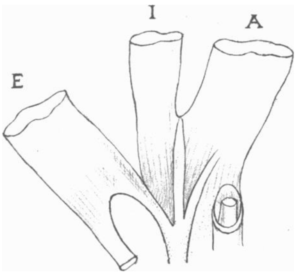


Fig. 1.

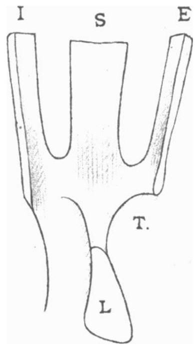


Fig. 2.

Fig. 3.

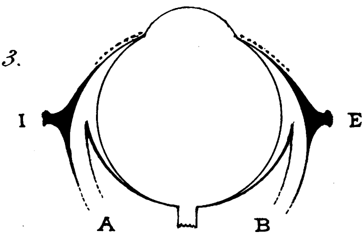


Fig. 4.

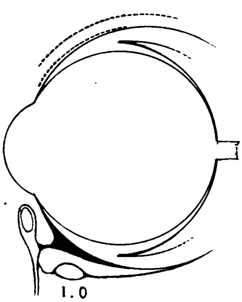
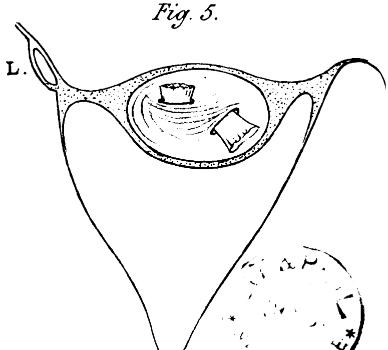


Fig. 5.



Journal of Anatomy and Physiology.

THE ANATOMY OF THE MUSCLES, LIGAMENTS, AND FASCIÆ OF THE ORBIT, INCLUDING AN ACCOUNT OF THE CAPSULE OF TENON, THE CHECK LIGAMENTS OF THE RECTI, AND OF THE SUSPENSORY LIGAMENT OF THE EYE. By C. B LOCKWOOD. (PLATE I.)

THE surgical and physiological importance which belongs to the anatomy of the orbit is so considerable, that anatomists of acknowledged repute have devoted themselves to its investigation. Hardly any fact of importance has escaped the attention of at least one observer; and any addition to the literature of the subject might seem needless, were it not that the greatest difference of opinion prevails upon many interesting points. The writer is not so presumptuous as to think that his decisions will be accepted where eminent men have disagreed, but it may be deemed of service if the various statements are collated, and, where necessary, amplified and explained.

Posterior Attachments of the Muscles of the Eye.—At the beginning of the present century Tenon wrote that the labours of Zinn, Sabatier, and Portal left nothing to be said concerning the posterior attachments of the muscles of the eye.[1] The first-mentioned author, Zinn,[2] described "a ligament common to the inferior, internal, and external recti," but the accounts of this

[1] *Memoire et Observations sur l'Anatomie, la Pathologie et la Chirurgie*, Paris, 1806, p. 195.

[2] *Descriptio Anatomica Oculi Humani*, Goettingæ, 1780, p. 148. Paragraph, "De ligamento communi unde oriuntur musculi adducens, deprimens et abducentis caput alterum."

structure given in English text-books,[1] are not free from ambiguity and often lead to misapprehension. The source of error seems to be in the word "ligament," which Zinn applied to his discovery; but he afterwards speaks of it as "tendinem verum splendentem," clearly implying its tendinous appearance. M. Sappey[2] always calls it the tendon of Zinn, and writes of it as follows:—"A fibrous cord which is attached to a very small fossa situated beneath and external to the optic foramen. This cord speedily divides into three slips—a middle, which goes to the inferior rectus; an inner, to the internal rectus; and an external, to the external rectus. Of these three bands the middle is the largest." It may be added that the fasciculus, which belongs to the external rectus, is prolonged up the posterior border of the muscle, and ends by blending with the origin of the superior rectus. The accompanying diagram, made from a dissection, may serve to give an idea of this structure (Plate I. fig. 1). The preparation from which it was taken was made in the following way:—The roof of the orbit was freely removed, so as to include the lesser wing of the sphenoid and the upper part of the optic foramen. The muscles having been exposed and cleaned, the levator palpebræ was divided from its posterior attachments and turned forwards. Next, the superior rectus and superior head of the external rectus were cut from their "apparent" origin, from the sheath of the optic nerve, and turned outwards. By this means the sheath of the optic nerve was exposed, divided in the optic foramen, and, together with its contents, removed. A little loose cellular tissue having been taken away, the part delineated was laid bare. It will be seen that the figure does not quite conform to M. Sappey's description, but, as is not infrequently the case, there is a slight departure from the normal.

A little reflection shows that the origins of the ocular muscles have not been studied from quite the same point of view. For instance, the group which comprises the inferior rectus, the lower part of the internal rectus, and the inferior head of the external rectus, has invariably been described with special reference to

[1] Quain's *Anatomy*, 9th ed., 1882, p. 281; also Gray's *Anatomy*, 10th ed., 1883, p. 212.

[2] *Traité d'Anatomie Descriptive*, Paris, 1876, p. 101 *seq.*

their inner surface, *i.e.*, that which is next the optic nerve; whilst the upper group, that which comprises the superior rectus, the upper part of the internal rectus, and superior head of the external rectus, has always been described with special reference to their external or orbital aspect.[1]

Each anatomist seems to have omitted to inspect the ocular or underneath surface of the upper group of muscles, although they all describe that part of the lower. This omission was repaired in the following manner:—

Orbits were taken intact from skulls which had been frozen as Dr Garson directs,[2] and horizontal sections were made through about the centre of the cornea and the centre of the optic foramen. The upper part of the orbit and its contents were then dissected in the usual manner. The optic nerve and its sheath together with loose connective tissue having been removed, it became evident that the under surface of the superior rectus possessed a tendon very similar to that of the inferior rectus. The structure is fastened to the upper and outer margin of the optic foramen. Anteriorly it is aponeurotic, and gives attachment to the superior rectus, the upper part of the internal rectus, and the superior head of the external rectus. The fasciculus, which belongs to the latter muscle, passes down its posterior border, and is continuous with the slip which this muscle receives from the tendon of Zinn. It will be seen from the diagram (Plate I. fig. 2), which I have made from a preparation, that the structure in question bears a strong resemblance to the tendon of Zinn; but, so far as I can ascertain, no observer has mentioned it.[3]

[1] The writings of Zinn (p. 148), Portal (*Cours d'Anatomie Médicale*, Paris, 1803, tome ii., p. 62), and Sabatier (*Traité Complet d'Anatomie*, Paris, 1791, tome ii., p. 82) shows this to be the case so far as they are concerned. The modern authors Henle (*Handbuch der Eingweidelehre des Menschen*, Braunschweig, 1873, p. 713), Hyrtl (*Handbuch der Topographischen Anatomie*, Wein, 1882, Erster band, p. 223), Cruveilhier (*Traité d'Anatomie Descriptive*, Paris, 1874, tome ii., p. 622 *seq.*), Sappey (p. 97 *seq.*), Quain (p. 281), and Gray (p. 212), have with little exception followed in the footsteps of their predecessors.

[2] *Human Morphology*, Reeves, London, 1st ed., i. 79.

[3] Merkel (Graefe und Saemisch, *Handbuch der Gesammten Augenheilkunde*, Erster band, Leipzig, 1874, p. 52), who undertook, he says, an original investigation of these origins, mentions tendinous fibres other than the ligament of Zinn, but it does not seem, from his account, that they are at all identical with the common tendon which has just been described and figured.

The conclusion arrived at, after studying the origins of the recti from every aspect, is that their orbital surfaces look fibrous, and seem intimately blended with the sheath of the optic nerve and the fibrous tissue which surrounds the optic foramen; examined from their inner ocular aspect, they look tendinous, and may be said to arise by a superior and inferior common tendon.

The Capsule of Tenon.—Since the way in which the capsule of Tenon is dissected has an important bearing upon the result, those which have usually been adopted will be mentioned. Tenon says—

"Saw off the skull-cap, following a line which passes immediately above the roof of the orbit; take away the posterior part of the skull as far forward as the optic foramen; separate the right from the left half of the face by a saw-cut passing through the nose; next, with a very fine saw, such as clockmakers use, saw the roof of the orbit from the internal angle to the optic foramen, and from the external angle to the same aperture; when this has been done, raise the portion of the bone, which is triangular, with its apex at the optic foramen, turn this fragment of bone over the upper eyelid without detaching the latter, then detach each of the muscles from around the optic foramen and optic nerve, raise their posterior extremities and dissect them with care from behind forwards; soon you will recognise the capsule in question."

Ferrall[1] says—"Divide the palpebræ vertically, and, turning the separate portions backwards towards the forehead and cheek respectively, fix them in their position by hooks; the conjunctiva is next divided at its angle of reflection, where it passes from the internal surface of the eyelid to the ball of the eye. . . . ." After commenting upon the inaccuracies of the previous descriptions of Zinn, Sœmmering, and Lawrence, he proceeds—"Having, however, separated the divided conjunctiva, we expose, not as has been described by anatomists, a cushion of adipose tissue but a distinct tunic of a yellowish-white colour and fibrous consistence, continuous in front with the posterior margin of the tarsal cartilage, and extending backwards to the bottom or apex of the orbit (?) where its consistence becomes less strongly marked. By proceeding in the manner I have mentioned, the parts are displayed without any elaborate dissection. The sharp end of the probe or director will be sufficient to separate the ball of the eye from the new organ, by probing gently the fine cellular tissue which connects them." Bonnet[2] adopts almost exactly the same method; but it will afterwards be seen that he did not obtain quite the same results. It may be stated at once that the dissections of Tenon, Ferrall, and Bonnet have been carried out by the writer, and

[1] *Dublin Journal of Med. Science*, 1841, p. 336.

[2] *Sections Tendineuses et Musculaires*, Paris et Lyons, 1841, p. 8.

serve to confirm, in a great measure, what they have stated. In addition, frozen sections of the orbit have been freely used. It seems quite unnecessary to dwell upon the advantages of this method. It greatly facilitates a very difficult dissection, and enables everything to be seen in its proper relation. The preparations were made in the manner described by Dr Garson. Entire heads were frozen and the orbits removed from them intact by appropriate saw-cuts. Vertical and horizontal sections were afterwards made, the parts being of course still firmly frozen. Any additional steps required to display the various structures will be indicated when they are treated in detail.

The Capsule of Tenon and Insertions of the Ocular Muscles.— The insertions of the ocular muscles are so intimately related to the aponeurosis which surrounds the sclerotic that it will be best to consider these insertions and the aponeurosis together. In studying the capsule of Tenon it is convenient to examine its exterior first. When the orbit is dissected in the customary manner, the membrane may be distinguished by its yellowish colour and closely matted appearance. When the levator palpebræ has been divided, the structure in question is quite easily separated from the orbital fat. When this has been done, three parts will be found to demand attention :—(1) A central part which surrounds the globe; (2) the prolongations which this sends along the muscles of the eye; and (3) its connections with the walls of the orbit[1] (Plate I. fig. 3).

Exterior of the Central Portion of the Capsule of Tenon.— Assuming that the orbit has not been treated with alcohol or any hardening solution, the central part of the capsule of Tenon may easily be seized and dragged from the sclerotic. From this it might be inferred that it is merely a loose and thin covering; but as only the upper and back portion can be approached in this way such a conclusion is hardly warranted. When vertical and horizontal sections are viewed, much more comprehensive ideas may be formed (Plate I. figs. 3 and 4). It is then perceived to be a fibrous capsule[2] which surrounds the globe from the ciliary margin of the cornea backwards to the entrance of the optic nerve; its anterior third is intimately related to the back of the ocular conjunctiva; its middle third sends prolongations to the muscles of the eye; its posterior third is in contact with and

[1] *Vide* Sappey, p. 105.

[2] Its strength and appearance were accurately indicated by Ferrall when he called it the "tunica vaginalis oculi."

loosely adherent to the orbital fat.[1] In addition, it is attached, in a manner which will be indicated, to the inner and outer sides of the orbit. Its thickness is not the same in every part, for it is strengthened by various fibrous bands, which require special description, but it is easy to see that it becomes thinner posteriorly, and is continuous with the sheath of the optic nerve, both structures being fastened to the sclerotic. The capsule is adherent for about the space of a quarter of an inch around the margin of the lamina cribrosa. The anterior attachments of the capsule of Tenon are more complicated, and cannot be dismissed so briefly. They have been variously described,[2] because a clear distinction has not been drawn between the ocular portion of the capsule and the underneath part of the sheath of the levator palpebræ muscle (Plate I. fig. 4).

The anterior third of the ocular portion of the capsule of Tenon blends intimately with the ocular conjunctiva, and together with it is fastened to the ciliary region of the sclerotic (Plate I. figs. 3 and 4). The thin membrane which the union of the conjunctiva and capsule forms may easily be separated to within an eighth of an inch of the margin of the cornea, but any further endeavour entails laceration. In order to avoid misconception, perhaps a further account of the anterior attachment may be permitted. In vertical sections of the orbit the ocular part of the capsule of Tenon seems to blend with the upper and lower fornix of the conjunctiva. Very slight manipulation is required to make it divide at this point—half going, with the conjunctiva, to the sclerotic; half, with that membrane, to the tarsal cartilages. That this manner of dissection, however, is somewhat artificial, is shown by examining horizontal sections. There is no fornix conjunctivæ in these, and the capsule simply blends with the mucous membrane to pass to its insertion on the globe (Plate I. fig. 3). Together with the capsule of Tenon the ocular conjunctiva constitutes a thin layer, separable, except near the margin of the cornea, with the greatest ease from the sclerotic and tendons of the subjacent muscles; but it is practically impossible to divide the ocular conjunctiva near the cornea without opening the interior of the capsule.

1 Sappey, p. 106.

2 Bonnet, p. 16; also Lenoir, "*Des Operations qui se pratiquent sur les muscles de l'oiel*, Paris, 1850, p. 10.

The capsule of Tenon was discovered about 1803, and frequent reference will be made to the singularly clear account contained in Tenon's *Memoire* (p. 193). It was forgotten for many years, and Hyrtl (p. 227) says that Malgaigne has the credit of having again brought it into notice. (For Malgaigne's account see his *Traité d'Anatomie Chirurgicale*, i. p. 692.) This author named it the orbital aponeurosis. Next, Bonnet wrote an elaborate description of it, and pointed out its great surgical importance (*Sections Tendineuses et Musculaire*, Paris et Lyons, 1841, p. 8). The labours of this observer have been held in such esteem that the aponeurosis is not infrequently called, after his name, "The capsule of Bonnet."[1] In the remainder of this paper the expression "capsule of Tenon" will be applied to the whole of the capsule. As far as can be ascertained, English anatomists do not appear to have paid minute attention to this subject. In 1841 a very excellent account was published by J. M. Ferrall in the *Dublin Journal of Medical Science*, 1841, p. 336. This surgeon was evidently unaware of Tenon's discoveries. The name "tunica vaginalis oculi" which he gave it seems very appropriate. Mackenzie (*The Cure of Strabismus by Surgical Operation*, London, 1841, p. 11) briefly described the capsule, quoting the accounts of previous writers. With the exception of Ferrall and Bonnet, none of the authorities who have been mentioned made any notable addition to Tenon's original discoveries.

The Muscular Prolongations of the Capsule of Tenon and Check Ligaments of the Internal and External Recti.—Six muscles receive prolongations or sheaths from the capsule of Tenon—the four recti, the superior and inferior oblique. These prolongations spring from the middle third of the capsule, and pass backwards along the recti as far as their middle, where they blend insensibly with their perimysium. The sheath for the superior oblique surrounds its reflected tendon as far as the pulley, and is there attached. The prolongation to the inferior oblique descends upon the muscle as far as the floor of orbit, where it ends. When the inferior oblique is dissected from the front its sheath is about a quarter of an inch long, and at its origin from the capsule of Tenon is yellowish and opaque, but gradually becoming thinner; at last it ends in an exceedingly delicate transparent membrane, which surrounds the rest of the muscle as far as its origin from the superior maxilla. This delicate

[1] Soelberg Wells (*Diseases of the Eye*, London, 1859, p. 587), speaking of this structure, says—"The posterior portion of the sheath, up to the passage of the tendons, has been called the capsule of Bonnet, the anterior portion, from the passage of the tendons to its insertion into the sclerotic, having been designated the capsule of Tenon."

transparent sheath is occasionally attached to the wall of the lachrymal sac.[1]

So far the anatomy of the muscular sheaths is easily ascertained and does not admit of much controversy. But, concerning the connections between the sheaths and the muscles they embrace, and between the sheaths and neighbouring parts, great divergence of opinion prevails. I will, therefore, consider their connections *seriatim*, beginning with the external and internal recti.

If the orbit is dissected in the usual way, or if one of the horizontal frozen sections be examined, it is easy to ascertain that, where the internal and external recti pass between the eye and the orbit, they are, in some way or another, attached to both.

The tendons of the muscles lie within the capsule of Tenon, and may be left for future consideration. The structures which connect the inner and outer recti to the malar and lachrymal bones are usually called the "internal and external check ligaments." The reason for this designation will be found in what follows. Of these check ligaments that which belongs to the external rectus is the strongest and easiest to dissect, and will be dealt with first.

It is a wedge-shaped structure about half an inch in length, and as wide as the muscle to which it belongs. The base of the wedge is fastened by a vertical attachment to the malar bone and suspensory ligament of the eye (p. 18); the apex is continuous with the sheath which the external rectus receives from the capsule of Tenon and with the muscle itself, the point of union being situated just behind the place where the muscle becomes tendinous.

Numerous muscular and tendinous fibres pass from the rectus externus into its check ligament, so that the part of the ligament in proximity to the muscle has a distinctly muscular and tendinous appearance, but near its bony insertion this is lost, and it looks yellow and matted. In dissecting-room specimens the muscular prolongations to the ligaments are sometimes hard to

[1] Merkel (p. 58) denies that the sheath of the inferior oblique reaches the floor of the orbit. Sappey (p. 108) mentions the attachment to the bone, and also that to the lachrymal sac.

see, but I have never failed to find them in frozen sections. The check ligaments of the internal rectus differs in no important particular from that which has just been described; it is somewhat smaller and thinner, and is attached to the lachrymal ridge[1] and suspensory ligament of the eye.

In conjunction with Dr V. D. Harris I have examined the microscopic structure of these ligaments. When portions of them were treated with acetic acid nothing but fine elastic fibres could be seen. Fearing lest this might not be deemed sufficient, they were hardened in alcohol and stained in logwood. It was again clear that fine elastic tissue constituted by far their greatest part, not however the whole, for it is to be remembered that they have been stated to contain prolongations of the muscles. Although the preponderance of elastic fibres in them was exceedingly great, nuclei were seen which strongly resembled those of unstriped muscle, but these were too few to permit any confident assertion being made concerning them. The observation that these ligaments are made of elastic fibres lends great significance to Lenoir's remark that "the insertions are by accessory tendons, perhaps even elastic," and to an observation of Tenon's already quoted, in which he says, "they are singularly supple and elastic."

Functions of the Ligaments which connect the Internal and External Recti to the Walls of the Orbit anteriorly.—At least two functions have been attributed to the elastic check ligaments. They have been said by Tenon (p. 197) to alter the direction of the muscles, and prevent them, when in action, from pressing on the globe. They have also been stated to act as check ligaments to limit the retraction of the recti, and prevent them rotating the eye too much.[2] I think that a rigorous examination of the anatomical conditions upon which the first theory rests will lead to its rejection. Doubt has been cast upon it by Cruveilhier (p. 628), but he adduces no reasons for his opinion, so that, although the pressure theory has met with general acceptance, I would urge the following arguments against it:—The internal and external recti diverge from their origin until they reach the equator of the eye, and then, applying themselves to the sclerotic, converge to gain their insertions.

[1] Sappey, p. 108; also Henle, p. 719, fig. 556. [2] Merkel, p. 59.

Each muscle, when it contracts, rotates the globe upon an axis drawn perpendicularly through its centre, but before it can produce this movement it must overcome, at least, the tonic resistance of its antagonist, *i.e.*, the other rectus. Obviously the force which is required to do this must be transmitted through the globe. In other words, each rectus presses upon the equator of the eye with a pressure equal to the tonic resistance of its antagonist. If this is true, it is clear that the mechanical arrangement which actually exists is such that, in the absence of any pressure-preventing apparatus, the eye must to a certain extent be squeezed whenever the recti contract. It need not be repeated that in the elastic ligaments a pressure-preventing apparatus has been recognised. The examination of horizontal frozen sections will show whether they conform to the required conditions. Taking origin from the wall of the orbit almost exactly opposite the equator of the globe, they run backwards nearly half an inch, and then become continuous with the muscles; this union is far behind the place where the latter begin to be in contact with the eye—indeed it is where they are still diverging to reach it; so that it renders the ligaments quite inefficacious for preventing pressure upon any part of the globe (Plate I. fig. 3).

If it is right to assume that the pressure of the muscles would be injurious to the eye, and that, in default of any restraining mechanism, the equator would bear the brunt, we may infer the place at which the required apparatus should be found. When the interior of the capsule of Tenon is described, it will be seen that such ligaments exist.

The statement that the elastic ligaments are of service to check the action of the recti is founded upon much better evidence than the theory which has just been discussed. If the muscles and ligaments be exposed in a fresh orbit, traction exerted upon the muscles makes the ligaments tense. Merkel (p. 59) points out that when they have been divided an excessive rotation of the eye is permitted. It therefore seems appropriate to call them the "internal and external check ligaments," understanding that they check the contraction of the muscles but do not prevent them pressing upon the globe.

It is convenient, before proceeding further, to mention that all the muscles of the eye are united by connective tissue and by muscular and tendinous fibres to the sheaths which they receive from the capsule of Tenon. The former attachment always exists, but the latter, although it is never absent when frozen sections are examined, may appear very scanty. As regards the object of these insertions of the muscles into the capsule of Tenon, they have been ingeniously compared to such muscles as the sub-crureus, sub-anconeus, &c.[1]

Great difference of opinion prevails as to the nature of the anterior attachments of the recti to the walls of the orbit. Tenon remarks that they were known to Zinn, and says they are in part prolongations of the muscles themselves; he calls them "faisceaux tendineux" because of their mixed appearance. Bonnet (p. 23) and Lenoir (p. 10) agree with Tenon, but Malgaigne (p. 703) denies their tendinous characters, and speaks of them as "pretendues tendons"; he also remarks that most French writers, including Tenon, failed to understand them. Sappey (p. 103), speaking more particularly of that which is external, says—"It is continuous at its point of origin with the fibrous sheath of the muscle, and never with the latter, as Tenon thought, and after him a great many authors." This writer proceeds to say they are neither tendons nor ligaments, but unstriped muscles, and names them the external and internal orbital muscles. That the check ligaments receive prolongations from the muscles into which they are inserted has been noted by many authors. Cruveilhier (p. 626) mentions the fact, but does not consider the presence of prolongation so constant as I have stated to be the case. Such an opinion might be formed if the muscles were dissected in the usual way, but frozen sections show that muscular prolongations are the rule. Lenoir (p. 13) also says that "the sheaths of the muscles adhere to them by a dense tissue in which are sometimes found tendinous and muscular bands." Henle makes similar statements, and depicts the tendinous prolongations (fig. 556, p. 719, and fig. 557, p. 721). As far as their structure is concerned, nearly all authorities, except Sappey, agree in calling them ligaments, implying, it may be supposed, that fibrous tissue enters largely into their composition. If it could be substantiated that the check ligaments contained unstriped muscle, and a sufficient quantity of it to pull forwards the recti, and with them the capsule of Tenon, important pathological problems would be solved.

Relations of the Superior Rectus to the Capsule of Tenon and Levator Palpebræ.—The prolongation which the capsule of Tenon sends backwards along the superior rectus differs in no important particular from those already described, but, of course, check ligaments like those of the inner and outer recti are wanting. Almost all authors are agreed that the superior rectus

[1] Merkel, p. 58.

is connected both to the superior tarsal cartilage and to the levator palpebræ, which is in contact with its upper surface, but they differ as to the manner in which it occurs. For instance, Lenoir (p. 10) says that the superior rectus is actually united by muscular and tendinous fibres to the superior tarsal cartilage and levator palpebræ, whilst Cruveilhier (pp. 624 and 614) and Bonnet (p. 26) affirm that the rectus is fastened to them by means of its sheath. This slight difference of opinion is easily explicable, and seems to be due to the fact that these anatomists have ignored the existence of a sheath which surrounds the front part of the levator palpebræ.[1]

In order to show how this omission could cause a difference of opinion, I will endeavour to describe the investment of the levator palpebræ, but it cannot be properly appreciated without a preliminary allusion to the anatomy of the muscle. The levator palpebræ is more or less like an isosceles triangle, the apex of which is behind at its origin, and the other angles in front, where they are attached to the rim of the orbit just behind the internal and external tarsal ligaments, with which they are continuous. The sides of the triangle are concave; the inner winds round in contact with the sheath of the tendon of the superior oblique, the outer touches the capsule of the lachrymal gland; the base of the triangle, which is in front, is attached to the upper tarsal cartilage. Owing to its structure and appearance the anterior third of the muscle is called the palpebral aponeurosis. The sheath of the levator palpebræ invests the belly of the muscle for at least half an inch before it, the levator, becomes aponeurotic, and there is no difficulty in demonstrating all its connections either upon frozen sections or by dissecting the orbit from in front. If the latter method be adopted, the roof of the cavity having been taken away, the upper eyelid should be removed layer by layer. Under the tarsal ligament a little yellow fat is found, and, beneath it, the levator palpebræ enclosed in a fairly thick investment of connective tissue. This sheath blends with the perimysium behind, and in front is strongly adherent to the palpebræ aponeurosis; its inner side is inseparable from the sheath of the reflected tendon of the

[1] Ferrall (p. 334) alludes to this sheath in a cursory manner, but does not describe it.

superior oblique, whilst its outer side is fastened to the capsule of the lachrymal gland, which overlies it. The part of the sheath which covers the under surface of the levator palpebræ is fairly thick, and is best examined in vertical frozen sections; anteriorly, it is firmly attached to the back of the palpebral aponeurosis close to the tarsal cartilage and palpebral conjunctiva; posteriorly, it unites at an acute angle with the sheath which the superior rectus receives from the capsule of Tenon (Plate I. fig. 4). Since both the superior rectus and levator palpebræ are intimately adherent to their respective sheaths, it is clear that, where these are continuous, a bond of union must exist between the two muscles. But, besides being connected to the levator palpebræ in this manner, the superior rectus sends muscular and tendinous fibres into the acute angle, or wedge formed by the union of its sheath with that of the levator; some of these fibres pass along the sheath of the levator palpebræ, and through it are connected to the palpebral aponeurosis and superior tarsal cartilage; others, by running forwards along the sheath of the rectus, reach the ocular portion of the capsule of Tenon. It depends upon the quantity of fibres which the rectus sends to the sheath of the levator palpebræ whether it should be considered to be connected to the tarsal cartilage by muscular fibres or by sheath. Except behind, where it unites with the sheath of the superior rectus, the underneath part of the sheath of the levator palpebræ is in contact with, but not united to, the ocular portion of the capsule of Tenon.

The manner in which the superior rectus is united to the levator palpebræ and upper lid having been discussed, the palpebral aponeurosis affords material for consideration. The anatomy of this structure has been sketched already. Its outer and inner orbital attachments, which have been named the internal and external orbital fasciæ,[1] are fastened to the rim of the orbit on a level with the tarsal ligaments (tendo oculi internum et externum), whilst its lower margin ends upon the cartilage of the lid. Just before its termination the aponeurosis is strengthened by a transverse band of fibres stretched from side to side across the front aperture of the orbit; and the extremities of this band constitute the internal and external

[1] Cruveilhier, p. 622.

orbital fasciæ, and when the levator palpebræ is pulled upon, the use of these fibres is evident. Owing to their attachments and direction they limit the retraction of the muscle, or, in other words, act as a check ligament.[1] They aid, moreover, in bringing about another result, for, as Cruveilhier points out,[2] "the movements of the lid, singularly limited at the sides by the orbital insertions of this muscle (levator palpebræ), is a movement of rotation which it performs round the transverse axis of the eye, like the visor of a helmet."

The importance of the connection between the superior rectus and levator palpebræ is now apparent. Owing to their mutual adhesion, one check ligament (the palpebral aponeurosis) serves for both, and besides, the rectus is enabled to lift the upper eyelid. The transverse band which strengthens the palpebral aponeurosis, when examined microscopically, appears throughout to consist of white fibrous tissue.[3]

The palpebral aponeurosis has another peculiarity which has hardly been recognised. As far as can be judged from a limited number of dissections, it consists of two layers. These are easily perceived in vertical sections, or when the dissection is made from the front. In the latter case, it is best to open the sheath of the muscle at the inner edge, where the layers may be easily separated. The anterior layer is inserted into the middle of the front surface of the tarsal cartilage, the posterior layer is continuous with the upper edge of the cartilage. A little loose connective tissue is found between the two layers of the levator palpebræ, except at the outer side, where the fore part of the lachrymal gland (glandula lachrymalis inferior) intervenes between them.[4] It might not be unreasonable to speculate whether this relation has anything to do with the secretion of tears. But although the levator palpebræ seems quite adapted to squeeze the lower part of the lachrymal gland, yet it is unlikely that the muscle could alter the position of the gland itself. There is a ligamentous union between the external surface of the lachrymal gland and

[1] Tenon, p. 199. [2] Cruveilhier, p. 622.

[3] Great difference of opinion exists upon this point. The matter has had full discussion at the hands of Sappey (p. 98) and Cruveilhier (p. 622). The former asserts that it consists of unstriped muscle, and names it the "orbito-palpebral muscle," whilst the latter is of opinion that it is fibrous.

[4] This interesting fact has been depicted by Sappey, p. 98, fig. 251.

the outer wall of the orbit, which would effectually prevent any movement. It seems appropriate to call these bands the "ligament of the lachrymal band."

Like all other muscles of the orbit, the levator palpebræ sends muscular and tendinous fasciculi to its sheath, which has been shown already to blend with those of the superior rectus, superior oblique, and with the capsule of the lachrymal gland. This circumstance explains many so-called abnormalities.[1]

It is hardly within the scope of this paper to discuss the anatomy of the unstriped muscles, superior and inferior palpebral, which are said to enter into the formation of the eyelids.[2] They have hardly any bearing upon the questions which have been raised.

Relations of the Inferior Rectus to the Capsule of Tenon, Inferior Oblique, and Lower Eyelid.—In general characters the sheath of the inferior rectus is the same as the others. Vertical frozen sections clearly display its arrangement (Plate I. fig. 4). Its upper part has no peculiarity, but merely unites anteriorly, at an acute angle, with that part of the capsule of Tenon which embraces the posterior hemisphere of the eye. The under part of its sheath may be said to consist of two superimposed layers—a superior and inferior (Plate I. fig. 4). If these are followed backwards, they will be found to unite at a very acute angle, into which the muscle sends numerous fasciculi. If the two layers of the underneath part of the sheath of the rectus be traced forwards, they separate; the superior layer keeps in contact with the under surface of the muscle, and is continuous with that part of the capsule of Tenon which supports the anterior hemisphere

[1] Professor Macalister, in his monograph "On Muscular Anomalies in Human Anatomy" (*Transactions of the Royal Irish Academy*, xxv., 1875, p. 7 *seq.*) says—"The levator palpebræ superioris I have seen joined to the superior rectus as described by Albinus. . . . A muscle has been more recently described as the tensor trochleæ by Professor Budge (Henle u. Pfeufer's *Zeitschrift*, Reihe 3, Bd. vii. p. 273) which is a lateral offshoot from the levator palpebræ superioris inserted by several slips into the trochlea for the superior oblique tendon. . . . . I have seen it attached to the upper margin of the tarsal cartilage. Into the tarsal cartilage and into the conjunctiva of the superior palpebral sinus; into the latter alone; into the ciliary fibres of the orbicularis palpebrarum, or into all three." It might be anticipated that, as the sheath of the levator palpebræ is adherent to that of the lachrymal gland fibres of the muscle might have been described going to the latter, but so far I have found no record of any.

[2] Cruveilhier, p. 614.

of the eye; the inferior layer is inserted into the posterior border of the sheath of the inferior oblique (*vide* fig. 4). So far this account is almost in accordance with what has been stated by others (Merkel, p. 58). The part which goes to the inferior oblique is sometimes considered a direct continuation of the muscle (Cruveilhier, p. 624), but I have described it in accordance with its anatomical appearance, and without regard to its supposed functions. These will be discussed presently. Further, by means of the lower part of its sheath, the inferior rectus forms connections with a structure, which probably has a very important influence upon its action, and which will now be described as follows:—

The Suspensory Ligament of the Eye.—Before endeavouring to describe the suspensory ligament systematically, its rough anatomy may be sketched, and, in doing so, it is hoped that its claim to be considered a distinct ligament may be substantiated.

It may, therefore, be stated that the suspensory ligament is a band of fibrous tissue, stretched, like a sling, from one side of the orbit to the other. The fibres which compose it converge at each end to be inserted into the malar and the lachrymal bones; in the middle they diverge to form a shallow cup upon which the eye rests. The widest part of the suspensory ligament is intimately woven with the capsule of Tenon, but not to such an extent as to conceal the identity of its fibres. In order to ascertain this, the lower eyelid should be removed layer by layer, until nothing is left but the tarsal cartilage and conjunctiva. After a little fat has been taken away from the neighbourhood of the inferior oblique muscle, many of the fibres of the ligament are easily seen crossing in front of the muscle. A more correct opinion of the relations of this ligament to adjoining parts, and especially to the globe, may be derived from a vertical section made through the long axis of the eye. In this the lower part of the capsule of Tenon will be found notably thickened, and (Plate I. fig. 4) the extent of this thickening may be indicated by saying that the lower quarter of the circumference of the globe rests upon it. The thickened portion of the capsule of Tenon is divided by an aperture through which the inferior rectus passes. The posterior part, and this is a very significant point, is thickest just behind this opening, but it gradually becomes thinner as it passes round the eye; whilst the anterior part looks crescentic, and sends a long thin horn backwards beneath the inferior rectus, forming the upper layer of the under part of its sheath, and another forwards to become continuous with the ocular conjunctiva and inferior tarsal cartilage (Plate I. fig. 4). It is united to the latter by a short thick process which it gives off in front. In the hollow of the crescent lies the sclerotic; in contact with its lower surface is the sheath of the inferior oblique. At its largest part, which is in close proximity to the conjunctiva, the crescent is at least a tenth of an inch thick, more than twice the bulk of the rest of the capsule of Tenon. This thickening is due to the presence of the suspensory ligament, and it is clear that the data afforded by this examination corroborate the preliminary sketch.

It may interest those who perform operations upon the dead body to know a simple way of demonstrating this ligament. Supposing that the upper jaw has been removed in the ordinary way, it is only requisite to take away a little fat to expose its under surface. If the capsule of Tenon be opened next, by dividing the ocular conjunctiva, a finger may be thrust into its interior and pressed downwards to make the suspensory ligament tense. The band of it which crosses in front of the inferior oblique is especially resistant. But by far the clearest idea of the suspensory ligament may be obtained from horizontal sections, although perhaps this method is slightly artificial. These should be made on a level with the canthi (Plate I. fig. 5). The insertions of the ligament into the malar and lachrymal bones are very distinct; each is about the eighth of an inch thick, and is attached vertically for at least half an inch. They are opposite the equator of the eye, and are about on a level with its lower half. The lowest parts of these bony insertions approach the floor of the orbit. The inner one is fastened to the periosteum which covers the lachrymal crest; in front its fibres pass over the lachrymal sac; behind it is continuous with the periosteum of the orbit and the lowest part of the check ligament of the internal rectus. As the ligament approaches the eye, it spreads out, and is continuous with the capsule of Tenon. The outer insertion of the suspensory ligament adheres to the periosteum of the malar bone just behind the external edge of the orbit, and at this point its posterior surface receives fibres from the check ligament of the external rectus. It is important to note that its under surface is fastened to the floor of the orbit by numerous irregular fibrous fasciculi; and it is further attached to the orbit through its connections with the sheath of the inferior oblique.

Uses of the Suspensory Ligament.—The most important duty of the suspensory ligament, to support the eye, is obvious. When the eye has been removed from its upper surface, either by an ordinary excision or by taking away the lower half of the globe from a horizontal frozen section, considerable pressure may be made upon the upper surface of the ligament without doing more than stretch it. It is a matter of common observation that immediately after excision of the superior maxilla, the eye maintains its position. The presence of the suspensory ligament offers a ready explanation of this circumstance. The expression "immediately" is used, because at later periods the globe may be drawn out of place by cicatrisation. Another qualification is also needed, for I am informed that when the inner and outer walls of the orbit are very freely taken away during the performance of the operation, the eye may drop so much as to entail its removal. Under these circumstances, the orbital insertions of the suspensory ligaments have been destroyed. And it is to be remembered that this accident is likely to occur whenever incisions are carried above the level of the canthi.

In addition to the function which has just been mentioned, the suspensory ligament seems to perform another, which depends upon its connection with the inferior rectus and inferior tarsal cartilage. I have already shown that this muscle is united by one prolongation to the sheath of the inferior oblique, and by another to the front edge of its aperture in the suspensory ligament, and I must now add that these connections contain so many muscular fibres that practically they are offshoots from the muscle. Authors have laid great stress upon the connection between the inferior rectus and the inferior oblique. Although the fact has not been alluded to before, the front edge of the inferior oblique is united by a long and slender fibrous band to the lower tarsal cartilage and its ligament (fig. 4). By this arrangement the inferior rectus is supposed to be enabled to depress the lower eyelid and cornea at the same time (Cruveilhier, p. 625; Henle, p. 720). There is no question that, when the rectus is pulled upon, the inferior oblique is drawn further into the orbit, but it is doubtful whether its connection with the eyelid is as efficacious as is thought. The fascia which forms the bond of union is so long and slender that it is not even made tense when the rectus is pulled. The lid is removed in quite a different way. When the muscle is in action, it swings the suspensory ligament backwards, and owing to the intimate union of the latter with the inferior tarsal cartilage, the lid also moves (Plate I. fig. 4). This only partially indicates the importance of the prolongation which unites the depressor muscle to the suspensory ligament. Arguments can hardly be required to show that there must be a limit to this swinging movement of the suspensory ligament, and its range seems to be so limited that it is able to control the contraction of the muscle, and so act as a check ligament. It may be mentioned that this function has been assigned to the lower tarsal ligament (Sappey, p. 108), and to the sheath of the inferior oblique (Cruveilhier, p. 224). The chief objection to these theories seems to be that the structures in question are insufficient for the performance of such an office; for it has just been stated that the other connection of the inferior rectus with the lower tarsal ligament is exceedingly meagre, and also that the sheath of the inferior oblique is so delicate that observers have actually doubted whether it reaches the floor of the orbit.

As far as I have ascertained the presence of the suspensory ligament has been strangely overlooked, although authors have attributed some some sort of suspensory action to the capsule of Tenon. Cruveilhier (p. 631) calls it "aponevrose orbito-oculaire, ou aponevrose d'isolement et de sustentation d'œil," but it is not clear from subsequent details that this author recognised the suspensory ligament or its orbital attachments. Lenoir says (p. 13) "the aponeurosis *of the muscles* of the eye form a ligamentous apparatus which maintains the eye in position." This statement speaks for itself.

Tenon, in his admirable monograph, clearly indicates the presence of a suspensory apparatus. He says (p. 201), speaking of the capsule—"Arriving at the insertion of the adductor and abductor muscles to the globe of the eye, that is to say, near the conjunctiva, and before applying itself to that membrane, it procures from each side a kind of ligamentous wing (aîle ligamenteuse) which attaches the globe of the eye to the orbit at the greater or lesser angles. These ligamentous wings are formed by the apposition of portions of the tunic which pass one above the other below the globe of the eye." It seems as if this account applies to the relations of parts as seen in transverse sections (Plate I. fig. 3), and Tenon's subsequent statements entirely bear out this view, for he proceeds to say that the ligamentous wings send prolongations forward to the conjunctiva and backwards to the recti (p. 202). In these pages the former were simply considered to be part of the capsule, and the latter the check ligaments. Although the writings of this author have been carefully perused, the fibres which pass beneath the globe, and which actually form the suspensory ligament, seem to have escaped his vigilance. The greater part of his "aîles ligamenteuse" seems to consist of its upper fibres seen in transverse section.

The Structure and Interior of the Capsule of Tenon.—The capsule of Tenon, in reality, consists of two very distinct layers; an external, which is tough, matted, and resisting, and an internal, which is soft, loose, and yielding. The former layer only has been mentioned so far, and the expressions "tunica vaginalis oculi" (Ferrall) and "tunica albuginea" (Malgaigne) which have been applied, accurately indicate its characters. Microscopically it consists of white fibrous and elastic tissue. The inner is made of loose areolar tissue, and completely lines the interior of the tunica vaginalis, surrounding the sclerotic and the intracapsular portions of the muscles. Bonnet calls it the "subconjunctival fascia," and says its presence was pointed out by Guérin and Malgaigne; and although this name has continued in use among surgeons,[1] it is hardly free from ambiguity. In the first place, although a small portion of this loose connective tissue is beneath the ocular conjunctiva, yet the thin anterior part of the capsule of Tenon intervenes between them. And, moreover, the expression scarcely conveys an adequate idea of the extent or appearance of the tunic, which invests not only the front but also the back of the sclerotic. Its close resemblance to the outer covering of blood-vessels, with which everyone is familiar, suggests that in the remainder of this paper it should be called the tunica adventitia oculi.[2]

Vertical and horizontal frozen sections afford the best means of examining the interior of the capsule of Tenon. In these it

[1] Wecker, *Maladies des Yeux*, i. p. 696, Paris, 1868, &c.

[2] The tunica adventitia is probably the structure involved in capsulitis, (Wecker, p. 697); also Power, *Illustrations of Disease of the Eye*, London, 1867, p. 15.

is quite easy, with a blunt instrument, to separate the sclerotic from the interior of the capsule, and it will be found that the tunica adventitia adheres to the latter but provides a covering for each tendon. These investments are continuous with one another, and unite the contiguous edges of the tendons, but the strength of this union is increased by fasciculi, which the muscles themselves send to the tunic.[1] The connection which is formed in this manner between the superior rectus and superior oblique is so definite that the muscles may be said to form "a loop capable of gliding in the trochlea."[2] Although adherent to the sclerotic by a definite semi-lunar insertion, the recti usually send fibres to the globe as soon as they touch it; in order, therefore, to hook up the tendons, as in a squint operation, the instrument requires to be carried well back.

The tunica adventitia must be taken away to expose the apertures by which the muscles pierce the capsule of Tenon (tunica vaginalis), and when this is done six openings are brought into view, transmitting, of course, the four recti and two oblique muscles. Each muscle is slightly attached to the margin of its aperture by the tunica adventitia, and when this has been removed, a band of fibres is seen crossing the posterior edge of the opening (*i.e.*, the edge between the muscle and the eye). These ligamentous bands are portrayed in the diagrams as slight thickenings of the capsule (Plate I. figs. 3 and 4).

Since no name has been given to these ligaments, in the ensuing pages they will be called the "intracapsular ligaments." Presumably they constitute the pulleys which Ferrall (p. 338) supposed protected the globe from pressure, but it is clear that many questions demand an answer before this assumption can be allowed to pass unquestioned. It must be proved that they have sufficient strength and immobility to resist the action of the muscles. And when this problem has been solved in a satisfactory manner, it remains to be seen whether their situation is appropriate.

The Intracapsular Ligaments.—In order to expose the intra-

[1] Wecker, ii. 994.

[2] Cruveilhier, p. 624. This loop is delineated by Lenoir (plate i. fig. 3), and Cruveilhier (pp. 629 and 630) considers that it makes a sort of check ligament for the superior oblique. Merkel, however, attributes this duty to a fascial prolongation which extends from the trochlea to the muscle.

capsular ligaments, all the back of the sclerotic as far as the insertions of the recti should be cut away or dragged forwards. Next, the tunica adventitia should be dissected from the interior of the capsule and from the surface of the tendons. When this has been accomplished, the arrangement of the fibres is distinct and perfectly easy to trace. The openings of the inner and outer recti look like vertical slits in the interior of the capsule, and are situated exactly opposite the equator of the eye, and a vertical band of fibres strengthens the inner (ocular) edge of each (Plate I. figs 3 and 4). If now a small hook be passed beneath the ligaments, *i.e.*, between them and the ocular surface of the tendons, the ligaments will be found to resist attempts to pull them away from the inner and outer walls of the orbit. This may be attributed to the fact that their ends are continuous with the insertions of the suspensory ligament which fastens them to the wall of the orbit. Although easily stretched, they seem to have quite enough strength to resist the action of the muscles. If the hook be pushed well beneath them, quite a strong tug is needed, in a spirit specimen, to cause displacement, and if the globe is drawn away from the capsule of Tenon the recti are bent at the place where they pass over the ligaments. In the recent state they are much more supple and elastic. Thus the intracapsular ligaments are, practically, fibrous loops which hold the tendons of the recti to the walls of the orbit, and, being situated just at the equator of the eye, seem admirably fitted to protect it from pressure. In short, these ligaments have sufficient immobility and strength and a position which enables them to act as pulleys and protect the eye from pressure. With regard to the intracapsular ligaments of the superior and inferior rectus, it has been pointed out already that the depressor muscle pierces the suspensory ligament. When, in order to demonstrate the aperture, the tunica adventitia is removed from the interior of the capsule of Tenon, the transverse fibres of which the ligament consists are brought into view. They cross before and behind the opening, and those which are posterior and above the tendon seem to form an intracapsular ligament. They resist endeavours made with a hook to pull them upwards from the floor of the orbit, and they are situated opposite the equator of the eye. In these respects they are qualified to act as pulleys.

It is probable that the suspensory ligament is held down by its insertions, for, as before stated, they descend towards the floor of the orbit, and perhaps the inferior oblique and its sheath, and the fibrous bands mentioned before (p. 18), may render assistance. The slight swinging movement which can be imparted to the suspensory ligament does not seem sufficient to incapacitate its posterior fibres for the performance of this fresh duty.

The intracapsular ligament which forms a pulley for the superior rectus is of considerable length. Its inner extremity is fastened to the trochlea. It reaches this point by uniting with the sheath which surrounds the reflected tendon of the superior oblique.[1] The outer end seems to be attached to the external wall of the orbit just above the abducens. This ligament, therefore, stretches obliquely across from the roof to the outer wall of the orbit, and it is this arrangement which alters the direction of the superior rectus; for the intracapsular part of this muscle makes a very decided bend inwards towards the nose. In other particulars the intracapsular ligament of the superior rectus resembles all the others.

The anatomy of the opening for the two oblique muscles may be briefly described. That for the superior is a simple circular opening, devoid of ligamentous apparatus. This might have been anticipated if the direction imparted by the trochlea to the reflected tendon be considered. The inferior oblique pierces the suspensory ligament (Plate I. fig. 5). Its aperture is just behind and external to the slit of the inferior rectus, but it is separated from it by the intracapsular ligament, which the suspensory ligament forms for that muscle, and, in addition, by a small oblique band of fibres which cross the upper surface of the suspensory ligament (Plate I. fig. 5). It is not improbable that this corresponds to an intracapsular ligament, and its connections endow it with sufficient immobility.

In concluding the account of these structures, allusion may be made to a function which they possibly perform. Although their attachments to the walls of the orbit have not been specified in very positive terms, this is merely because they have not been traced there as distinct bands. Speaking more particularly of

[1] It is interesting to note that Quain comments upon the strength of the investment of the superior oblique tendon, p. 284.

the internal and external intracapsular ligaments, there seems to be little doubt but that they are firmly fixed above and below each tendon. Clearly this would prevent the muscles following the globe in any movement of rotation, and the arrangement of the tendons and openings of the superior and inferior rectus would assist. In other words, they seem adapted to check the tendency of the oblique muscles to rotate the eye. As far as I can ascertain, the oblique muscles are quite unprovided with check apparatus of any kind; but, seemingly, the intracapsular ligaments are perfectly capacitated by their relations to the recti to act as such.

The interior of the capsule of Tenon has been best described by Bonnet, Ferrall, and Lenoir. These observers expose it from in front by first dividing the ocular conjunctiva and tunica vaginalis, and afterwards the tendons of the muscles and optic nerve. The apertures for the muscles have been described and portrayed by Bonnet, but very inadequately (p. 13, plate i.), and Lenoir doubts the correctness of his observations, and says the openings do not exist. Such a conclusion might easily be arrived at if the inner tunic (tunica adventitia) was ignored. Neither of these writers seem to have been aware of the researches of Ferrall, published in 1841; the same year as Bonnet's work, and nine years before Lenoir's. Speaking of the interior of the capsule, Ferrall (p. 338) says—"In the concavity of this tunic, and about half an inch posterior to its anterior or orbital margin, are to be found six well-defined openings, through which the tendons of the muscles emerge in passing to their insertions into the sclerotic coat, and over which they play, as over pulleys, in their course. The tendons are loosely connected to the edges of the apertures by fine cellular tissue, which opposes no obstacle in their gliding movements." This anatomist says nothing more about the anatomy of these openings, but the accompanying figures seem intended to show that a band of fibres extends along the edge of each.

Specimens which illustrate these observations have been placed in the museum of St Bartholomew's Hospital. It is to be noted that whatever has been said applies to specimens which have been hardened in spirit. There is no question but that in the recent state the various ligaments which surround the eye are very yielding and elastic, and that hardened specimens hardly convey a perfect idea of this, but in other respects the results which they afford appear to be reliable.

EXPLANATION OF PLATE I.

Fig. 1. Tendon of Zinn. E. I. and A., external, inferior, and internal recti. Drawn from a specimen.

Fig. 2. Common tendinous origin of superior (S.), external (E.), and internal (I.) recti. L., root of the lesser wing of the sphenoid, to the front of which it is attached. T., tendon.

Fig. 3. Horizontal section of orbit through the centre of the cornea. I., internal, E., external, attachments of the suspensory and check ligaments (aîles ligamenteuse, Tenon). A., sheath of adductor, and B., sheath of abductor muscles (the latter making a greater bend). Only the tunica vaginalis is delineated, the tunica adventitia being omitted. The ocular conjunctiva has been dotted in.

Fig. 4. Vertical section. The sheath of the levator palpebræ is dotted in above the superior rectus. The capsule of Tenon is thicker below in the region of the suspensory ligament. I. O., inferior oblique. Only the tunica vaginalis is delineated; the tunica adventitia has been omitted.

Fig. 5. Horizontal section through the orbit at the level of the canthi. L., lachrymal sac. The front aperture is crossed by the suspensory ligament, which is pierced by the inferior rectus and inferior oblique. Drawn from a specimen.