Summary

A case of juvenile amaurotic idiocy with a mild degree of arachnodactyly is described.

There is abnormality of the water-salt metabolism, shown by a chloride retention and a delayed urinary secretion in response to sodium chloride excretion and urine dilution tests.

I would like to thank Mr. Arnold Sorsby, Mr. A. Harold Levy and Dr. R. M. Stewart for the help that they have given me.

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THE MECHANISM OF AQUEOUS SECRETION IN MAMMALIA

BY

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IN their recent communication "Some observations on the present position of our knowledge of the intra-ocular fluid"¹, Duke-Elder and his collaborators make the challenging statement that "there is no conclusive or indeed persuasive evidence that the intra-ocular fluid is a secretion." A theory of function however plausible, particularly one depending on physical properties, is invalid unless it is substantiated by suitable mechanical and structural data. It is exactly on this score that dialysis fails both in its original form as in its latest modification of filtrate-dialysis.

Like all who received their early training in ophthalmology at the beginning of the century, I was brought up on the then current view of Leber, that the aqueous was a filtrate. At an early stage in my research it became manifest that structure and alleged function did not go hand in hand, as the essential mechanism for filtration of aqueous does not exist in the ciliary region². The ciliary body is not a closed region but its areolar tissue is permeated by aqueous and therefore the one and only essential factor for filtration—a difference in hydrostatic level on either side of a passive epithelial membrane—does not exist. The anatomical conditions of the eye being what they are, a dialysate from the ciliary capillaries can not gain admission into the posterior aqueous

chamber by filtration. Further, the consideration of the clinical manifestations of an annular synechia and its relief by iridectomy indicate two points that no laboratory experiment can equal.

The first fact is that the ciliary processes are the source, and sole source of aqueous formation. The second and equally apparent fact is that if the epithelial layer covering the ciliary processes is a mere passive and porous membrane, equally so is its continuation lining the posterior surface of the iris. As every clinician is aware however, the direct consequence of an annular synechia is to demonstrate that the pigmented epithelium of the iris is not porous, hence the necessity of performing iridectomy.

The insurmountable obstacle to the theory of aqueous formation by filtration or dialysis, or any combination of the two, is the presence of the double layer of epithelial cells covering the ciliary processes and lining the back of the iris. If this membrane is inert, dialysis alone will not explain iris bombé. A dialysate from the ciliary capillaries is still on the wrong side of the membrane and till the aqueous gets into the posterior chamber, a bulging of the iris cannot be produced. Filtration alone is no more effective. A filtrate would pass out of the *cul-de-sac* of the posterior chamber as readily as it filters in, and there would be no iris bombé. The bulging forward of the iris is practical proof not only of the impermeability of the iris pigment layer, but also that fluid can only get into the posterior aqueous chamber by the interposition of cellular activity on the part of the ciliary epithelium; in other words, secretion.

Dialysis and filtrate-dialysis are conceptions of function without any mechanism. To substantiate this statement I would refer to some relevant data as found at the angle of the anterior chamber in mammalia.

The Angle of the Anterior Chamber in Mammalia

The comparative anatomy of the angle of the anterior chamber in mammalia presents nothing but a tangle of meaningless details until the guiding principle that dominates the variations present, is appreciated.

As Gairdner, in the introduction to his work on the microscope very appropriately puts it, "details without guiding principles lead but to a busy foolishness." At the angle, the guiding principle responsible for the numerous modifications present in mammalia, is the evolution of the ciliary muscle, to ensure that the act of accommodation be, not merely performed, as in the lower orders, but maintained with increasing amplitude in primates. Man is the only mammal capable of sustained accommodation for near work by the hour, and in consequence the human mechanism of accommodation represents the summit of mammalian perfection.

As detailed in my Doyne lecture³ the angle in mammalia can be

classified into three main types. The first and most primitive type comprises all the orders from marsupials to ungulata. The second and intermediate type is met with only in carnivora. The third and most efficient type is encountered in primates, monkeys and man.

Throughout mammalia, without exception, the ciliary muscle is attached to the corneal circumference by a perforated ligament of origin, the cribriform ligament, which runs along the inner side of Schlemm's canal. Because this ligament is perforated, the aqueous is able to come into direct contact with Schlemm's canal and likewise pass through the fasciculi of the muscle into the supra-choroidal space. In quadrupeds there is, in addition, a pectinate ligament of the iris to anchor the ciliary body and iris root and maintain them in position against the lenticular traction transmitted

FIG. 1.

The Kangaroo. Nasal section. The ciliary muscle (C.M.) consists of a single fasciculus attached to its cribriform ligament (C.L.) which arising from the inner lamellae of the cornea (D.M.) proceeds backwards along the inner side of Schlemm's canal (S.C.). Its open network allows the ready access of aqueous into the supra-choroidal space (S.C.S.). The ciliary process extends from the back of the iris to the retina (R.). The iris root is kept in position against the traction of the lens (L.) by a stout pectinate ligament of the iris (P.L.) while auxiliary fibres support the ciliary base. These subsidiary fibres give the angle a honey-combed appearance, the spaces of Fontana, which are in direct association with the interspaces of the areolar tissue of the ciliary process.

through the zonule. The difference between these two structures can be made out in the illustration of the kangaroo (Fig. 1). It is the fibres of the pectinate ligament which give the angle of the anterior chamber in quadrupeds its characteristic honey-combed appearance, known as the spaces of Fontana, which allow the aqueous to percolate freely into the tissue stroma of the ciliary region and processes. Fontana, however, never saw the spaces ascribed to him in the human eye.

In the anthropoid eye, monkeys and man, as the whole of the lenticular tension is supported by muscle, a pectinate ligament is not required and therefore not developed. The structure so-called in primates is the cribriform ligament of the ciliary muscle present throughout mammalia⁴. As shown in the feline douroucouli (Fig. 2) the angle of the anterior chamber is freely permeable and aqueous can percolate as readily between the fasciculi of the ciliary muscle as into the stroma of the ciliary body. In primates, as in the lower orders of mammalia, the angle of the anterior chamber is open and the aqueous permeates the adjacent tissues and tissue spaces.

FIG. 2.

Feline Douroucouli. On the inner side of Schlemm's canal (S.C.) lies the cribriform ligament giving attachment to the ciliary muscle. Its open network allows free communication between the aqueous at the angle and the tissue stroma of the ciliary body.

Anatomical Factors in the Secretion of Aqueous in Mammalia

The ciliary processes are the most vascular portion of the mammalian eye, a fact which, by itself, indicates the important and vital function these vascular excrescences have to perform. The capillary network is kept together by a loose areolar stroma continuous with that of the ciliary body, the whole structure being lined with a double layer of epithelial cells, the *pars ciliaris retinae*. The clinical manifestations of iris bombé are practical proof that the ciliary processes are alone the seat of aqueous formation and if further proof is desired, it can be found in aniridia, either congenital or following evulsion of the iris.

A survey of the nature and anatomical relationship of the structures about the angle of the anterior chamber fails to demonstrate in the mammalian eye, any water-tight compartments in this region (Figs. 1 and 2). If the aqueous were a filtrate-dialysate, such compartments are an essential mechanism to force the aqueous into the posterior chamber. The acknowledged course of the aqueous is from the ciliary processes into the posterior chamber, through the pupil, into the anterior chamber, and so to the angle. At the angle (Fig. 1) the tissue of the iris root and the base of the ciliary body, as well as the fasciculi of the ciliary muscle and the loose areolar stroma of the ciliary processes, all lie bathed in the same fluid. The way round by the pupil is obviously not the most direct route for a filtrate-dialysate to follow, seeing that the way is open for the fluid to percolate direct into the angle. Why is it that the shortest route is not followed, and what is the power that drives the fluid through the double layer of epithelial cells covering the ciliary processes? It cannot be filtration, for the ciliary stroma is permeated by aqueous and there can be no difference of hydrostatic level between the two sides of the filtering membrane. Neither can it be dialysis, for once the molecules composing the fluid had dialysed out of the capillaries they would still be lying on the wrong side of the ciliary epithelium and be unable to get into the posterior aqueous chamber by further dialysis. It is a basic principle of biology that structure and function are inseparable and complementary. In mammalia, the theory of aqueous production by filtrate-dialysis is that of a device without a mechanism, for the conditions essential for such purely physical procedures are simply non-existent. Aqueous formation, that is the transference of fluid from the capillaries of the ciliary processes to the posterior aqueous chamber, can only be brought about by a vital activity on the part of the cells of the ciliary epithelium. This activity of the ciliary epithelium is secretion, and the "hypothetical glands" responsible for the intra-ocular fluid, are to be found in the ciliary processes.

Conclusions

A study of the comparative anatomy of the angle of the anterior chamber in mammalia demonstrates the following:—

(1) The anatomical conditions in the eye negative aqueous formation by mere physical operations.

(2) The first insurmountable obstacle to the theory of aqueous formation by dialysis or filtration or any combination of the two, is the fact that the stroma of the ciliary body and processes is in free communication with the aqueous at the angle.

(3) The second and equally insuperable objection is the presence of the double layer of epithelial cells covering the ciliary processes and lining the back of the iris,

(4) The aqueous cannot be a dialysis from the capillaries of the ciliary processes because such a fluid will still be on the wrong side of the ciliary epithelium, only to drain directly into the angle.

(5) The aqueous cannot be a filtration as there is no difference of hydrostatic level between the two sides of the ciliary epithelium.

(6) The aqueous cannot be a filtrate-dialysis as the components of the combination are mechanically ineffective.

From the clinical aspect, the condition of iris bombé and its relief by iridectomy are practical proof that the epithelium covering the processes and back of the iris is not an inert membrane. Only by secretory activity can fluid be transmitted from the capillaries of the ciliary processes into the posterior chamber and iris bombé results because pigmented iris epithelium is not porous. Filtrate dialysis is a conception of function operating without a mechanism.

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“BILATERAL (MESIAL) DEFICIENCY OF THE SCLERA”: SCLERAL PLAQUES*

BY

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A REPORT of another case of scleral plaques may be of interest. The reader may be referred to the previous articles on this subject in the issues of the Journal for October 1937, pp. 534-537, January

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