Virchows Arch. Abt. A Path. Anat. 353, 110—127 (1971)

Electron Microscopy of the Trabecular Meshwork in Eyes with Exfoliation Syndrome (Pseudoexfoliation of the Lens Capsule)

AMUND RINGVOLD
University Eye Department, Rikshospitalet, Oslo, Norway

TORGEIR VEGGE
Anatomical Institute, University of Oslo, Oslo, Norway

Received February 15, 1971

Summary. The trabecular meshwork of three human eyes involved with the exfoliation syndrome were studied. The intraocular tension in the eyes represented successive stages. Exfoliation material was found in all three eyes: In Eye 1 (no glaucoma) only in intertrabecular spaces, in Eyes 2 and 3 also within trabecular beams and in the juxtacanalicular tissue. In addition, abnormal basement membranes were revealed. In Eye 3 (uncontrollable glaucoma), the disorganized trabecular meshwork contained increased amounts of connective tissue elements as well as small vessels. The concept is advanced that the accumulation of exfoliation material in the meshwork impedes aqueous outflow and thus is a pathogenetic factor of importance in glaucoma capsulare.

Introduction

Deposits of a light-grey substance, called exfoliation material, is sometimes found in the anterior segment of the eye by slit-lamp examination. This condition has been termed exfoliation syndrome (Sunde, 1956), and is frequently associated with increased intraocular tension. Vogt (1932) suggested that flakes of exfoliation material, which he believed to originate from the lens capsule, might accumulate in the anterior chamber angle and obstruct the aqueous passage, thus causing glaucoma.

Busacca (1928) published the first histological study of eyes with exfoliation syndrome. Since then several studies have appeared (for references see Sunde, 1956), and the exfoliation material has been demonstrated in multiple locations within the aqueous humour area. Electron microscopic studies have shown exfoliation material on and within the lens capsule, on the zonular fibres, on the posterior surface of the ciliary body, on both iris surfaces as well as within the iris itself (Blackstad *et al.*, 1960; Bertelsen *et al.*, 1964; Ashton *et al.*, 1965; Shakib *et al.*, 1965; Dark *et al.*, 1969; Ringvold, 1969, 1970a, b, c).

Although some researchers have shown by light microscopy what probably is exfoliation material in the trabecular meshwork (Theobald, 1954; Hørven, 1966), we know of no electron microscopic study dealing with this problem. Such a study is necessary, both in order to identify possible exfoliation material, and to elucidate its distribution in the trabecular meshwork.

Material and Methods

This study includes three eyes with exfoliation syndrome. The eyes were from three different patients, and were enucleated for different reasons:

Eye 1. 71 year old woman with a gradual loss of vision during the last 6 months due to a malignant melanoma in the macula region of the retina. She had used no drugs. By slit-lamp examination exfoliation material was seen on the anterior lens surface, and a slight depigmentation of the pupillary margin was observed. Otherwise, no abnormality was found. Intraocular tension was 10.2 mm Hg (Schiøtz) and the visual field, examined by Donders' method, was normal. Gonioscopy showed that the angle of the anterior chamber was open.

Eye 2. 71 year old woman with a 1 year history of increased intraocular tension kept normal by the use of pilocarpine drops three times daily. She underwent surgery for a malignant melanoma of the maxilla which had extended into the right lacrimal sac. She had received no medical or radiation treatment for her tumour. On slit-lamp examination exfoliation material was found on the anterior surface of the lens and on the pupillary margin of the iris. Vision was unimpaired, visual fields were normal, examined by campimetry. In spite of pilocarpine treatment, the intraocular tension was 20.6 mm Hg (Schiøtz). The anterior chamber angle was found open by gonioscopy, and the optic disc was normal.

Eye 3. 74 year old man treated with pilocarpine and adrenalin drops for the past three years because of capsular glaucoma. During the last few months the left eye developed a painful keratopathy, which could not be controlled by medication, and the eye was therefore enucleated. The eye showed a moderate ciliary injection, and a band-shaped, partly bullous keratopathy. The anterior chamber angle was open, and a moderate aqueous flare was observed. Exfoliation material appeared on the anterior lens surface and on the pupillary margin of the iris. Extensive cataractous changes in addition to the corneal affection prevented ophtalmoscopic examination. Intraocular tension was 30.4 mm Hg (Schiøtz). Vision was light perception at 4 m, and there was loss of light projection in the nasal part of the visual field.

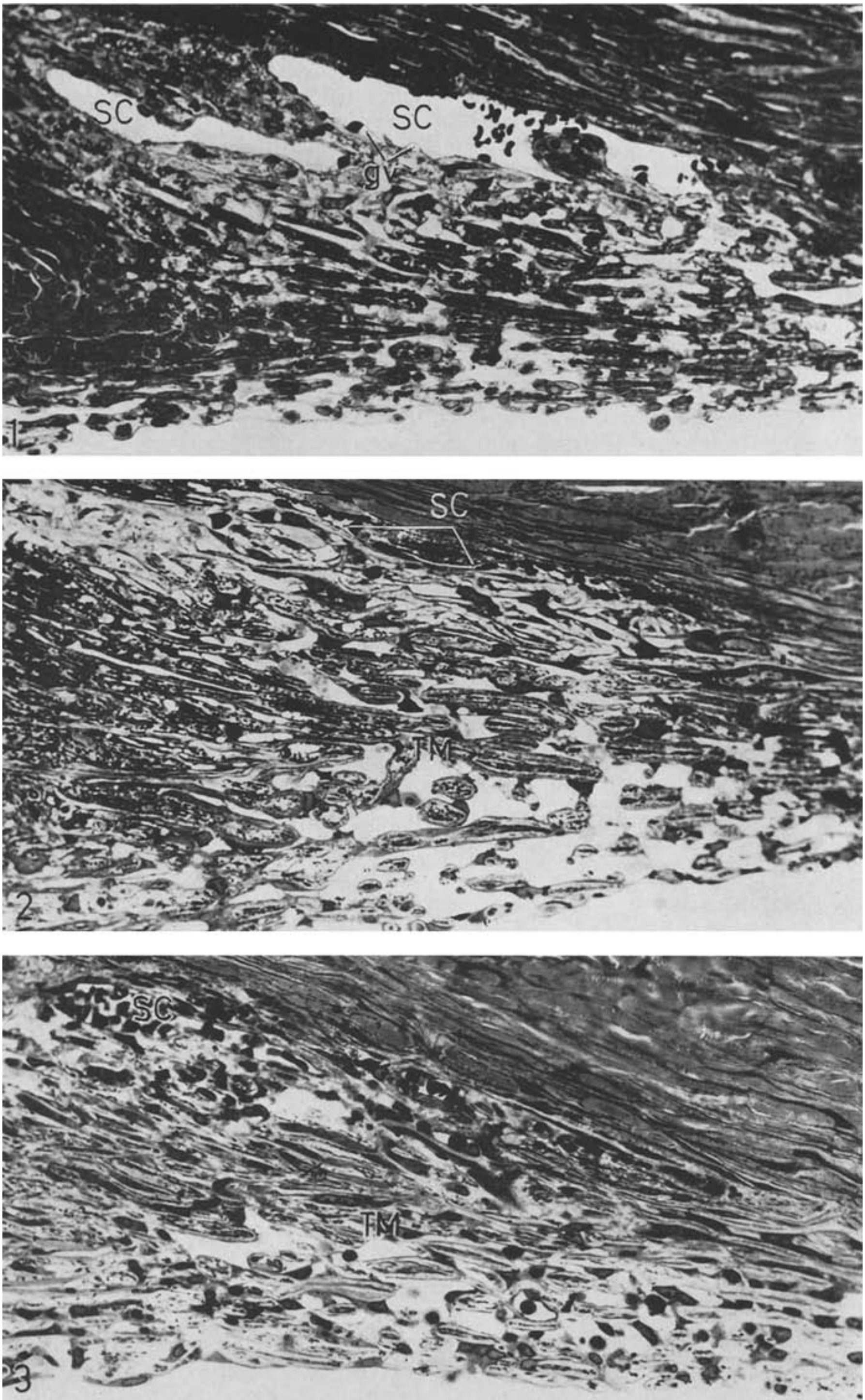
Immediately after enucleation, the anterior segments of the eyes were cut off at the ora serrata, and fixed for 1–2 hours by immersion in precooled 1% OsO_4, buffered to pH 7.3 with phosphate buffer. Tissue blocks were dehydrated in graded acetone solutions and embedded in Araldite. Sections were made with an LKB Ultrotome both for light and electron microscopy. Sections of 2–3 μ thickness were stained for light microscopy with 1% toluidine blue buffered to pH 7.3 with phosphate buffer and decolorized in isopropylalcohol. Ultrathin sections were stained with an aqueous solution of uranyl acetate followed by lead citrate. Siemens Elmiskop 1b and 1A were used.

Results

Light Microscopy. The trabecular meshwork from Eye 1 showed well-defined trabeculae and intertrabecular spaces (Fig. 1). The Canal of Schlemm was open, and sometimes divided by tissue bridges into two or three lumina. Giant vacuoles (Holmberg, 1959) were seen in the inner wall endothelium, and a few erythrocytes were present in the lumen of the canal. A greyish substance was frequently found in the intertrabecular spaces, but this substance could not be identified by light microscopy.

Eye 2 (Fig. 2) also showed well-defined trabeculae and intertrabecular spaces in the light microscope. The Canal of Schlemm appears collapsed in Fig. 2, but in most sections its lumen was wider, and it could be identified fairly easily in all sections studied. In this eye also a greyish substance was found in the intertrabecular spaces, but otherwise no conclusive signs of abnormal structure could be observed.

The light microscopic appearance of the trabecular neshwork in Eye 3 differed considerably from that of Eyes 1 and 2 (Fig. 3). Although some intertrabecular spaces could be observed, the trabecular beams appeared in many areae to have



Figs. 1–3

fused, thus obliterating the spaces between them. On the whole, the trabecular meshwork appeared more compact than in the two other eyes; particularly so its outer parts, i.e. adjacent to Schlemm's canal. The canal itself was partly obliterated, and could be identified only in some of the sections.

Electron Microscopy. Exfoliation material was present in the trabecular meshwork from all three eyes studied. The fibrillar component (Ringvold, 1969) dominated, only occasionally were elements of the granular component found. In addition, all the normal extracellular components of the trabecular meshwork (Vegge and Ringvold, 1971) were present, and we did not observe any disproportion in their relative amounts. Rather frequently gaps between endothelial cells could be seen, causing defects in the endothelial covering of the trabecular beams.

In Eye 1, the exfoliation material was found only in the two or three innermost intertrabecular spaces, i.e. closest to the anterior chamber. It appeared as clumps of varying density and size (10–20 μ), often touching the trabecular endothelium on both sides of a space (Fig. 4). The material was not found within the trabeculae, nor inside the cells. The endothelium of Schlemm's canal and the juxtacanlicular tissue appeared normal (Feeney and Wissig, 1966; Vegge, 1967).

Also in Eye 2 the exfoliation material was present in the intertrabecular spaces, similar to the findings in Eye 1. Additionally, it was found in several other locations. In some trabeculae, the material was found in irregular vacuoles inside the endothelial cells. Such vacuoles were bordered by a unit membrane, and measured up to 1 μ in diameter (Fig. 5). Invaginations of the endothelial cell membrane were also found, with a size corresponding to that of the vacuoles and containing the same material. These invaginations were seen on both aspects of the endothelial cells, i.e. both facing the intertrabecular space (Fig. 6) and facing the connective tissue core (Fig. 7). Even inside the trabeculae the exfoliation material was often present (Fig. 8). In these cases, it was usually found in aggregates interposed between areae showing the usual arrangement of normal extracellular components. In some sections, however, elements of exfoliation material could be seen intermingled with normal elements, such as 1000 Å-banded material (Fig. 9) or basement membrane substance (Fig. 8). In the juxtacanalicular tissue of this eye, exfoliation material was present in abundance (Fig. 10), both adjacent to the inner and to the outer wall of Schlemm's canal. Still, there was no appreciable increase in the over-all density of this tissue (Holmberg, 1965; Vegge, 1967). Giant vacuoles were present, and whereas they mostly appeared empty,

Fig. 1. Eye 1 (exfoliation syndrome without glaucoma). Light micrograph of trabecular meshwork (*TM*) and Schlemm's canal (*SC*) which at this point has two lumina and in the anterior lumen another tissue beam almost crossing the lumen. Giant vacuoles (*gv*) in inner wall endothelium. ×350

Fig. 2. Eye 2 (exfoliation syndrome and glaucoma). Schlemm's canal collapsed but patent. Intertrabecular spaces open. ×350

Fig. 3. Eye 3 (exfoliation syndrome with uncontrollable glaucoma). Schlemm's canal partly obliterated. Trabecular beams partly coalesced, but some intertrabecular spaces still open. ×350

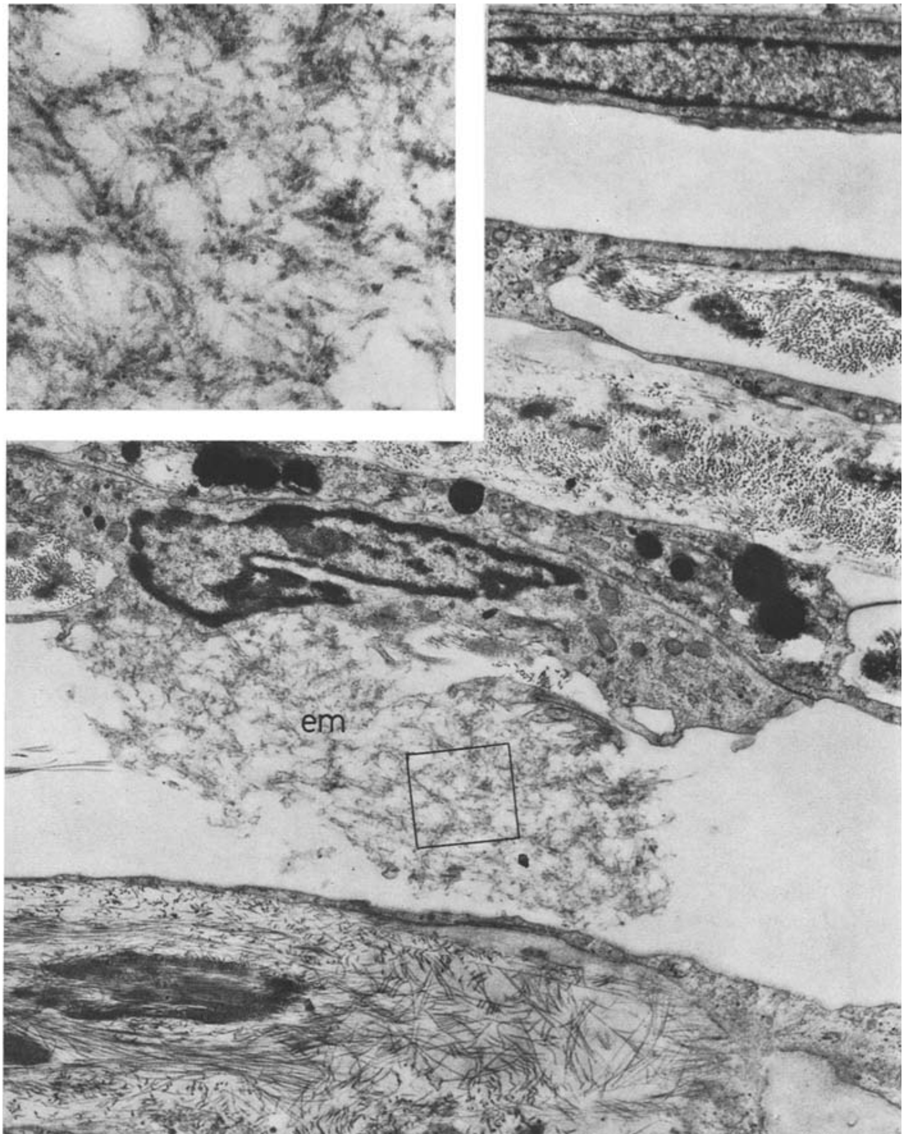
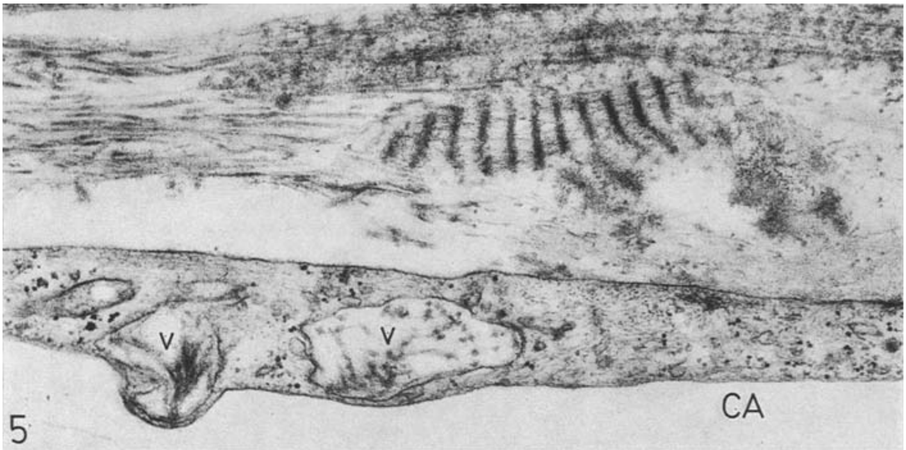
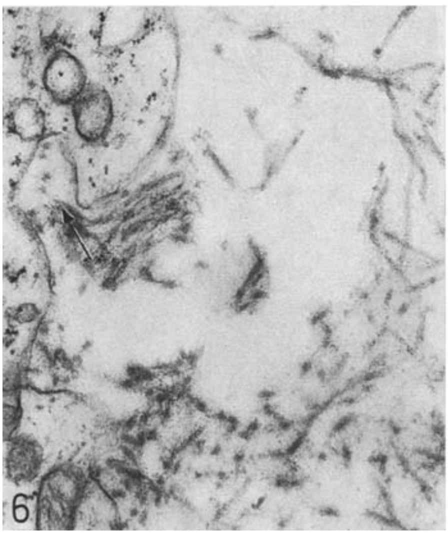


Fig. 4. Eye 1. Exfoliation material (*em*) in intertrabecular space close to anterior chamber (*CA*). Trabecular structure normal. ×7500. Inset: Higher magnification of boxed area identifying the material. ×30000

a few of them were filled with exfoliation material (Fig. 11). In this area, vacuoles and invaginations containing exfoliation material similar to those found in trabecular endothelial cells, were found also in non-endothelial cells, i.e. in cells





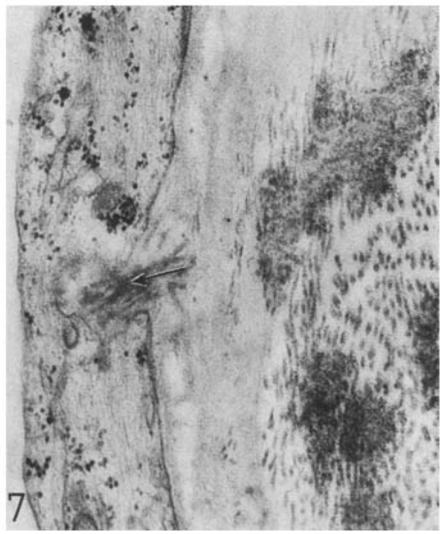


Fig. 5. Eye 2. Cytoplasmic "vesicles" (*v*) of trabecular endothelium at anterior chamber (*CA*), containing exfoliation material. ×30000

Fig. 6. Eye 2. Cytoplasmic invagination (arrow) of trabecular endothelium containing exfoliation material and facing an intertrabecular space. ×30000

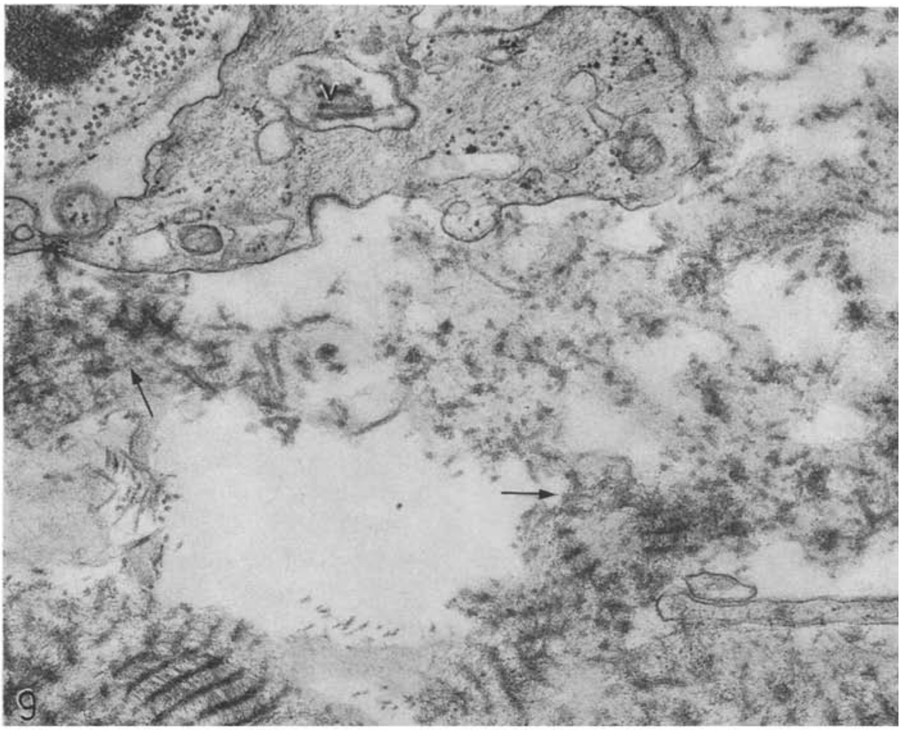
Fig. 7. Eye 2. Invagination (arrow) as in Fig. 6, but facing the connective tissue core of the trabecular beam. ×30000

that were not lining any aqueous space. In a few instances, sharply demarcated areae of the inner wall endothelium were extremely thin, but otherwise no changes were observed in the endothelial lining of Schlemm's canal.

In the trabecular meshwork of Eye 3, where increased intraocular tension had been present for some time, the amount of exfoliation material was much greater than in the other two eyes. As seen with the light microscope, the meshwork

Fig. 8. Eye 2. Exfoliation material (*em*) within a trabecular beam (*tr*). A slight mixing with basement membrane substance is seen at arrows. Some material also seen in intertrabecular space (*isp*). Otherwise, normal structure. ×7500

Fig. 9. Higher magnification of boxed area in Fig. 8, showing cytoplasmic vesicle (*v*) with exfoliation material and mixing of exfoliation material with 1000 Å-banded material (arrows). ×30000



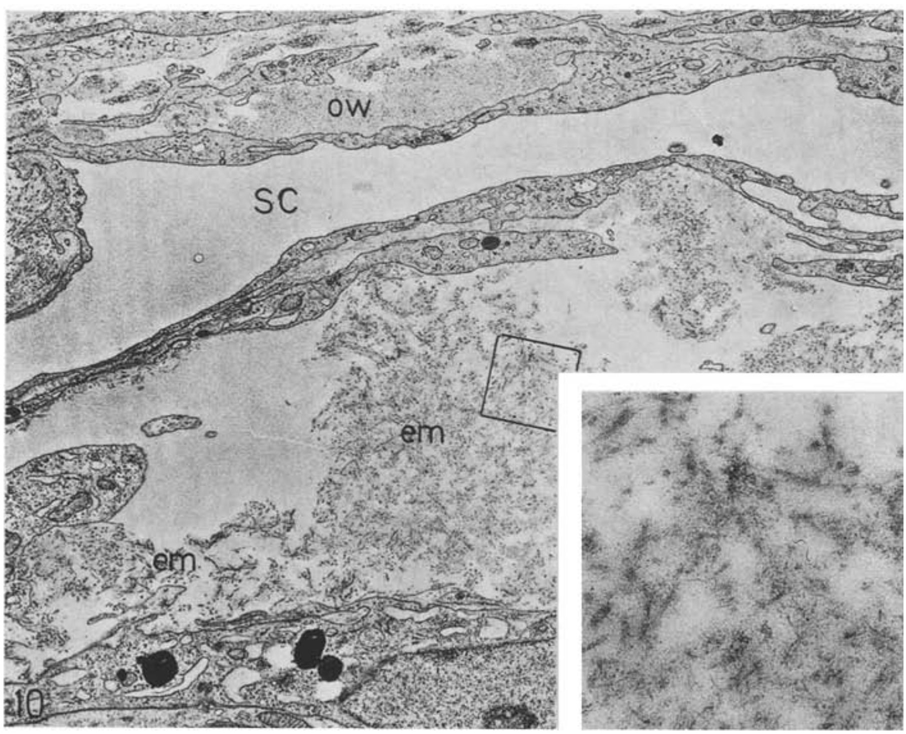


Fig. 10. Eye 2. Schlemm's canal (*SC*), outer wall area (*ow*). Note abundance of exfoliation material (*em*) in juxtacanalicular tissue still showing "low density". ×7500. Inset: Higher magnification of boxed area. ×30000

Fig. 11. Eye 2. Inner wall endothelium (*E*) of Schlemm's canal (*SC*) with giant vacuole (*gv*) containing exfoliation material. Exfoliation material (*em*) also beneath the endothelium. Basement membrane partly lacking. ×30000

Fig. 12. Eye 3. Connective tissue cores (*C*) of trabecular beams still recognizable but endothelial covering disorganized. Increased amount of collagen fibrils (*cf*), aggregates of so-called elastic fibers (*e*). Note area of exfoliation material (*em*) probably corresponding to intertrabecular space. Also high content of rough surfaced endoplasmic reticulum in some cells (arrow). ×7500

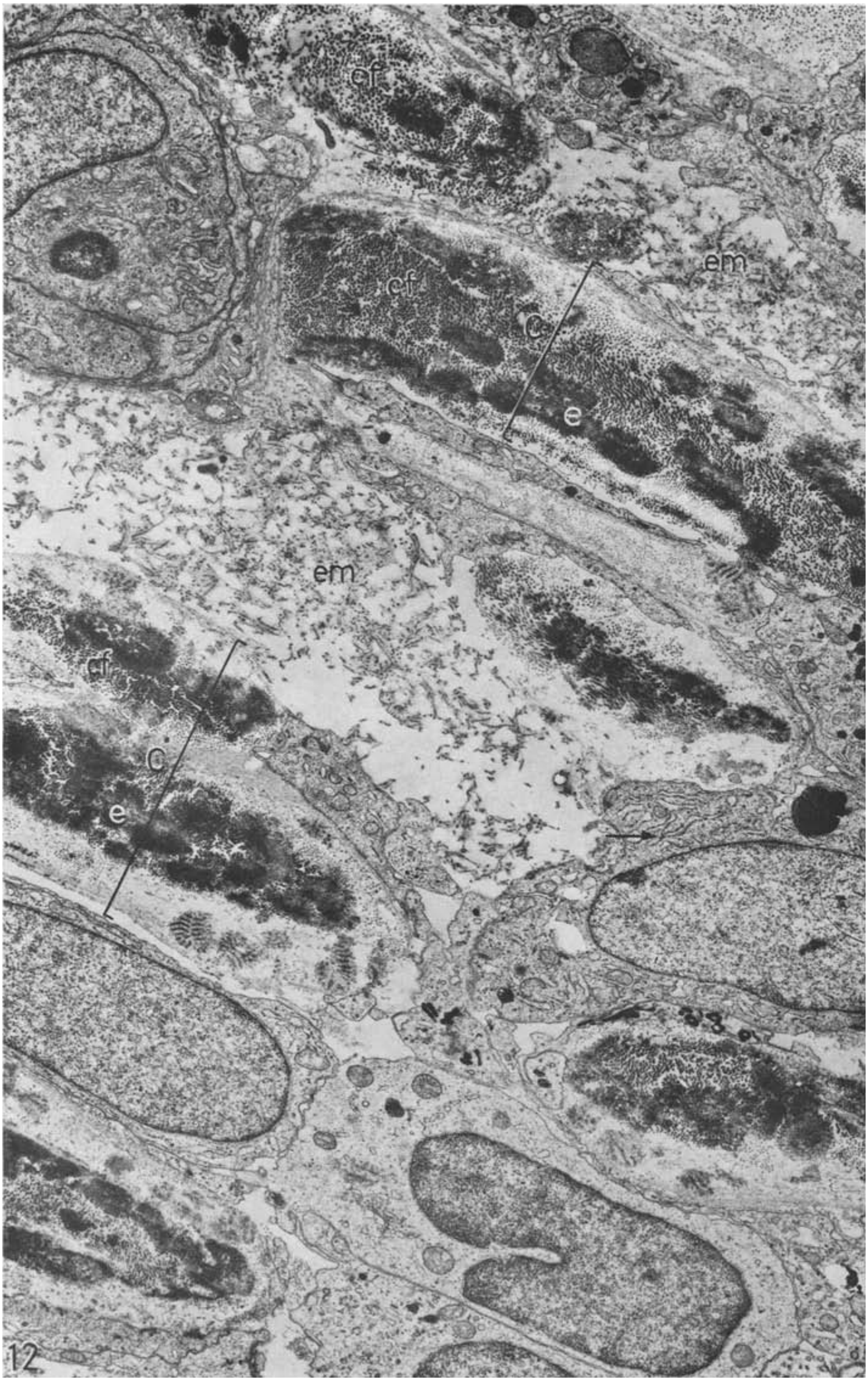


Fig. 12

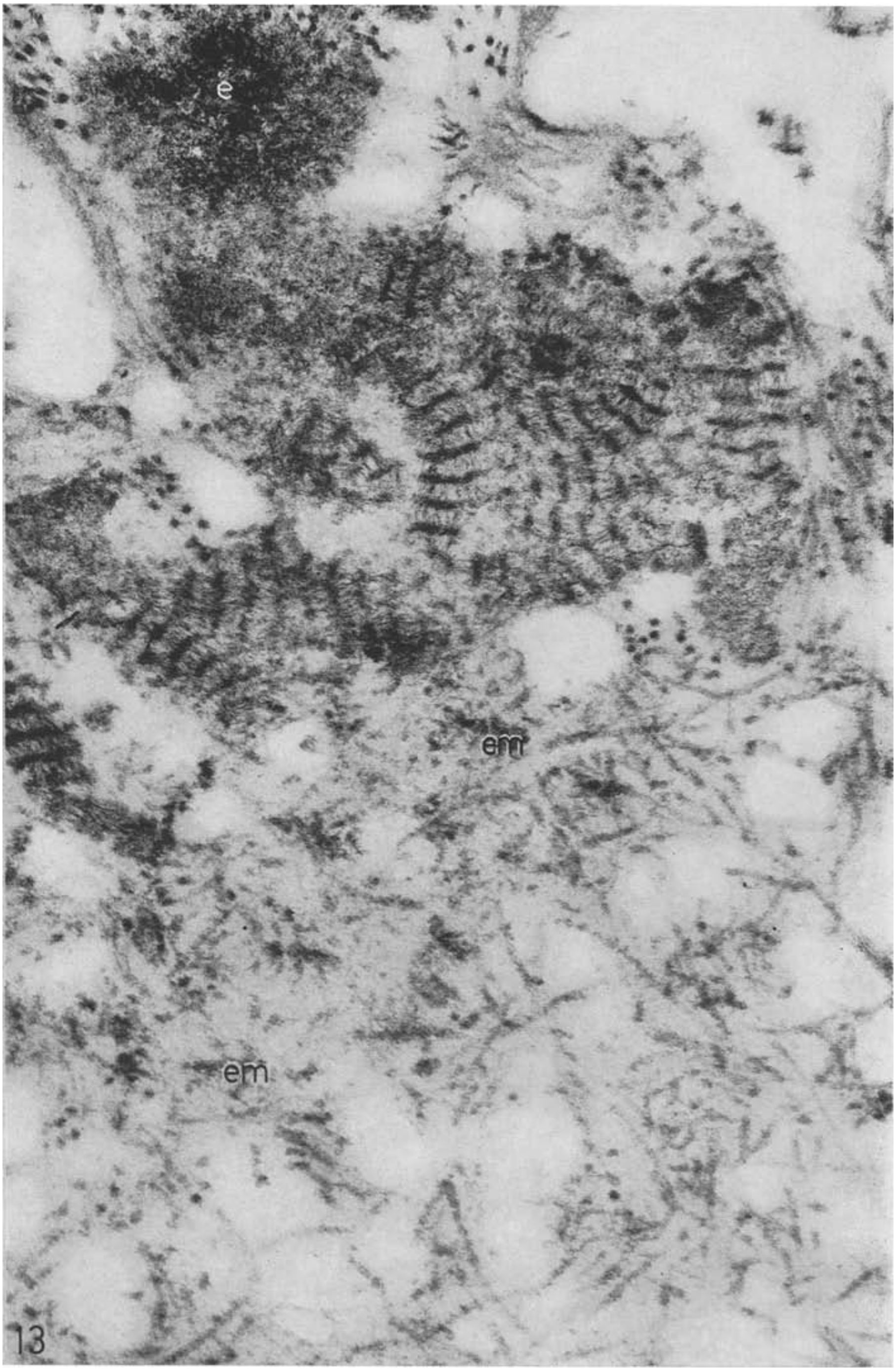


Fig. 13. Eye 3. 1000 Å-banded material merging with exfoliation material (*em*). So-called elastic fiber (*e*) in cross section. $\times 30000$

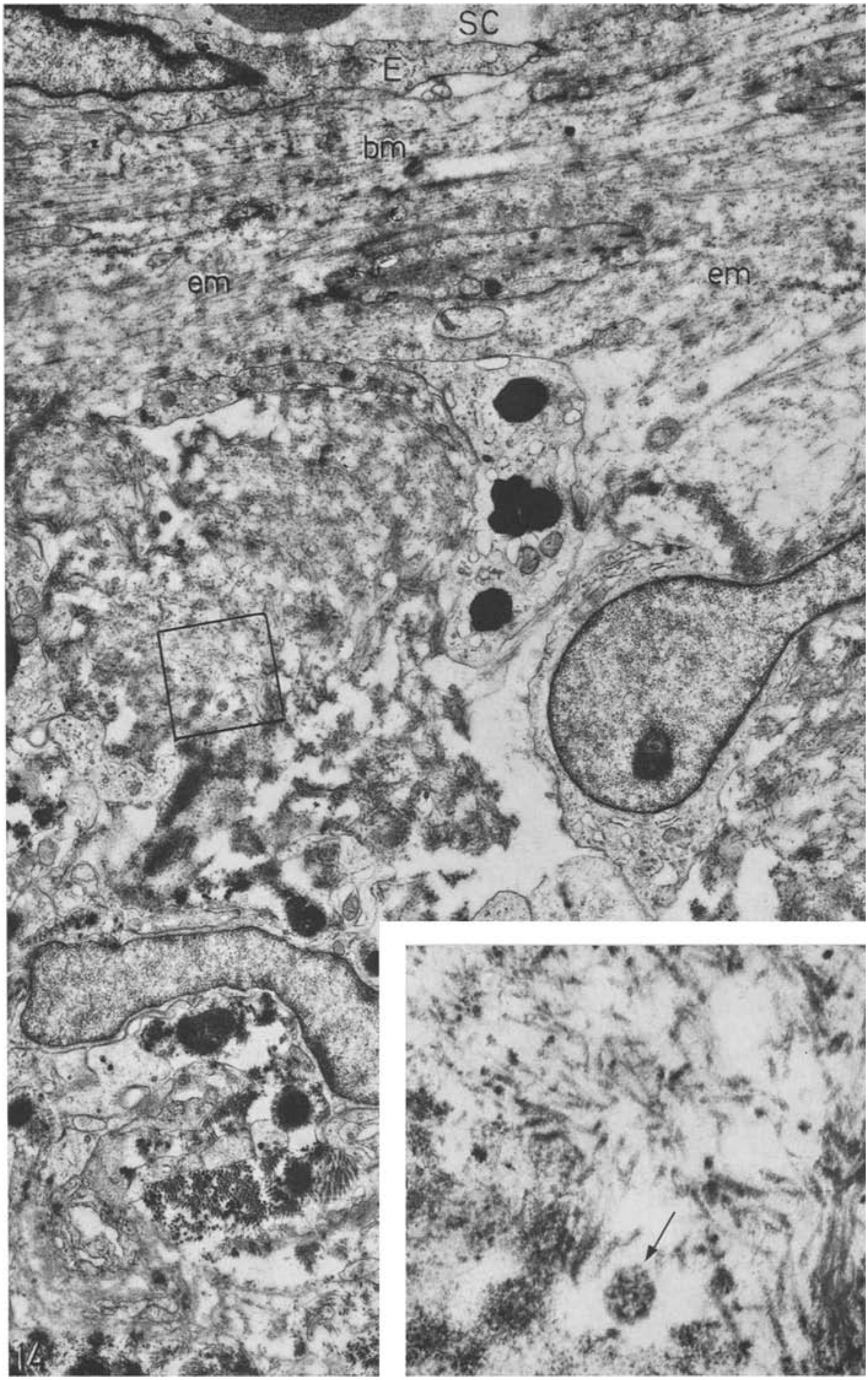
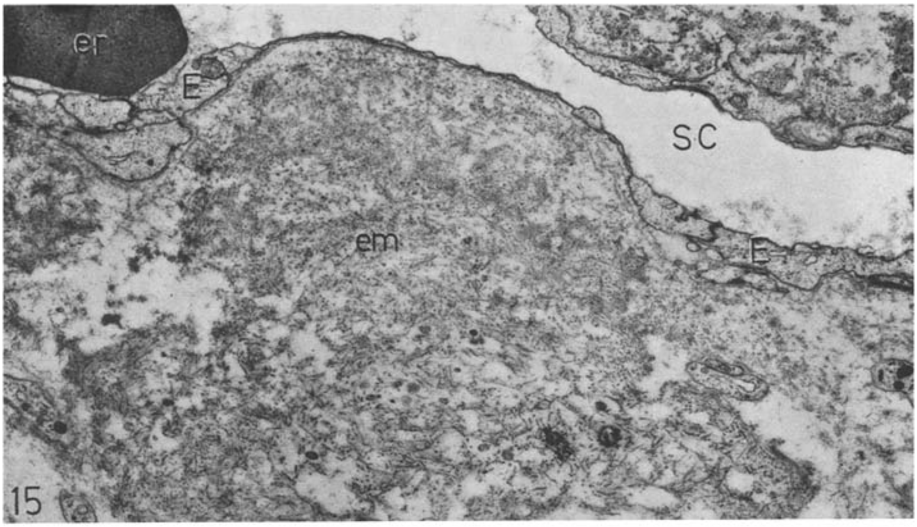


Fig. 14. Eye 3. Schlemm's canal (*SC*) and juxtacanalicular tissue packed with exfoliation material (*em*). Several layers of basement membrane (*bm*) beneath the inner wall endothelium (*E*). ×7500. Inset: Higher magnification of boxed area showing that both fibrous and granular component (arrow) of exfoliation material is present. ×30000



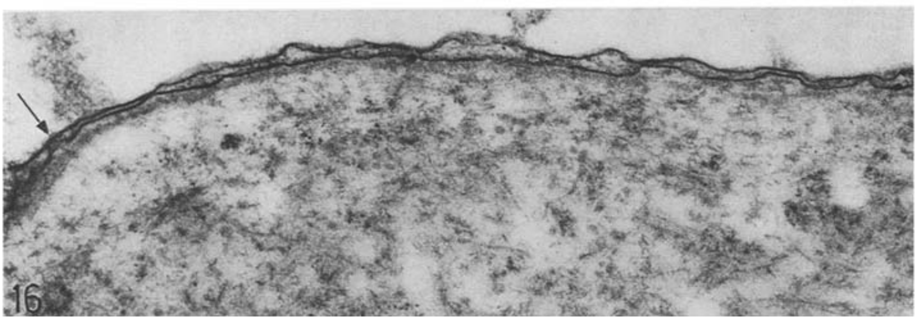


Fig. 15. Eye 3. Inner wall endothelium (*E*) of Schlemm's canal showing extreme thinness. Note abrupt transition to thicker area. Exfoliation material (*em*), erythrocyte (*er*) in lumen of Schlemm's canal. ×7500

Fig. 16. Detail of thin area in Fig. 15. Apical and basal plasmalemma appears to have fused (arrow), simulating a capillary endothelial fenestra. ×60000

was somewhat disorganized, and intertrabecular spaces were to a certain extent absent. In the electron microscope the structure of the trabecular beams could still be recognized. The internal (i.e. extracellular) part of the beams seemed to have retained their general appearance (Fig. 12), but gave the impression of a marked increase in the amount of regular collagen fibrils, and perhaps also in the amount of so-called elastic fibers. The 1000 Å-banded material appeared in normal or rather less than normal amounts (Fig. 12). Basement membranes were often normal, but sometimes appeared multi-layered (Fig. 14). In this eye, as in Eye 2, a mixing of exfoliation material with normal extracellular components appeared (Fig. 13), but was infrequent. Usually, the exfoliation material was found in segregated areae, alternating with cells or with areae of normal extracellular components. In some places, it appeared as if the exfoliation material filled an intertrabecular space with a more or less defect endothelial lining (Fig. 12).

The cells were richer than normal in rough-surfaced endoplasmic reticulum (Fig. 12); otherwise, their cytoplasm did not differ from that of ordinary trabecular endothelial cells. They were only sometimes situated so as to provide a covering for trabecular beams. More frequently, the cells were surrounded by extracellular components on all sides simulating a connective tissue fibroblast, or they were lying several cells close together. There was no striking deviation from the normal cell content of the meshwork, perhaps a slight increase in total cellularity. In this eye, occasional small vessels were observed between the anterior chamber and the Canal of Schlemm. They showed a non-fenestrated endothelium and the basement membrane was often multi-layered. The juxtacanalicular tissue was virtually packed with exfoliation material (Fig. 14), giving this tissue a considerably more dense appearance than in normal eyes, but in the tissue blocks where Schlemm's canal could be identified, we found no increase in the cellularity of the juxtacanalicular tissue.

The endothelium of the inner wall of Schlemm's canal frequently showed areae where it was extremely thin. There was usually an abrupt transition from areae of normal thickness to the thinner areae, where the total endothelial thickness was only a few hundred Ångstrøm (Fig. 15). In a very few instances, the inner and outer cell membrane of an inner wall endothelial cell appeared to have fused (Fig. 16), simulating the appearance of a capillary endothelial fenestra. Otherwise, there was no obvious abnormality in the inner wall endothelium; in one instance a giant vacuole was even found. The basement membrane of the inner wall endothelium was sometimes absent, but more frequently it was multilayered as elsewhere in the meshwork (Fig. 14). We did not observe exfoliation material in the lumen of Schlemm's canal in any of the eyes.

Discussion

The term *exfoliation syndrome* was first used by Sunde (1956) to designate the presence of exfoliation material on the anterior lens surface and in various other locations in the anterior segment of the eye. Several designations have been given to this condition, e.g. pseudoexfoliation of the lens capsule (Theobald, 1954). Some authors have included other symptoms under the same heading, notably increased intraocular tension (see Tarkkanen, 1962). We should like to emphasize that in our terminology, the term exfoliation syndrome designates only the mere presence of exfoliation material in the anterior segment of the eye, and no reference to the origin or cause of the material is intended. Furthermore, increased intraocular tension is not included under the term.

It is established beyond doubt that people with exfoliation syndrome have a higher incidence of glaucoma than the general population (Hansen and Sellevoll, 1968). Several studies that confirm this exist and are summarized by Tarkkanen (1962). Many authors have speculated on the causative relationship between the two conditions, and it has been shown that many eyes with exfoliation syndrome subsequently develop increased intraocular tension (Hansen and Sellevoll, 1969). It seems, therefore, reasonable to assume that exfoliation syndrome is an ethiological factor in the development of some cases of glaucoma, viz. glaucoma capsulare.

Eye 1 of the present study had exfoliation syndrome, but no sign whatever of raised intraocular tension. The two other eyes represent two successive stages of glaucoma capsulare. It is indeed interesting that the findings in the present study show that the three eyes represent also three successive stages of exfoliation syndrome as far as the trabecular meshwork is concerned. Thus, Eye 1, showed exfoliation material in the intertrabecular spaces only, and in sparse amounts. Otherwise, the trabecular meshwork showed a normal morphology. In Eye 2, the intraocular tension was slightly raised, but had been kept within normal limits with pilocarpine treatment, and there was no functional impairment. In this eye, a progression is noted inasmuch as the exfoliation material is present in greater amounts, and in new locations, viz. inside the trabecular beams, and in the loose tissue surrounding the Canal of Schlemm (the juxtacanalicular tissue). Eye 3 had an uncontrollable glaucoma that had affected the optic nerve. In this eye, masses of exfoliation material was present. In the normally loose juxtacanalicular tissue, the material so packs the tissue that it has become considerably denser than in normal eyes (Vegge, 1967), and the normal structure of the trabecular meshwork proper was disorganized.

This question then arises: Does this accumulation of pathological material in the trabecular meshwork so obstruct the aqueous passage that glaucoma ensues? In order to discuss this profitably, we would like to touch briefly on the mechanism of outflow in normal eyes.

There is general agreement that the better part of the resistance to outflow is located in the outer part of the trabecular meshwork (see Davson, 1963), and therefore caused by the structures in the juxtacanalicular tissue or the endothelium of Schlemm's canal. Experiments with perfusion of hyaluronidase (Bárány, 1953; Bárány and Scotchbrook, 1954; Grant, 1960) have shown that the facility is increased by such perfusion, indicating the presence of hyaluronic acid or a related compound in the aqueous pathway. Zimmermann (1957) has shown that such a substance really exists in the juxtacanalicular tissue of normal eyes. These observations, along with the ultrastructure of the juxtacanalicular tissue (Fine, 1964; Holmberg, 1965; Feeney and Wissig, 1966; Vegge, 1967; Vegge and Ringvold, 1971) agree very well with the concept that the final pathway of the aqueous humour before entering Schlemm's canal is the layer of loose connective tissue called the juxtacanalicular tissue. Pore size determinations by particle perfusion (Huggert, 1955, 1957; Karg *et al.*, 1959; Hørven, 1964) furnish no proof that such pores exist anatomically; only that particles of considerable size can pass through the area without damage and that, therefore, "functional pores" exist. In other words, the concept that the aqueous humour must pass through a layer of tissue with its content of mucopolysaccharides and other extracellular elements in order to gain access to the Canal of Schlemm, may well be true. The viscosity of this layer, then, will be of the utmost importance, inasmuch as an increased or decreased viscosity will cause a decrease or increase in facility, other factors being equal. An increased viscosity may be brought about either by the introduction of a raised concentration of mucopolysaccharides or by a higher degree of polymerization. Reversely, a decrease in resistance through depolymerization would certainly result on the introduction of the proper depolymerizing enzyme, as it indeed was done by Bárány (1953) and Grant (1960).

The resistance to flow through the juxtacanalicular tissue would also be increased by the introduction into this layer of any other element that would tend to increase the viscosity. In Eye 2 of the present study, exfoliation material was found in considerable amounts in the juxtacanalicular tissue, while the intertrabecular spaces were still patent. In Eye 3, there is a vast accumulation of such material. In addition to the material that is visible in the electron microscope, there are almost certainly other substances that evade detection with this method. The conclusion seems obvious, that in Eyes 2 and 3 the presence of exfoliation material in the trabecular meshwork and particularly in the juxtacanalicular tissue will have been instrumental in impeding outflow and thereby raising the intraocular tension. We believe, therefore, that a causative factor in the development of glaucoma capsulare is the accumulation of exfoliation material in the angle of the anterior chamber. The presence of other possible factors are, of course, not ruled out. What role the multi-layered basement membranes may play in this respect, is difficult to tell.

The increased amounts of rough surfaced endoplasmic reticulum may be connected with the increased collagen content. Seen in conjunction with the observed vessels, we believe that a transformation of the trabecular meshwork into a simple connective tissue may be in progress. Such transformation, or connective tissue proliferation, has been seen in the trabecular meshwork of animals when implanted into the anterior chamber of the opposite eye (Rohen, 1963; Berggren, 1959). It has also been seen in glaucomatous eyes (Unger and Rohen, 1960). Berggren (1959) suggested that the filtration process had a preserving effect on trabecular structure, and that in the absence of filtration the tissue becomes more dense. Our findings that indications of connective tissue proliferation only occur in Eye 3, i.e. an uncontrollable, late glaucoma, seem to support this view.

The observation of thin inner wall endothelium is puzzling. Such areae resemble the endothelium of fenestrated capillaries, whereas ordinarily, the endothelium of Schlemm's canal resembles that of closed capillaries or lymphatics. Although we have no explanation of this phenomenon, it is interesting to note that in the iris from Eye 3 we also found blood capillaries with infrequent fenestra in the endothelium (unpublished results).

The cytoplasmic vesicles of the trabecular endothelium containing exfoliation material, are difficult to evaluate; they may not even be vesicles but merely invaginations of the cell surface.

A question of importance is whether the exfoliation material is produced *in situ*, or brought here by the aqueous humour from other production sites. Ringvold's studies (Ringvold, 1969, 1970c) lend argument to the theory, that the production of exfoliation material is associated with the appearance of abnormal basement membranes, and infere that the material is produced at several different places in the anterior segment of the eye. If this is true, it is probably also produced in the trabecular meshwork to some extent, since we found abnormal basement membranes here, too. In Eye 1, however, no abnormalities were found except exfoliation material in intertrabecular spaces. This, in our opinion, indicates that the material has arrived with the aqueous humour in this case. Also Eyes 2 and 3 showed exfoliation material in areae that might well be remnants of intertrabecular spaces. The question cannot be settled on the present evidence, but our guess is that the material is brought by the aqueous humour, as well as produced in the meshwork.

References

Ashton, N., Shakib, M., Collyer, R., Blach, R.: Electron microscopic study of pseudoexfoliation of the lens capsule. I. Lens capsule and zonular fibers. Invest. Ophthal. **4**, 141–153 (1965).

Bárány, E. H.: In vitro studies of the resistance to flow through the angle of the anterior chamber. Acta Soc. Med. upsalien. **59**, 260–276 (1953).

— Scotchbrook, S.: Influence of testicular hyaluronidase on the resistance to flow through the angle of the anterior chamber. Acta physiol. scand. **30**, 240–248 (1954).

Berggren, L.: Autologous transplants of chamber angle tissue into the anterior chamber in albino rabbits. Observations on vascularization and content of acid mucopolysaccharides. Acta Soc. Med. upsalien. **64**, 111–125 (1959).

Bertelsen, T. I., Drabløs, P. A., Flood, P. R.: The socalled senile exfoliation (pseudoexfoliation) of the anterior lens capsule, a product of the lens epithelium. Fibrillopathia epitheliocapsularis. Acta ophthal. (Kbh.) **42**, 1096–1113 (1964).

Blackstad, T. W., Sunde, O. A., Trætteberg, J.: On the ultrastructure of the deposits of Busacca in eyes with glaucoma simplex and so-called senile exfoliation of the anterior lens capsule. Acta ophthal. (Kbh.) **38**, 587–598 (1960).

Busacca, A.: Struktur und Bedeutung der Häutchenniederschläge in der vorderen und hinteren Augenkammer. Albrecht v. Graefes Arch. Ophthal. **119**, 135–176 (1928).

Dark, A. J., Streeten, B. W., Jones, D.: Accumulation of fibrillar protein in the aging human lens capsule with special reference to the pathogenesis of pseudoexfoliative disease of the lens. Arch. Ophthal. **82**, 815–821 (1969).

Davson, H.: The physiology of the eye. London: J.& A. Churchill Ltd. 1963.

Feeney, L., Wissig, S.: Contributions of electron microscopy to the understanding of the production and outflow of aqueous humour. Outflow studies using an electron dense tracer. Trans. Amer. Acad. Ophthal. Otolaryng. **70**, 791–798 (1966).

Fine, B. S.: Observations on the drainage angle in man and rhesus monkey: A concept of the pathogenesis of chronic simple glaucoma. Invest. Ophthal. **3**, 609–646 (1964).

Grant, W. M.: Discussion to: Ashton, N.: The role of the trabecular structure in the problem of simple glaucoma, particularly with regard to the significance of mucopolysaccharides. In: Transactions of the Fourth Conference of Claucoma (F. W. Newell, ed.), p. 112. New York: Josiah Macy, Jr., Foundation 1960.

Hansen, E., Sellevoll, O. J.: Pseudoexfoliation of the lens capsule. I. Clinical evaluation with special regard to the presence of glaucoma. Acta ophthal. (Kbh.) **45**, 1095–1104 (1968).

— — Pseudoexfoliation of the lens capsule. II. Development of the exfoliation syndrome. Acta ophthal. (Kbh.) **47**, 161–173 (1969).

Holmberg, Å.: The fine structure of the inner wall of Schlemm's canal. Arch. Ophthal. **62**, 956–958, 1047–1056 (1959).

— Schlemm's canal and the trabecular meshwork. An electron microscopic study of the normal structure in man and monkey (*Cercopithecus ethiops*). Docum. ophthal. (Den Haag) **19**, 339–373 (1965).

Huggert, A.: Pore size in the filtration angle of the eye. Acta ophthal. (Kbh.) **33**, 271–284 (1955).

— An experiment in determining the pore-size distribution curve to the filtration angle of the eye. Acta opthal. (Kbh.) **35**, 12–19 (1957).

Hørven, I.: A radioautographic study of erythrocyte resorption from the anterior chamber of the human eye. Acta ophthal. (Kbh.) **42**, 600–608 (1964).

— Exfoliation syndrome. A histological and histochemical study. Acta ophthal. (Kbh.) **44**, 790–800 (1966).

Karg, S. J., Garron, L. K., Feeney, L., McEwen, W. K.: Perfusion of human eyes with latex microspheres. Arch. Ophthal. **61**, 68–71 (1959).

Ringvold, A.: Electron microscopy of the wall of iris vessels in eyes with and without exfoliation syndrome (pseudoexfoliation of the lens capsule). Virchows Arch. Abt. A Path. Anat. **348**, 328–341 (1969).

— Light and electron microscopy of the wall of iris vessels in eyes with and without exfoliation syndrome (pseudoexfoliation of the lens capsule). Virchows Arch. Abt. A Path. Anat. **349**, 1–9 (1970a).

— Ultrastructure of exfoliation material (Busacca deposits). Virchows Arch. Abt. A Path. Anat. **350**, 95–104 (1970b).

— The distribution of the exfoliation material in the iris from eyes with exfoliation syndrome (pseudoexfoliation of the lens capsule). Virchows Arch. Abt. A Path. Anat. **351**, 168–178 (1970c).

Rohen, J. W.: Experimental studies on the trabecular meshwork in primates. Arch. Ophthal. **69**, 335–349 (1963).

Shakib, M., Ashton, N., Blach, R.: Electron microscopic studies of pseudo-exfoliation of the lens capsule. II. Iris and ciliary body. Invest. Ophthal. **4**, 154–161 (1965).

Sunde, O. A.: On the so-called senile exfoliation of the anterior lens capsule. A clinical and anatomical study. Acta ophthal. (Kbh.), Suppl. **45** (1956).

Tarkkanen, A.: Pseudoexfoliation of the lens capsule. A clinical study of 418 patients with special reference to glaucoma, cataract, and changes of the vitreous. Acta ophthal. (Kbh.), Suppl. **71** (1962).

Theobald, G. D.: Pseudo-exfoliation of the lens capsule. Amer. J. Ophthal. **37**, 1–12 (1954).

Unger, H. H., Rohen, J. W.: Biopsy of trabecular meshwork. Amer. J. Ophthal. **50**, 37–44 (1960).

Vegge, T.: The fine structure of the trabeculum cribriforme and the inner wall of Schlemm's canal in the normal human eye. Z. Zellforsch. **77**, 267–281 (1967).

— Ringvold, A.: The ultrastructure of the extracellular components of the trabecular meshwork in the human eye. Z. Zellforsch. **115**, 361–376 (1971).

Vogt, A.: Weitere histologische Befunde bei seniler Vorderkapselabschilferung. Klin. Mbl. Augenheilk. **89**, 581–586 (1932).

Zimmerman, L. E.: Demonstration of hyaluronidase-sensitive acid mucopolysaccharide in trabecula and iris in routine paraffin sections of adult human eyes. A preliminary report. Amer. J. Ophthal. **44**, 1–4 (1957).

Drs. A. Ringvold and T. Vegge
Anatomical Institute
Karl Johansgt. 47
Oslo 1, Norway