VI. *On the Anatomical and Optical Structure of the Crystalline Lenses of Animals. Continued from a former Paper* (*Phil. Trans.* 1833, *p.* 332.). *By Sir* David Brewster, *K.H. LL.D. F.R.S. &c. &c.*

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§ 2. *On the Anatomical and Optical Structure of the Crystalline Lenses of Animals, particularly those of the Hare and the Salmon.*

In describing the various structures which exist in the crystalline lenses of animals, I shall proceed from the most simple to the most complex combination of fibres. In the paper which I have already submitted to the Society, I took the lens of the cod as the type of the *first* or simplest structure, in which the fibres, like the meridians of a globe, converge to two opposite points of a spheroidal or lenticular solid; and I shall now proceed to describe the *second* or next simplest structure, as exemplified in the lenses of the salmon and the hare.

This structure is shown in Plate IV. fig. 1, where A A is the anterior and B B the posterior hemisphere of the spheroidal lens of the salmon. A lens thus constituted is said to have *two septa* at each pole, A and B (fig. 2.), namely, the septa A *b*, A *c*, and B *d*, B *e*, in different points of which all the fibres have their origin and termination. One of the fibres, for example, which has its origin in A, passes over N, and terminates in *d*; while the other passes from A to O, and terminates in *e*. In like manner, the fibre which begins at *b* passes over P, and ends in B; while the fibre which begins at *c* passes over M, and terminates in B. The different parts of these four fibres lie in one plane, like the meridians of a globe. All the other fibres, which have their origin between A and B, have their termination between *d* and B; and all those which have their origin between A and *c* have their termination between *e* and B. All these fibres, or every fibre in each lamina except *four*, have their different parts lying in different planes, or form curves of contrary flexure. In order to understand this structure, and appreciate its beauty, it is necessary to draw the fibres upon a globular surface. A perspective view of such a globe is given in fig. 3, where A *b* is one of the anterior septa, and B *c* one of the posterior ones. The two curves which go from the poles A and B to the ends of the septa *c*, *b*, are ellipses, while all the rest are curves of contrary flexure.

The length of the septa A *b*, A *c*, &c. varies in different fishes; and when they are very short, as they must necessarily be in small lenses, we are apt to mistake the structure which they indicate for that of a diffused polarity round the two extremities of the axis of the lens. When such an ambiguity, however, presents itself, we must observe carefully if the diffusion is more elongated in one direction than another. If it is not, and especially if there is seen a small circular dimple or depression at the poles when we follow the light reflected from the surface of the lens, there can be no doubt that the fibres converge to two opposite poles, like the meridians of a globe. But if the diffused polarity be of an *oval* form, and if the greater axis of the oval on one side of the lens be perpendicular to the same axis on the other side, we may then safely infer that the fibres are related, as in the lens of the salmon, to *two* septa at each extremity of the axis of vision. When these methods fail, the ambiguity may sometimes be removed by boiling the lenses, and observing the manner in which they crack at the poles.

From a too hasty generalization of a small number of facts, LEEUWENHOEK maintained that all fishes and birds have two short septa; and M. SATTIG * has advanced the same opinion in reference to fishes, and committed the additional mistake of making every part of the fibres lie in the same plane. Dr. THOMAS YOUNG maintains that there are no septa in the lenses either of birds or fishes †; and in pursuing the chimæra of a muscular lens, he not only renounced discoveries of his own, after LEEUWENHOEK, but adopted grave errors which have no foundation whatever either in observation or analogy.

It is a very remarkable circumstance, that the hare and the rabbit should be the only quadrupeds whose lenses have two septa, like that of the salmon. This fact was observed by LEEUWENHOEK‡ and also by SATTIG, who remarks that the septa are larger in the lenses of these animals than in those of fishes.

The fibres of the lenses of the hare and the rabbit are curves of contrary flexure, like those of the salmon, and they are distinctly toothed, though the teeth are much smaller than those of the salmon and the cod, of which I have given a representation in a former paper.

Although I have stated that the hare and the rabbit are the only quadrupeds whose lenses are known to have the same structure as that of the salmon, yet there is a rare marsupial quadruped, the *Perameles nasuta* of GEOFFROY, whose lens will probably be found to have two septa on each of its surfaces. Professor GRANT was so good as to send me a single lens of this curious animal; but as one of its faces was much injured, I was able only to discover the two septa on the side of the lens which was uninjured. It is highly probable that the fibres will have a similar arrangement on the other side of the lens; but until this is actually determined, it is possible that

* Lentis Crystallinæ Structura Fibrosa. Preside Reil Defendit SAMUEL GODOFREDIUS SATTIG SILESIUS. Halæ, 1794. It is not surprising that the author of this thesis should have followed LEEUWENHOEK in this mistake, as he seems to have examined the lenses *only* of the carp and the perch, in which the two septa are most distinctly developed.

† Elements of Natural Philosophy, vol. ii. p. 599. col. 1. and Plate XII. fig. 100.

‡ Opera, vol. ii. p. 66. Lugd. Batav. 1722.

the *Perameles nasuta* may have its lens formed according to another class of structures which will afterwards be described. The fibres of the lens of this animal are extremely small, and the teeth upon them, though very minute, are distinctly seen with a high magnifying power.

The structure indicated by two septa is perceived very distinctly in the lens of the *Cobra Capella* and the *Lacerta Gecko,* and indistinctly in that of the *Stellio Gecko* and the *Frog*. The lenses of the *Cobra Capella* and the *Lacerta Gecko* are nearly spherical; and the laminæ of the lens of the *Stellio Gecko* are composed of a fibrous tissue, and not of fibres united by teeth.

In the following Table I have given the names of the different animals whose lenses have the structure shown in fig. 1.

	QUADRUPEDS.	
Hare.	Rabbit.	*Perameles nasuta* (one side).
	REPTILES.	
Cobra Capella.	*Lacerta Gecko.*	*Stellio Gecko* (probably).
Frog (probably).	Alligator.	
	FISHES.	
Salmon.	Tench.	Hickory Chad.
Dolphin.	Carp.	Cavala (Georgia).
Shark.	Perch.	Stingarie.
Porpoise.	Sturgeon.	Skip-jack.
Skate.	Gudgeon.	Chad.
Thornback.	Cat-fish.	Black-fish (Georgia).
Boneto.	Par.	Fish from Singapore.
Dog-fish.	Red Trout.	Sheep-head.
Sword-fish.	River Trout, common.	

1. *Hare.*—I have examined the lenses both of the common hare and the blue mountain hare, which have the same structure. In observing their action upon polarized light, I find that they depolarize *two series* of luminous sectors, the inner sectors having the *negative* structure like *calcareous spar,* and the outer sectors the *positive* structure like *zircon.* In order to perceive the inner sectors, the lens must be taken out of the eye with great care, and subjected to no pressure, and the polarized light must be transmitted through its axis.

2. *Rabbit.*—The lens of the rabbit resembles that of the hare in its general properties. The cornea of a rabbit depolarized faint sectors of light, and its polarizing structure was *negative.*

3. *Perameles nasuta.*—When the lens of this animal was taken out of the spirits which preserved it, and the outer coat removed, its fibres were crossed perpendicularly by irregular and slightly serrated lines, much more distinct than the fibres. As

these lines are not now visible in the indurated lens, I cannot even form a conjecture respecting their origin.

4. *Stellio Gecko* and *Frog*.—The lenses of these animals require to be re-examined.

5. *Salmon*.—The length of the septa in the lens of the salmon is less than those in the hare and rabbit, and the teeth upon the fibres are extremely distinct. The lens depolarizes *three* series of luminous sectors, the *inner* and outer series being *negative* and the intermediate series *positive**. The polarizing structure of the cornea was *negative*, and it depolarized very high tints at its junction with the sclerotic coat. The structure of the *sclerotic coat* is very remarkable. In the eye which I examined, the thickness of the sclerotic was about the fifteenth of an inch, and with a sharp knife it could be cut like a piece of cheese. It had a milky transparency like some opals. When a slice with parallel faces, nearly perpendicular to the surface, was exposed to polarized light, it exhibited the system of biaxal rectilinear fringes†, exactly like those in a plate of glass heated by boiling water or oil, and in the act of rapid cooling. The same structure exists in the sclerotic coat of the *Cod*.

6. *Dolphin*.—The lens of the dolphin is decidedly an oblate spheroid, the axis of which is that of vision. In an indurated lens the axis of the spheroid is 0·254 of an inch, and the equatorial diameter 0·307. The teeth of the fibres are small and irregular, like those of quadrupeds.

7. *Shark*.—The lenses of the common and blue-eyed shark have the same structure. The sclerotic coat has the remarkable property (when cut in the manner already described in the case of the salmon) of depolarizing light like *a plate of bent glass*‡; but, what is very curious, the *concave* side of the sclerotic has the same action upon light as the *convex* side of the bent glass.

8. *Alligator*.—The lens of the alligator is nearly spherical: the teeth of the fibres, as in the dolphin, are shorter than those in fishes.

9. *Skate*.—The lens of this fish depolarizes *three* series of luminous sectors, but the inner series is not so distinct and near the axis as those of the cod. The inner and outer series are *negative*, and the intermediate series *positive*. The horny sclerotic of the skate has the very same polarizing structure as that of the salmon. The teeth of the fibres of the lens are exceedingly small.

10. *Thornback*.—The fibres are very delicate, and their teeth small but distinct. The lens depolarizes luminous sectors; but from the imperfection of the lens I could not observe their character.

11. *Boneto*.—The lens is an oblate spheroid, whose axis is that of vision. The teeth of the fibres are very distinct§.

12. *Sword-fish*.—The diameter of the lens of this fish which I examined was 1·10th of an inch. The teeth of the fibres were so distinct that *three* circles of the secondary colours produced by them were distinctly seen‖.

* Philosophical Transactions, 1816. † Ibid., 1816. ‡ Ibid., 1816.

§ Ibid., 1833, p. 332. ‖ Ibid., 1833, p. 327.

13. *Tench.*—This fish has a very small eye, and a small lens. Owing to the faintness of the polarized tint I have observed only one series of luminous sectors, whose character is *positive.*

14. *Perch.*—The lens of this fish, like that of the tench, exhibits only one set of luminous sectors by polarized light, and their character is also *positive.*

15. *Gudgeon.*—The teeth of the fibres are very distinct. I have observed only one series of luminous sectors, which are *positive.*

16. *Cat-fish.*—This is a poisonous fish from Georgia. The teeth of the fibres are very fine.

17. *Red Trout.*—Its lens was nearly spherical, and 0·244 of an inch in diameter. It distinctly depolarized *three* series of luminous sectors, the inner and outer ones being *negative,* and the intermediate one *positive.* The teeth of the fibres are very distinct.

18. *Hickory Chad.*—This fish is from Georgia. The fibres are distinctly seen.

19. *Cavala.*—This fish is from Georgia. On one side of the lens there are two short septa. The secondary colours produced by the teeth of the fibres are very distinct.

20. *Stingarie.*—This is a poisonous fish from Georgia. The lens is of an oblong form when viewed in the direction of the axis of vision. The two septa on one side are very long.

21. *Skip-jack.*—The teeth of the fibres are short, like those of quadrupeds.

22. *Black-fish from Georgia.*—The fibres of its lens are large, and the colours which they produce very finely seen near the septa.

23. *Sheep-head from Georgia.*—The fibres of its lens are unusually large*.

24. *Fish from Singapore.*—Mr. GEORGE SWINTON sent me a number of the eyes of this fish, but the name has been lost. Its lens has the form of an oblate spheroid, the axis of which is the axis of vision. This axis is 0·60 of an inch, and the equatorial diameter 0·70. The secondary colours produced by the teeth are finely displayed.

§ 3. *On the Anatomical and Optical Structure of the Crystalline Lenses of Animals, particularly those of the Lion, Tiger, Horse, Ox, and other Quadrupeds.*

In the two preceding sections I have described the two simplest combinations of fibres which characterize the structure of the crystalline lens in animals. The lenses of birds possess the *first* or simplest structure; the lenses of fishes in general exhibit either the *first* or the *second* structure; and we shall now show that the lenses of the Mammalia in general, with the exception of the *hare* and the *rabbit,* and other quadrupeds of peculiar habits, are characterized by a *third* and a more complex structure, in which *three* septa diverge from each pole of the lens at angles of 120°, the

* See Philosophical Transactions, 1833, p. 329.

septa of the posterior surface bisecting the angles formed by the septa of the anterior surface.

This beautiful structure is shown in Plate V. figg. 1. and 2; fig. 1. representing the anterior, and fig. 2. the posterior, surface of the lens, which in quadrupeds is a real lens or lenticular solid, the curvature of the posterior surface having a shorter radius than that of the anterior surface.

The progress of the fibres round the edges of the lens in their passage from the one surface to the other is shown in fig. 3, where the lens is supposed to be transparent, the dark continuous lines representing the *three septa* and the fibres of the anterior surface, and the dotted lines the three septa and the fibres of the posterior surface. From this representation it will be seen that there are *three* fibres having their origin in the anterior pole, and terminating at the extremities of the posterior septa; and other three having their origin in the posterior pole, and terminating in the extremities of the anterior septa, which have their parts all lying in one plane, while every other fibre of the lens forms a curve of contrary flexure, in order to carry it to its proper termination in the opposite septum. Hence it follows, that with the exception of the six fibres originating in the poles, the parts of all the other fibres which constitute the margin or rim of the lens are not parallel to its axis.

The arrangement of fibres shown in figg. 1. and 2. may frequently be seen, particularly in the lenses of old animals when they are large, by examining them in their entire and transparent state within their capsule. In some cases I have seen them distinctly by looking down upon the surface of the lens; but when they are visible in this way they may be seen to most advantage by looking through the surfaces with a small magnifier, when the lens is placed in a fluid of nearly the same refractive power.

In tracing the fibres to their termination in three *septa*, I employed the optical method already described in a preceding paper; but in general the superficial coloured images are not so distinct as those in the lenses of fishes, though, like them, they may be transferred to wax, and are like the colours of mother-of-pearl.

The fibres of the lenses of quadrupeds gradually diminish in size from the equator or margin of the lens, where they are a maximum, to their termination in the anterior and posterior septa. They are united together by small teeth, like those of fishes; but generally speaking the teeth are smaller and less distinctly pronounced; and in some lenses I have found it extremely difficult to exhibit them with the finest microscopes. As the teeth can only be seen in the indurated state of the fibres, it is probable that their form may be in a great measure altered or obliterated by the process of induration, especially when we consider that the lenses of quadrupeds are very much softer than those of fishes, and that the evaporation of the aqueous portion must produce a greater change upon the indurated albumen when it is most abundant.

The existence of three septa was observed by LEEUWENHOEK, and afterwards by SATTIG, in the lenses of the ox, the horse, the sheep, the goat, the fox, the dog, and

No. III.

Fig. 3.

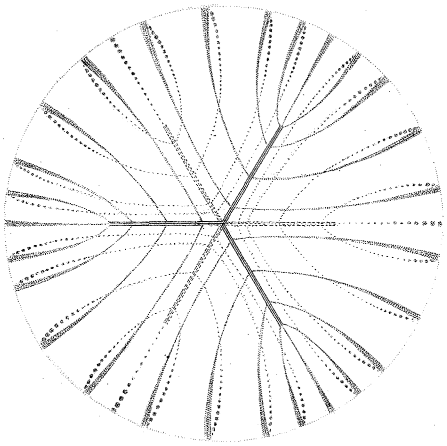


Fig. 2.

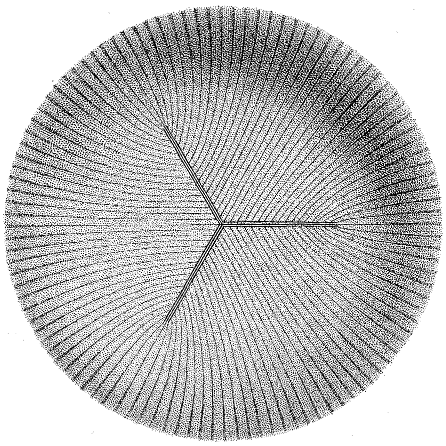
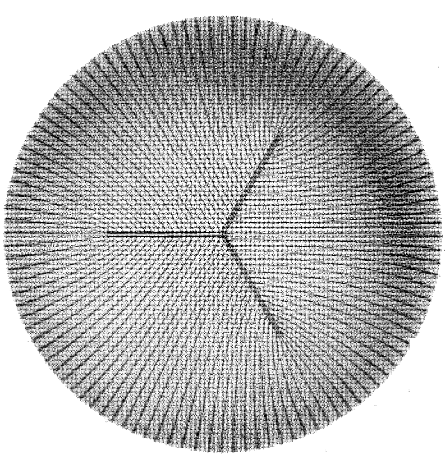


Fig. 1.



No. IV.

Fig. 2.

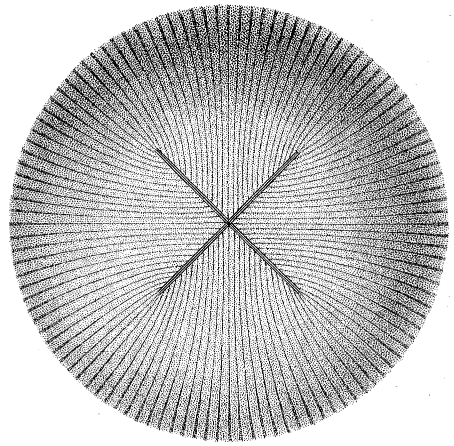
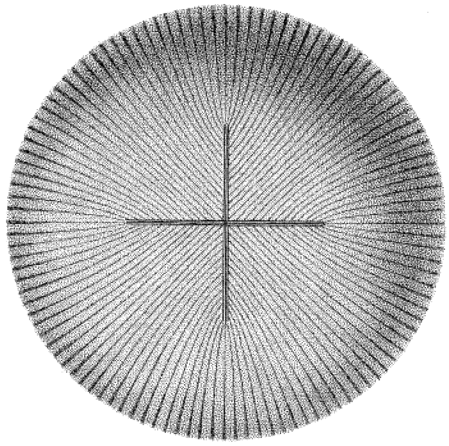


Fig. 1.



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the cat; but LEEUWENHOEK committed the strange mistake of supposing that each coat or lamina of the lens consists of circumvolutions of a single fibre, whereas each fibre has a distinct termination in the septum at both its extremities. Dr. THOMAS YOUNG seems to have been occupied with the examination of the crystalline lens of the ox in 1792 or 1793, previous to the publication of SATTIG's thesis; and in his observations on Vision, read before the Royal Society on the 30th of May, 1793, he has given a drawing and description of the result of his observations*. This description is exactly the same as that previously given by LEEUWENHOEK, excepting that Dr. YOUNG erroneously maintains that each of the coats of the lens "consists of fibres intermixed with a gelatinous substance," which we presume he considered to be necessary for cementing the fibres into a compact body.

In Dr. YOUNG's subsequent and more elaborate paper on the Mechanism of the Eye†, he renounces as erroneous the description which he had given of the arrangement of the fibres in the crystalline of the ox; and he substitutes, in place of his former correct drawing, another, which is altogether visionary. "In man," says he, "and in the most common quadrupeds, the structure of the lens is *nearly similar*. The number of the radiations is of little consequence; but I find that, sometimes at least, in the human crystalline there are *ten* on each side, not *three*, as I once, perhaps from a too hasty generalization, concluded. Those who find any difficulty in discovering the fibres must have a sight very ill adapted to microscopical researches." Notwithstanding the assertion in this passage that the structure of the lens in man and the most common quadrupeds is *nearly similar*, yet fig. 93, in which he represents "the order of the fibres of the human crystalline," is essentially different from fig. 95, in which he shows the "ramifications (of the fibres) from the margin of the crystalline lens" in quadrupeds. In the first of these figures there are no ramifications of the fibres from the margin of the lens, whereas in the second there are no fewer than six, placed without any symmetrical relation either to the septa or to one another.

The following Table contains the names of the different animals in whose lenses I have found the structure shown in Plate V. figg. 1, 2, and 3. These animals are all quadrupeds, with the exception of the anonymous fish caught near the Azores, to which I shall have occasion again to refer‡.

Lion.	Ox.	Goat.
Tiger.	Cow.	Sow.
Horse.	Sheep.	Deer, Fallow.

* Elements of Natural Philosophy, vol. ii. p. 525. "In examining," says he, "the crystalline from an ox, I discovered a structure which appears to remove all the difficulties with which this branch of optics has long been obscured."

† Elements of Natural Philosophy, vol. ii. p. 597.

‡ For the lenses of several of the rarer animals contained in the following Table, I have been indebted to the liberality of the Zoological Society of London.

Deer, Roe.	Dog.	Baboon.
—— Indian.	Cat.	Monkey, Douroucouli.
—— Moose.	Otter.	——— Black Spider.
Buffalo, Wild.	Rat.	——— Entellus.
Nilgao, India.	Mouse.	——— Green.
Llama.	Opossum.	——— Lesser White-nosed.
Puma.	Squirrel.	——— Jacketed.
Cheetah.	Lemur, Black.	Vicugua.
Antelope, Melampus.	——— Red-fronted.	Capybara.
——— Pygmy.	——— Nocturnal.	Chinchilla.
Fox, Common.	Coati, Brown.	Ichneumon.
—— Black, from America.	Suricate.	Fish caught near the Azores.

1. *Lion.*—The posterior surface of the lens is the most convex. The fibres which compose the lens are exceedingly distinct, and the teeth smaller and sharper than those of fishes.

2. *Tiger.*—The fibres and the teeth which unite them are very distinct, and like those of the lion. In a lens preserved in spirits, and deprived of its external lamina, the lamina shone with all the incommunicable colours of mother-of-pearl. When the lens was dried these colours disappeared.

3. *Horse.*—When the lens of the horse is thrown for a second or two into boiling water, and is allowed to dry slowly, it splits in such a manner as to show the septa and the general structure of the lens very satisfactorily. The fibres are well seen, and the teeth distinct and small like those of the lion and the tiger.

4. *Llama, Puma, Capybara,* &c.—The fibres and teeth are exceedingly distinct in the lenses of these animals, and equally or less so in all the other animals in the Table.

5. *Cat.*—In order to observe if the fibrous structure was the same in the young animal, I took the eyes of three kittens, six in number, about eighteen hours after birth; and what was very remarkable, I found that the lenses in all the six were white and opake, with a perfectly transparent rim. The three septa were distinctly seen in all the lenses. It will be interesting to ascertain, if in all animals which are born blind, the crystalline is opake at their birth, and gradually becomes transparent from the margin to the centre during the period in which the eye is closed against the admission of light.

6. *Chinchilla.*—The lens of the chinchilla seems to fill the whole ball, and the cornea is exceedingly large, forming almost a hemisphere.

7. *Suricate.*—The cornea of the suricate is nearly of the same size as that of the chinchilla.

8. *Unknown Fish from the Azores.*—The lens of this fish, which was sent to me without a name by Mrs. Green of Cumberland Island, is in every way remarkable. It is the only lens of a fish which has the structure belonging to quadrupeds; and it is equally peculiar in having the form of a prolate spheroid, the axis of which coin-

No. IV.

Fig. 3.

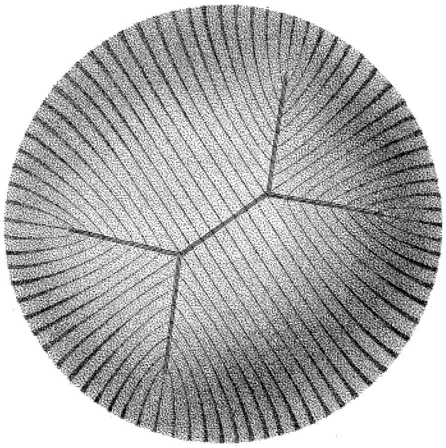


Fig. 4.

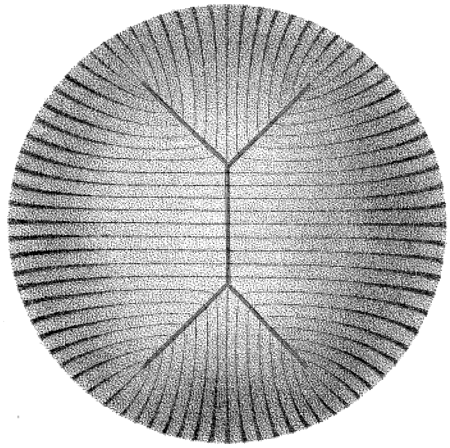


Fig. 5.

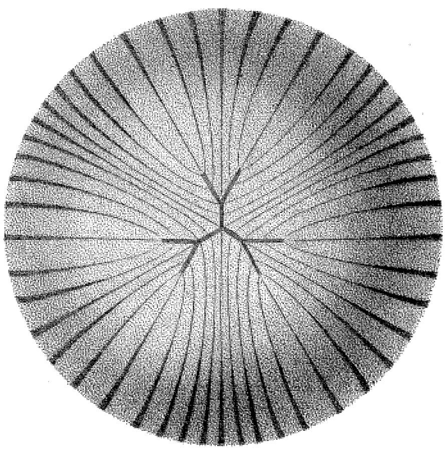
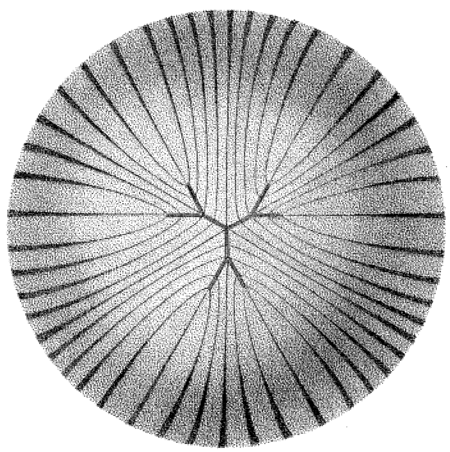


Fig. 6.



No. V.

Fig. 1.

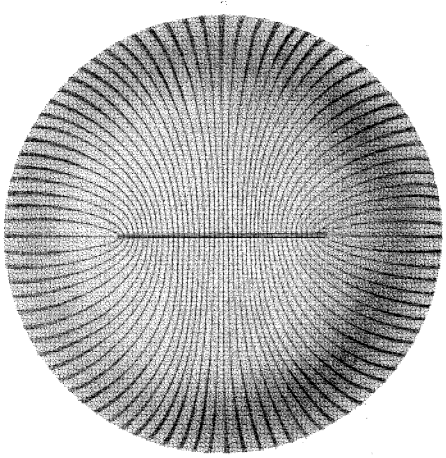
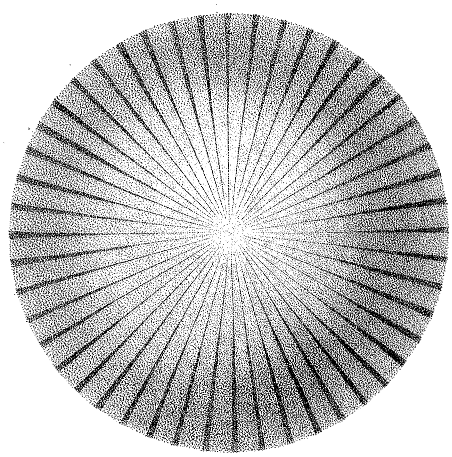


Fig. 2.



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cides with that of the eye. The length of the axis is 0·327, and its equatorial diameter 0·273 of an inch.

In some quadrupeds I have observed an irregularity in the septa, which may have arisen either from an original malconformation of the lens, or from some accidental injury. In the lens of a horse I observed a spurious septum, one of the three being double. The same fact will be more particularly noticed in describing the lens of the elephant, in which it is more common.

§ 4. *On the Anatomical and Optical Structure of the Crystalline Lenses of Animals, particularly those of the Whale, the Seal, the Bear, and the Elephant.*

From the lenses of quadrupeds in which the fibres are related to three septa, I shall now proceed to describe the fourth and last class of symmetrical structures, in which the fibres are related to four septa, placed at right angles to one another. This combination of fibres is of rare occurrence, and I have found it only in the lenses of the *whale*, the *seal*, and the *bear*.

The character of this structure will be understood from Plate V. figg. 1 and 2, where fig. 1 represents the anterior surface, and fig. 2 the posterior surface, of the lens. The septa on the posterior surface are inclined 45° to those on the anterior surface, so that if the lens were transparent, the septa when seen at the same time would appear like the eight radii of an octagon, inclined 45° to one another. In this structure there are eight fibres, all the parts of which lie in one plane, passing through the axis of the lens; namely, *four* extending from the extremities of the four anterior septa and terminating in the posterior pole, and other *four* extending from the extremities of the *four* posterior septa and terminating in the anterior pole. All the other fibres of the lens, except these *eight*, are curves of contrary flexure, which necessarily change their direction in passing from one septum in the one face to another septum in the other inclined 45° to it.

The structure which I have now described is exhibited in the crystalline lenses of the *whale* and the *seal*. I found it distinctly developed in the lens of a whale, forty-six feet long, caught by Captain Ross in his first voyage in the Arctic regions, and also in a specimen of the great seal, or *Phoca barbata*, which Lieutenant Robertson of the Isabella brought home from Baffin's Bay in the same year.

In the lenses of other whales and seals, however, I have found a different structure, which is represented in Plate VI. figg. 3 and 4. This combination of fibres differs from that in figg. 1 and 2, in having two centres of divergence in place of one in each surface of the lens; but if we conceive these two points to coincide, the two structures become identical. In both, the principal septa are at right angles to each other on the same face, and inclined 45° to those on the opposite face; so that the general character of the two structures is the same.

In the lenses of one of the bears killed by Captain Ross during his first voyage, I found the structure shown in figg. 2 and 3. The distance between the centres of divergence was greater on one side of the lens than on the other, in both lenses; and in one it was so small as to show very nearly the structure in figg. 1 and 2.

In the lenses of other whales, one of which was thirty-five feet long, I found the structure shown in figg. 1, 2, 3, and 4, in which there are *four* radiations of fibres, or vortices, as I believe LEEUWENHOEK calls them, on each surface of the lens; but I have found in one lens a spurious structure, in which there are *five** radiations on one face and *three* on the other face of the lens.

When the lens of the whale has been preserved in spirits, the coats have often a brilliant pearly lustre, a phenomenon which I have seen with equal beauty in the lenses of some quadrupeds, especially in that of the tiger. The fibres of the lens of the whale are extremely distinct, and the teeth upon them, which are visible with high powers, resemble those in the fibres of quadrupeds.

The crystalline lens of the *elephant* possesses many remarkable peculiarities. The following are the dimensions of the eyeball of an elephant, which Mr. GEORGE SWINTON was so kind as to send me from Bengal.

Eyeball.

	Inches.
Longest diameter	1·82
Shortest diameter	1·10

Cornea.

Longest diameter	1·35
Shortest diameter	0·92

Crystalline Lens.

Longest diameter	0·700
Shortest diameter	0·627
Thickness	0·400

Ratio of the two diameters, 1 to 1·1125.

In another eye the dimensions of the lens were as follow:

Crystalline Lens.

	Inch.
Longest diameter	0·784
Shortest diameter	0·700
Thickness	0·450

Ratio of the two diameters, 1 to 1·116.

* LEEUWENHOEK says that there are *five* septa in the lens of the whale; but I have not his paper beside me in order to ascertain whether he means by this five radii inclined 72° to each other, or *five* radiations such as I have found in the spurious structure here mentioned.

Hence it is obvious that the crystalline lens of the elephant differs from that of most other animals, in being of an *elliptical* form, the horizontal diameter of the ellipse being the longest.

When the lens has been preserved in spirits, and the outer coats are removed, it resembles a piece of the finest amber. In this condition, when dry, it does not crack, like other lenses, but exfoliates in thin scales, which give it the appearance of a flat pearl. When these scales are rubbed off it resumes its appearance of amber, and when well dried, after two or three exfoliations, it becomes as permanent in its appearance and colour as that substance, and almost as hard and durable.

This peculiar property of the elephant's lens arises from the peculiar structure of its coats or laminæ. These coats are not, properly speaking, composed of fibres, but are of a fibrous tissue, the elementary fibres of which are not united mechanically by teeth, but by some other process, probably that of agglutination, which I cannot discover by the finest microscopes which I possess *.

Owing to this structure of the laminæ, the superficial colours are not displayed, as in other lenses, and it is very difficult to trace the elementary fibres into the septa, to which they are related. I have succeeded, however, in determining that there are *six* radiations of fibres and *three* centres of divergence on each surface of the lens.

This structure is shown in Plate VI. figg. 5 and 6, in which there are *three* septa diverging from the poles of the lens, as in quadrupeds, and from the extremity of each *two* additional septa, which are the real septa, to which the fibrous radiations are principally related. The three central septa are inclined 120° to each other, and the two additional septa seem to be inclined at an angle of 60° to each of the central ones; but these measures are of course only rude estimates of the inclination of lines, which in animal and vegetable organizations, and even in those of the mineral world, approximate only to the mathematical type of their characteristic structure.

In the combination of fibres shown in figg. 5 and 6, there are twelve fibres whose parts all lie in the same plane, all the rest forming curves of contrary flexure.

In some lenses of the elephant, I have found the three septa which meet in the poles of the lens exceedingly small, and approaching to evanescence; and I have no doubt that, as happens in the case of four septa, these three central septa will in some lenses be wanting; so that the other six septa will diverge from the poles at angles of 60°, like the radii of a hexagon. Such a lens will bear the same relation to the structure shown in figg. 5 and 6 as the structure in figg. 1 and 2 bears to that in figg. 3 and 4.

* In extremely thin and highly-dried fibres, the fibres are better seen with the microscope; and I have observed something like a mechanical union of them.

§ 5. *On the Structure of the Crystalline Lens of the Turtle and other animals in which the Fibres are differently combined in the anterior and posterior Surfaces.*

In the various structures of the crystalline lens which have been described in preceding communications, the fibres are similarly arranged on both the surfaces of the lens, whether these two surfaces are similar, or have different degrees of convexity. In this respect they resemble the artificial lenses of the optician, in which there is no other deviation from symmetry but in the curvature of their surfaces. I have discovered, however, in the lens of the turtle, and in that of several fishes, a new combination of fibres, in which they are differently arranged in the anterior and posterior faces of the lens.

Ever rich in her forms and fertile in her resources, Nature thus presents to us in the crystalline lens four singular properties, which the most skilful optician, even if he knew their design, is not likely ever to attempt to imitate. But the study of these properties is not on this account the less interesting; for though we may never be able to produce the same effect, either by similar or analogous means, yet we may be led to discover some other principle within the sphere of art by which the desired result may be obtained. The four properties to which I refer are the increase of density from the surface to the centre of the lens; the alternations of negative and positive structures, as exhibited by the action of the lens on polarized light; the arrangement of the fibres in reference to different numbers of septa; and the defect of symmetry in this arrangement in the turtle and a few fishes. The first of these properties, namely, a variation of density, is no doubt intended to correct spherical aberration, an effect which may be produced by the union of several spherical surfaces, or by hyperbolical or elliptical surfaces, or by surfaces of contrary flexure; but the design of the other three properties has not even excited the ingenuity of conjecture, and will probably remain among the numerous problems which will exercise the sagacity of another age.

When I first observed a defect of symmetry in the arrangement of the fibres in the two halves of the lens of the turtle, I was extremely doubtful of the accuracy of my observations, and was therefore at peculiar pains to confirm the result by examining several lenses of the turtle. In every lens, however, I found the deviation from symmetry was clearly indicated, though it did not possess the same character in every lens which came under my notice.

In the eye of the *turtle* which I first examined, the ball was one inch in diameter, and the diameter of the lens only 0·200 of an inch. The lens was nearly spherical; and it had on its anterior face *two* septa, like the hare and the salmon, as shown in Plate VI. fig. 1; but on its posterior face the fibres converged to a single pole, as shown in fig. 2. In this structure there are only four fibres in each lamina, which have their different parts lying in the same plane. All the other fibres are concave towards a plane passing through the two anterior septa, and of course convex towards a plane at right angles to it, so that in this structure the fibres exhibit no contrariety of flexure, as in all the other lenses with septa at each pole. The very same structure appeared in the other lens of the same turtle; and was found likewise in both the lenses of another turtle, in which the diameter of the eyeball was 1·2 of an inch, and that of the lens 9·23.

The fibres and their teeth are nearly the same in the turtle as in the lenses of quadrupeds, the teeth being very short, though perfectly distinct.

The structure represented by figg. 1 and 2 (Plate VI.) is possessed by the lenses of the following fishes:

The Drune.	Crocer.	Grey Gurnard.
Bass.	Angel Fish.	Red Gurnard.
Whiting from Georgia.	Mullet? from Georgia.	

1. The *Drune*, or *Drum*, from Georgia.—The lenses of this fish, along with those of the other fishes in the above table, except those of the gurnard, were sent to me with their common names by Mrs. Green of Cumberland Island. In both the lenses of the drune the different structures were very distinctly seen. The fibres varied greatly in diameter as they approached the pole; and though the secondary colours were not visible, yet the teeth of the fibres were beautiful and distinct.

2. The *Bass* from Georgia.—In this lens the double arrangement of the fibres is distinctly seen.

3. The *Whiting* from Georgia.—The same structure is clearly seen in both the lenses of this fish.

4. The *Crocer* from Georgia.—In both the lenses two short septa are seen in the anterior face, and a single pole in the posterior one. The teeth of the fibres are very close, but distinct.

5. The *Angel Fish* from Georgia.—In the lenses of this fish the two structures are very distinct, and also the teeth of the fibres.

6. *Mullet* from Georgia.—I am in some doubt respecting the existence of the double structure in the lens of this fish. The observation which I made many years ago is thus recorded: "A sort of diffused polarity round two poles, as if there were two septa on each side, like those of the hare, or on one, like that of the turtle." As a diffused polarity was the only fact actually observed, I find that I have placed the mullet in the list of fishes without septa.

7, 8. *Red* and *Grey Gurnard*.—In the lenses of both these fishes there were two short septa on one side and none on the other.

In examining the lens of a very large turtle, in which the eyeball was 1·4 of an inch in diameter, and that of the lens 0·25 of an inch, I found to my great surprise that there were three septa in front, as in quadrupeds, and *four* septa, or rather *six*, as in the seal. The following is the account of the observation which I recorded at the time: "I saw distinctly the above septa on both sides when the lens was fresh and transparent, and plunged in oil of almonds, and I confirmed this result by boiling the lens and removing the laminæ. The four septa require nice observation to be seen. One of the *three* was inclined about 45° to one of the *four* septa. The other lens of this turtle has most distinctly four septa, but *only two on the other side.*" A similar variation of structure has already been referred to as existing in the lenses of the horse and the whale.

Belleville by Kingusie,
November 14*th*, 1835.

No. II.

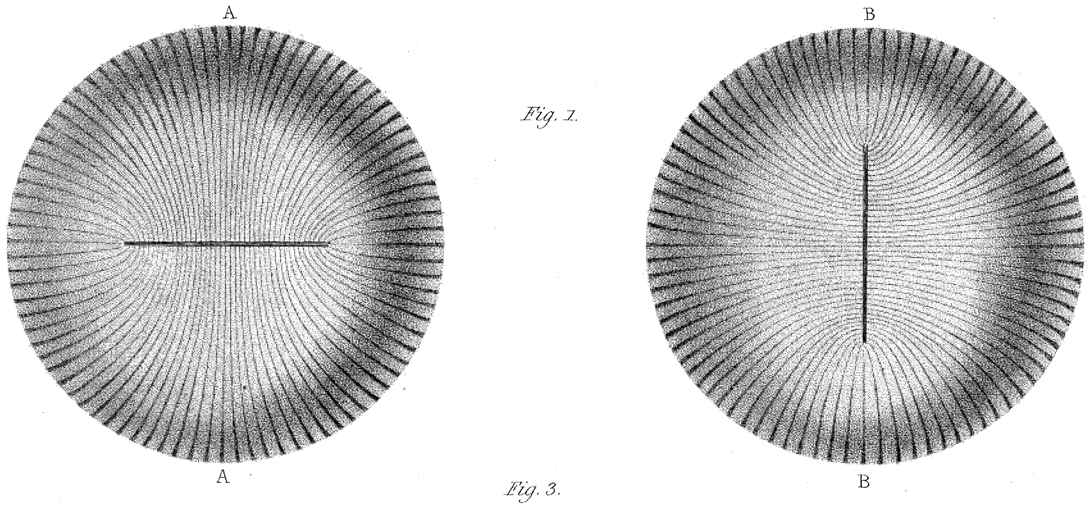
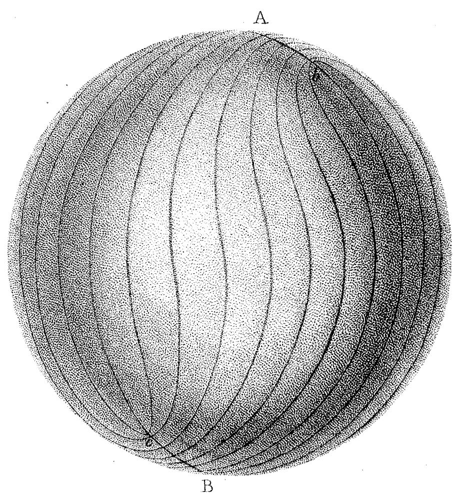


Fig. 1.

Fig. 3.



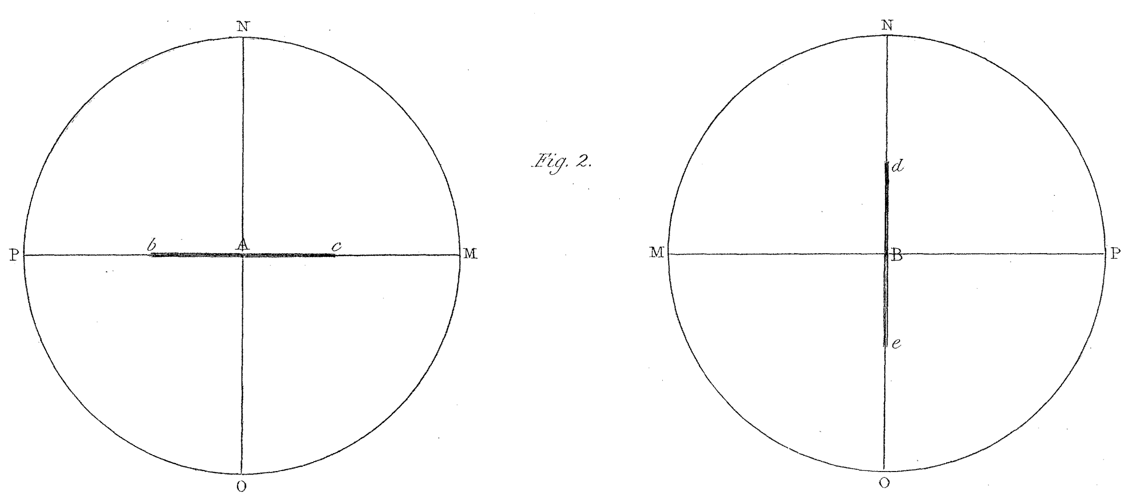


Fig. 2.

J^s. Basire sc.