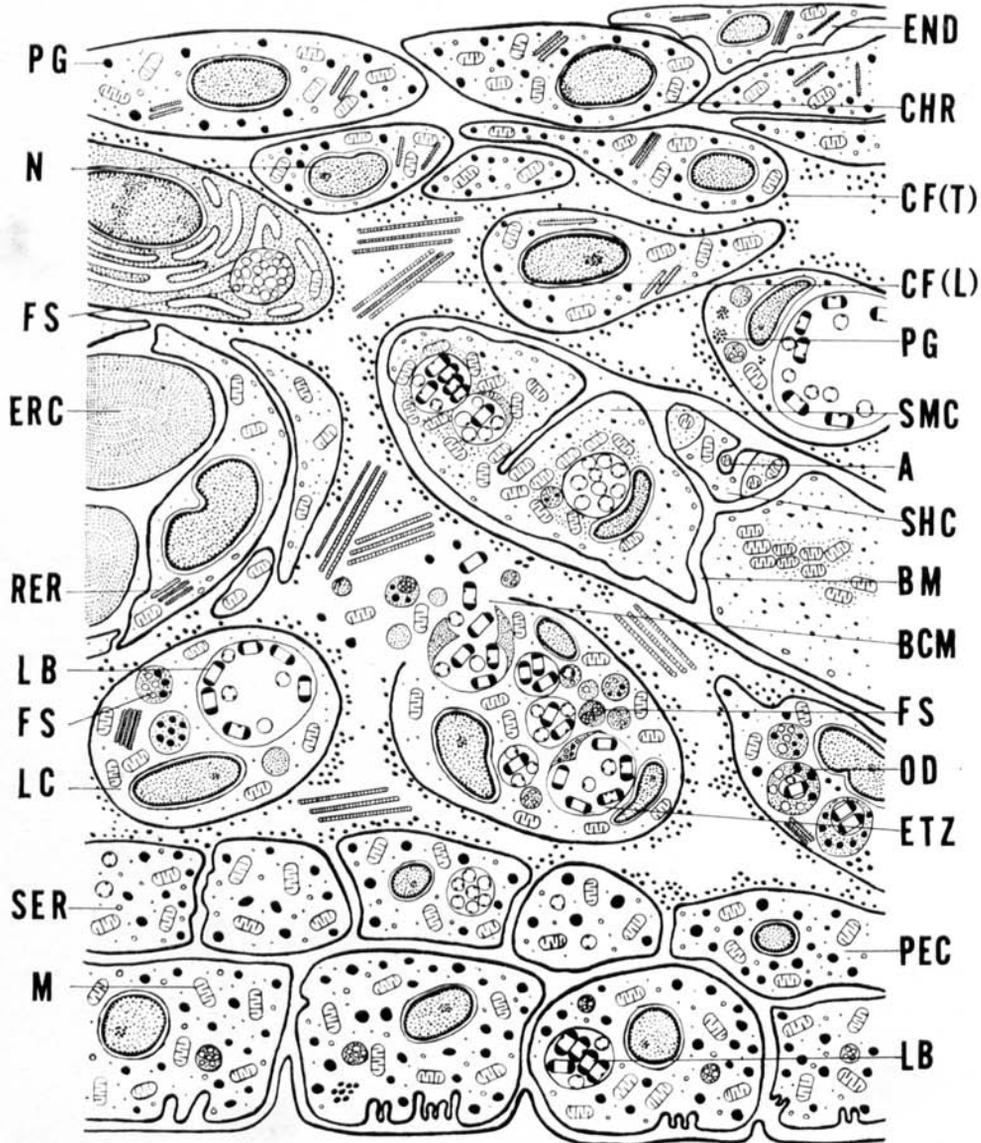


FIG. 1. Electron microscopic character of the lepromatous iris. The figure shows an entire cross section of the iris, in which the upper part is endothelium (END) and the lower part pigment epithelial cells (PEC). Lepromatous changes are more frequent in the posterior half of the iris. Leprosy bacilli (LB) are found as single bacilli or groups of bacilli in pigment epithelial cells, and various structures, such as small vacuoles, smooth-surfaced endoplasmic reticulum (SER) and mitochondria (M) are recognized in the cytoplasm. Chromatophores (CHR) with oval nuclei are shown grouped together immediately beneath the endothelium, in the anterior border layer.

Lepra cells (LC) similar to those found in lepromatous skin lesions are seen here and there in the iris stroma. In their cytoplasm, not only the normal cytoplasmic components are seen, such as rough-surfaced endoplasmic reticulum (RER), mitochondria, and pigment granules (PG), but also pathologic components such as leprosy bacilli, foamy structures (FS) and opaque droplets (OD). The figure shows that the cell membrane of lepra cells is broken (BCM) and the cytoplasmic components named above are extruded from the cell.

A slender group of cells shown at the right of the center of the figure is composed of smooth muscle cells (SMC). The transverse section of a normal nonmyelinated nerve demarcated by a basement membrane (BM) is adjacent to the cell. Leprosy bacilli form

Chief findings in the lepromatous iris are (a) infiltration of lepra cells in iris stroma, (b) changes in the nonmyelinated nerves of the iris, i.e., enlargement or shrinkage of the axons, and the presence of *M. leprae* in axons, (c) the presence of *M. leprae* in endothelial cells of the capillaries of the iris, (d) the presence of *M. leprae* in smooth muscles of the sphincter pupillae and the dilatator pupillae, and also in the interstitium between muscle fibers, and (e) the presence of *M. leprae* in pigment epithelium of the iris.

In the specimens used in this study, we were able to study the details of (1) lepra cells in iris stroma, (2) lepromatous changes in smooth muscles in the iris, and (3) lepromatous changes in the pigment epithelium (Figs. 1, 2.) We were not able to find distinct lepromatous changes in the blood vessels and nerves in the iris stroma of these specimens.

General appearance of lepromatous changes in the iris.—Lepromatous changes are usually more abundant in the posterior part of the iris stroma than in the anterior part (^{4, 13, 21}). A characteristic feature of lepra cells in the iris, which differs from their appearance in skin and peripheral nerve trunks, is the presence in most of them of pigment granules in varying numbers in their cytoplasm.

The iris is a tissue rich in pigments. Clump cells, chromatophores of iris stroma, and pigment epithelial cells contain numerous pigment granules in the physiologic state. Smooth muscle cells of the dilatator pupillae and macrophages also contain a few pigment granules (¹⁰).

In iris stroma lepra cells are usually not packed together tightly, as in lepromas of the skin. In most cases they are separated from each other and located in the posterior layer of the iris. In advanced cases, however, in which "iris pearls" or "miliary lepromata" are found clinically, many lepra cells are found tightly packed together in the anterior layer of the iris (²¹). At times the cell membranes of lepra cells are broken, and leprosy bacilli, opaque droplets, foamy structures, pigment granules and mitochondria are extruded from the cells into the extracellular environment.

Collagen fibers are usually normal in appearance in the extracellular media, but sometimes slight edema is found.

In advanced lesions of the stroma of the lepromatous iris, plasma cells and many vacuolated cells, which represent the final stage of degenerative change in lepra cells, are found. Also, many cytoplasmic organelles derived from broken lepra cells are scattered in the extracellular media (Fig. 3).

groups in smooth muscle cells, especially in juxtannuclear parts, containing many mitochondria; an electron-transparent zone (**ETZ**) is observed around the area.

Leprosy bacilli are not found in the upper endothelium of the iris and also not in the vascular endothelial cells around the erythrocyte (**ECR**) on the left side of the picture. Vacuoles are found in cells resembling plasma cell rich in rough-surfaced endoplasmic reticulum. Various correlations between leprosy bacilli, pigment granules, foamy structures and opaque droplets in lepra cells may be noted. In the extracellular part of the iris stroma, transverse (**CF(T)**) and longitudinal (**CF(L)**) sections of collagen fibrils are found; they show no pathologic changes.

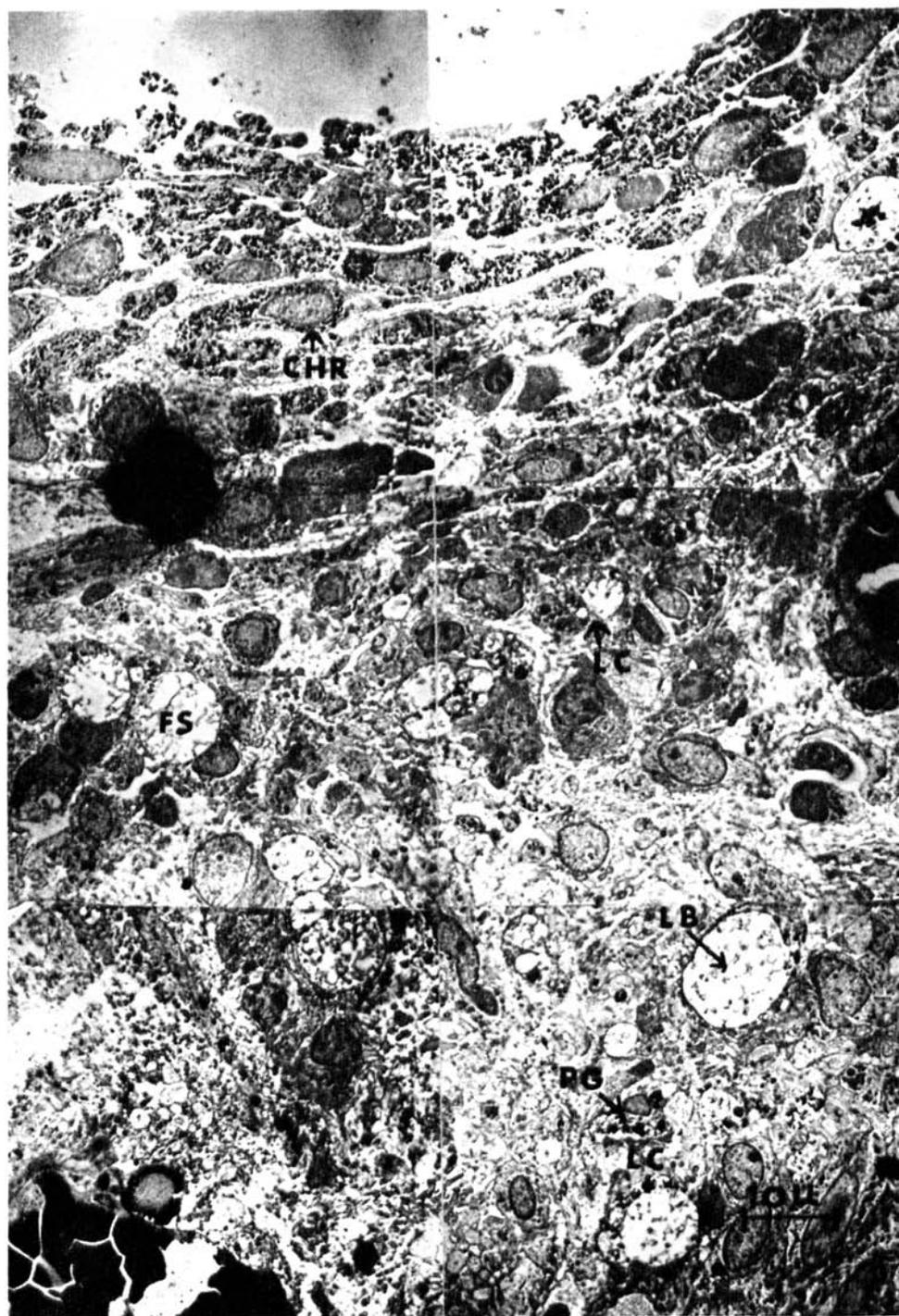


FIG. 2. Electron micrograph of an ultrathin section of a lepromatous iris. The illustration is a composite one made up of low-magnification electron micrographs showing all lepromatous changes. The upper part is the layer of endothelium of the iris and the lower is the posterior part of the iris. Lepra cells containing pigment granules of varying size and irregular distribution, foamy structure, and leprosy bacilli, are found in several places. Magnification 1,300 \times .

Symbols: FS, foamy structure; LB, leprosy bacillus; PG, pigment granule; LC, lepra cell; CHR, chromatophore.

Lepra cells in the iris.—Lepra cells in the iris resemble those of lepromatous skin and peripheral nerves. The chief differences are that lepra cells in the iris frequently contain pigment granules, and have at times slender protrusions.

Lepra cells in iris stroma have an oval nucleus. When leprosy bacilli multiply in their cytoplasm and later degenerate, leaving large electron-transparent vacuolar structures behind, the nucleus of the lepra cell is pressed aside by the contents of these vacuoles. In the cytoplasm of lepra cells various cytoplasmic organelles are seen, such as mitochondria and smooth-surfaced and rough-surfaced endoplasmic reticulum with Palade's granules. Mitochondria are not frequent, just as in ordinary lepra cells of the skin. Usually in the cytoplasm of lepra cells, various-sized vacuoles, opaque droplets, pigment granules, and leprosy bacilli are seen (Fig. 4). Some of the vacuoles are separated from each other, but others have coalesced. Especially in old and degenerated lepra cells, most of the cytoplasm is occupied with large vacuoles. Opaque droplets are of varying size, electron density and quantity in different lepra cells, but in most cases they are surrounded by a limiting membrane. Usually vacuoles of varying size and pigment granules are embedded in opaque droplets, but there are also opaque droplets that have an electron density uniform with that of electron-dense small granules (0.2-0.6 $m\mu$ in diameter). Sometimes 1-3 leprosy bacilli are found in an opaque droplet (Fig. 5). There is a tendency for small opaque droplets to be round and for large ones to be of irregular shape. These opaque droplets closely resemble those of the skin and peripheral nerves, which have been described by Nishiura *et al.* (17, 18).

On the other hand, opaque droplets, which are related to the pigment granules in lepra cells of the lepromatous iris stroma, resemble normal and abnormal pigment formations seen by electron microscopy in epithelioid cells of the uvea in sympathetic ophthalmia, which were described by Ikui *et al.* (5, 6). On the basis of electron microscopic findings he concluded that epithelioid cells in the uvea in sympathetic ophthalmia might originate from chromatophores.

The similarity thus noted might suggest that the lepra cells seen in iris stroma in our studies also have been derived from chromatophores. However, normal clump cells and chromatophores have many uniform-sized pigment granules, and they too are uniformly distributed throughout the cytoplasm. In contrast, the quantity of pigment granules in lepra cells is usually small, and the size of the granules varies. They are distributed unevenly in the cytoplasm, and frequently from small numbers up to several dozens of pigment granules are grouped together in the cytoplasm. Sometimes they are found isolated in the cytoplasm of lepra cells, but in many cases they are embedded in opaque droplets together with leprosy bacilli. The pigment masses vary in size from powder-like fine granules of low electron density to electron-dense large granules with capsules. In old and degenerated lepra cells in which

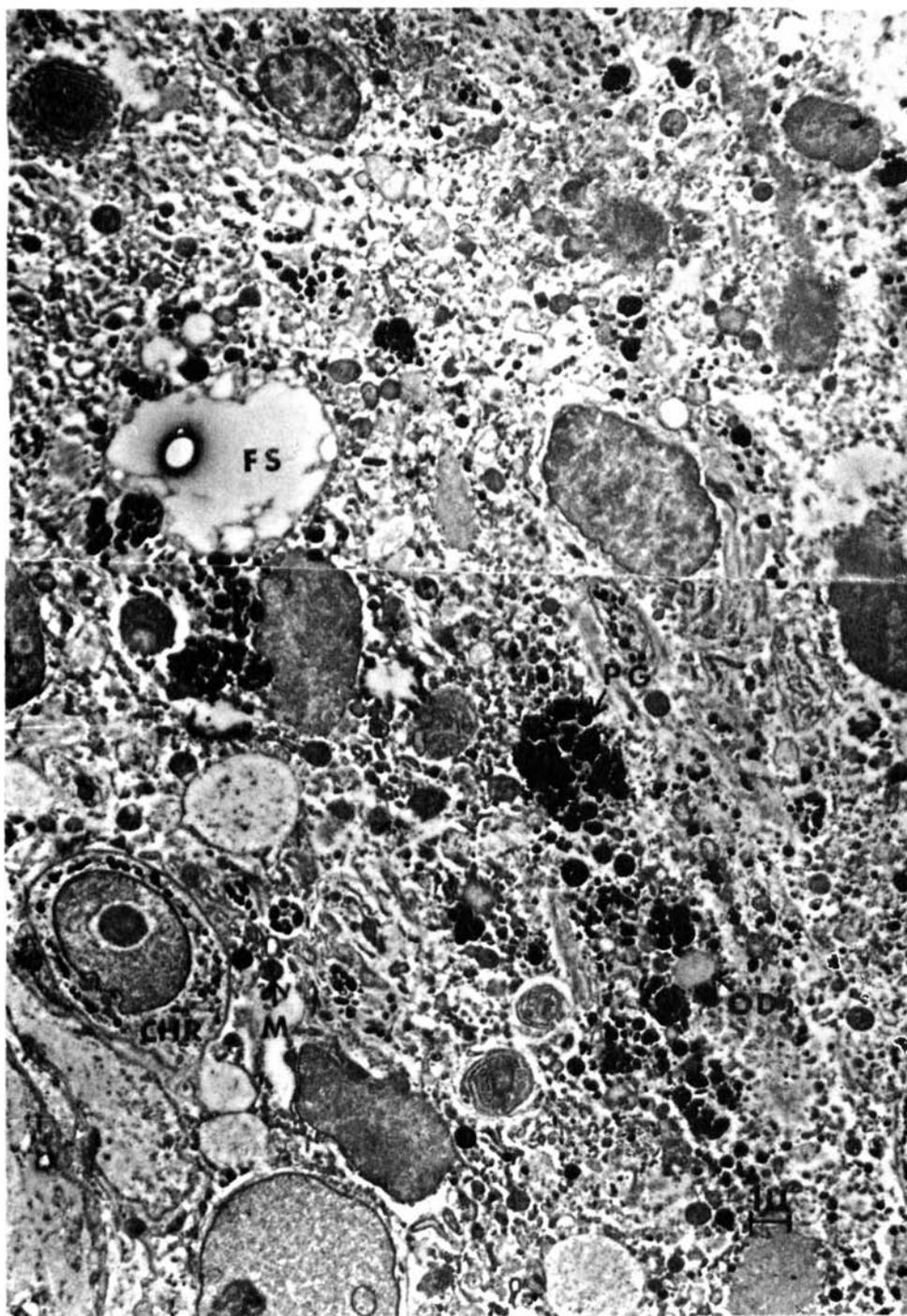


Fig. 3. Electron micrograph of an ultrathin section of an obsolete lepromatous iris. Large foamy structure, degenerated pigment granules, opaque droplets, and mitochondria are scattered extracellularly in the iris stroma. The cell, on the left, containing pigment granules of uniform character, is a normal chromatophore. Several lamellar structures are seen. Magnification 5,800 \times .

Symbols: **FS**, foamy structure; **PG**, pigment granule; **OD**, opaque droplet; **M**, mitochondria; **CHR**, chromatophore.

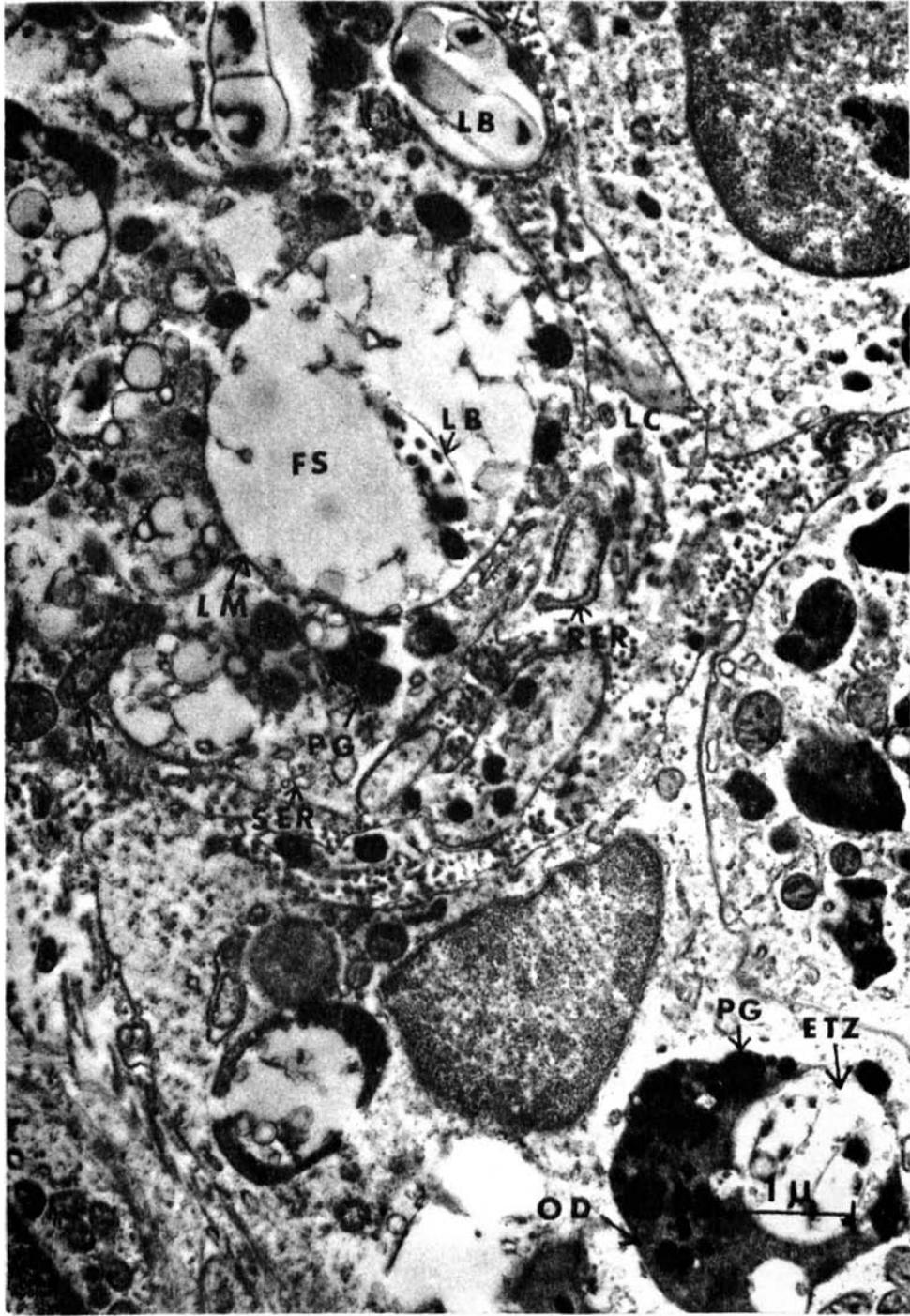


FIG. 4. Electron micrograph of an ultrathin section of typical lepra cells in the iris stroma. Leprosy bacilli showing various stages of degeneration in the cytoplasm are found as single isolated bacilli and groups of bacilli. An electron-transparent zone and opaque droplets are observed around them. Mitochondria are not numerous and rough-surfaced and smooth-surfaced endoplasmic reticulum is seen. Magnification 19,500 \times .

Symbols: LC, lepra cell; LB, leprosy bacillus; ETZ, electron-transparent zone; RER, rough-surfaced endoplasmic reticulum; SER, smooth-surfaced endoplasmic reticulum; OD, opaque droplet; M, mitochondria; LM, limiting membrane; FS, foamy structure; PG, pigment granule.

most of the cytoplasm is occupied by electron-transparent vacuolar structures, opaque droplets and pigment granules are few.

Characteristics of the smooth muscle of the iris.—There are two smooth muscles in the iris stroma, viz., the sphincter pupillae and the dilatator pupillae. Some smooth muscle is found also around arterioles. Numerous electron microscopic studies on the ultra structures of the sphincter pupillae and the dilatator pupillae of the normal human eye have been reported (19, 25, 27, 28, 29). According to these studies, the two muscles related to the movement of pupillae are constructed of smooth muscle cells containing myofibrils, myofilaments, mitochondria, endoplasmic reticulum, Golgi apparatus, and a small number of pigment granules. Mitochondria of the smooth muscles of the sphincter pupillae are located in a juxtannuclear part of the cytoplasm; they are of long-rod-shape, with distinct cristae inside them. In contrast, the mitochondria of the smooth muscle cells of the dilatator pupillae are distributed evenly throughout the cytoplasm, and they are of short-rod-shape, with the cristae not well developed. There are basement membranes outside the plasma membranes of smooth muscles. When smooth muscle cells are separated from each other a little more widely (0.2 μ), collagen fibrils and nerve fibers are found between the adjacent basement membranes (25, 29). As observed by light microscopic studies, many nerve fibers are distributed in a definite pattern, and smooth muscles of the iris are innervated by the vegetative nervous system. Electron microscopy also has shown that smooth muscles of the iris are richly innervated by vegetative nerves (25, 29).

Electron microscopic features of lepromatous changes in the smooth muscles of the iris.—A few descriptions based on light microscopy have been reported on lepromatous changes in the sphincter pupillae and the dilatator pupillae (4, 13, 21). According to these, leprosy bacilli are found in smooth muscle cells and also extracellularly between muscle cells.

In the biopsy specimens examined in the present study, smooth muscle cells were found in the sphincter pupillae and around arterioles, but lepromatous changes were seen only in smooth muscles of the sphincter pupillae.

In these specimens most of the sphincter pupillae cells are grouped together forming muscle cell bundles, but some of them are isolated by collagen fibers and nerve fibers from the main muscle cell bundles. Each muscle cell has a basement membrane around the plasma membrane, and in their cytoplasm there are mitochondria, endoplasmic reticulum, Golgi apparatus, small vacuoles, myofilaments, and pigment granules in small number. Numerous smooth muscle cells contain leprosy bacilli and foamy structures in their cytoplasm (Figs. 6 and 7). Most of the mitochondria are of long-rod-shape; they are located along the axis of the cell body and especially near the nucleus. In smooth muscles affected by lepromatous change, many mitochondria are found, accumulated around the foamy structures. In such cells

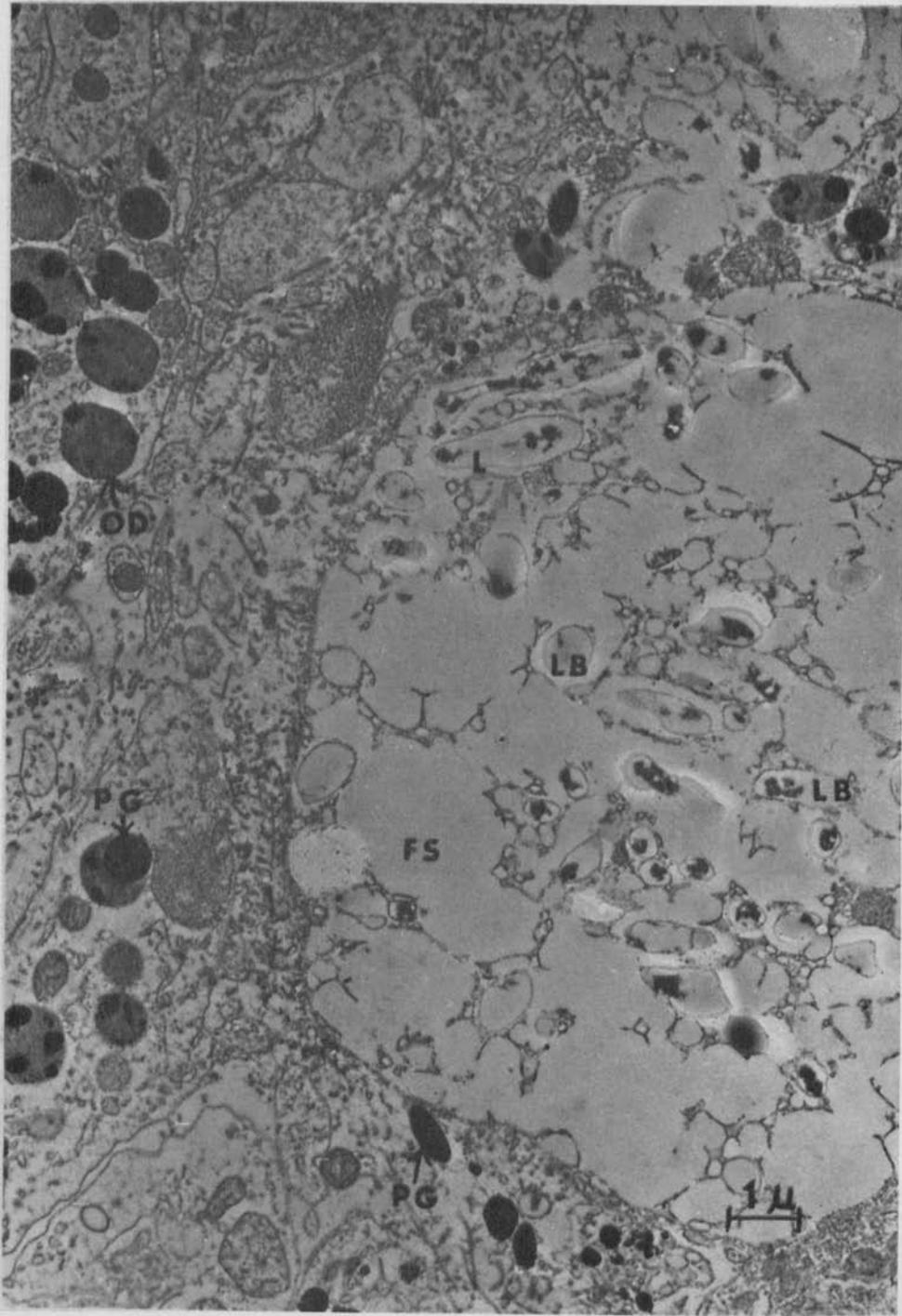


FIG. 5. Electron micrograph of an ultrathin section of a lepromatous iris. Large foamy structures containing many degenerated leprosy bacilli, opaque droplets and pigment granules of varying size, with high electron-density, are shown. Magnification 9,800X.

Symbols: **LB**, leprosy bacillus; **FS**, foamy structure; **PG**, pigment granule; **OD**, opaque droplet.



FIG. 6. Electron micrograph of an ultra-thin section of a lepromatous iris. A high magnification picture of a smooth muscle cell in the iris. The transverse and longitudinal sections of many leprosy bacilli and mitochondria are observed in the central area of the smooth muscle cell, surrounded by basement membranes. The electron-transparent zone is shown, but no opaque droplet is evident near leprosy bacilli. A slender cell process, seen on the right side of the smooth muscle cell, which contains pigment granules, is regarded as a part of a chromatophore. The pinocytotic vesicles are visible directly under the plasma membrane of the smooth muscle cell. Magnification 19,500 \times .

Symbols: **SMC**, smooth muscle cell; **LB**, leprosy bacillus; **M**, mitochondria; **PV**, pinocytotic vesicle; **PG**, pigment granule.

swelling and vacuolization of mitochondria are noted, and the cristae mitochondriales have become indistinct.

In the smooth muscles with lepromatous changes, pigment granules are absent or present in small numbers only. The picture is in striking contrast to that of lepra cells in the iris stroma, which almost always contain many pigment granules. Pigment granules in affected smooth muscle cells do not differ from those in intact smooth muscle cells.

As already noted, pigment granules in lepra cells of the iris stroma are of varying size and different electron density, and are distributed unevenly in their cytoplasm. Most of the pigment granules in lepra cells are embedded in opaque droplets. On the other hand, in smooth muscle cells, only 2 or 3 pigment granules of uniform size, with the same electron density, lie isolated in the cytoplasm. These findings suggest that leprosy bacilli have no essential relationship to pigment granules in smooth muscles.

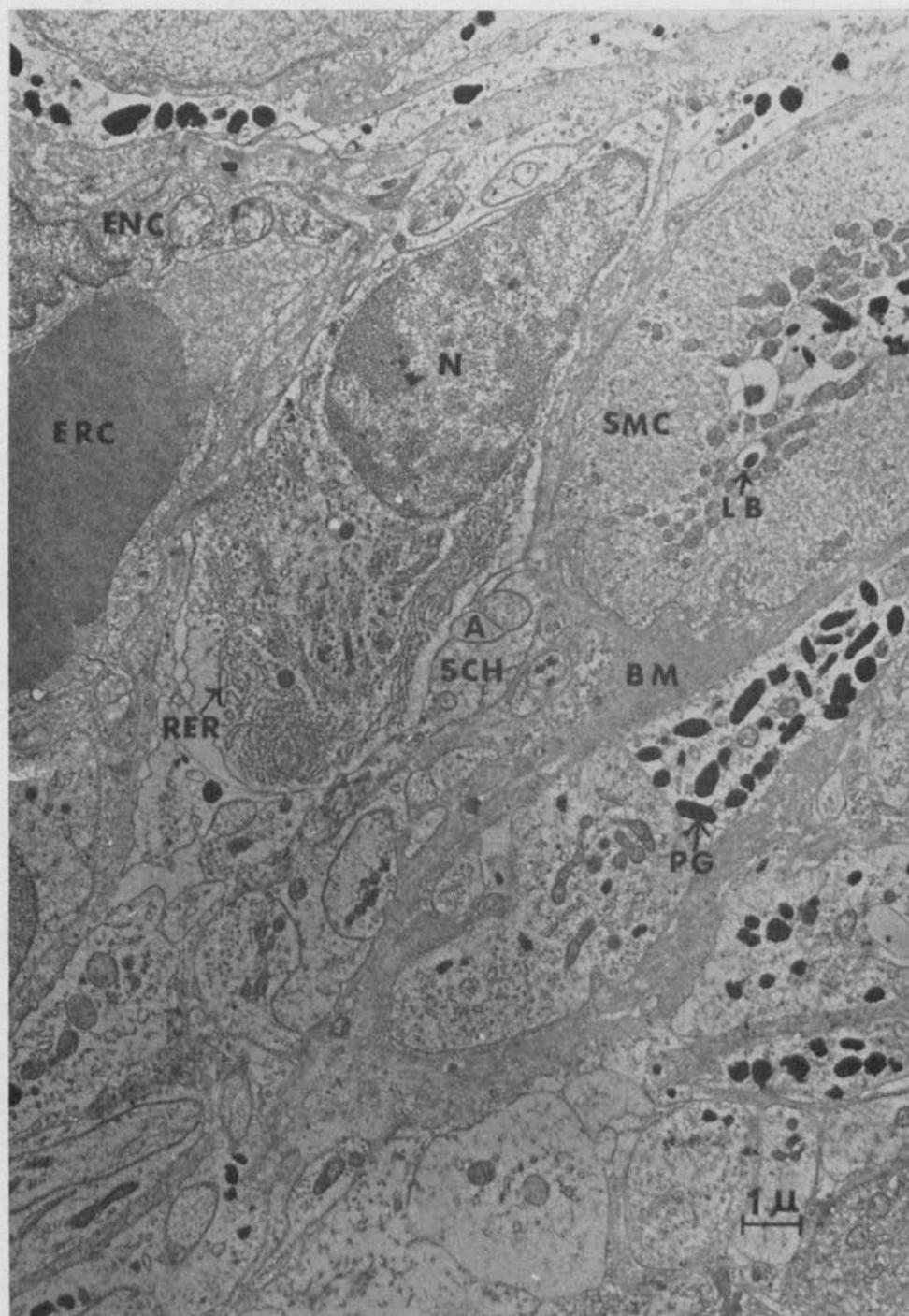
Leprosy bacilli are usually found in the central part of the sphincter pupillae cells. Some of them lie in solitary positions in the cytoplasm, while others are aggregated. The size of the bacilli and the degree of bacillary degeneration in smooth muscle cells resemble what is seen in the bacilli in lepra cells of the iris stroma. When several bacilli are aggregated, they tend to be arranged along the long axis of the smooth muscle cells. In obsolete lepromatous cases, foamy structures with fragments of degenerated bacilli are found near the nucleus of the smooth muscle cells. Frequently mitochondria are accumulated around groups of leprosy bacilli or electron-transparent foamy structures (Fig. 8). The texture of the juxtenuclear portion of the smooth muscle cell is looser than that of other portions of the cytoplasm where there are abundant myofibrils, and leprosy bacilli and mitochondria accumulate in this part because of its lesser resistance.

Opaque droplets, which are observed almost constantly in ordinary lepra cells, are not found in lepromatous lesions of smooth muscles of the iris. No particular changes are found in the nucleus, endoplasmic reticulum, pinocytotic vesicles, plasma membranes, and basement membranes of smooth muscles infected with leprosy bacilli.

Around the smooth muscle bundles and also between the individual smooth muscles, where there are thick layers of basement membranes, there are numerous nonmyelinated nerve fibers and nerve endings. Even at the neuromuscular junction, there was always a basement membrane, and no direct contact of the plasma membrane of smooth muscle cells and axon membrane or cell membrane of the nerve ending was found in these specimens. In the materials examined in the present study, no pathologic changes were found in nerve fibers adjacent to smooth muscle fibers with distinct lepromatous changes (Fig. 9).

Lepromatous changes of the pigment epithelium of the iris.—The posterior surface of the iris is covered with double layers of pigment epithelial cells. Posterior-layer pigment epithelial cells facing the posterior chamber have pigment granules, mitochondria, endoplasmic

reticulum, and Golgi apparatus in their cytoplasm. Infolding of the free cell membrane facing the posterior chamber is observed in many cells. Anterior pigment layers make direct contact with the posterior pigment epithelial cells by apposition of the cell membranes.



nuclear portions of the dilatator pupillae are located in this layer. Cytoplasmic organelles of anterior pigment layer cells are few as compared with those of the posterior pigment epithelial cells (²⁵).

Lepromatous changes affecting the pigment epithelium of the iris, as studied with the light microscope, have been reported by Mitsuda (¹³), Shionuma (^{21, 22, 23}), and Hibi (⁴). They stated that in light microscopic studies in general, even when leprosy bacilli have multiplied and degenerated in pigment epithelial cells, no distinct foamy structure formation is found there. Some of the globi formed in the posterior pigment epithelium of the iris are thrown out of the cells through the broken cell membranes and later attach themselves to the posterior surface of the iris or float in the posterior chamber.

Characteristic features of leprosy bacilli and degeneration of mitochondria in pigment epithelial cells were observed in detail by electron microscopy. Electron microscopy of the pigment epithelium of the lepromatous iris has also revealed the presence of foamy structures in small quantity in pigment epithelial cells, which could not be found by light microscopy (Fig. 10).

Leprosy bacilli are found in the cytoplasm as single organisms or in groups. Some groups of bacilli are also found near the nucleus. The appearance of leprosy bacilli in pigment epithelial cells is similar to that of leprosy bacilli in ordinary lepra cells. As the degeneration of leprosy bacilli advances, the breadth of the electron-transparent zones around degenerated bacilli becomes greater. In a few pigment epithelial cells examined in this study, we have found large foamy structures, with limiting membranes, which contained severely degenerated leprosy bacilli. Opaque droplets, which are usually found in ordinary lepra cells, were not found in pigment epithelial cells of the iris.

Pigment granules of the pigment epithelial cells of the iris are larger than those of the chromatophores, and are distributed evenly in large number in the cytoplasm. Even in the pigment epithelial cells with lepromatous changes, the number, size, morphology and distribution of the pigment granules do not differ from those of the pigment granules in normal pigment epithelial cells. This finding of the pigment granules is different from that of the pigment granules in lepra cells of the iris stroma. In the lepra cells of the iris stroma, the "compound body" of Dalton and Felix (²), and opaque structures resembling

FIG. 7. Electron micrograph of an ultrathin section of a lepromatous iris. The section shows a blood vessel, a cell rich in rough-surfaced endoplasmic reticulum, nonmyelinated nerves, and a smooth muscle cell. On the extreme right, two leprosy bacilli are observed among many mitochondria in the central area of a smooth muscle cell; a few pigment granules are included in the cell. Half of the longitudinal section of a single bacillus is shown slightly downward from the center of the right edge. A cell rich in rough-surfaced endoplasmic reticulum, and with a clear Golgi apparatus, is found between the endothelial cell of a blood vessel and a smooth muscle cell. Leprosy bacilli are not found in it. Pathologic changes are not found in nonmyelinated nerves. Magnification 8,300X.

Symbols: **ENC**, endothelial cell of blood vessel; **ERC**, erythrocyte; **A**, axon; **SCH**, Schwann cell; **SMC**, smooth muscle cell; **BM**, basement membrane; **LB**, leprosy bacillus; **PG**, pigment granule; **RER**, rough-surfaced endoplasmic reticulum; **N**, nucleus.

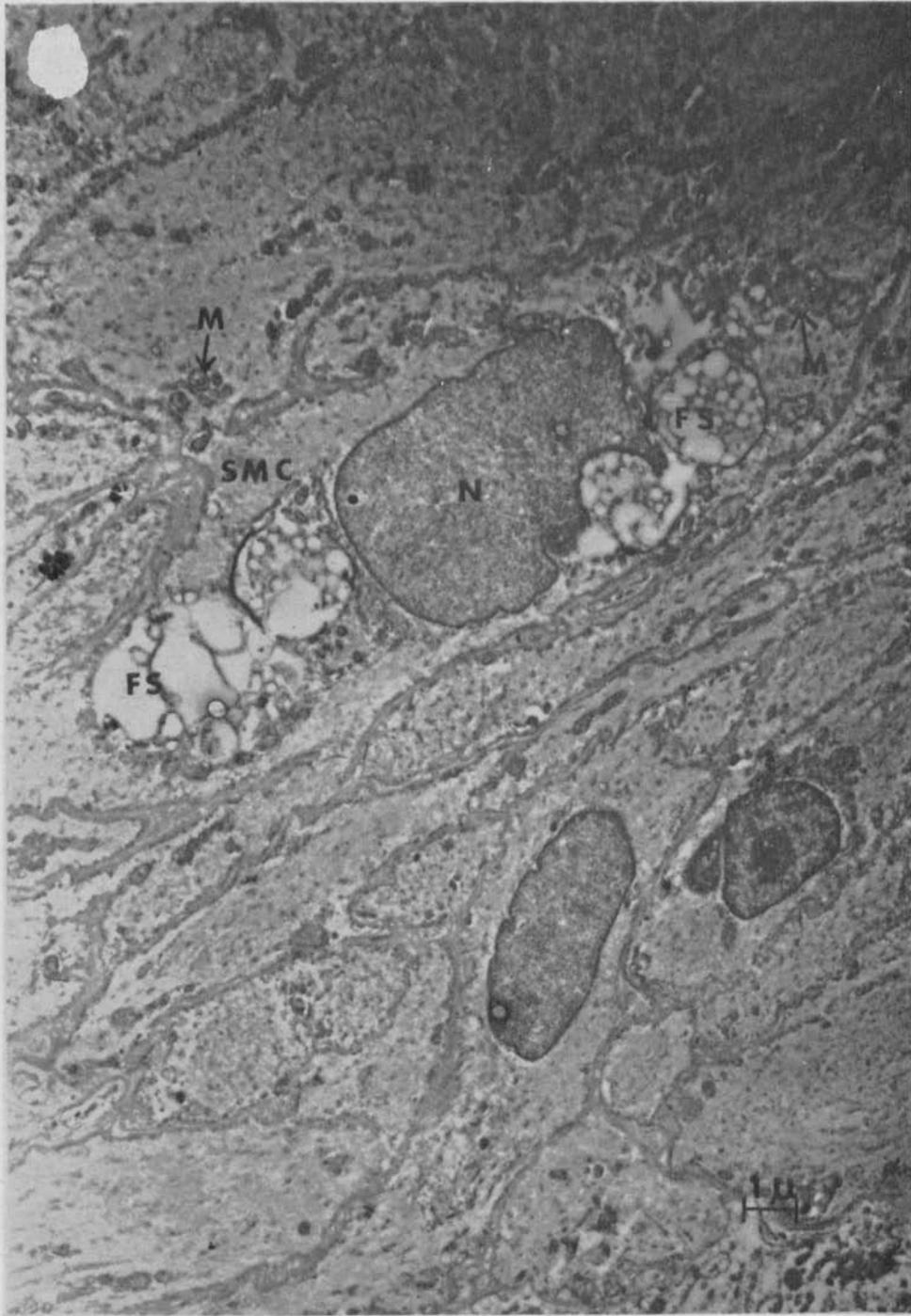


FIG. 8. Electron micrograph of an ultrathin section of a lepromatous iris. This shows the foamy structure of a smooth muscle cell in an obsolete lepromatous iris. Many foamy structures are observed in the neighborhood of a nucleus, and leprosy bacilli are not found. Magnification 7,300 \times .

Symbols: **SMC**, smooth muscle cell; **FS**, foamy structure; **M**, mitochondria; **N**, nucleus.

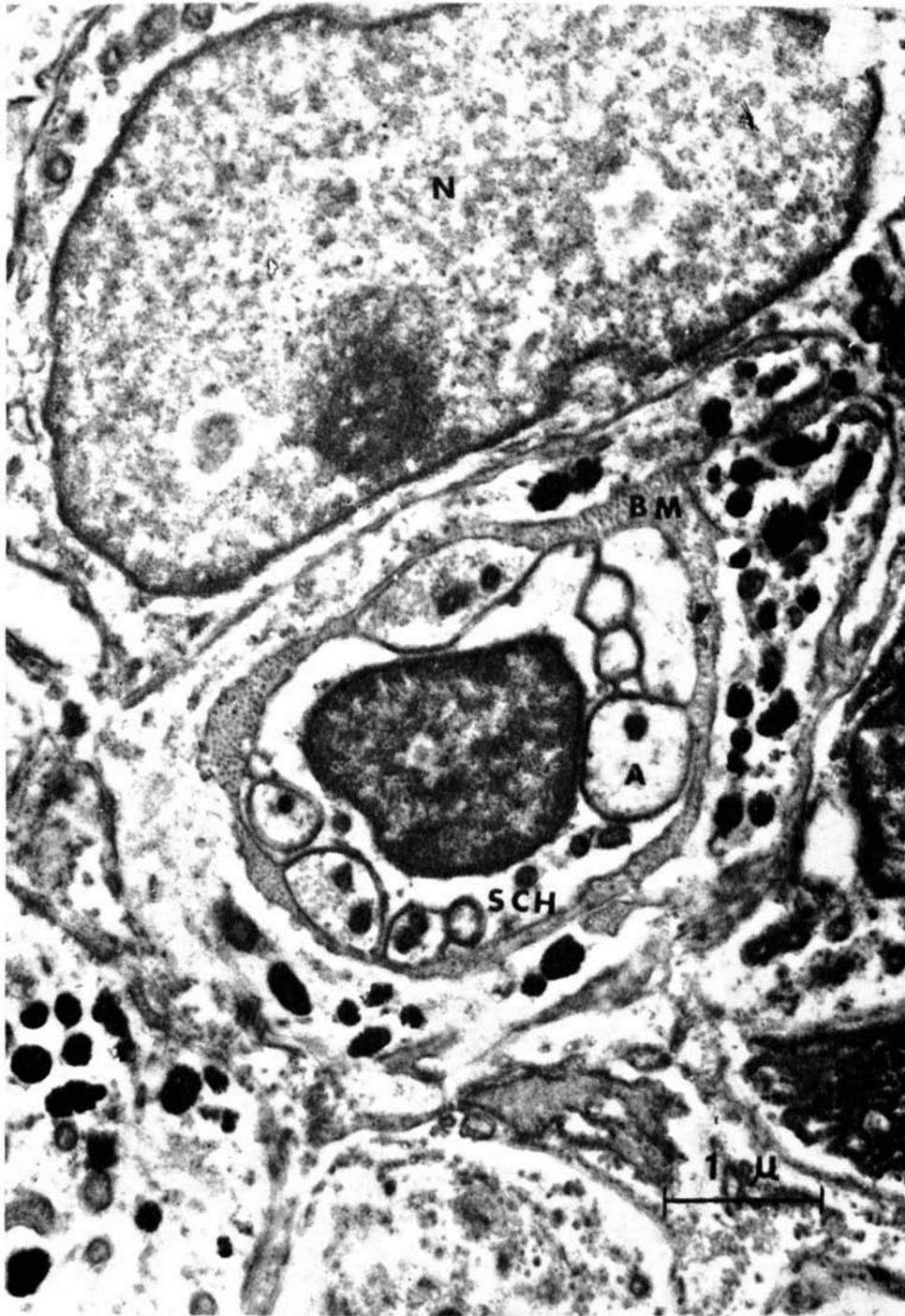


FIG. 9. Electron micrograph of an ultrathin section of a lepromatous iris. Transverse section of a nonmyelinated nerve in the iris. Leprosy bacilli and other pathologic changes are not found. Magnification 22,400 \times .
Symbols: SCH, Schwann cell; A, axon; N, nucleus; BM, basement membrane.

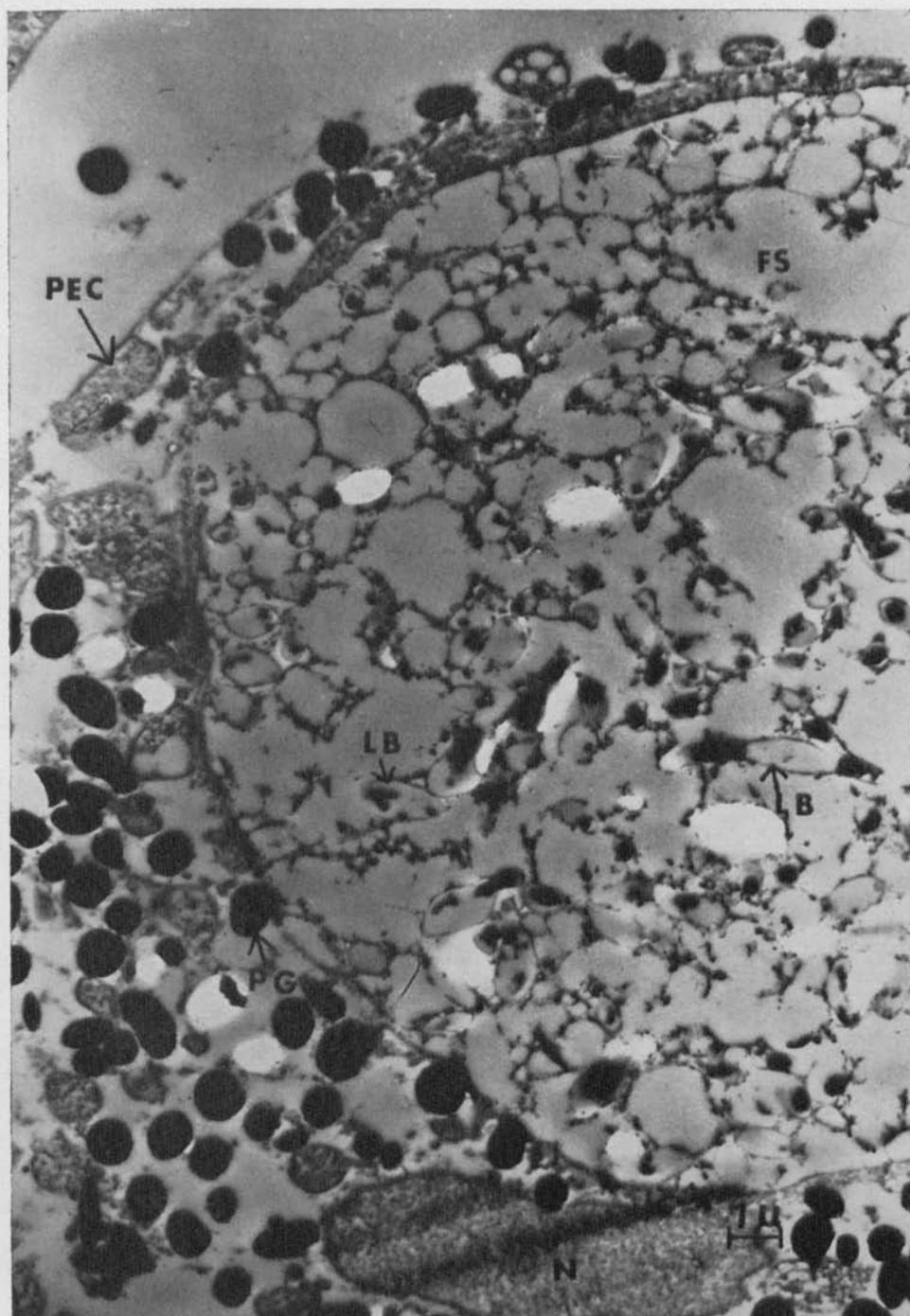


FIG. 10. Electron micrograph of an ultrathin section of a lepromatous iris. It shows a large vacuole and degenerated leprosy bacilli in a pigment epithelial cell of the iris. A nucleus is pressed laterally and has become flat. The size and distribution of pigment granules are almost normal. Magnification 7,100 \times .

Symbols: **LB**, leprosy bacillus; **FS**, foamy structure; **N**, nucleus; **PEC**, pigment epithelial cell; **PG**, pigment granule.

“melanin inclusion bodies” were found (Fig. 11), but in the pigment epithelial cells such bodies were not found.

The number of mitochondria is not so large, but often they become enlarged, with signs of degeneration, such as vacuolization and obscuring of the cristae mitochondriales.

DISCUSSION

There are several hypotheses on the origin of lepra cells in the iris. Phillipson and Babes stated that chromatophores in the iris stroma could change into lepra cells, and Gon (³) reported that both clump cells and chromatophores phagocytize leprosy bacilli and also that histiocytes change into lepra cells by phagocytizing leprosy bacilli and pigment granules. According to his description pigment granules of chromatophores infected with leprosy bacilli are more irregular and larger than those of normal cells, and also some of the cytoplasmic processes of infected chromatophores are being torn off. In contrast, Shionuma stated that chromatophores that cannot take up carmine or India ink when stained vitally will not take up leprosy bacilli, and for this reason he concluded that lepra cells in the iris are derived from clump cells that have phagocytized leprosy bacilli and from histiocytes that have taken up leprosy bacilli as well as pigment granules (^{22, 23}).

As noted above, electron microscopy of lepra cells in the iris has shown that most of these cells contain pigment granules in the cytoplasm. Morphologically there seem to be two types of lepra cells in the iris. One type consists of lepra cells containing pigment granules of varying size with differing electron density, together with precursors of the pigment. This type of cell has also slender processes projecting from its body. These findings suggest that this type of lepra cell was derived from chromatophores in which various stages of pigment formation can be seen. The other type of lepra cell has pigment granules of uniform size, which surround groups of leprosy bacilli in their cytoplasm. The appearance of cells of this type suggests an origin from macrophages. These electron microscopic findings might suggest that both chromatophores and macrophages can convert themselves into lepra cells in the iris, but final conclusions on this problem still need further investigation.

With reference to lepromatous change in smooth muscles, it is noteworthy that by electron microscopy Nishiura found leprosy bacilli in smooth muscles around blood vessels of the nasal mucosa, and that with light microscopy Hirako found leprosy bacilli in smooth muscle cells of the erectors pili and also between muscle cells. Ultrastructural detail of lepromatous changes in smooth muscle cells in the iris is similar to that of smooth muscles in the nasal mucosa.

According to our clinical experience, some lepromatous patients have pupils fixed in the state of miosis, with no light reaction of pupils. As about 70 per cent of patients with lepromatous disease have chronic iridocyclitis, the lesion is likely to be complicated by posterior synech-

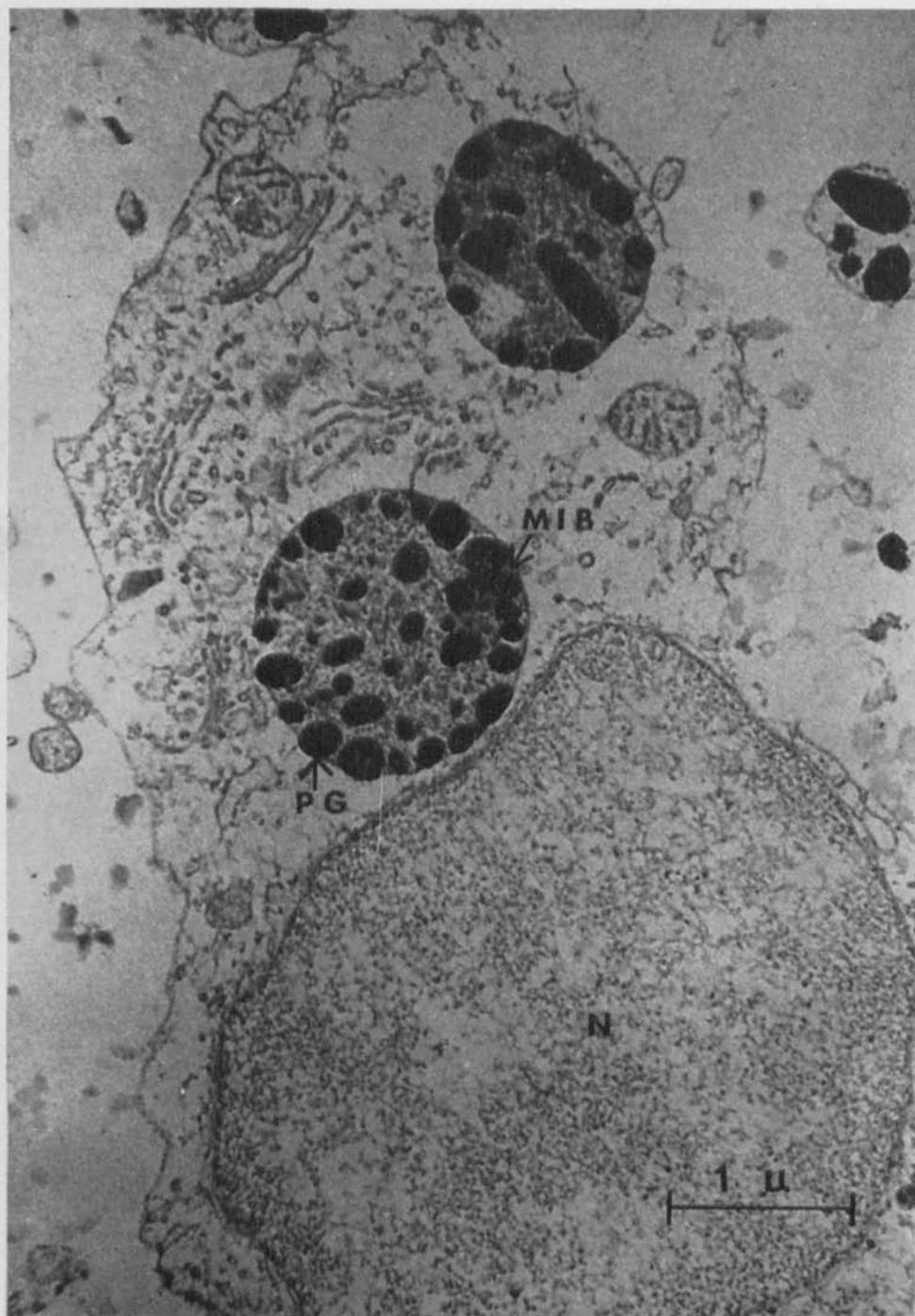


FIG. 11. Electron micrograph of an ultrathin section of a lepromatous iris. A "melanin inclusion body (Dalton and Felix)" is observed in a so-called macrophage in the iris stroma. Leprosy bacilli are not found. Groups of pigment granules with such clear limiting membranes are rare in the cells of lepromatous lesions. Magnification 26,200 \times . Symbols: **N**, nucleus; **PG**, pigment granule; **MIB**, melanin inclusion body.

iae, because the posterior half of the iris is more frequently affected by leprosy bacilli. Although synechiae are the most frequent cause of miosis in lepromatous patients, there are cases of miosis in which there are no synechiae, the shape of pupil is round, and mydriatic drugs do not change the state of miosis. In such cases of miosis paralysis of the dilatator pupillae is most probable.

In other lepromatous patients, however, the pupil is fixed in the state of mydriasis by paralysis of the sphincter pupillae.

The electron microscopic finding of lepromatous changes in smooth muscles, and the intact state of the nerves of the iris, suggest that direct damage of smooth muscle by leprosy bacilli might be one of the causes of smooth muscle paralysis in functional disturbance of the pupil in lepromatous patients.

Although some cases of tuberculoid leprosy show continuous mydriasis during the course of tuberculoid reaction, it is considered that such mydriasis is caused by nerve damage in the parasympathetic system during the phase of reaction, and not due to direct damage of smooth muscles in the iris by leprosy bacilli.

It is generally said, on the basis of light microscopic studies, that foamy structure is not found in the pigment epithelium of the iris. In our studies by electron microscopy, however, small quantities of foamy structures were found around leprosy bacilli in the cytoplasm of pigment epithelial cells of the iris. We have identified these cells as pigment epithelial cells on the basis of their location in the iris and the appearance of the pigment granules in them.

SUMMARY

Ultrastructural features of lepromatous change in the iris stroma, smooth muscles and pigment epithelial cells of the iris are described.

Lepra cells are more abundant in the posterior half of the iris stroma than the anterior half, and these lepra cells frequently contain pigment granules. This is in contrast with the condition of lepra cells in the skin and peripheral nerves, which have no pigment granules in the cytoplasm.

The origin of lepra cells in the iris stroma is discussed on the basis of electron microscopic features of these cells. Both chromatophores and macrophages seemed to change into lepra cells in the iris, but a decisive conclusion could not be reached even by electron microscopy.

Leprosy bacilli were found in smooth muscle cells of the iris. There were also electron-transparent zones and foamy structures in smooth muscle cells, and, in obsolete lepromatous cases, large vacuolar structures without bacilli in the cytoplasm of smooth muscle cells, believed to be the result of complete disintegration of bacillary bodies. Smooth muscles of the iris are richly innervated by nonmyelinated nerve fibers, but no nerve changes were found in specimens examined in the present study, in striking contrast to distinct damage of smooth muscle cells. Lepromatous change of smooth muscles in the iris is of exceptional

interest as a cause of disturbance of the light reaction of the pupil in lepromatous patients.

Leprosy bacilli were found also in pigment epithelial cells, either in groups within the cytoplasm, or lying free but separated from each other. Small quantities of foamy structures were found in pigment epithelial cells. This finding is contrary to the general opinion that foamy structures are never encountered in pigment epithelial cells.

RESUMEN

Se describen los aspectos de los cambios lepromatosos en el estroma del iris, como así en los músculos lisos y las células epiteliales pigmentadas.

Las células leprosas son más abundantes en la mitad posterior del estroma del iris que en la mitad anterior, y estas células leprosas contienen frecuentemente gránulos pigmentarios. Esto contrasta con las condiciones de las células leprosas en la piel y nervios periféricos, las cuales no contienen gránulos pigmentarios en el citoplasma.

Se discute el origen de las células leprosas en el estroma del iris en base de los aspectos microscópicos electrónicos de estas células. Tanto los cromatóforos como los macrófagos parecen convertirse en células leprosas en el iris, pero no se puede llegar a una conclusión decisiva aun por el microscopio electrónico.

Se encontraron bacilos leprosos en las células de los músculos lisos en el iris. También hubo en las células de los músculos lisos zonas electrónicas transparentes y estructuras espumosas, y en casos lepromatosos obsoletos, estructuras vacuolares grandes sin bacilos en el citoplasma de las células de los músculos lisos, lo que se cree es el resultado de la completa desintegración de los cuerpos bacilares. Los músculos lisos del iris están ricamente inervados por fibras nerviosas no mielinizadas, pero no se encontraron cambios nerviosos en los especímenes examinados en el presente estudio, en fuerte contraste con el daño distintivo de las células de los músculos lisos. En pacientes lepromatosos los cambios lepromatosos de los músculos lisos en el iris son de excepcional interés, como una causa de alteración de la reacción a la luz de la pupila.

Los bacilos leprosos también fueron encontrados en las células pigmentarias epiteliales. Estos hallazgos son contrarios a la opinión general de que las estructuras vacuoladas nunca se encuentran en las células epiteliales pigmentarias.

RÉSUMÉ

Sont ici décrites les caractéristiques de la fine structure des changements lépromateux dans le stroma iridien, les muscles lisses et les cellules épithéliales pigmentaires de l'iris. Les cellules lépreuses sont plus abondantes dans la moitié postérieure du stroma iridien que dans la moitié antérieure, et ces cellules lépreuses contiennent fréquemment des granules pigmentaires. Ceci est en contraste avec les caractéristiques des cellules lépreuses dans la peau et dans les nerfs périphériques, qui n'ont pas de granules pigmentaires dans le cytoplasme. L'origine des cellules lépreuses dans le stroma de l'iris est discutée sur la base des caractéristiques révélées au niveau de ces cellules par la microscopie électronique. Tant les chromatophores que les macrophages semblent se transformer en cellules lépreuses dans l'iris, mais aucune conclusion définitive ne peut être obtenue, même par la microscopie électronique.

Des bacilles de la lèpre furent trouvés dans les cellules des muscles lisses de l'iris. Il y avait aussi dans les cellules musculaires lisses des zones transparentes aux électrons et des structures spumeuses et de plus, dans les vieux cas lépromateux, des grandes structures vacuolisées, sans bacilles cette fois, dans le cytoplasme des cellules musculaires lisses, et que l'on croit être l'aboutissement de la désintégration complète des corps bacillaires. Les muscles lisses de l'iris sont richement innervés par des fibres nerveuses non myélinisées, mais aucune modification dans les nerfs n'a toutefois été notée dans les échantillons examinés au cours de cette étude, ce qui est en flagrant contraste avec les

lésions caractérisées des cellules musculaires lisses. Les changements de type lépromateux au niveau des muscles lisse de l'iris sont d'un intérêt exceptionnel en tant que constituant une cause de réaction anormale de la pupille à la lumière chez les malades lépromateux.

Des bacilles de la lèpre ont aussi été trouvés dans les cellules épithéliales pigmentaires, soit groupés à l'intérieur du cytoplasme, soit libres mais séparés les unes des autres. Des structures spumeuses en petit nombre ont été trouvées dans les cellules épithéliales pigmentaires. Cette observation est en opposition avec l'opinion généralement admise que des structures spumeuses ne sont jamais trouvées dans les cellules épithéliales pigmentaires.

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