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On the Structure of the Eye of the Swordfish (Xiphias gladius, *Lin.*)

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FROM the great density and obscurity of the medium through which fishes receive the rays of light, compared with those of the atmosphere, their organs of vision necessarily present considerable differences in form and structure, from those of land animals. Predatious fishes, which frequent great depths, have very large eyes, from the general darkness of the ocean, and probably from the diminished energy of the nervous system in animals so low in the scale. The eyes of the common swordfish, here described, were four times as large as those of an ox, although the bulk of the fish did not equal one half of the bulk of that quadruped. Blainville has observed, that fishes which inhabit the open sea have the eyes larger and better developed than those which frequent the shore. As the refractile power of the aqueous humour of the eye is the same as that of water in which fishes constantly reside, this humour is unnecessary, and nearly absent, in that class of animals,

and consequently their cornea is flat. This flatness of the cornea, however, could not be preserved, if the eyes of fishes were formed of soft membranes, like the eyes of quadrupeds, as the lens would then be pressed forward by the muscles surrounding the eyeball against the iris, and completely prevent the pupil from changing its dimensions. Hence we find a firm cartilaginous or osseous framework in the eyes of fishes, to preserve the flatness of the cornea, analogous to what is employed in birds to preserve a great convexity of that part. The great thickness of the sclerotic coat, the presence of the choroid gland and adipose matter between the sclerotic and choroid coats behind, and the flatness of the cornea before, shorten very much the axis of the eye in fishes. Hence a complete spherical form, and greater hardness of the crystalline lens, is necessary in these animals, to bring the rays of light more quickly to a focus. Two small portions of a sphere would have been sufficient, if the texture of the lens were homogeneous like glass; but this organ possesses a highly complicated structure, consisting of fibrous layers, beautifully disposed to check the aberration of light, and increasing in density from the surface to the centre. The distance between the cornea and the retina in the swordfish is about one inch and a half, while the transverse diameter of the eye is three inches. The shortness of the axis, and the enormous size and spherical form of the lens in the eyes of fishes, reduce greatly the proportion of their vitreous humour. In the common herring, the axis of the vitreous humour is only a fifth part of that of the lens; whereas in man, it is nearly four times greater than the axis of the lens. In the large eye of the swordfish, the axis of the vitreous humour is not one-half of that of the lens. The ciliary processes and foramen centrale are not found in fishes. The choroid gland, the solid sclerotic coat, the fatty matter within it, and many other peculiarities in

the structure of the eye, belong exclusively to this class of animals; and besides many general peculiarities, the eye presents in the individual species all the variety and irregularity which characterize the organs of animals low in the scale, and exhibits a gradual transition to the apparently anomalous eyes of molluscous animals. The broad flat irregular form of the eye, and the quantity of matter interposed between the outer coat and the retina, in the swordfish, closely resemble the appearances presented in the eyes of the Octopus and Loligo. From the great size and simple structure of this organ in fishes, a minute examination of these peculiarities might throw much light on the nature of many parts, the uses of which are still perfectly unknown in the higher orders of animals. The eye of the common swordfish appears not to have been hitherto examined; and I am indebted for the opportunity of making the following observations to Professor JAMESON, who kindly presented me with the two recent eyes, and the whole of the viscera, of the beautiful male specimen of that rare animal, lately taken in the Frith of Forth, and now preserved in the Museum of the University.

The eyes of the swordfish are so perfectly lateral in their position, and so flat anteriorly, that that animal can perceive objects only with one eye at a time. This is probably another reason, besides those stated above, for the eyes of this fish being usually large. In the specimens I examined, the transverse diameter measured 3 inches, the axis $2\frac{1}{4}$ inches, and the entire animal 7 feet 2 inches from the point of the sword to a line drawn between the tips of the tail. The general form of the eye is that of an irregular hemisphere, a little depressed in the direction of the axis, the anterior part corresponding to the flat base of the hemisphere. The eye is circular round the axis, but its sphericity on the back part is very imperfect from the irre-

gular form of the osseous plate of the sclerotic coat. The sphericity of the retina within is not interrupted by this irregular form of the external coat, as there are several soft parts interposed between them. The conjunctiva is black, like the skin of the animal, to the margin of the transparent cornea. The pupil is irregularly circular, as in many other fishes. The iris has a greenish-white colour, and a beautiful metallic lustre. The cornea is flat, and about $1\frac{3}{4}$ inch in diameter. The anterior edge of the osseous plate projects beyond the margin of the cornea, so as to make the anterior part of the eye a little concave externally. There is no eyelid, but a looseness of the conjunctiva round the edge of the orbit, to admit of the motions of the eye. The conjunctiva does not pass loosely over the cornea, as in the haddock and many other fishes, but adheres so strongly as only to be separated from it with difficulty, after long maceration. The muscles of the eyeball are very strong and red coloured, like those of a quadruped, and correspond with the extensive distribution of the red globules of the blood through the other parts * of this animal. The adipose substance, in which the eye is imbedded, is very different from the soft white watery substance we usually find in this situation in smaller fishes. It is firm, of a yellowish-white colour, and filled with an oily matter, which agrees much in its smell, colour, and other properties, with the oil procured from the whale.

The tunica conjunctiva can be separated with ease from the surface of the sclerotic as far as the margin of the cornea, where it is firmly connected with the projecting edge of the osseous plate. After long maceration, it can be torn

* See my account of the anatomy of the thoracic and abdominal viscera of the Swordfish, in the Transactions of the Medico-Chirurgical Society of Edinburgh, vol. iii.

from the whole surface of the cornea, with which it appears to be connected by cellular substance. But, by the same treatment, the cornea can as easily be separated into many layers, as into the two formed by tearing off the conjunctiva. The cornea is very thin, compact, and of equal thickness throughout; it is lodged in a small groove of the osseous plate; but, at the nasal side of the eye, it passes a little over the inclined margin of that plate. The outer layer of the sclerotic coat consists of strong white shining tendinous fibres, forming a compact membrane, which adheres firmly to the whole outer surface of the osseous plate. The fibres of the outer covering of the optic nerve, which is considered to be a continuation of the dura mater, are very distinctly seen to mix and disappear among the fibres of the sclerotic, so as to form with it a continuous membrane. This layer of the sclerotic is connected, like the conjunctiva, to the outer margin of the cornea. The osseous plate of the sclerotic covers the whole of the eyeball, excepting the aperture on the fore part covered by the cornea, and a space nearly of the same size on the back part of the eye. The irregular round opening on the fore part of the plate is $1\frac{3}{4}$ inch in diameter, with an inflected margin 3 lines in thickness. The plate is hard, translucent, somewhat brittle, of a yellowish-white colour, and strongly marked fibrous texture. It is thinnest and most pellucid where its diameter is greatest, and it terminates posteriorly by a thin and very uneven margin. It does not effervesce in nitric acid, like substances containing carbonate of lime, and appears to be of a condensed horny texture, containing a quantity of oily matter between its fibres. It is divided into two equal parts, an upper and a lower, by an uneven suture, passing from before backward, or in the direction of the axis. The tendinous extremities of the straight and oblique muscles of the eye pass through the outer layer of

the sclerotic, and are firmly inserted into the osseous plate. On the upper half of the plate, about half an inch from its ragged posterior margin, there is a perforation about two lines in diameter, for the passage of the arteries and veins of the eyeball. On the inside of this perforation there is a bony ridge, about a line in thickness, for the protection of the vessels passing through it. This hard inner layer of the sclerotic is continued in a membranous form, and in firm union with the outer layer, from the ragged posterior margin, to the optic nerve. The broad anterior inflected margin of the plate affords attachment to the iris and the cornea, and gives lodgment to a white adipose thick band surrounding the eye, and placed anteriorly to the ciliary ligament. Immediately within the osseous plate we observe a very delicate black coloured membrane, adhering loosely to it as far as the ciliary ligament, where it becomes inseparably united with the vascular layer of the choroid. This thin membrane lies immediately over and in contact with the fatty substance enveloping the choroid gland, and occupies the situation of the white silvery pigment which forms the outer layer of the choroid coat in many osseous fishes. Near the ciliary ligament this black membrane acquires a light grey colour and metallic lustre; but at the ciliary ligament, where it unites inseparably with the vascular layer of the choroid for a line and a half, it again becomes dull, and has a deep purple colour. On the fore part of the ciliary ligament it resumes its metallic lustre, becomes detached from the choroid, and can be traced with ease dipping into an angular recess between the uvea and the iris, and again mounting to descend over the fore part of the iris. In this animal there is a wide angular space, a line in breadth, between the uvea and iris, which contains a white cellular substance. The iris is thick and firm, like cartilage, and, on removing its metallic pigment from the

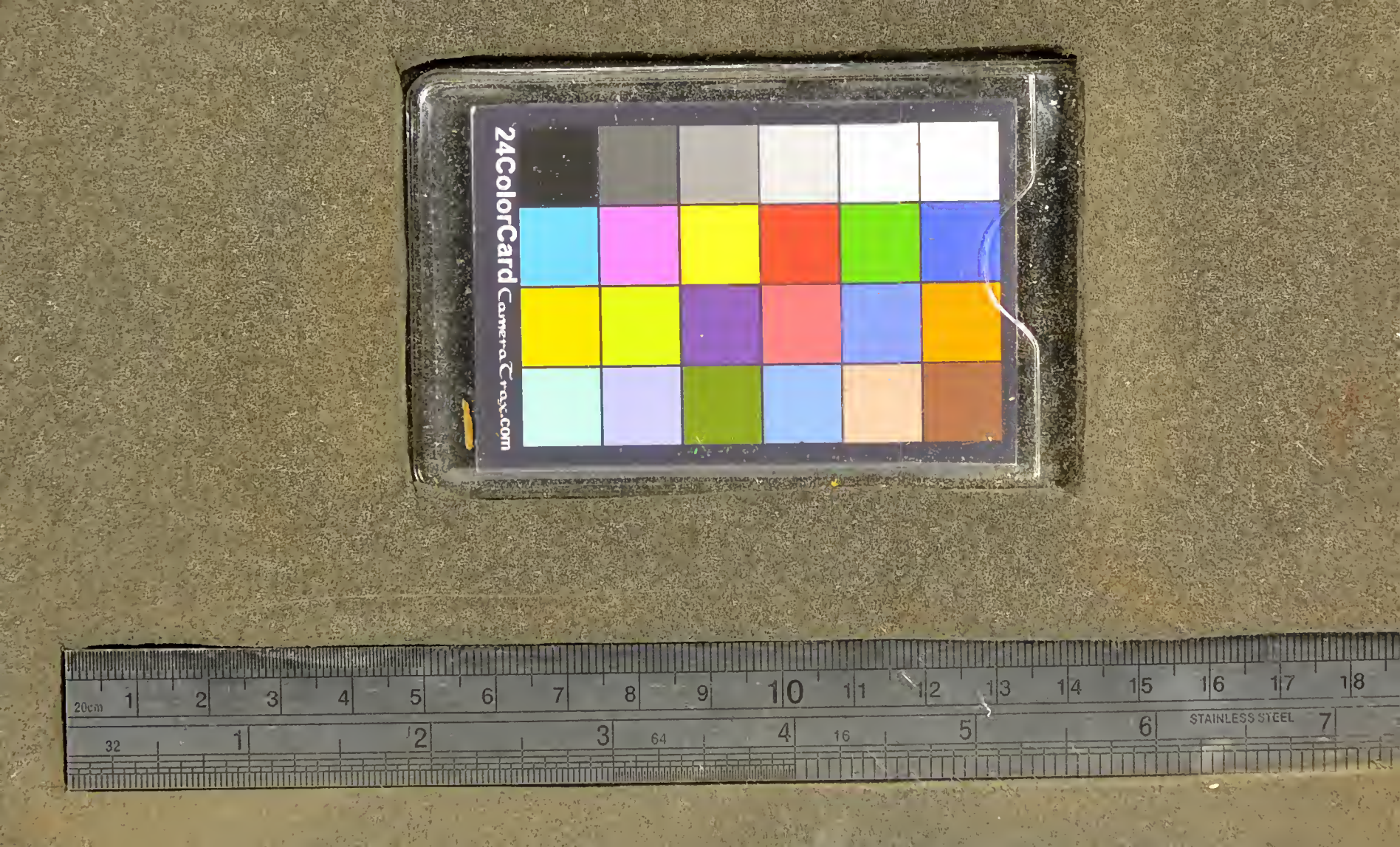
fore part, it presents a black surface. The white adipose band surrounding the eye before the ciliary ligament, rests on a peculiar thin membrane, which separates it from the outer dark layer of the choroid, and extends forward as far as the cornea. The dark coloured external layer of the choroid, in the Xiphias, somewhat resembles the thin black lining of the sclerotic of quadrupeds, which was thought to be a continuation of the pia mater. There is no silvery pigment in this animal covering the choroid gland, which we find so abundant in many osseous fishes, as the cod and haddock.

Between the thin dark outer layer of the choroid and its thick vascular layer, there is an immense deposit, of a white semifluid fatty substance, half an inch in thickness, on the back part of the eye, and extending as far forward as the ciliary ligament. The fatty deposit is thickest on the back part, near the optic nerve, and becomes gradually thinner towards its anterior termination; it is traversed in every part by numerous large branches from the ocular artery, and by the ciliary veins returning to the choroid gland. These vessels are filled with red blood, and are so numerous as to give a red tinge to the oily substance through which they are ramified. The great bed of fat completely envelopes that singular organ the choroid gland; it enables the great trunks of the ciliary arteries to subdivide, before penetrating the choroid, to form its innermost layer; and it enables the internal parts of the eye to assume a sphericity which the osseous plate of the sclerotic is far from possessing. The choroid gland has the same deep blood-red colour, firm consistence, and vascular texture, as in other fishes; it is composed of two parts surrounding the optic nerve, the one shaped like a horse-shoe, and the other nearly straight. These two pieces are flat, about half an inch broad, and nearly a quarter of an inch thick. The venous

sinus, described by Blainville (*Anat. Comp.* t. i. p. 425) as occurring in the inner part of this singular fleshy mass, is large and distinct in the Swordfish, where it appears like the pelvis of a kidney, with numerous openings, probably of the ciliary veins, terminating in it. Blainville considers the choroid gland of fishes as a vascular ganglion, or sinus, for the reception of the ciliary veins. I may observe, that, on cutting open this body, in the Swordfish, we find its outer part composed of a compact parenchymatous texture, and, as we approach its inner sinus or pelvis, it consists of distinct straight parallel fibres, which may possibly be ducts or vessels, leading to the central cavity. After remaining long in spirits, the inner concave margin of the organ splits spontaneously, and always in the direction of these parallel fibres. The vascular membrane of the choroid, which lies immediately beneath the bed of fat, is distinctly separable, in the Swordfish, into two layers. The outer, or venous layer, has a bluish-grey colour, and a strongly marked corded or striated appearance, produced by the straight veins which compose it. The inner, or arterial layer, termed the Tunica Ruyshiana, and composed of the ramifications of the ciliary arteries, has a deep brownish-purple colour on the surface where the pigment rested. At the place of the ciliary ligament, this inner layer of the choroid assumes a yellowish-white colour, and continues of this light colour over the whole of the uvea to its free margin, where it unites at an acute angle with the iris. This white part of the choroid, and the white surface of the uvea, are covered, in the natural state, like every other part of the choroid, with a thick layer of a brownish-black pigment. There are no ciliary processes projecting in towards the margin of the lens, but in their place we find the choroid distended by the white adipose band I have already mentioned as surrounding the fore

part of the eye, on the outside of the choroid, and near the margin of the uvea. Blainville thinks he has observed ciliary processes in the eye of the *Squalus maximus*. At the place where the optic nerve penetrates the inner layers of the choroid, it has a very contracted and strangled appearance; and the retina which it forms, is proportionally the most bulky I have yet met with in any animal. The retina forms a thick pulpy coat, of a bluish-white colour, and becomes more thick and opaque as it advances towards the uvea, near the base of which it terminates by a smooth and even margin. We observe a straight white line or fissure extending, on the nasal side of the eye, in this animal, from the entrance of the optic nerve to the base of the uvea, along the inside of the choroid coat. Along the whole of this line the retina is firmly bound to the choroid coat, and it has no connection with the choroid at any other part. This remarkable appearance has the closest resemblance to the long fissure of the choroid through which the retina enters in the class of birds, but is very rarely met with in fishes. The eyes of the cod, the haddock, and many other osseous fishes, present no appearance of this kind, but have the retina quite free round the optic nerve. The retina appears to form a larger mass than could result from the mere expanded filaments of the contracted part of the optic nerve. The pulpy external layer of the retina is so thick in the Swordfish, particularly near its anterior termination, that it can be torn with the forceps, like cellular substance, into several layers. The white membrane or ligament, corresponding to the pecten of birds, already discovered by Blainville, in six different genera of fishes, is strong and distinct in the Swordfish, proceeding from the anterior end of the fissure of the choroid, through which the retina enters, to the capsule of the lens. Although the lens is a solid sphere, an inch in diameter, the pecten is so firmly at-

tached to its capsule, as to bear its weight with ease when suspended out of the water. On the opposite side of the lens there is a smaller ligament of the same kind. The great body of the lens, inclosed in a capsule of almost tendinous consistence, after remaining some weeks in spirits, splits spontaneously into concentric lamellæ, and deep rents in the direction of its axis, and separates easily into coarse fibres having for the most part the same direction.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