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THE DOYNE MEMORIAL LECTURE, 1922*

BY

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BATH

MR. MASTER, LADIES AND GENTLEMEN,

I deeply appreciate the dignity, honour and privilege of being counted worthy of contributing to the memory of our late revered Master, Robert W. Doyne.

He was a man of exceptional all-round ability and attainments, a capable oculist, a wise councillor, and a kind and generous friend. His contributions to ophthalmology were extremely liberal and marked by rare quality.

Impressions of his manly and dignified bearing and his genial presence as he walked amongst us at such meetings as these are still fresh in the memories of us all.

"Time, like an ever-rolling stream, bears all its sons away."

His achievements—the founding of the Eye Hospital, the University Diploma in Ophthalmology and this great Congress, in some respects unique not only in the beauty of its setting but in the spirit that animates it—remain with us to-day; a monument of industry, zeal, and insight, a masterpiece of symmetry, and a gospel of inspiration to those who would follow.

His contemporaries and those of us who have watched the development of his work here in Oxford with admiration and pride have this confidence, that they can leave to those who have followed

*Read at the Oxford Ophthalmological Congress on August 7, 1922.

him the office of enshrining his work and memory in the history of ophthalmology, of which he was such a distinguished ornament.

For—

"Time shall, with his ready pencil stand,
Retouch your figures with his ripening hand,
To future ages shall your fame convey
And give more beauties than he takes away."

AETIOLOGY OF CATARACT

Introductory and Historical

CATARACT is now generally regarded as synonymous with want of pellucidity of the crystalline lens or its capsule; its aetiology is a subject which has stimulated enquiry from the very remotest times, and the term includes all diseases of the lens associated with visible opacity.

Throughout the middle ages and up to 1643 cataract was considered to be due to a corrupt inspissated humour in a wholly imaginary space between the pupil and the lens. In 1643 Quarre, a Frenchman, taught that cataract was really the lens itself opacified.

Rolphink, a German, 1656, was the first actually to demonstrate the truth of this statement. Brisseau, a native of Tournai, 62 years later, from an examination post-mortem of the eyes of a soldier who had died in a hospital there, confirmed Rolphink's discovery that cataract was nothing but an opaque lens. Brisseau fought manfully for the acceptance of the truth of his observation, and succeeded only after a severe fight which cost him his position in the French Academy.

Heister introduced the teaching into Germany, and Morgagni, of cataract fame, did the same for Italy.

Since the discovery of the ophthalmoscope in 1851, and the settlement, by its means, of the confusion existing between cataract and glaucoma, there has grown up a literature on the subject second to none, either in importance or volume.

I have chosen the subject of aetiology as that which would give the greatest latitude in reviewing our present knowledge of the lens and cataract. Aetiology includes pathology (or the nature and causes of disease) and pathogenesis, its development and generation.

While the study of the latter must necessarily be clinical, aetiology is based not only on clinical observation of the changes which may occur locally, but also in the organism generally by conditions of life which observation leads us to think are causative factors of disease.

It is most essential in the present stage of our knowledge of the aetiology of cataract that the different branches of the subject be

kept distinct, and that the data arrived at from the study of each branch be carefully collated and estimated before the final question of aetiology is settled. For instance, to attribute the cause of cataract to the presence of fat or crystals in the lens or increase in its mineral content is erroneous. It is true that each or all may constitute the opacity, but the fact is that they are only indicators of a change, the actual cause of which may be much further afield than the lens itself.

Sub-capsular senile cataract is undoubtedly a chemical decomposition of the lenticlo-proteid, and the trend of opinion now is that it is more acceptable to regard it as due to alterations in the whole organism rather than to any mechanical explanation based on local causes, and more especially a still unproven pathological contraction of the lenticlo-nucleus. In short, it may be associated with a number of widely different pathological conditions which ought to be taken into account quite as much as the lenticular condition. It is of the highest moment to discover, if possible, the nature and character of the change occurring in the lens itself from a consideration of the products of that change, and it is on these lines that my own investigations have proceeded.

Among the commoner causes known to us as producing opacity in the crystalline lens we have traumatism direct, or in the vicinity of the lens, heat, cold, chemical poisons, electric discharges, light, errors in refraction, general diseases, such as Bright's disease, diabetes, arterio-sclerosis, malaria, phosphaturia, oxaluria, ingestion of poisons like naphthalene, ergot, tetanic spasms, changes in the ductless glands, autotoxaemias, and finally heredity, which all play part in its aetiology. Cataract may occur spontaneously and, though generally considered to be a senile degeneration (or better, associated with senility, as it is in the majority of cases), may be a secondary disease, as all pathological states of the eye may produce it.

Before proceeding to anything like a detailed consideration of the aetiological factors in cataract we must know something of its pathology, and for this a knowledge of normal lenticular nutrition is essential.

Our present knowledge of the nutrition of the lens is most meagre and fragmentary. Science so far has left unsolved the problem of the nutrition of the individual cell, and the lens, owing to its complexity, presents problems as regards its nutrition of well-nigh insuperable difficulty. Endowed with the property of persistent growth by equatorial accretion of fibres born of its capsular epithelium, and completely isolated from blood supply, surrounded only by the intra-ocular fluid which we know is subject to physiological fluctuation in such physical constants as osmotic pressure and surface tension, it possesses a remarkable elasticity (controlled by muscular action) and a pellucidity, growth and

construction of the greatest complexity, features all of which argue for a productive nutrition most perfect and complex.

The metabolism of the lens is its nutrition through suitable substances; those not assimilated or poisonous tell us nothing of its nutrition. For this reason experiments performed with human and animal lenses *in vivo* and *in vitro* have led to unjustifiable conclusions regarding its normal nutrition and metabolism.

Outside the body, death of the lens is indicated by separation of the epithelium from its capsule, imbibition of water, with increase in weight and volume and the escape of the soluble albumen through its capsular walls. All observers agree that its metabolism is slow.

There can be no doubt that its nutrition depends on its relation to the constituents of normal blood and aqueous, and there is almost universal agreement that the nutritive fluid is supplied by the ciliary body and partially by the ciliary processes.

Our knowledge is defective of the composition and physical constants of the normal intra-ocular fluid, the manner in which the lens appropriates its food, what it takes up, and the quantity, and time taken in assimilation, as well as the anabolic and katabolic activity of the crystalline cells.

The intra-ocular fluid on which the lens depends has a volume of two to three cc., a specific gravity of 1006–9, is alkaline, and contains about 1 per cent. of inorganic substances, sodium chloride, alkaline sulphates, phosphates and alkaline earths. In addition to albumin and globulin, it has been found to contain glucose, urea, paralactic acid, and an unorganised ferment. The vitreous fluid is similar, but contains a substance resembling mucin (hylo-mucoid). Both contain oxygen and carbon dioxide. The amount of salts is approximately the same as in the lymph, but it contains about 400 times less albumin, which Botlazzi and Scalinci have shown probably has its origin in the blood, as it has not the character of the lenticular protein. It contains no fibrinogen, and the albumin is made up of equal portions of serum globulin and serum albumin. According to Roemer the aqueous is remarkably free from cytotoxins, the secretory apparatus of the eye apparently excluding all bodies (derived albumins with strong chemical affinity) with cyto-toxic action from the intra-ocular fluids.

These derived albumins of which we have spoken are probably superfluous for the nutrition of the lens, and it is hardly likely that they are injurious, as the latter does not appear to be affected by their increase in the aqueous after, say, a sub-conjunctival injection of sodium chloride. If they are, it points to the secretory apparatus of the eye having an important rôle to fulfil as regards the preservation of the lens.

An important question in lental nutrition is that of the osmotic

pressure of the aqueous in its relation to the blood serum, and on this point there is great difference of opinion. Some agree that it is higher, and others that it is the same. Hamburger believed that the aqueous was hypertonic as compared with serum, and that the lens was in equilibrium with its natural medium. Hamburger's method of determining the osmotic pressure we consider is crude for such a fluid as the aqueous. He measured the height of the column of blood cells in the different fluids, and deduced the osmotic pressure from the assumption that in two fluids of similar osmotic pressure the height of a given volume of blood cells was the same. Nuel found the osmotic pressure of the aqueous and blood serum the

FIG. 1.

same, and Roemer apparently demonstrated that the physiological fluctuations of the osmotic pressure of the blood serum (which were not inconsiderable) were transmitted to the aqueous, and that the lens was adapted to them as blood cells to the blood serum.

I have carefully studied in senile cataract the surface tension of the aqueous humour, which I prefer to the osmotic pressure, both for ease of determination and accuracy, and found that it approximated more to that of water than in the normal, and from it have gathered that there was a more rapid interchange proceeding between the aqueous and the lens in cataract than in normal metabolism, with the abstraction of the soluble albumin and products of the cataractous change resulting finally in diminution in size. I have a chart (Fig. 1) showing the difference between the

surface tension of the aqueous in the normal eye, in cataract and also in glaucoma, and also one (Fig. 2) showing the close agreement between the surface tension and specific gravity curves of urine, which demonstrate clearly that high-surface tension (approximating to water) coincides with low molecular concentration and high freezing point.

It is of interest to notice the relation between the surface tension of the aqueous in cataract, and the diminished osmotic pressure and high freezing point of the urine as found by Grilli in cataract patients. A high freezing point and low osmotic pressure indicate a deficiency in urea and probably other substances. The agreement

FIG. 2.

of the two observations is very suggestive of a kidney deficiency in senile cataract, and a similarity in function between the secretory organ of the eye and that of the kidney.

The lens, by its capsule, is probably protected in much the same manner as blood corpuscles, their envelope preventing the escape of haemoglobin and limiting the entrance of water. In an analogous manner the capsule and epithelium guard the lens. As to the latter there is complete unanimity of opinion, and experimental evidence is overwhelmingly strong. That both are of importance is highly probable, for if a small capsular wound is made and remains open many more lens fibres becomes swollen and disintegrated than when such is not the case, although little of the epithelium has been

injured. It may be objected that the posterior capsule has no epithelium, and yet the lens is protected against the intra-ocular fluid, but it must be remembered that the lens fibres are inserted in the posterior capsule by broad ends, forming a fine mosaic which acts like an epithelium. Fluid from the vitreous enters the lens only with difficulty, hence a wound in the posterior capsule results in little opacity.

We come now to the important question as to how the lens obtains its food, and here we are largely indebted to Leber.

He has shown that while fluid may possibly enter by filtration it is most unlikely, if not highly improbable, that filtration ever occurs in the living eye. There are no canals in the lens or pores in the capsule, and the question arises, Is the latter permeable, and for what kind of substance?

Leber found that the inorganic salts penetrate the lens most easily. Organic substances exhibit considerable difference. Of the carbohydrates glycogen does not enter at all. Cane sugar enters in small quantities during the first twelve hours and rapidly in the succeeding twelve.

Of the albumins, haemoglobin penetrates the outermost layers of the cortex. Peptone does not enter at all. Isotonic solutions of different substances showed that the lens possesses little or no diffusion power. The diffusion of such bodies as iodide of potassium into the lens is extremely slow, and is slower still with the lens in the eye. Substances introduced into the blood are always demonstrable in the lens much later than in any other part of the body, if at all. The remarkably slow diffusion into the lens is probably due to the fact that the endosmosis is not a true one on account of the protective selective action of the epithelium.

The path of the nutritive substances is evidently the intercellular material, protoplasm itself exerting much greater resistance.

The crystalline lens is remarkably hygroscopic, a feature due to its albumin, and of considerable importance not only in connection with the production of traumatic cataract, but also the maintenance of its normal nutrition and transparency by molecular imbibition.

There are two distinct periods in the swelling of the lens after injury. In the first, water penetrates the lens and causes it to swell uniformly, and in the second it accumulates between the capsule and the lens. Experiments have shown that the percentage increase in weight is less when the capsule is removed than when it is present. This is due to the diffusion from the lens of the soluble protein, so that the larger the rent made in the capsule the less the swelling. In frogs only localised opacity in the capsule results from needling, and this may clear up completely.

Important as diffusion and osmosis are in the nutrition of every cell, they are insufficient alone to account for cell nutrition, for it is

highly probable that all cells, including those of the lens, appropriate their nutriment by specific affinity, each cell selecting the substance it needs, and that only those which have a specific affinity can enter it.

Leber's idea probably is the correct one—namely, that the lens draws its food supply from any and every place where nutriment has free access.

There is a difference of opinion as to the importance of the anterior surface in this connection, but I think there is clinical evidence to prove (the beginning of diabetic cataract, for instance) that upon the anterior surface rests largely the onus of meeting the main food supply of the lens. This is further substantiated, as Hess pointed out, by the presence of vessels on its anterior surface up to the time of birth, and such vascular development indicates the need of nutrition at this place. It is most unlikely that this should suddenly cease here. How the nutrition is appropriated by the crystalline lens is at present beyond our ken. We know that both anabolic and katabolic activity take place in all living protoplasm, but of the processes we know nothing. The same may be said of the lens.

So far, therefore, we can state that the food of the lens is secured by it through a modified endosmosis of the intra-ocular fluid, a molecular imbibition and in all probability a specific affinity of its protoplasm. Disturbance of this nutrition is the initial factor and cause of cataract. When the nutrition is interfered with deleterious substances obtain access to its protoplasm, resulting in secondary chemical changes, the products of which constitute the opacity.

An investigation of these changes leads us naturally to a consideration of the pathology of cataract, but first a word or two on pigmentation of the lens. The lens in the evolution of senility becomes sclerosed, a process which consists in the transformation of its protein from soluble to insoluble albuminoid. With this sclerosis, increasing progressively with age, the more central fibres composing the nucleus become coloured, the colour varying between light amber and brownish-red. In extreme cases, clinically known as black cataract, no opacity is present, defective vision being due to absorption and reflection of the light and not to opacity. Some writers consider the condition one of pure sclerosis, others that it is due to haematin or melanin or other colouring matter derived from the blood, but this is hardly tenable to-day, Dor wisely remarking that the tinting has no relation whatever to the pigment of the blood as it starts in the nucleus. Spectroscopic examination of the lenses by Hess, Roemer, Witalinski and others have failed to detect the presence of blood pigment in any one of them. My own examination of two cases have convinced me that the pigmentation is due to the oxidation of tyrosin, the amino acid being

split off from the albumin molecule probably by a very slow hydrolysis, and oxidised immediately by an oxidase in the lens.

If a portion of a cataract freshly removed from the eye is placed under the microscope and rendered slightly acid with the weakest mineral acid in the presence of light, a pigment in all points similar to that of the black cataract is seen to develop. If the portion of the lens be boiled and then acidulated no change occurs because the ferment has been destroyed. Florence Durham (*Proc. Roy. Soc.*, 1904) has shown the same in connection with the skin of animals. When an aqueous extract of the skins of rabbits, guinea pigs or chickens is allowed to act on tyrosin, pigmented substances result. This she suggests is due to a ferment, the action taking place most readily at 37°C, and being destroyed by boiling, which is precisely similar to what I have found to occur in the lens.

I have examined and measured by the Tintometer the colour index (Fig. 3) of over a hundred lenses kindly sent me by a friend in India

Tints of 126 Indian Cataractous Lenses

No.	UNITS.	MEAN.	
8	had a tint of 4-6	5	
32	" " 5-7	6	
37	" " 10-13	12	66 per cent. tint of 18
40	" " 17-20	19	
7	" " 20-24	22	
2	were black	2	
<hr/>		<hr/>	
126		11	

European Lenses

439	6-8	7	
97	10-14	12	88 per cent. tint of 10
73	14-18	16	
<hr/>		<hr/>	
609		11	

FIG. 3.

(66 per cent. of the Indian lenses had a tint of 18 units, 88 per cent. of lenses removed at home had a tint of 10 units), and I have noted a greater density of colour than in those I have examined, which were removed from patients at home. I have to thank the Deputy Master for a large number of cataractous lenses kindly lent me for this enquiry. I think the difference in colour is due to the influence of the light and probably heat out there on the activity of the oxidase and its production is to be considered as protective in character. Pigmentation of the skin is known to be associated with light, and also drying. I shall show some slides subsequently, showing how similar the lens is to the skin, nails and enamel of the

teeth in its reactions. Blackening of the teeth, decay, is due to the same process and they all yield tyrosin on hydrolysis (Fig. 13). I think from the time of the formation of the nucleus, as indicated, say, by the appearance of Hess nuclear images or even before, the fibres composing the nucleus differ entirely from those not so sclerosed. Both chemical and physical examination go to prove this, and I much doubt whether the nucleus could be spoken of as possessing any productive nutrition whatever, and if this is the case it is not difficult to imagine retrograde changes occurring in it, and reversion to similar substances.

I think the conversion of cortex into insoluble albuminoid of the nucleus, accelerated by light, and possibly heat, accounts for the observation of Hirschberg that cataract matures 20 years earlier in India than it does with us. The rarity of black cataract (Elschnig and Zynek found one black and seven amber cataracts in 1,500 extractions in five years) is, I believe, a function of the ferment which I am satisfied is a variable quantity.

The work of Gatti on naphthalene cataract (which he has shown may be made black or white according to whether an oxidising agent is present or not) seems to indicate that naphthalenè by its action on the liver and kidney liberates a greater quantity of oxidases from the splitting up of the proteid molecule which oxidise tyrosin already existing in the lens.

Ferments are certainly present in cataractous lenses, and in the normal and cataractous aqueous. In black cataract the whole lens becomes as hard as the nucleus, the fibres become homogeneous without fissures or granulation, and the presence of vesicular cells at the equatorial regions is a marked feature.

This slide shows in a crude form the absorption in the ultra-violet region of the solar spectrum occasioned by the interposition of a black cataract. Below is the solar spectrum itself. The next slide shows how it was produced. (Two lantern slides not reproduced here). For accurate work quantitative absorption spectra are required. Here are three of four charts (see p. 396) showing the quantitative absorption spectra in the visible and ultra-violet regions of two European and two Indian (brown and yellow) cataractous lenses. They have been obtained by means of the sector spectro-photometer. The results obtained in the charts, which are actual photographs, are expressed in the curves I now put on the screen (Fig. 6). Wave lengths are plotted as abscissae and the extinction coefficients as ordinates. The latter unit is the expression of the light absorbing power of the substance. Although the thickness of the slides vary, the curves are all calculated to their equivalents for a thickness of 1/10 mm., so they all represent approximately the same thing and are therefore comparable. All follow approximately the same course, but certain differences exist, and in particular the following details are

notable: the two white European cataracts A and B are very similar, following practically the same course with only a small space between; this applies even to the form of the slight hump between 4600 and 5000. In C, Indian cataract, similar to the last but a trifle more transparent, the curve lies lower than A or B, while between 3600 and 3200 ultra-violet it exhibits considerable transparency. D, Indian lens (brown) shows lower extinction coefficient, therefore higher transparency in the region 7000 to 5500. Between 5500 and 4500 it is nearly the same as the others, but beyond the curve

FIG. 6.

risks steeply, signifying that practically no ultra-violet light is transmitted. There is no evidence of oxyhaemoglobin which exhibits bands between 5200 and 5700 and there is no Soret band at 4150, such as is given by the colouring matter of the blood and is usually intense over a narrow region. If the pigment were due in black or amber cataracts to any derivative of the blood there would have been a sharp absorption at that point, but there is nothing to indicate this. The rise at this wave length is in keeping with the proteid nature of the lenses. These results, which are only a preliminary attempt to determine accurately the spectrum absorbing

INDIAN CATARACT.—Notice general transparency, and transparency to ultra-violet light.

INDIAN CATARACT.—Shows lower extinction coefficient. Higher transparency in region 7000-5500 (A units). Beyond 4500, practically no ultra-violet light transmitted.

EUROPEAN CATARACT.

properties of cataractous lenses, represent remarkable regularity and though they do not fully satisfy me, yet it would seem that I had determined the true character of the spectrum absorbing properties of cataractous lenses. I have spent considerable time over this to prove that tinting has nothing to do with the blood, that light is necessary, an altered chemical change preceding the development of the tint, that the tint would appear to be protective and is undoubtedly an expression of a retrograde phase in the life of the lens.

As the lens has no blood supply and no mesoblastic tissue in its composition there is no such a thing as primary phakitis. The commoner microscopical changes met with in primary cataract are well known and need no description.

Looked at from a purely anatomical and histological point of view these changes are of little value in arriving at the cause of cataract. They are the only too patent indicators of some gross change taking place in the lens. The most important elements in the conglomeration are undoubtedly the chemical ones, as is being increasingly recognised, judging by recent work, as by their identification alone can we possibly arrive at the nature of the change really taking place.

The chemical pathology of senile cataract has interested me since 1906, when I first discovered the amino acid tyrosin in the senile cataractous lens, which I have shown is the result of a hydrolysis of the lento-proteid. It has occurred in all lenses I have examined, and also in the aqueous humour. It appears to exist in larger amount associated with Bright's Disease and when albumin is present in the urine, and is much less in diabetic cataract. Cholesterin has been known to occur in the healthy lens for years, to the extent of about 6 to 7 per cent. Leucin to the same amount and many of the cases of crystals shown clinically in the lens are due to cholesterin.

In 50 cataracts examined by Zehender and Mattiesen the average amount of cholesterin was about 7 per cent. Jacobson, Kühne and Leber have all shown an increased cholesterin content, and Leber an increase in cholesterin and leucin.

From my own investigations cholesterin appears to occur in greater quantity in diabetic cataract than in any other. As is well known, it belongs to the class of alcohols and I am almost certain that in the lens, at any rate, it is a reduction product of a previously formed acid.

Other crystalline bodies resembling tyrosin and leucin have been observed to occur in senile cataract by Becker, Baas, Coats and Hess.

Becker found crystals resembling leucin within the globules; Axenfeld and Hess crystalline bodies in lamellar cataract.

I have a slide (Fig. 7) kindly sent me by Dr. Verhoef, of Boston, which shows a mass of crystals (unidentified), composing the core of a coralliform cataract, which was examined microscopically by him. There is nothing improbable in the fact that both leucin and

FIG. 7.

tyrosin might occur in a cataractous lens, as the table showing the cleavage products of the crystalline lens shows (Fig. 8).

Cleavage Products of the Crystalline Lens

PRODUCT					PERCENTAGE
Alanin	...	...	...	...	4·7
Valin	...	...	...	...	1·9
<i>Leucin</i>	...	...	...	...	6·8
Aspartic Acid	...	...	...	...	1·4
Glutamic Acid	...	...	...	...	15·5
Lysin	...	...	...	...	1·6
Arginin	...	...	...	...	3·3
Phenylalanin	...	...	...	...	1·9
<i>Tyrosin</i>	...	...	...	...	4·5
Prolin	...	...	...	...	2·2
Histidin	...	...	...	...	1·6
Tryptophan	...	...	...	...	—
Adenin	...	...	...	...	—

FIG. 8.

The presence of crystalline or other chemical bodies occurring in the lens in cataract associated with Bright's disease, diabetes, lamellar cataract, coralliform cataract, and probably other types, if carefully examined, proves conclusively that cataract is the result of chemical decomposition occurring in the lens, at any rate in its primary forms, however diverse in character they may appear, the

apparent diversity being, I think, a function of the existing cause, and I am rapidly coming to the belief that all primary cortical cataracts are alike, and that differences in clinical appearance are to be attributed to variation in the origin, character and critical concentration of the exciting cause.

Lately a great deal of attention has been paid to the mineral constituents of the lens, and notably by Burge in America. He examined some thousands of lenses removed for cataract in the United States and India, and found that the potash which constitutes about 38 per cent. of the ash in the normal lens had been reduced in cataract to 9·8 per cent. and the calcium increased from an almost negligible quantity, 0·08 per cent. to 15 per cent., in cataract. The increase in magnesium, while not so marked as in the case of calcium, was quite definite. Indian lenses were marked by a large amount of silicates without any increase in the magnesia. He attributed this to diet and, I think, with a measure of truth.

In later experiments in the production of cataract the same observer, who was one of the first to produce opacities artificially, using ultra-violet light, found that, although such rays had no immediate effect alone on the lens proteid when there was an excess of lime and magnesia present in the fluid in which the lenses were suspended, coagulation took place and opacity resulted.

At the present moment it is difficult to arrive at the relative importance of three factors: an unorganised ferment undoubtedly present, and which may be produced by destruction of the lens protoplasm by light (although it is quite likely to have, and probably has, in senile cataract, another origin); the presence of calcium salts and those of the alkaline earths, which are probably essential to the ferment; and light which activates it and may produce it. If Burge's analysis be correct and potash is deficient, its place being taken by lime, one of the first changes would apparently be the robbing of the lens of its normal potash content, and at one time I thought this took place by means of acids in the aqueous, but later investigations on the ionic concentration of the aqueous, determined by accurate colourmetric methods, have shown that in all cases so far examined, including diabetes with large quantities of sugar in the urine, the aqueous was alkaline (Fig. 9).

The strength of caustic soda or sodium bicarbonate corresponding to a P_h of 8 would be about 1 million normal to caustic soda, but such a solution could hardly be made, as traces of impurities in the alkali and water would have considerable effect. The method of testing was by indicator papers—cresol red, thymol blue, methyl red, and phenol red. The results are within 0·1 and 0·2 P_h . They were all checked by buffer solutions. In every case the specimens were alkaline, and special precautions were taken to avoid alkali contamination from the glass which, by the way, we found was

negligible. The exact method of testing by buffer solutions would take too long to describe in detail.

Potash is a cell food, and while I am unable to account for its reduction in cataract, such certainly agrees with the visible evidence of a depraved nutrition, which we find pathologically, and I have a shrewd suspicion that alkalinity of the aqueous is maintained as far as possible for nutrition of the lens, though the tissues of the body generally are deprived of their normal alkali reserve, and that the deficiency of potash represents a lack of supply rather than excessive demand. For this reason the exhibition of alkalies, especially potash, in the treatment of primary cataract is of the greatest importance. A lot of work has been done in connection with variation in such constants as weight, volume and water content of the clear lens at different ages and in cataract, in the hope that some clue as to the cause of the latter might be found.

These factors enter largely into the elaboration of the old

P of specimens of Aqueous Humour in cases
of Senile Cataract.

operation	name	age	P.
P I. R	W R.	52	8.1.
P I L	C S	70	8.1.
P I L	R T	65	8.2.
E X T	W H	59	8.0.
P I L	W W	65	8.2-4
E X T	H B	59	8.4-6
P I L	H D	68	8.4-6
P I	R C	-	8.0-2.

FIG. 9.

dehydration nuclear shrinkage theory of Becker and De Wecker and the later hydration theory of Dor. Both weight, volume and water content decrease, as Kühne and Collins have shown, in mature cataract, the latter weighing lenses in their capsules.

Sir William Collins says the prevalent teaching of solidification and cornification of the crystalline lens as a natural senile change is responsible for the equally prevalent doctrine that changes in the lens which we speak of as senile cataract are, in fact, merely intensified or accelerated senile changes.

My investigations lead me to believe that they are nothing of the kind, and in some respects the changes exhibited by cataractous lenses are the reverse of those which age alone brings. Such lenses are unlike old lenses, less in bulk, and lighter in weight than clear lenses of corresponding ages. It is rare to find a cataract weighing as much as 200 mgms., a weight usually passed by the healthy lens at 40. If cataracts were premature senility we should expect to find cataract weighing heavier and not lighter than a healthy lens. In addition

there are certain chemical bodies—cholesterin, leucin and fat—found in excess. Alcoholic and aqueous extract both show increase over those of the healthy lens. The presence of such favour the view that they have been occasioned by transformation of the albumin of the normal lens, presumably due to some failure in nutrition. My theory of hydrolysis easily explains what Collins here suggests.

The late Professor Dor, of Lyons, whom some of us may remember as a distinguished visitor to this Congress at one of its earliest meetings, in a critical review of the pathology of cataract in the French Encyclopaedia advanced the theory that cataract is not a dehydration but a hydration. His theory was based on:—

1. Deutschman's analysis, which showed that cataract contains more water than clear lens.
2. That in cortical cataract the nucleus gains and the cortex loses in density, and that albumin escapes.
3. The percentage of soluble albumin is less in cataract than in the clear lens, and sometimes disappears altogether from the nucleus.
4. That the electrical resistance of the aqueous is diminished.

These facts Dor thought were an argument in favour of hydration of the lens as a cause of cataract. I have considered Dor's theory very carefully, and I do not think he meant hydration, though he says this, but I think hydrolysis was in his mind, though I never got this confirmed.

Deutschman's figures, showing that cataracts contain more water, are of doubtful accuracy and do not agree with others. All his other points are, I think, true. No chemist could, I think, possibly imagine that hydration alone (the term means nothing more than added water), without decomposition, would account for the presence in the lens of the dissimilar chemical substances found there.

I hope I may be pardoned here for alluding to the hydrolysis theory of primary cataract for which I am responsible. I have stated on a previous occasion, and have shown, that the first change which takes place in the lens in the production of a permanent opacity (as distinct from coagulation, which may completely clear up) is the elementary one of hydrolysis. Briefly described, it is a simple decomposition resulting from the assimilation by the proteid molecule of the lens of the constituents of a molecule of water, to use a chemical phrase, with the production of new substances entirely.

It was the detection of tyrosin, one of its cleavage products, which led me to the recognition of the nature of this change, and I have no doubt that the fat or fatty acid, also present in cataract, will, when identified, confirm my belief.

The theory accounts for many changes in lental pathology :—

1. The presence of *tyrosin* in the *aqueous* after *needling* the clear lens. I have found it *after discission for myopia*. The changes here are imbibition, decomposition, solution and abstraction by the aqueous of soluble products—in short, the cataractous process.

2. Its presence *in the aqueous and lens in senile cataract*.

3. *My findings in albuminuria and glycosuria*. This is the only theory which *accounts for black cataract and pigmentation of the lens generally*, and for the *diminished weight of the cataractous* as compared with the clear lens of the same age.

It accounts for the more *frequent position* of the *opacity in the cortex* (subcapsular cataract being the most common form of senile cataract clinically), the nucleus often being quite free, the cortex hydrolysing more readily than the nucleus.

It accounts for the *observation of Dor* that the *lental albumin is much less and sometimes disappears, because it is hydrolysed and carried away by the aqueous*.

Coming now to a consideration of pathogenesis of senile cataract, and in particular its commonest form, the subcapsular variety, a name given it by Hess, we are tempted to ask, Is senile cataract a true disease or is it simply incidental to age and a sign of decay consequent on advancing years? This latter idea is based on the frequent association of lenticular opacity in old people. Conceding the fact, it still remains that only a small proportion develop senile cataract. If we recognise that degeneration, wherever it occurs, is abnormal and that the description of different forms of senile cataract is justified, this cataract is a disease of the lens, the outcome of a diseased condition of the whole organism. Of the rarer nuclear forms, perinuclear and punctate, we know nothing, save that they have never been produced experimentally, and we cannot explain them by referring to clinically similar forms. Subcapsular is the best known type.

Its cause has been sought for in the lens, in alterations in the chemical and physical properties of the aqueous, and changes in the general bodily condition.

Becker considered it due to irregular sclerosis of the nucleus. If this theory is correct, why does sclerosis only occur in some lenses and not in all? Becker suggested an anomalous chemical behaviour of the nucleus to account for it, and considered that chemical changes in the nucleus preceded by years those in the cortex; this is correct. Deutschman, who agreed with Becker, suggested that the water given up in the sclerosing process clouded the faulty lens by swelling its fibres.

Becker made use of Priestley Smith's observation that the lenses with commencing cataract were lighter and smaller than clear

lenses of the same age, but Hess pointed out, and rightly, in his objection to this theory that fluctuation in weight and volume were not only variable, but the observations too few to permit of any conclusion that contraction and shrinkage of the nucleus had taken place. Against Becker's theory, too, is the fact that in early cataract the lens distinctly increases in volume. Contraction of the nucleus has not been proved or even made plausible, and should it occur it can only be due to injuries from the outside.

In 1897 the late Dr. Schoen published a book, the object of which was to show that senile cataract was attributable to increased effort of accommodation, bringing about the train of conditions very similar to those found in cataract associated with convulsions.

Schoen's argument failed to bring the conviction he desired and,

FIG. 10.

owing doubtless to his death shortly after, his theory passed into oblivion. He considered that cataract was brought about in eyes in which there was increased effort of accommodation, causing tears in the capsule between the zonular filaments.

Hess, though agreeing with the Helmholtz conception of accommodation as implying a lessened strain, does not deny a connection between accommodation and opacity, the latter resulting from slits between the zonular filaments from peripheral pressure against a non-yielding nucleus as age advances.

There is no doubt whatever that refractive error has a decided influence on the nutrition of the lens in the production of opacities. I came to this conclusion 12 years ago after a review of 2,808 refraction cases, among which I found 6 per cent. of cataract.

I studied them carefully, dividing them into two groups, those above 50 and those below that age, and in order to avoid error formulated my ideas only on those which were below the age of 50,

and which were as free as could be proved clinically from all bodily diseases and local eye trouble. The charts I show you give a good idea of the results arrived at in the examination of those cases above 50 years of age.

The first (Fig. 10) shows the age instance; the average was 61. In those below, it was 40.

The second chart (Fig. 11) indicates within small compass the result of an examination of a huge mass of figures. Hypermetropia associated with astigmatism occurred in 47 per cent. with a mean of

FIG. 11.

0.5 D.; myopia in 40 per cent. with a mean of 1.5 D.; astigmatism was oblique in 52 per cent. of the cases, not oblique in 28 per cent., with the rule in 36 per cent., against the rule, 30 per cent., mixed in 54 per cent., pure hypermetropia occurred in 86 per cent., with a mean of 1 D., and pure myopia in 66 per cent., with a mean of 6 D. The oblique astigmatism in 28 per cent. of the cases was 0.25 D., in 19 it was between 0.5 D. and 0.75 D., in 7 it was 1.75 D., and in 8 per cent. it was 4 D. The commonest axes were 60, 150, 15, 30, 75, using the binasal method. In the chart hypermetropia shows a greater percentage than myopia, in my case the difference was 7. The figures prepared by Schoen

show a greater difference ; I think Schoen's figure is much too low for myopia. My feeling is, though I would not like to be dogmatic on the point, that hypermetropia has a much greater influence than myopia on the production of opacities in the lens (and I exclude myopia with degenerative change) owing to the greater accommodation necessary to its correction, and the adverse influence on the ligament and capsule.

From an examination of 1,300 cases recently published by Miss Granger, from the Mayo clinic, hypermetropia and hypermetropic astigmatism would seem to be twice as common as myopia and myopic astigmatism. Notice the proportion of oblique astigmatism in the cases, which I believe is more potent than astigmatism at either

AGE	CATARACT	RIGHT REFRACTION	LEFT
12	INCIDENT R	$\frac{+1}{-4} \frac{+1}{-10}$	$\frac{+0.75}{+0.75} \frac{+1}{-12}$
28	L	$\frac{-0.75}{-0.75} \frac{+1}{-10}$	$\frac{-3}{-3} \frac{+1}{-12}$
32	R	$\frac{-0.75}{-0.75} \frac{+1}{-10}$	$\frac{-0.75}{+0.75} \frac{+1}{-12} \times$
40	L	$\frac{-0.75}{-0.75} \frac{+1}{-10}$	$\frac{-0.75}{+0.75} \frac{+1}{-12}$
45	R.L	$\frac{-0.75}{-0.75} \frac{+1}{-10}$	$\frac{-0.75}{-0.75} \frac{+1}{-12} \times$
40	DOUBLE FUSED	$\frac{-6}{-6} \frac{+1}{-10}$	$\frac{-6}{-6} \frac{+1}{-12}$
42	L	$\frac{-0.75}{-0.75} \frac{+1}{-10}$	$\frac{-6}{-6} \frac{+1}{-12}$
45	R.L	$\frac{-1.75}{-0.75} \frac{+1}{-10}$	$\frac{-1.75}{-0.75} \frac{+1}{-12}$
34	R	$\frac{+1.75}{-0.75} \frac{+1}{-10}$	$\frac{+0.75}{+0.75} \frac{+1}{-12}$
48	R.L	$\frac{+1.75}{+0.75} \frac{+1}{-10}$	$\frac{+1.75}{+0.75} \frac{+1}{-12}$
25	L	$\frac{+1}{-2.75} \frac{+1}{-10}$	$\frac{+2.5}{-5.5} \frac{+1}{-12} \times$
26	L	$\frac{+0.75}{+0.75} \frac{+1}{-10}$	$\frac{+0.75}{-0.75} \frac{+1}{-12} \times$

FIG. 12.

90° or 180°. Few doubtless have failed to notice in testing the eye the variation of an oblique axis, with alteration in accommodation brought about by varying the spherical. This variation is not due, I think, to alteration in the shape of the cornea or torsion, but is evidence of an irregular torsional accommodation effort which produces an irregularity in lens shape and alteration in the axis. It is this sort of condition occurring in the main in hypermetropic astigmatism which I consider so potent in producing lens opacity. It imposes undue and irregular strain on the suspensory ligament and capsule, which, when kept up for years without relief gives rise to lens opacity. In another chart (Fig. 12) I have tabulated a dozen cases of incipient cataract below 50 at random. I have now some 70 of these. These cases are conclusive to my mind. In them there was no hereditary influence, as far as I could ascertain, or general systemic disease, or local eye trouble. Notice the marked error in refraction in the defective eye, the cataract

being on the side of the greater error, and the astigmatism in most of them oblique. 403 B was a most interesting case; she had what apparently was typical senile cataract in her left eye at the age of 26, and was certified as perfectly sound by her doctor. I found dark radial sectors in the left lens; with this exception, the eyes were normal. Refraction gave 3 D. of hypermetropia and 0.75 D. of astigmatism at 170° in the defective eye. The ophthalmometer showed 3 D. of corneal astigmatism. In this case nature had diminished both the hypermetropia and the astigmatism with great expense to herself. These refraction cataracts present the interesting feature that they invariably see well, even when the lens is apparently nearly completely cataractous. It will often be found that there is a clear slit-like interval definitely related to the axis of the astigmatism through which the patient sees, nature having safeguarded this to serve her ends.

I have devoted more time to refraction as an aetiological factor in the development of cataract than perhaps I ought, but I have a strong conviction that if during the working decades of life important refractive errors were corrected and this came to be recognized as part of a prophylactic treatment, we should in time see a proportionately lessened incidence of at least one type of cataract with definite aetiology.

Of theories referable to the aqueous, Peters sees the cause of cataract in changes in the ciliary epithelium, alteration in the concentration of the aqueous, impaired nutrition and shrinkage of the nucleus. According to him, there must be a higher molecular concentration in the lens than in the anterior chamber, and the maintenance of this devolves on the capsule. Increase in the osmotic pressure of the aqueous would be detrimental to the lens as its normal process of nutrition would be interfered with. It is possible that by a senile change in the secreting organ the aqueous may contain more salt, a slight increase of which he considers of great importance (as so little is found), not so much in diminishing subcapsular pressure, but, in disturbing normal exchange with the lens by establishing osmotic equilibrium between it and the aqueous, condensation in its central parts and, finally, disturbance of its cortical layers, diminution and pressure within the capsule being the essential factor.

Against this theory is the fact of osmosis itself, and that blood cells will obtain nutriment in an isotonic solution, and it is also doubtful whether a marked difference of osmotic pressure exists between the lens and the aqueous. Some say the aqueous is higher. Roemer and Rossling think that the osmotic pressure of the intra-ocular fluid is not higher than the blood, and that fluctuations in the latter are transmitted to the aqueous, and the lens adapts itself to them. From a study of osmosis he believes it is impossible for a

high degree of molecular concentration to be maintained in the aqueous. Should salt occur owing to senile change in the secreting organ, osmotic equilibrium, we should think, ought to be restored by osmosis with the vitreous fluid and the contents of the blood vessels. Salt injected into the aqueous is absorbed immediately, and that it is harmful is contradicted by the result of injections of salt into the anterior chamber. It has not been proved that senile cataract begins with the shrinkage of the nucleus. Salfner's observations in naphthalene cataract suggest admission of water to the cortical layers as the first symptom, and not shrinkage. My experiments on the surface tension of the aqueous show that in senile cataract the aqueous approximates more to water than in the normal, and that there is not a higher molecular concentration. If this is the case and the lens albumin hygroscopic, it is highly probable that what actually takes place is an imbibition of the aqueous through a depraved nutrition of epithelium from a deficiency in the nutrient elements in the fluid bathing it.

The main objection to Peters' theory is that it leaves out other nutrient substances. Salt is not the only factor amid conditions which are evidently complicated.

Scalinci suggests, as the phaco-proteid is an alkali albumin, that the presence of acetic, formic, oxybutyric acids or their salts in the aqueous may cause cataract by its precipitation! There are other agents than acids which are capable of effecting a chemical change, in the lens, *viz.*, alkali and ferments, and he apparently ignores these.

The fact that senile cataract occurs invariably in both eyes suggests its origin from some dyscrasic or metastatic condition affecting the organism as a whole. This idea has been prevalent from the earliest times, as the therapeutics of cataract show, and although our ideas of the latter have altered with advance in knowledge, the importance of the general condition in the genesis of primary cataract is perhaps to-day more firmly fixed than ever it was.

Becker, whom we have shown considered the cause in the lens alone, indicated that he was not forgetful of the rest of the organism. He says, although we see the cause in the sclerosis of the lens, as every individual does not suffer there must be an exciting cause and, as both eyes are involved, that cause must be general. Graefe gave similar indications, pointing out that as the second eye afforded a more favourable prognosis, the first being invariably less healthy, the cause was to be found partly in the eye itself.

Numerous hypotheses have from time to time been promulgated which attributed the main factor to vascular sclerosis.

von Michel, for instance, saw the cause in sclerosis of the carotid, which is sometimes uni-lateral and sometimes bi-lateral. The want of uniformity in the development of senile cataract in the

two eyes he attributed to this. He reasoned that as metabolism was influenced by blood supply, and that as the circulation of the eye was in direct communication with the area supplied by the carotid, disturbances of circulation in the eye influenced it, and particularly the lens. He suggested other associations than those attributable to the circulation, such as prolonged general disturbance and ill-health, with depraved conditions of the blood. Although atheroma of the carotid has not been found clinically the cause of cataract, even Becker admitted a morbid condition of the blood vessels is of importance, and it is to von Michel's credit that he pointed this out. For years the idea has been current that the kidney was at fault. Fraenkel attempted to clear up the point by testing the penetrability of the kidneys by injections of methylene blue, and he has studied extensively the bearing of arterio-sclerosis, blood pressure and kidney trouble on cataract. The conclusions arrived at were that senile cataract was seldom accompanied by hypertension, and that this latter was always met with where there existed a general affection, which by itself was the cause of it—namely, nephritis and diabetes. Age and sex he found had no influence on hypertension, as was shown by Montier. If it be true, as was suggested by Potain and Huchard, that arterio-sclerosis is always accompanied by a certain degree of hypertension then it can be affirmed that spontaneous cataract does not habitually accompany arterio-sclerosis, and that the latter does not in any way affect its production.

Fraenkel also showed quantitative modifications in the mineral elements of the urine with considerable diminution in urea and increase in chlorides.

Grilli, employing the cryoscope, showed that the osmotic pressure of the urine was much lower in cataract than normal. He concluded that there was diminution of toxicity in the urine, and that cataract occurred in individuals with senile kidney.

Both Fraenkel and Guaripui, after a study of efficiency of the kidney in cataract, concluded that the kidney does not eliminate in the ordinary way toxic products elaborated by the organism, but this inefficiency is unaccompanied by the usual clinical signs of kidney trouble. It is not a typical urinary inefficiency, but an intermediate stage between the normal and one in which the kidney is manifestly diseased. From their work they concluded that *this* state of the kidney had no appreciable effect on the general circulation. Whilst urinary inefficiency is always productive of increased blood pressure, the latter is rarely found in cataract. The diminution in renal permeability inferred by Fraenkel is only detectable by cryoscopic methods. My own examination of cataract in which kidney trouble was present seems to confirm the idea that

there is a definite inefficiency on the part of the kidney in senile cataract, for the following reasons:—

First, that the chemical examination of the lens in senile cataract associated with definite kidney trouble has shown in all the cases I have examined a larger increase in tyrosin, and that the latter is more abundant in such cases than in uncomplicated senile cataract.

Secondly, the marked similarity in the variations from normal between the molecular concentration and surface tension of the aqueous, and similar constants of the urine is so defined that it makes one think that the secretory organ of the eye may have an analogous function to that of the kidney. It would seem that there is no reason to admit the existence of a general or local arterio-sclerosis in any form whatever, either of big vessels or small, as almost without exception senile cataract does not accompany general vascular hypertension. The presence and accumulation of cyto-toxins in the organism is probably a constant physiological phenomenon without detriment to the lens, unless there is inefficient destruction or elimination. It is highly probable that to heredity is to be attributed the predisposition to the accumulation of cyto-toxins of sufficient degree to produce cataract and an inefficiency of the regulating organs of the general economy, such as kidney.

An important point in the treatment of senile cataract, and one which I have realized for some years, is that based on an observation of Brun's—that both bicarbonate and chloride of sodium taken internally result in marked diminution in diuresis of a measured quantity of water, and that the salts are eliminated with difficulty.

If the first stage of cataract is one of imbibition of water, it is well therefore to limit the amount of common salt in the diet.

Schnizler and others have attributed senile cataract to ultra-violet light, but judging from the work of Hess, Widmark, Hertzog and more recently of Burge in America, to which we shall refer again, it is extremely improbable that light alone can produce it. I am certain actinic light affects the lens; but its effect is cumulative over considerable time and not rapid like heat. In a person with a blue and brown eye, cataract always develops in the blue eye, or if both eyes be blue, it occurs in the lighter coloured eye.

Fuchs believes that in the absence of other causes there may be something connected with the lack of pigmentation on the assumption that disturbances of nutrition are at the bottom of both morbid conditions. Interesting is the fact that in the lighter coloured eye evidence of a mild cyclitis in the shape of minute deposits is often forthcoming. The influence of heredity in senile cataract has often been alluded to, and I think there can be no doubt that it plays a part. Cahusac found from a review of the literature from 1720 to 1906 that in 45 families with 400 sufferers from grey cataract the

influence of heredity was marked in 10 per cent. of the cases. What it is we do not know.

The ultimate causes of senile cataract are not yet known, but we can hardly be wrong if we hold responsible for it not a local cause, but that a disturbance of the general condition is a co-operating factor. Physiological and biological factors should not be lost sight of, or given undue prominence, as probably neither alone could produce cataract.

Roemer considered senile cataract a specific metabolic disease, the outcome of a cyto-toxic process occurring in the epithelium and lens fibres. He says that cataract is nothing else than physiological death of the protoplasm, and to say that the life of the cell ends sooner in cataract than in patients without it is not sound reasoning, as in subcapsular cataract those parts of the lens which we might reasonably suppose to be physiologically dead are, through the normal process of the development of the nucleus, just those parts least effected by the cataractous process. The seat of the disease is in the younger cortical fibres. It is probably incorrect, to assume, as has been done, that senile cataract is nothing more than the sign that the pre-determined life of the cells ends sooner in some persons than in others. The occurrence of constitutional cataract in early life, when the cause is certainly not lack of nutriment, makes it probable that it is not the sole cause which renders the lens cataractous, nor is there any undue evidence of marasmus or other sign of faulty nutrition, and the nutrition of old age is often quite enough to suffice for the needs of the lens. If it is due to lack of nutriment from the secretory organ through senile changes we are faced with the fact that there must be many eyes where senile changes are present and yet such have no cataract.

If the albumin of the aqueous in cataract comes from the blood, then the lens may have more than it needs. Lack of nutrition alone does not satisfactorily explain cataract. The lens may remain clear for a long time in oil, and Leber states that it needs additional nutrition only to maintain growth. Accordingly the lens may remain clear when there is a deficiency in nutrient substances, and it is certain that these cannot be definitely absent in old age. Roemer thinks it due to the injurious action of some substance or substances on the lens cells or fibres, and if this is so it is as truly a metabolic disease as diabetic cataract. The nature of these products, and how they originate is at present unknown. In the case of naphthalene cataract no separate product could be demonstrated as responsible for the cataract. The association of vitreous opacity with cataract leads to the assumption that the fluid surrounding the lens is abnormal. What constitutes the abnormality and what the hypothetical substances we do not know. That specific cell poisons for the lens exist is proved by the naphthalene poisoning

of rabbits. I myself have seen one specimen of senile cataract in which the presence of a saponin could be inferred by active haemolysis of the blood, which had smeared the specimen in its removal. Ransome showed that in the case of saponins it was the cholesterin of the blood cells which fixed the poison first. What parts such chemically-defined protoplasmic poisons play with regard to senile cataract is so far unknown, but we know that they exist. The study of haemolysis has shown that there is a large class of haemolysins which combine with certain groups of atoms of the protoplasm. Among them are the haemolysins of *plants, bacteria of the lower animals, glandular secretions* and of *blood serum*. They can be increased by immunization, and are present not only in normal metabolism, but can be manufactured in response to stimulation under certain conditions. Conditions for the development of antibodies are abundantly present in the metamorphosis of the human organism. If we consider changes in the skin, absorption of fat, atrophy of organs, and vascular changes it is not surprising that the products of this regressive metamorphosis are reflected in the composition of the blood. It would appear clear that when once senile involution has begun, regulative devices must intervene to prevent the formation of noxious products of metabolism. If these fail, either in a greater or lesser degree, there may appear among the products such as would injure the lens.

Regressive changes in metabolism and senile cataract are invariably associated, and thus it would appear that senile cataract is a specific metabolic disease. Such a process seems to take place particularly in diabetic cataract. Diabetes is a disease in which there is a great change in intermediary metabolism, and it is possible that both may own their origin to the same substance.

Roemer claims to have shown that the secretory apparatus of the eye keeps back cyto-toxins of the serum from the intra-ocular fluids, and also that only antibodies penetrate the capsule and enter the lens which have a specific affinity for it. Salus considers that Roemer's receptors are lipoids, but Roemer prefers to think otherwise. Ulenhuth has prepared specific anti-sera for the lens albumin; such presuppose specific receptors, but while these have been prepared and used it is only right to say that little success has been achieved, and opinions at variance with Roemer's are current. Roemer's theory is an advanced one, and is a wonderful exposition of reasoning, and I doubt not that more will be heard of it in the future. The papers dealing with this part of our subject at the recent Ophthalmic Congress in America bear out this last statement of mine.

The characters of the different types of senile cataract are fairly well known. In the subcapsular senile variety opacification and disintegration occur in the outermost cortical layers. These give

rise in the first case to the appearance of cracks or fissures, and later on to the dark radial sectors so commonly observed. The changes evidently start by an increased permeability to water. Hess noticed minute roundish vacuoles beneath the anterior capsule in the pupillary area, evidently the indicators of an impaired regulation of water by the capsular epithelium. All histological changes are due to direct disintegration of the fibres. In the nuclear variety the nucleus only is involved, though occasionally it may be associated with cortical opacity. Nothing is known as to its aetiology, but I believe pure nuclear cataract to be an entirely different disease. Nuclear cataract is more commonly seen in high myopia, and it may pass into black cataract, associations that are not without significance and interest. The cataractous lens is generally larger in this class of case where sclerosis is advanced than in uniformly mature cataract. The punctate variety is probably of a different type, too, to either of the above. It may be congenital and occur at any age. The opacities in punctate cataract are finely granular and lie between the normal fibres, and the aetiology at present is unknown. I would suggest that discrete opacities generally occurring at various depths in the lens depend on the critical concentration of the active advancing poison. The lens has been likened to a block of gelatine, and it is known that an electrolyte, such as nitrate of silver penetrating into gelatine, or other colloid containing sodium chloride, is not precipitated uniformly, but in layers. Ostwalt explained this by assuming that precipitation begins only when the critical concentration of the advancing solution is reached, and continues until the solution is brought back to the stable condition. When this has taken place, another development of the labile condition maintains and another stria after an interstriae zone is formed. As the solution becomes more and more dilute, concentration is attained later, and later, so that new striae are separated by interstriae zones of increasing width. Some such process as this, I think, occurs in the development of discrete opacities in the lens.

(To be concluded.)