The influence of changes in the intraocular circulation on the intraocular pressure / by E.E. Henderson and E.H. Starling.

(10.) With the authors' compliments

THE INFLUENCE OF CHANGES IN THE INTRAOCULAR CIRCULATION ON THE INTRAOCULAR PRESSURE.

By E. E. HENDERSON, F.R.C.S., and E. H. STARLING, F.R.S. (Nine Figures in Text.)

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THE INFLUENCE OF CHANGES IN THE INTRAOCULAR CIRCULATION ON THE INTRAOCULAR PRESSURE[1]. By E. E. HENDERSON, F.R.C.S., AND E. H. STARLING, F.R.S. (Nine Figures in Text.)

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In a recent investigation by one of us (E. H. S.), of the factors determining the amount and composition of the intraocular fluid which is constantly being poured out into the eyeball, it was found impossible to arrive at definite conclusions on account of the striking discrepancies which exist between the results of various observers as to the dependence of intraocular pressure on blood-pressure; and we have therefore subjected the question to a fresh examination.

The problem of measuring intraocular pressure is analogous to that of measuring the intracranial pressure. We have a cavity with walls which, under the conditions of the experiment, can be regarded as approximately rigid. In this cavity fluid is being constantly poured out from the ciliary process, and absorbed through the canal of Schlemm at the anterior angle of the eye. Under normal conditions the intraocular tension determines an exact balance between the amount of fluid secreted and the amount absorbed. If we wish to determine this pressure it is evidently necessary that in the determination no fluid shall either enter or leave the eyeball. For this purpose, therefore, it is not sufficient to attach a manometer to the interior of the eyeball. We must use a method similar to that employed by Bayliss and Hill[(1)] in the determination of intracranial pressure, namely, a method in which there is no movement of fluid, but a bubble of air, serving as an indicator, is kept at a given position in the manometric apparatus by opposing a counter-pressure equal to that which obtains in the interior of the eyeball.

The arrangements we made use of are represented in the accompanying diagram (Fig. 1), and consist of a gilt-steel needle which is

[1] Towards the expenses of this research a grant was made by the British Medical Association on the recommendation of the Scientific Grants Committee of the Association.

introduced into the anterior chamber. This needle may be open at the end, or may be closed at the end and be provided with a lateral opening. Connected with the needle is a capillary glass tube with a T-piece,

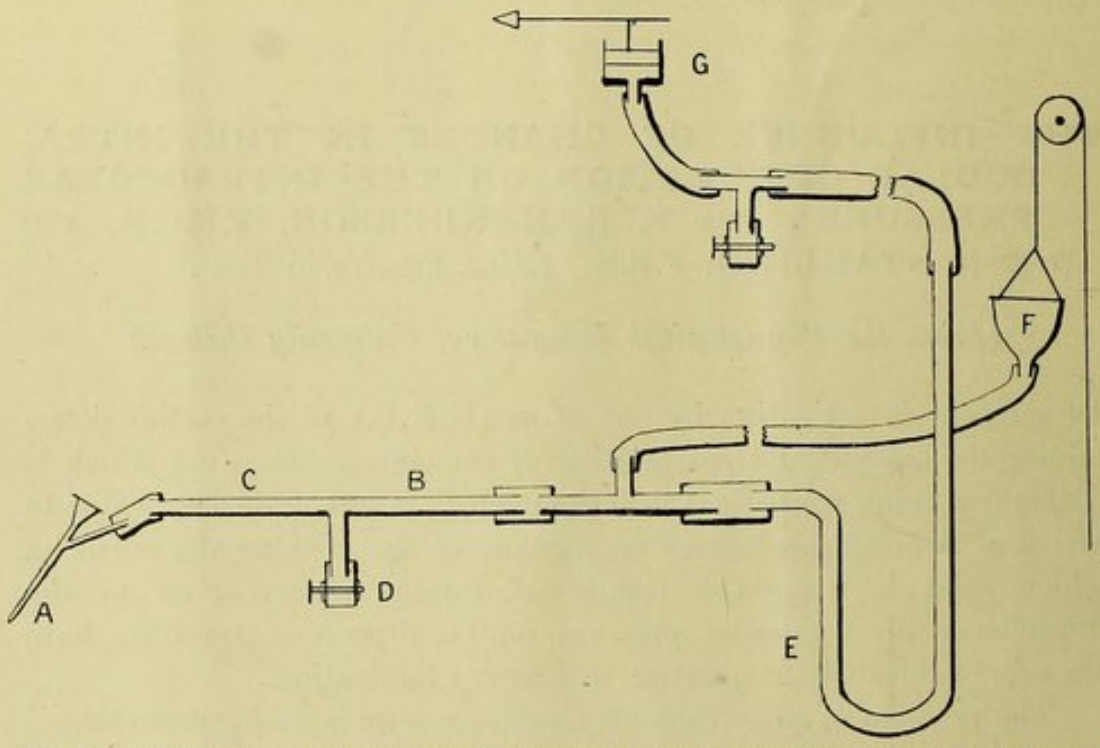

Fig. 1. *A*, intraocular pressure cannula, connected by pressure tubing with *B*, a piece of capillary tubing provided with a T-piece *D*. Through *D* is introduced the air bubble *C*. This serves as an indicator. The other end of the capillary tube is connected by means of a T-piece with the manometer *E* and the pressure bottle *F*. By adjusting the height of *F* to the various intraocular pressures no movement of the air bubble is allowed to take place. *G* is a piston-recorder connected with the top of the manometer.

through which a bubble of air can be introduced into the tube. The capillary tube is connected again by a T-piece with a water manometer, and with a reservoir containing ·9 % of salt solution. In order to record the excursions of the manometer the air space over the column of fluid is connected by a rubber tube to a piston-recorder, and the delicacy of the piston-recorder was adjusted so that an excursion of 1 cm. of its writing point denoted a change of pressure of about 5 cm. of water.

Before introducing the needle into the anterior chamber the pressure in the apparatus was raised to about 25 cm. H_2O, which represents the ordinary intraocular pressure. While the fluid was dropping from the end of the needle it was thrust through the lateral part of the cornea so as to lie in the middle of the anterior chamber, and was supported in this position. A bubble was then introduced into the capillary tube, and the reservoir adjusted as quickly as possible to such a height that

the bubble remained stationary. In this way one could be certain that only a minimum quantity of fluid escaped or entered the eye, and within 5 minutes of initiating the operation the height of the fluid in the manometer represented exactly the normal intraocular pressure. A rise of intraocular pressure was indicated at once by a movement of the bubble outwards, and was met by raising the reservoir until the bubble was brought back to its previous position. In this way there was no movement of fluid into or out of the eye, but there was an accurate representation of the changes in the intraocular pressure recorded on the blackened surface of the drum.

In every experiment a blood-pressure tracing was taken throughout the experiment. In the case of cats it was found most suitable to take this pressure by attaching the lower part of the abdominal aorta to a mercury manometer. In dogs the pressure was taken either in the femoral artery or in the opposite carotid artery to the side on which the eye was being investigated.

The animals used for the experiments were cats and dogs. The cats were anæsthetised with ether, a subcutaneous injection of morphia was given and the trachea opened, and artificial respiration instituted, using air charged with the anæsthetic. When the anæsthesia was constant an injection of curare was given sufficient to paralyse the skeletal muscles. The administration of the anæsthetic was kept up throughout the experiment. Dogs were anæsthetised by a previous injection of morphia followed by the administration of A.C.E. mixture. Here again artificial respiration was induced, using air charged with the anæsthetic, and curare then administered, the administration of the anæsthetic being also continued throughout the experiment.

Effects of mechanical interference with the intraocular circulation.

Most observers have found a general parallelism between the height of the intraocular pressure, however determined, and the height of the general blood-pressure, or at any rate of the pressure in the blood vessels of the eyeball investigated. Thus Adamük[2] found that ligature of the carotid artery on the same side caused a fall of 6 to 8 mm. intraocular pressure. Heine[3] under similar circumstances obtained a fall of only 1 to 2 mm.; von Schulten[4] a fall of 8 to 15 mm. The last-named observer obtained a rise of 20 to 34 mm. as a result of compression of the thoracic aorta, and similar results were obtained by von Hippel and Grünhagen[5]. These workers vary in detail and in accuracy of

observation, but all agree in the main principle that the intraocular tension, in the absence of special local vaso-motor influences, follows the general blood-pressure, and the same result was obtained by Parsons.

The effect of mechanical interference with the circulation can be best judged of by giving a record of a typical experiment on a dog. At the commencement of the experiment a rubber capsule on a metal tube was passed through the left femoral artery so as to lie in the thoracic aorta. The left vertebral and subclavian arteries were tied. Adjustable ligatures were put loosely round the right vertebral and subclavian arteries. The blood-pressure was measured by a cannula in the left carotid artery, and the intraocular pressure was taken in the right eye. At the beginning of the observations the blood-pressure stood at 128 mm. Hg. and the intraocular pressure at 26 mm. Hg. The aortic obturator was then distended. The blood-pressure immediately rose to 158 mm. Hg. and the intraocular pressure to 34, both remaining practically constant at this height for 100 seconds (see Fig. 2, *A*). The aorta being still

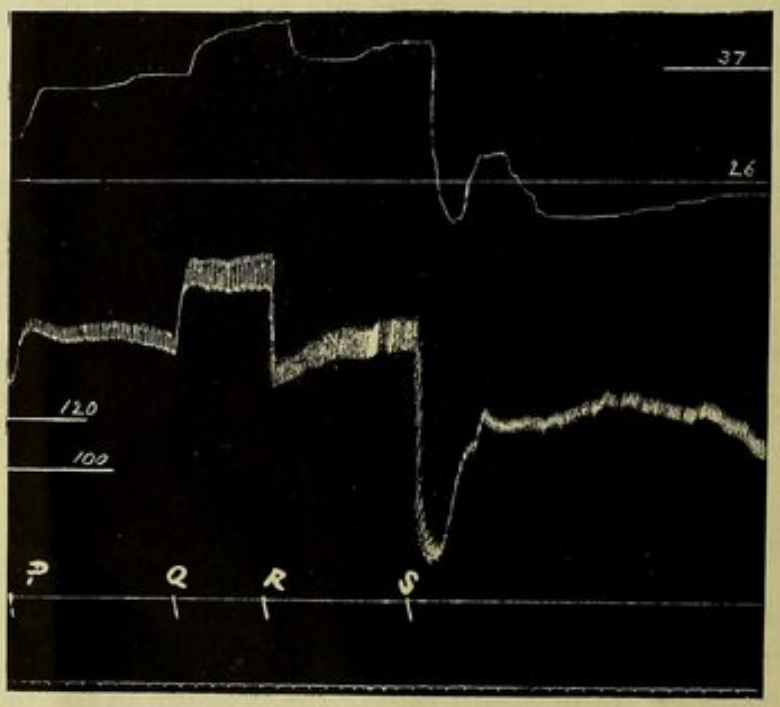

Fig. 2, *A*. To illustrate the effects of mechanical interference with the circulation in a dog. Blood-pressure measured in left carotid, intraocular pressure in right eye. From *P* to *S* the aorta was occluded. From *Q* to *R* the right vertebral and subclavian were also occluded. In this, as in all the tracings, the scale to the right indicates the intraocular pressure reduced to millimetres of mercury. Time marker 10 seconds intervals.

obstructed, the ligatures round the right vertebral and subclavian arteries were drawn tight. The blood-pressure now rose to 180 mm., and the intraocular pressure rose to 40. After another 50 seconds this

ligature was once more loosened. The blood-pressure fell to 170 mm. and the intraocular pressure to 35. After a further interval of 90 seconds the aortic obstruction was relieved. The blood-pressure fell to 70 mm. and the intraocular pressure to 23, the pressures rising in the following 10 seconds to 120 and 29 respectively.

We next proceeded to investigate the effect of closure of the carotid on the same side. In the same animal 10 minutes after the observations just recorded, the arterial pressure was 100 and the intraocular pressure 21. The right carotid was now occluded. The blood-pressure began to rise, the rise being occasioned partly by the mechanical interference with the circulation, partly by the state of asphyxia of the vaso-motor centre produced by obstruction of the chief remaining vessel to the brain. In 3 minutes the arterial pressure reached 160. The intraocular pressure fell at once to 13, and remained practically constant during the whole time the ligature was round the carotid artery. Three minutes later the ligature round the right subclavian and vertebral arteries was pulled tight. These were the last large vessels supplying the vaso-motor centre, and the blood-pressure therefore rose steadily until at the end of 2 minutes it mounted to 190.

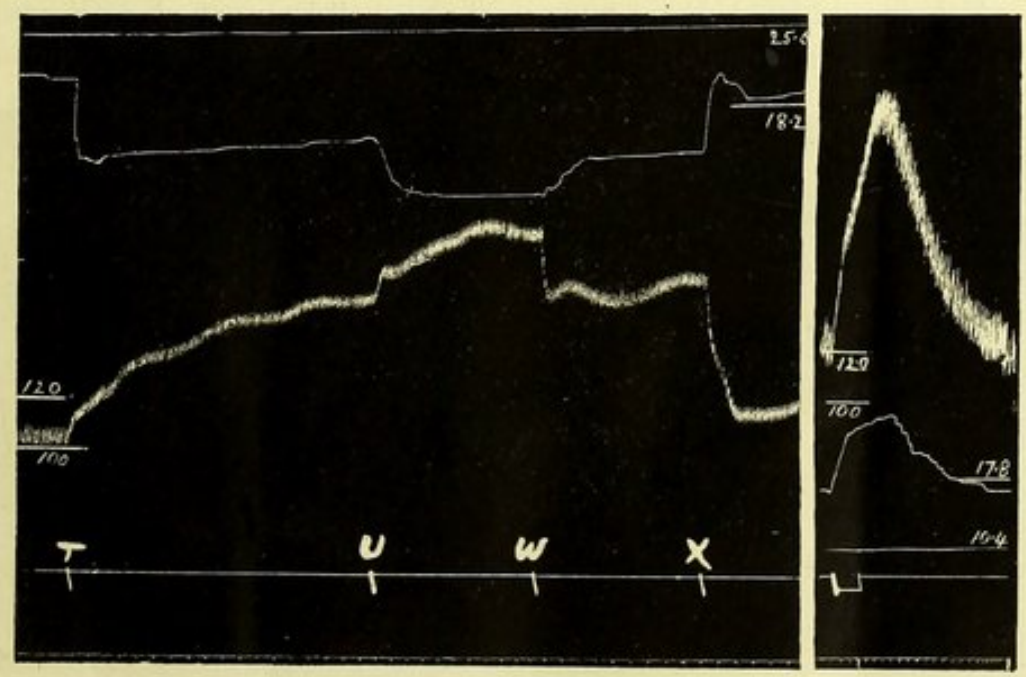

Fig. 2, *B*. Dog. Blood-pressure in left carotid, intraocular pressure in right eye. From *T* to *X* occlusion of right carotid, from *U* to *W* occlusion of right vertebral and subclavian.

Fig. 3. Effect of stimulation of splanchnic nerves in a dog. Blood-pressure measured in femoral artery, intraocular pressure in right eye.

The intraocular pressure fell to 9, showing that the eye had been receiving some blood by collaterals or through the circle of Willis. On relaxing, at the end of 2 minutes, the ligature round the right vertebral and subclavian, the blood-pressure fell to 140, and the intraocular pressure rose to 12. And on finally relaxing the right carotid the blood-pressure fell to 116, and the intraocular rose to 20 (Fig. 2, *B*). The same complete parallelism between the changes in the local blood-pressure and changes in the intraocular pressure is obtained when the changes in blood-pressure are produced not by mechanical means, but by vaso-constriction or dilatation in other portions of the vascular area. Thus, stimulation of the depressor nerve in the cat causes a fall of intraocular pressure. Stimulation of the peripheral end of the divided splanchnic causes a rise of arterial pressure, and a simultaneous rise of intraocular pressure. Thus in the experiment represented in Fig. 3, on stimulation of the splanchnic nerve the blood-pressure rose from 122 to 214; and the intraocular pressure rose from 16 to 24, falling again to its original height as the blood-pressure fell on discontinuing the stimulation.

Effects of asphyxia.

Although as we shall see later on the eyeball is supplied with vaso-constrictor fibres, stimulation of which has a distinct influence on intra-

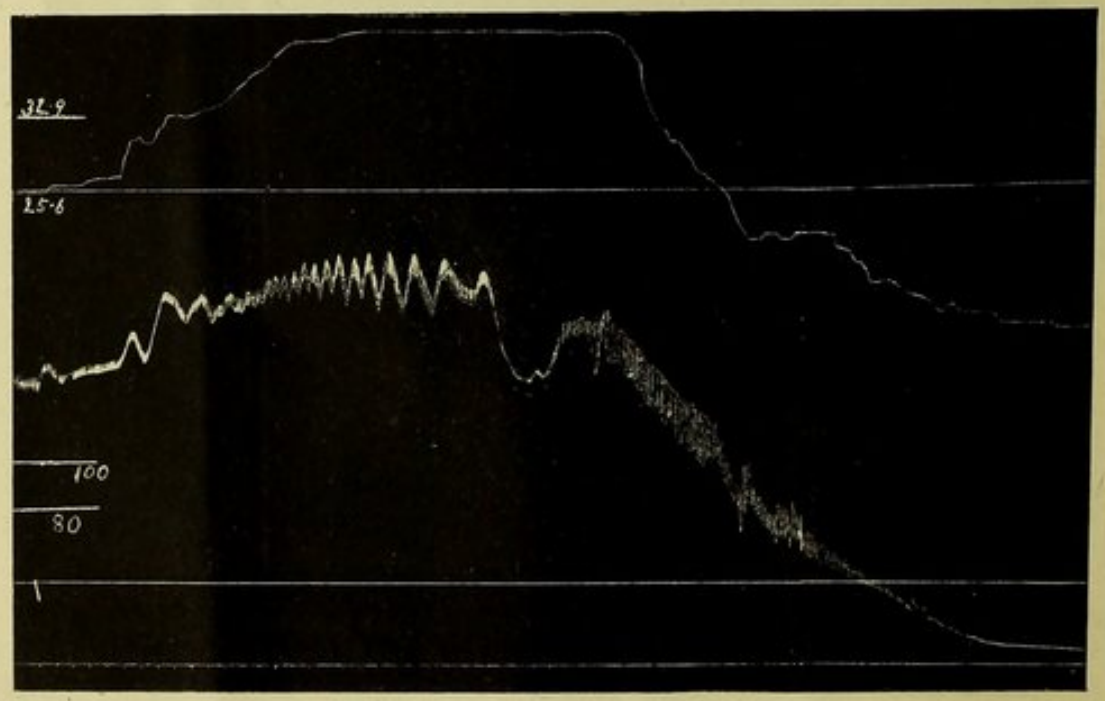

Fig. 4. Asphyxia in a dog. Blood-pressure measured in left carotid, intraocular pressure in right eye.

ocular pressure, the local effects produced by stimulation of these nerves are unable to counteract the passive influence of large changes affecting the whole of the vascular system. We therefore find that in asphyxia, when the connection of the splanchnic area with the vaso-motor centre is intact the intraocular tension follows exactly the course of the general blood-pressure. An example of this behaviour is given in the experiment from which Fig. 4 was taken. At the beginning of the observation the intraocular pressure was 25·6, and the blood-pressure 130. On cessation of artificial respiration the blood-pressure rose steadily to 170, and the intraocular pressure rose to 41. As the heart began to fail the blood-pressure dropped steadily, until it ceased to beat at about 10 mm. Hg. The intraocular pressure followed the curve exactly, falling with the blood-pressure until it became stationary at about 11. It is worth noting that the intraocular pressure is not altered at all by the rise of venous pressure which is known to occur as the heart begins to fail. In this respect our results do not confirm the conclusion arrived at by Parsons[6].

The effects of the sympathetic nerve on the intraocular pressure.

All observers are agreed that the sympathetic conveys vaso-constrictor fibres to the vessels of the eye. This fact can be directly observed both in the retinal vessels and in albino rabbits in the vessels of the iris and ciliary processes. Most observers state that section of the sympathetic produces, if anything, only a temporary effect. Besides this constrictor effect certain observers, namely Poncet[7] and Doyon[8], have observed dilator effects to follow stimulation of the sympathetic in the thorax. It is not stated in these experiments whether the nerve was stimulated in continuity, nor is any record given of the blood-pressure. Our observations on the effects of asphyxia show that a local constriction can be overcome by a rise of blood-pressure due to general vaso-constriction; and therefore, in the absence of a record of the general blood-pressure, it is absurd to judge of the presence of vasodilator fibres in a nerve because the vessels are seen to enlarge on stimulating it. One may in fact get a reflex rise of blood-pressure either through the sensory fibres entering the upper dorsal roots or by the common mixture of vagus fibres with the sympathetic nerve in the neck. In many cases the sympathetic nerve fibres are mixed with depressor fibres. Here stimulation of the peripheral end will produce a fall of general blood-pressure, and an apparent constriction of the vessels in the eye might be passive

in consequence of this general fall. One other effect of the sympathetic nerve on the eyeball must be mentioned as of great importance in relation to the intraocular pressure. The cervical sympathetic, as is well known, supplies motor fibres to the unstriated muscle of the orbit and to the nictitating membrane. Contraction of the orbital muscle will in itself cause a compression of the eyeball and therefore a rise of intraocular pressure. Assuming that the intraocular pressure is dependent on variations of the blood-flow through the eye, it must also be affected by changes in the state of contraction of the orbital muscle, and we shall therefore expect on stimulating the sympathetic to get effects on the intraocular pressure which are the resultant of these two effects, namely,

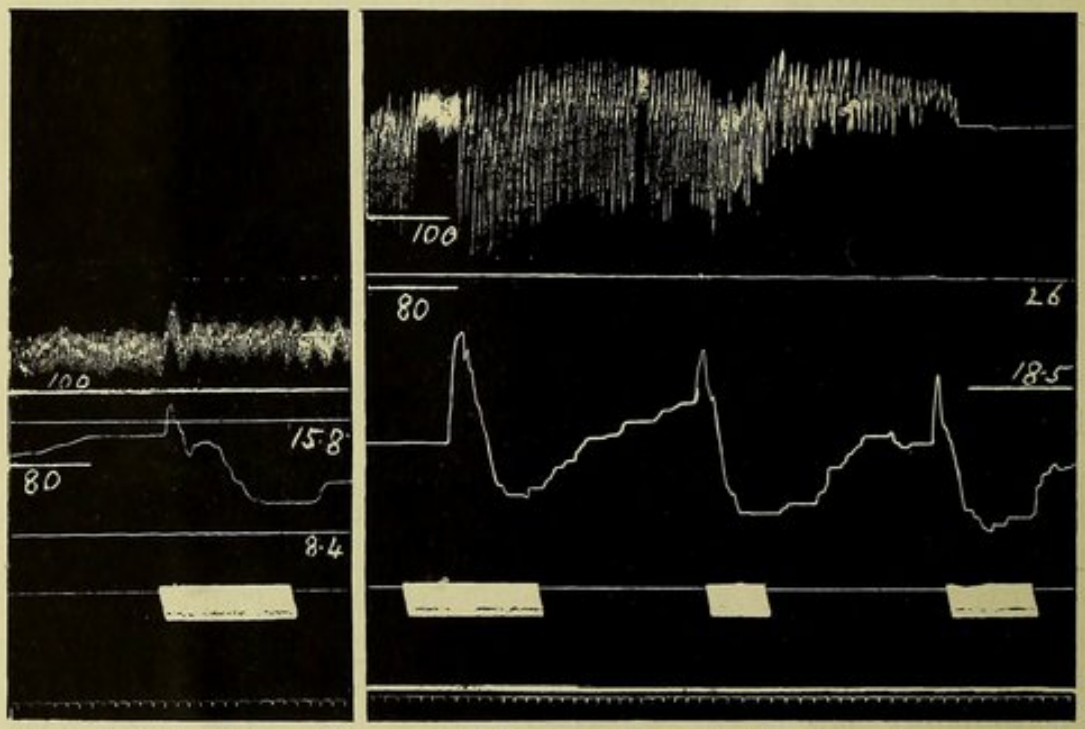

Fig. 5, *A*. Stimulation of the sympathetic nerve in a cat. Blood-pressure measured in aorta, intraocular pressure in right eye. Both vagi have been cut, and the right sympathetic stimulated.

Fig. 5, *B*. Stimulation of the sympathetic nerve in a dog. In this experiment the stimulus was applied to the annulus of Vieussens. It is repeated three times with similar effect.

on the blood vessels and on the orbital muscle. That this is so is shown by the results of one experiment, which may be quoted as a type of many others which were performed. A record of one of these in a cat is given in Fig. 5, *A*. At the commencement the blood-pressure was 110, and the intraocular pressure 13. On stimulating the cervical sympathetic on the same side the blood-pressure rose slightly to 118, and the

intraocular pressure to 16. The latter, however, almost immediately fell gradually to 10 ; and 1 minute after the cessation of the stimulus was still only 11. In another experiment on the dog (Fig. 5, *B*) the blood-pressure was 124, and the intraocular pressure 14. Stimulation of the sympathetic left the blood-pressure unaltered, but raised the intraocular pressure to 21. On attaining this point the intraocular pressure began to fall, and during the next 30 seconds had fallen to 11. Thirty seconds later the stimulus was stopped, the intraocular pressure began to rise, but did not reach its former height for another minute. In these two experiments the initial rise of the intraocular pressure is evidently due to contraction of the orbital muscle, since in each case it is attended by a retraction of the nictitating membrane. The constriction of the blood vessels which occurs as a result of the stimulation comes on more slowly, and causes a diminution in the amount of intraocular fluid which leaves the blood vessels. We therefore get a slow fall of pressure, until it has fallen below the normal height. On stopping stimulation the vessels slowly dilate again, and, with the dilatation, the intraocular pressure returns to normal. That this interpretation is correct is shown by the effect of stimulating the sympathetic immediately after death when all circulation has ceased. Fig. 6 represents a tracing of the intraocular pressure taken from an animal which had been bled to death, so that the vessels were empty. It will be seen that in this case, a dog,

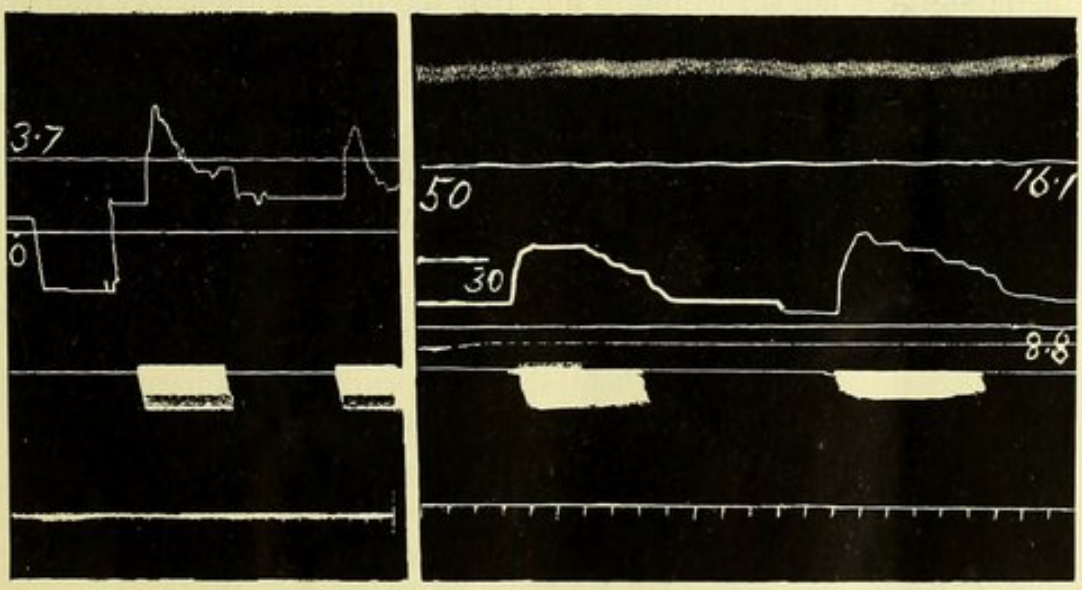

Fig. 6. This is taken from the same animal immediately after it had been bled to death and the blood-pressure had fallen to zero. The stimulus as in the last figure was applied to the annulus of Vieussens.

Fig. 7. Cat. Stimulation of the Gasserian ganglion after section of the root of the fifth.

stimulation of the sympathetic nerve causes a rise of intraocular pressure but no fall, and it was seen that here also the rise of pressure was synchronous with a contraction of the muscle of the nictitating membrane. Similar results to our own were obtained by Bellarminow[9] and by Adamük, though, curiously, the former observer came to the conclusion that the first rise was not due to the orbital muscle because the eyeball as a whole did not move when attached to a Marey's tambour, although Adamük had previously shown that this rise of pressure occurred even after the death of the animal.

Influence of the fifth nerve on the intraocular pressure.

The occurrence of trophic disturbances or of dilatation of the conjunctival vessels after section of the 5th nerve or as a result of irritative lesions of the Gasserian ganglion, has long inclined physiologists to locate in this nerve vasodilator fibres, and a number of experimental results are to be found in the literature of the subject, which are interpreted as showing that this nerve has a marked vasodilator influence on the vessels of the eyeball, or that it is actually a secretory nerve for the intraocular fluid. The action of this nerve, however, is much more difficult to investigate than that of the sympathetic, and it is not surprising to find that the most contradictory results have been obtained by different observers. Thus von Hippel and Grünhagen[5], with the idea of stimulating the 5th nerve, put electrodes into the side of the brain and of the medulla, and sent strong shocks through them. They obtained a rise of intraocular pressure to 200 mm. mercury, and conclude that such a rise could not be due to rise in blood-pressure, and must therefore be due to vasodilator effects in the eye. They do not mention, however, that they took the blood-pressure, and their results are evidently worthless. The exposure of the 5th nerve and its stimulation without spread of current to adjacent structures in the cranial cavity is not effected with ease, and we are therefore inclined to doubt the reliability of the results obtained by Bellarminow[9]. This observer states that he stimulated different portions of the Gasserian ganglion, and obtained different effects according to the part of the ganglion stimulated. Thus, stimulation of the ganglion at the centre caused a quick rise of intraocular pressure to 2 or 3 times its normal height, beginning earlier and reaching its maximum sooner than the simultaneous rise of blood-pressure. Stimulation between the origin

of the first and second branches caused at first a rapid fall, followed by a rise. He does not mention whether the central end of the nerve was divided or how he prevented spread of current, nor do any blood-pressure tracings accompany the paper. Von Schulten[4], who condemns previous experiments on this subject, admits that in his own experiments many were worthless owing to the bleeding and other operative difficulties. He found that division of the 5th produced no considerable effect on the intraocular pressure. He gives a detailed experiment in which a marked rise of pressure took place as a result of stimulating the cut 5th nerve, but does not accompany his paper with any tracing of the blood-pressure. It is therefore impossible to judge whether or not he had any escape of current to adjoining tissues which might cause a simultaneous rise in blood-pressure.

All our successful experiments on the action of the 5th nerve were performed on cats, since this nerve is much more accessible in these animals. Endeavours to expose the Gasserian ganglion in the dog were unsuccessful, owing to the severity of the operation required. In the cat the skin and temporal muscle were turned back from one half of the skull. The skull was opened by means of a trephine, and the skull cap removed between the superior longitudinal and lateral sinuses, the bone being removed as far down as the tentorium behind, and as the zygoma in front. The dura mater was not opened. Plugs of cotton-wool were now packed carefully into the cranial cavity between the dura and the skull, and the animal was left for 5 to 10 minutes. During this time the fluid is gradually squeezed out of the cerebral hemisphere on the operated side, and on now removing the cotton-wool it is possible to retract the brain and expose to view the upper surface of the petrous portion of the temporal bone, with the Gasserian ganglion lying on it beneath a thin layer of dura mater. At this stage bleeding may be troublesome, but may be largely avoided by a temporary ligature round the carotids, which can be drawn on as required. In some cases we managed to obtain a clear view of the ganglion by raising the animal's head, so diminishing the oozing from the venous sinuses which surround the ganglion. The proximal end of the 5th as it entered the ganglion was then hooked up and divided between ganglion and brain. It is easy in this part of the operation to miss some of the fibres, so that the ganglion is left connected to a certain extent with the central nervous system. Such a mishap is at once revealed on stimulating the ganglion, by the reflex rise of blood-pressure that occurs. Needle electrodes were then thrust into the ganglion and

packed into the cranial cavity by means of modelling wax, which held them in position.

The anterior chamber of the eye was then connected with a recording apparatus, and the effect of exciting the Gasserian ganglion noted. In all cases the results obtained were identical. The blood-pressure remained, as was to be expected, unaltered, unless there had been insufficient division of the nerve. The intraocular pressure rose directly the nerve was stimulated, remained constant for a time, and then fell slowly, but remained above the base line during the whole period of stimulation. On ceasing the stimulation the intraocular pressure fell to normal (see Fig. 7). Thus, in one typical experiment the blood-pressure was 60 throughout the observation. The intraocular pressure, which was 10 to commence with, rose immediately on stimulation to 13. Thirty seconds later it began to fall, but did not reach its former level until the stimulus was discontinued 30 seconds later. On observation of the eyeball it was seen that stimulation of the 5th nerve caused retraction of the nictitating membrane and contraction of the orbital muscle, in addition to the well-known dilator effects on the pupil. The question at once arose whether the rise of intraocular pressure observed was to be ascribed to these effects, which are associated with the stimulation of sympathetic fibres passing through the ganglion, or whether, as has been so often imagined, they are due to a direct stimulation of vasodilator fibres, or of secretory fibres running in the 5th nerve itself. To decide this point it was necessary to eliminate any possible action of sympathetic nerve fibres. In three cats, therefore, the superior cervical sympathetic ganglion was excised on one side under antiseptic precautions. The animals were allowed to recover, and were kept alive for 3 to 4 weeks in order to allow time for the sympathetic fibres which run to the Gasserian ganglion from the superior cervical sympathetic ganglion to degenerate. At the end of this time the animals were again anæsthetised, and the 5th nerve divided, provided with electrodes, and the effect of stimulation of the 5th nerve on intraocular pressure recorded in the usual way. Stimulation of the 5th nerve was absolutely without effect on the intraocular pressure. Observation of the eyeball showed that the sympathetic fibres had degenerated, as was proved by the absence of any contraction of the orbital muscle or nictitating membrane, or any movement in the pupil.

We may therefore conclude that the 5th nerve contains no secretory or vasodilator fibres to the eye, at any rate no fibres which can be stimulated by electrical excitation of the Gasserian ganglion. All the

results obtained by previous observers relating to the rise of intraocular pressure following stimulation of the 5th nerve were due either to the stimulation of the sympathetic fibres running in this nerve, and therefore to contraction of the orbital muscle, or to faulty experimentation and the escape of current to adjacent portions of the brain, causing a reflex rise of blood-pressure and consequent passive rise of intraocular pressure. It is interesting to note that the path for the external unstriated muscles of the eyeball is similar to that of the dilator fibres to the pupil, and differs from that for the vaso-constrictor nerves to the vessels of the eyeball. (Compare Fr. Franck[10].)

The action of drugs on intraocular pressure.

We have investigated by the same method the action of two drugs, namely, nicotin and adrenalin, on the intraocular pressure.

As these drugs raise the general blood-pressure and constrict the peripheral arterioles, it is evident that we have to deal with the resultant of these two effects in measuring the intraocular pressure. It is therefore not surprising to find that the actual effect on the intraocular pressure will vary with the individual. Thus the local effect may predominate, neutralize, or be overpowered by the general rise of blood-pressure. Thus Parsons[6] states that the intraocular pressure runs parallel to the general blood-pressure. He however employed much larger doses than we have done.

We have employed for the adrenalin Parke Davis's 0·1% solution in doses of about 0·12 c.c. (2 minims). To ensure the condition of the drug, we have employed the small tubes put up by Martindale. The nicotin we employed was a 2% solution and we have used doses of about 0·06 c.c. (1 minim). The drug was introduced intravenously, the femoral vein being usually selected, and in every case the drug was washed in with a subsequent syringeful of normal saline solution. Cats only were employed and the blood-pressure was measured in the aorta. Four experiments were made on intact animals, three on animals in whom the superior cervical ganglion on one side had been removed immediately prior to the observation, and one on an animal in which this had been done four weeks previously.

Of the first four in two the local effect predominated with both drugs. The blood-pressure rose while the intraocular pressure fell. In one the two effects nearly counterbalanced one another, the rise of blood-pressure being accompanied by a very slight rise of intraocular pressure. In the fourth, the intraocular rise appeared to be entirely passive.

Of the three cats in which the superior cervical ganglion had been removed immediately before the observation, in one a purely passive effect occurred in both eyes. In the remaining two the local effect to adrenalin was extremely well marked (Fig. 8). The blood-pressure at the beginning of the observation was 114, and the intraocular pressure 25. On injecting 2 minims of 0·1% adrenalin the blood-pressure rose to 130, while the intraocular pressure fell to 19. A similar effect was obtained at a later stage of the experiment on the opposite eye, in which the sympathetic system was intact. Nicotin on the contrary showed no local effect on the eye of the side on which the superior cervical sympathetic ganglion had been excised (Fig. 9, *A*). Here immediately before the injection of one 0·06 c.c. of a 2% solution of nicotin, the blood-pressure was 106, while the intraocular pressure was 20. The blood-pressure immediately rose to 154, and the intraocular to 25. In the other eye, however, a similar dose though causing a rise of blood-pressure from 98 to 130 was practically without effect on the intraocular pressure (Fig. 9, *B*.) In the fourth cat, in which

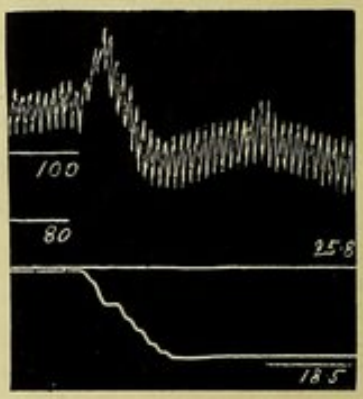

Fig. 8. At the spot marked on the intraocular pressure line, 0·118 c.c. of a 0·1% adrenalin solution was injected into the femoral vein. The superior cervical ganglion had been removed immediately prior to the observation.

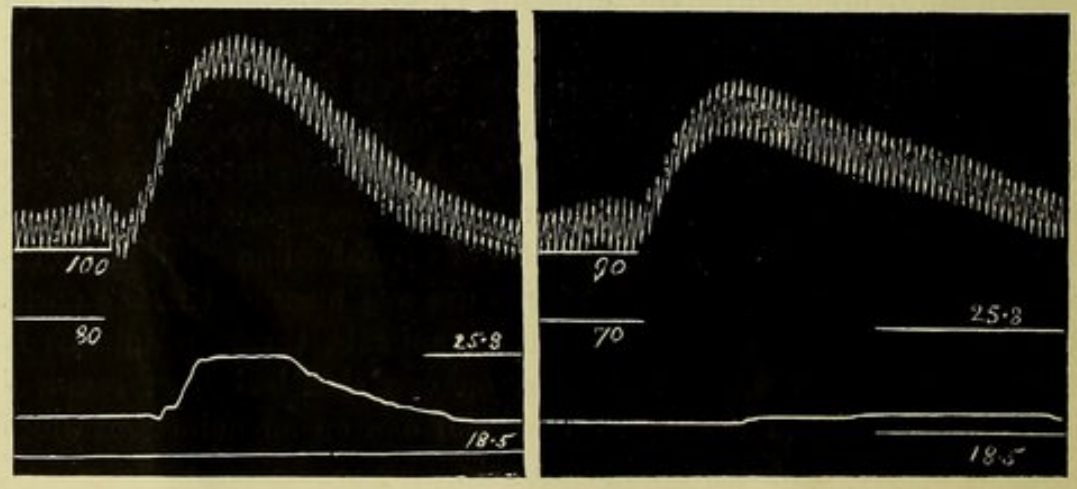

Fig. 9, *A*. The same eye of the same cat as in the last tracing being still used for the measurement of the intraocular pressure, 0·118 c.c. of a 2% solution of nicotin was injected into the femoral vein at the place marked on the intraocular pressure tracing.

Fig. 9, *B*. The opposite eye of the same cat was now employed. On this side the sympathetic was intact. At the place marked on the intraocular pressure curve 0·118 c.c. of the same nicotin solution was again injected, the effect of adrenalin remained exactly as in Fig. 8 and is therefore not reproduced.

time had been allowed for degeneration in the sympathetic to take place, the rise of blood-pressure which in each case followed the administration of the two drugs in question was followed by a purely passive rise of intraocular pressure. As we have already seen this may however occur in an animal in which the sympathetic is intact. It is not therefore permissible to use such experimental data for a foundation for any theory as to the action of adrenalin.

Summary of results.

1. The intraocular pressure is a function of the blood-pressure in the ocular blood vessels, and varies directly as this latter.

2. The intraocular pressure rises and falls with the general arterial blood-pressure, and is not appreciably affected by a certain degree of rise in the pressure in the great veins.

3. Stimulation of the sympathetic (head end) causes a preliminary rise of intraocular pressure, due to contraction of the orbital unstriated muscle, followed by a slow fall of pressure occasioned by contraction of the intraocular blood vessels.

4. Stimulation of the peripheral end of the divided fifth nerve root causes a rise of pressure due to contraction of the orbital unstriated muscle. This effect is absent if the fibres coming to the Gasserian ganglion from the sympathetic nerve degenerated in consequence of preliminary extirpation of the superior cervical ganglion.

5. There is no evidence of vasodilator fibres to the eyeball either in the fifth or cervical sympathetic nerves. Previous statements to the reverse effect are based on imperfect experimentation.

6. The effects of adrenalin and nicotin on the eye vary according as the local or general effect on the blood vessels preponderate.

BIBLIOGRAPHY.

(1) Bayliss and Hill. This Journal, xviii. p. 334. 1895.
(2) Adamük. Centralbl. f. d. med. Wissensch. xxxvi. 1886.
(3) Heine. Klin. Monatsbl. f. Augenheilk. xl. p. 25. 1902.
(4) v. Schulten, v. Graefe's Arch. f. Ophth. xxx. p. 3. 1884.
(5) v. Hippel and Grünhagen. Arch. f. Ophth. xiv. p. 3, and xv. p. 1. 1868 and 1869.
(6) Parsons. The Ocular Circulation, Lond. 1903.
(7) Poncet. Bullet. de la Soc. de Biol., Apr. 2, 1881.
(8) Doyon. Arch. de Phys. norm. et path. ii. p. 774, and iii. p. 134. 1890 and 1891.
(9) Bellarminow. Pflüger's Arch. xxxix. p. 449. 1886.
(10) Franck, Fr. Compt. Rend. lxxxvii. p. 175. 1878.