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Mr. Thomas Smith

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ing with lime-water. In this vessel was placed a glass dish, containing an ounce of finely pulverized charcoal. The charcoal was left to stand in the oxygen for 24 hours; and at the expiration of that time no trace of carbonic acid was to be found on passing the remaining gas through lime-water.

This experiment was three times performed in the same manner, and with precisely the same result.

I have here given a brief and simple statement of the observations and experiments which I have yet made upon this curious and interesting subject. The spontaneous combustion of charcoal is, I apprehend, now fully established; and I have endeavoured, to the best of my ability, to determine some of the circumstances under which it takes place. I have abstained from any theoretical speculations; contented, for the present, to have related the facts which experiments alone have elicited. If in future any new facts should present themselves, I shall be happy to submit them to the Society.

II. *On the Muscular Structure and Functions of the Capsule of the Crystalline Lens and Ciliary Zone.* By Mr. THOMAS SMITH, Surgeon, Fochabers*.

HAVING found by observations on the eyes of the three principal classes of animals, that the capsule of the crystalline lens, and the radiated circle of the hyaloid membrane to which it is attached, are endowed with a fibrous structure and contractile property which admirably fit them for changing the figure of the lens, by rendering it more or less spherical; and that the optical phænomena attending the accommodation of the eye to different distances, as well as certain changes which the lens itself is found to undergo, correspond in a singularly happy manner with those which ought to result from the functional action of the capsule as the organ of adjustment,—I venture, in compliance with the advice of some intelligent friends to whom my observations have been submitted, to offer an account of them for publication; for though the induction from the phænomena is not in certain respects so complete as I have been anxious to make it, yet I trust it may be found sufficiently so to vindicate me from the charge of presumption in directing into this new channel the attention of persons better qualified than I can pretend to be, to carry it to perfection.

The extreme transparency of the capsule of the lens in its sound state renders its structure difficult to be ascertained by

* Communicated by the Author.

direct ocular observation. Certain peculiarities, however, which have not been mentioned by anatomical writers, are sufficiently distinct to be seen by the help of the microscope, or even with the naked eye, in a favourable light. If the whole vitreous humour, and lens imbedded in it, are taken out of the eyeball, by cautiously separating the hyaloid membrane from its connexions with the parts around the iris, the lens in its capsule is seen surrounded by a beautiful radiated circle or zone, which has been generally but erroneously described as merely the marks left by the ciliary processes on the hyaloid membrane. Even the celebrated Cuvier speaks of it as nothing more. Dr. Knox of Edinburgh corrects this mistake. The zone around the capsule exhibits, he says, "a very complicated structure. On that part of the hyaloid membrane on which the ciliary processes rest, we find an equal number of folds or laminæ, which projecting outwards, are dove-tailed, as it were, with the ciliary processes. These membranous folds are vascular, the vessels pass in great numbers from the ciliary processes to them, and these vessels, together with the dove-tailing of the two sets of processes, form, as every anatomist ought to know, the bond of union between the choroid and hyaloid membranes, which otherwise would have no connexion with each other*." The radii, which are here termed *membranous folds*, unite together in a circular ring around and close to the capsule, and even seem to spread over the circumference of the capsule itself, giving it a notched appearance, noticed by M. Cloquet, and forming a pretty broad belt all round the capsule. To the naked eye, the radii of the zone, when washed free from the black paint which generally adheres to them, the ring in which they unite, and the belt which I have described as surrounding the capsule, have a remarkable resemblance to the muscular fibre of the haddock or of the whiting; and when they are viewed through a powerful microscope, the fibrous structure is seen in the most distinct manner *along* the ridges of the radii and *across* the ring and belt.

If we divide the eyeball of any of the larger quadrupeds into two nearly equal parts, by a section of the sclerotic coat and vitreous humour parallel to the plane of the iris, and invert the section containing the lens, that body will be seen through the remaining part of the vitreous humour surrounded by a radiated circle, consisting of the zone of the hyaloid membrane above mentioned in conjunction with the ciliary processes of the choroid coat, and forming what has been termed the ciliary body,—the following particulars respecting which deserve at-

* Vide Translation of Cloquet's Anatomy, p. 552.

tention. It consists of about 80 larger radii or ridges regularly arranged around the capsule, and pointing to the centre of the lens, but terminating abruptly where they touch the capsule. These ridges swell out and assume a bulging appearance towards their middle, from whence they divide both ways into more slender ramifications. Of these smaller branches, those which proceed to the capsule anastomose together branch to branch of the contiguous larger ridges, so as to support or act upon, equally, almost every point of the circumference of the capsule. Those branches that go out in the opposite direction are nearly twice as numerous; and as they lay hold of the retina, they must support or act upon it, because the ciliary ligament which binds the ciliary body to the sclerotic coat is situate directly behind the bulging part of the radii. The breadth of the ciliary ligament is never equal to that of the ciliary body, consequently part of the ramifications of each ridge must be loose both ways; so that whatever be the function of the radii, the ciliary ligament must be the fulcrum or point of support on which the action of the smaller ramifications bears, both ways.

Reflecting on these circumstances, (the force of which the reader will better understand by examining the parts with his own eyes,) and on the fibrous structure and fleshy appearance of the ridges of the zone and belt surrounding the capsule,—the muscularity of these parts appeared to me highly probable, particularly when the elegant regularity of their arrangement and their constancy in all classes of animals, even where no ciliary processes were to be found, were taken into view; together with the manifest provision made by nature to supply them plentifully with fresh blood, contrary to what is found in parts whose office is merely ligamentous.

Unwilling, however, to depend on such evidence alone, I endeavoured to find a method by which muscular fibre might be distinguished from other tissues, for which, as in the present instance, it might be mistaken. The description given by such physiological writers as I had access to, of the changes produced on some of the animal tissues by boiling water, suggested to my mind an experimental inquiry with that agent, from which I was enabled to deduce the test I was in search of. The general results of the inquiry were;—that all animal tissue that was certainly muscular contracted in the direction of the fibre, when immersed in boiling water: all tissue that was certainly tendinous or ligamentous contracted in the direction of the fibre, but more largely. By the contraction, muscle lost about one third, tendon more than one half its length. All purely membranous envelopes, such as the peritoneum, pericardium, &c. contracted like tendon, but in all

directions. All muscular tissue, from being transparent before immersion in boiling water, became opaque and white after it. The transparency of the muscular fibre of clear-blooded animals, such as the *cod*, *whiting*, &c. is obvious; and in red-blooded animals the transparency of the fibre permits the colour of the blood to be seen through it. Tendon or ligament, from being white and glistening, became semitransparent and yellowish in boiling water; and purely membranous tissues, whose office is akin to that of ligament, remained transparent after immersion in boiling water, as they were before it.—From these facts I have ventured to deduce the following test, by which the muscularity of *transparent animal tissue* may, if the principle appears well founded, be tried.

Test.—Immerse in water boiling hot the transparent part of animal tissue to be tried: If it contract about one third part of its length and become opaque and white, it is *muscular*: if it does not contract, it is not muscular, though it become white: if it contract more than one third, and remain transparent, it is of a ligamentous nature.

The late Dr. Young, it will be remembered, taught that the crystalline lens consisted of a muscular and tendinous structure arranged in concentric layers and intermixed with a gelatinous substance, and that by the action of the muscular parts of the layers the convexity of the lens was adapted to the different distances of objects. The entire want of communication between the lens and capsule by means of nerves and blood-vessels, on which anatomical writers appear to be agreed, is a strong objection to Dr. Young's hypothesis,—not to mention the perfect fluidity of the foetal lens, so very unlike any other muscular or tendinous part at the same period. But to remove all doubt I plunged the lens, deprived of its capsule, in boiling water. If Dr. Young's opinion were correct, the lens, from the contraction of both the muscular and tendinous parts of each coat, ought to have become much more spherical, and we should have been able, on separating the intervening coagulum of gelatinous substance, to obtain a succession of thin transparent tendinous layers, surrounded by the muscles attached to it, made white by the boiling water. But in numberless instances which I tried, the lens was not found to undergo the smallest appreciable increase of sphericity. It became opaque and white, but continued of the same diameter and thickness after immersion in boiling water as it was before. It therefore is not muscular.

A very different result was obtained when the lens, *covered by its capsule*, was immersed in the same manner. The lens of a cow, with its capsule around it, measured in diameter 0·7 inch, in thickness 0·5 inch, before immersion. After it had

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lain in boiling water till it became quite opaque and white, it measured on being taken out 0·65 inch in diameter, and 0·55 inch in thickness. In losing in diameter and gaining in thickness, the lens of course acquired a greater degree of sphericity. The alteration in this respect, indeed, was so remarkable, that a gentleman of science,—to whom I showed the two lenses of the same animal after they had been immersed in boiling water, the one with, the other without the capsule,—pronounced without hesitation, that they must have belonged to very different animals. The following Table shows the effects of immersion on the lens of a variety of animals taken at random from a very great number of experiments which I made at different times; and I can faithfully assure the reader that I have not, in all the trials I have made, met with a single exception to the principle which it exhibits.

Name of Animal.	Measurements of the Crystalline, in Parts of an Inch.							
	With the Capsule on it.				Without the Capsule.			
	Before Im-mersion.		After Im-mersion.		Before Im-mersion.		After Im-mersion.	
	Dia-meter.	Thick-ness.	Dia-meter.	Thick-ness.	Dia-meter.	Thick-ness.	Dia-meter.	Thick-ness.
Ox	Inch. 0·74	Inch. 0·5	Inch. 0·7	0·54	0·745	0·49	0·745	0·49
Stag	0·70	0·5	0·64	0·54	0·71	0·49	0·71	0·49
Sheep	0·60	0·42	0·55	0·48	0·61	0·41	0·61	0·41
Pig	0·41	0·32	0·39	0·36	0·43	0·31	0·43	0·31
Roe	0·39	0·28	0·37	0·32	0·39	0·28	0·39	0·28
Rabbit	0·36	0·26	0·34	0·29	0·38	0·25	0·38	0·25
Rat	0·20	0·16	0·18	0·18	0·20	0·16	0·20	0·16
Domestic Fowl	0·26	0·13	0·2	0·15	0·28	0·12	0·28	0·12
Codling	0·42	0·39	0·415	0·415	0·42	0·39	0·42	0·39
Herring	0·26	0·22	0·24	0·24	0·26	0·22	0·26	0·22
Whiting	0·265	0·24	0·26	0·255	0·27	0·24	0·27	0·24
Flounder	0·200	0·18	0·19	0·19	0·20	0·18	0·20	0·18

From this Table it is obvious that the change of sphericity produced by immersing the lens in boiling water is due to a contractile power in the capsule alone. By measuring the breadth of the capsular belt above mentioned before and after the immersion, I found that it was rendered narrower as well as shorter by a boiling heat; and as the *transverse* circumference of the lens in its capsule was, as nearly as I could determine, the same before and after immersion, this proves the important fact that the contraction of the transverse fibres of the belt is compensated for by an expansion of the elastic membrane constituting the rest of the capsule. In order to try to what class

of tissue the capsular belt and radii surrounding it belonged, I removed the lens from the capsule, and immersed the capsule attached to the radiated zone, along with the whole vitreous humour, in boiling water. The *belt* contracted both in length and breadth, and became white; the anterior part within the belt became white, but did not contract; the posterior part within the belt remained transparent. The radii of the hyaloid zone contracted, and became white. These radii, therefore, and the belt around the capsule exhibit the properties of muscular tissue.

Assuming the muscularity of the capsule and hyaloid zone as declared by the test, it remains to try whether such a structure in action is capable of performing the function of adjustment, as it is found to be performed, in the perfect eye.

The function of the muscular belt around the capsule is made sufficiently evident by its effects on the figure of the lens when plunged in boiling water; but the function of the radii of the zone around the capsule can only be understood by attending to the fixed points towards which their contraction must carry their extremities. I have stated above, that these fixed points correspond to the position of the ciliary ligament. Hence the contraction of that part of each of the radii that lies between the capsule and the ligament must draw the circumference of the capsule towards the ligament, and increase the diameter of the lens. The function of the radii, therefore, is antagonist to that of the belt.

As a sense of straining or effort is experienced when the eye is adapted for a considerable length of time, either to very near or very distant objects, followed by a sense of fatigue, it would appear that there is a middle point, to which the convexity of the lens is naturally adapted, and that the adjustment of the eye to nearer or more distant objects is made by a functional exertion. If the adjustment to near objects is made by contraction of the capsule, and to distant objects by contraction of the radii, I find by a calculation founded on optical principles, that the changes of curvature of both surfaces of the lens, easily made by these means, fully account for a range of distinct vision equal to that which the young and healthy eye actually commands. What increases the probability that the adjustment of the eye to different distances is really effected by these means, is, that the accommodation made in this way is attended with no change of the optical centre of the eye; whereas it can be demonstrated that by every other method that has been proposed, a change in the position of the optical centre, and consequently an apparent motion of stationary objects, must occur during the act of adjustment to different

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distances. Sir David Brewster* employs this argument successfully against the hypothesis that the eyeball is lengthened, or the convexity of the cornea increased, to accommodate the eye to near objects. It is of equal force against the supposition that the lens is drawn forward by any means; for this would move the centre of the lens, and consequently the optical centre of the eye, forward,—an occurrence which the apparent stability of stationary objects out of the axis of vision during the adjustment, disproves beyond any doubt.

In attempting to ascertain the seat and mechanism of a hidden function, as this is, it appears incumbent upon us not only to show, as I have endeavoured to do, that a structure exists which is capable of performing the function; but also to prove that the physical effects which the action of that mechanism ought to produce, are actually produced in the living body, in connexion with the exercise of the function itself. If this can be done in the present case, all that the most cautious and rigorous induction can demand, will, I venture to hope, be fulfilled.

In its natural state the crystalline lens appears to be a thin gelatinous fluid, with a refractive power of about 1·377; for I have repeatedly found it wholly so in the eye of the *foetus*. It is condensable even to solidity without destroying its transparency, and its refractive power keeps pace with its density, as may be proved by suffering the fluid part of it to condense by drying in a hollow prism made with two plates of glass.

Now, if the capsule is the organ of adjustment, the lens, from its condensability, ought to exhibit the following effects of the capsular function:—

1st. The contraction of the capsule ought, by pressing upon its contents, to render them denser towards the centre than towards the surface. For if the lens is a sphere consisting of concentric layers or shells of equal thickness, it is obvious that the pressure of the capsule, being propagated from the surface to the centre, is equal over the whole of each layer. But as the layers towards the centre occupy less space than those which are towards the surface, the pressure on equal portions must increase in the same proportion towards the centre; consequently the central parts must in the course of time be rendered denser by the reiterated action of the function, pressing equal portions in the inverse duplicate ratio of the distance from the centre.

2nd. The more spherical the lens is, the denser, *cæteris paribus*, ought its nucleus to be. For in a perfectly spherical

* See Lardner's *Cyclopædia*, Article OPTICS, p. 301.

lens, the whole pressure of the capsule is sustained by a single central particle. But in a flat lens the same pressure is sustained by a number of particles occupying an extended space. If the force of pressure is the same in all lenses, the density, at the centre of a flat lens, ought to be the same as it is found to be at the same distance from the surface of a spherical lens.

3rd. The more the eye has been employed in surveying near objects, the harder ought its central nucleus to be. Hence the central density ought to increase with the age of the animal; and it should be found, *cæteris paribus*, harder in individuals that are much employed in near vision than in those of a contrary habit. Even short-sightedness may, in some instances, be expected as the consequence of long intense adaptation to near objects.

4th. The hardest part of the crystalline ought to be in the centre of pressure. This is an evident and important corollary of the theory; and as the convexity of the two surfaces of the lens is seldom or never equal, the position of the hardest point of the nucleus will furnish an excellent test of its truth. If the capsule is the organ of adjustment, the distance of the hardest point from the anterior surface will be to its distance from the posterior, as the radius of curvature of the former is to the radius of curvature of the latter. For there the centre of pressure of the two surfaces must be.

5th. The indurated nucleus of the unadjusted lens ought to be more spherical than the soft external part. For when the central parts have gained that degree of firmness and consistence that enables them to retain any figure given to them, the figure which they will assume will obviously be determined by the figure of the contracted capsule adapting the eye to the nearest distance. If the external soft parts are sufficiently abundant, this will enable the capsule to adapt the eye to distant objects by moulding the soft parts, while the indurated nucleus retains the convexity given to it by the contracted capsule. This therefore will furnish another important test by which the truth of the theory may be tried; for no other cause that I am aware of could produce the same effect.

It now remains to ascertain, by examination of the lens itself, whether or not its structure and appearances correspond with the theory in these respects.

1st. The greater density of the crystalline at the centre than at the surface has long been known, and is universally acknowledged by physiologists. Sir David Brewster demonstrates in an elegant manner its gradual increase of density from the surface to the centre. Upon exposing a recent human crystal-

line lens to polarized light, he found it depolarize four faint sectors of light considerably below the white of the first order; "thus indicating a positive doubly refracting structure, like a sphere of glass rapidly cooled, and increasing in density towards the centre."

2nd. The celebrated Cuvier, in his Lectures on Comparative Anatomy, mentions as a general fact that the nucleus is hardest in those lenses that are most convex. My own observations on the lenses of quadrupeds, birds and fishes, confirm this fact in its fullest extent. The greatest hardness of the nucleus of the ox is not greater than the hardness of the lens of the cod half way between the surface and the centre; and very flat lenses, such as those of fowls in general, are scarcely more dense at the centre than those of the cod very near the surface. These appearances are in strict accordance with the theory; but surely they do not correspond with those which might be expected if the lens were a solid organized for the express purpose of correcting the spherical aberration of light. The fact I have stated above, that I had found the very young foetal lens entirely fluid, and of the same refractive power as the soft or fluid external part of the maternal lens, together with the universally soft state of young lenses,—strongly impress on my mind a conviction that the substance of the lens is a secretion of a peculiar fluid; and what has been termed the *liquor Morgagni* is probably this fluid recently secreted. This impression is greatly strengthened by the account of experiments made by Messieurs Cocteau and Le Roy d'Etiolle, and published in the *Journal de Physiologie* for January 1827. These gentlemen performed the operation of extraction on many rabbits, cats, and dogs; and they found that in most instances, though not in all, the capsule, examined at the end of four or six weeks, contained a new body, of a lenticular form, and approaching in consistence to that of the extracted lens. In one of these experiments they allowed the animal, a rabbit, to live six months after the operation. "The crystalline capsules were then found perfectly transparent without a visible cicatrix; and they contained each a lens of the same volume and consistence as those extracted. For the sake of greater certainty, they were immersed in hot water, when they became opaque, hard and friable like ordinary lenses; the sole difference being, that the disposition in brilliant plates was evident only on the outer layers." This fact shows the importance of preserving the capsule in the operation for cataract when it is not diseased, and completely disarms any objection that may be urged against our theory from some individuals having been

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known to have the power of adjusting the eye to different distances, after the lens had been extracted by an operation.

3rd. All anatomists agree that in young eyes the lens is entirely soft and pulpy; whereas in old eyes, which of course have been often adjusted to near objects, it is firmer, and has a hard nucleus at the centre. In the foetal calf and lamb I have found the whole lens so fluid that it formed the capsule into the figure of a globule. In very young calves, lambs and rabbits, after birth, the consistence was firmer, but still pulpy throughout; but in old cows, sheep, &c. the central part constituted a nucleus hard or firm enough to retain any form given to it. In this respect, therefore, observation also agrees with the theory.

4th. The position of the hardest part of the crystalline, ascertained by observation on the lenses of oxen, sheep, deer, rabbits, pigs, &c. agrees also in the most correct manner with the theory. I made this observation several years ago with considerable surprise, and long before the slightest idea of its cause had entered into my mind. Wishing to divide the lens into two equal sections in the direction of the axis, without deranging the curvatures of its surfaces, I applied the edges of two sharp scalpels to the opposite faces of the lens, and holding the blades in the same plane pressed them gently together along the axis till they met, which they did of course, in the hardest point. By a memorandum, taken at the time, the distance of this point was 0.28 inch from the anterior, and 0.22 inch from the posterior surface. The lens was that of a cow, its diameter being 0.7 inch, its thickness 0.5 inch. By measurements taken with the utmost care, the radius of curvature of the anterior surface was 0.5 inch, the radius of the posterior surface 0.39 inch. By the theory, I have shown that the centre of pressure, and consequently the hardest point of the nucleus, ought to be so situate, that its distance from the anterior surface may be to its distance from the posterior, as the radius of curvature of the former is to that of the latter. But 28 is to 22 as 50 to 39 very nearly. In short, in all animals that have the anterior surface of the lens flatter than the posterior, which I have been able to examine carefully, I have found the hardest part of the lens nearer to the posterior than the anterior surface. But in the roe, in the lens of which I found the anterior surface the most convex, I found the hardest point nearer to it than to the posterior surface. In this respect, therefore, the theory is strongly supported by observation. The lenses of the cod and most other fishes are so nearly spherical, that the relative position of the hardest

point is difficult to be determined by the method I have mentioned. I regret that it is not in my power to try the question by means of polarized light; for it would be highly interesting to know whether the want of symmetry of structure of the crystalline lens of fishes, observed by Sir David Brewster on exposing it in different positions to polarized light, was owing to the hardest or densest part lying nearer to the more convex surface than to the other, and whether the ratio of the difference could be found in that way.

5th. The figure of the nucleus corresponds admirably with the theory, and if carefully attended to it may enable the intelligent observer, who has full opportunities of examining the human lens, to ascertain, by comparing the whole lens and its nucleus in different eyes, the degree of sphericity which the functional contraction of the capsule can produce. Haller is the only author that I know of, who has noticed the greater sphericity of the nucleus than of the whole lens. That distinguished physiologist mentions having found the nucleus of the badger quite spherical, though the whole lens itself was not so*. Notwithstanding the silence of other authors, the fact is very evident, and may be easily demonstrated as follows:—Deprive the lens of its capsule and plunge it in boiling water: when it has become opaque and firm, take it out of the water and divide it into two equal parts, without deranging its curvatures, by a section along the axis. The greater sphericity of the nucleus than of the whole lens will then appear in the most distinct manner; for the change it undergoes in boiling water produces no sensible effect on its convexity.

It is an interesting fact, that the figure which the whole lens acquires by contraction of the capsule in boiling water, is almost or altogether the same as that of the nucleus in its natural state. In the lenses of several old cows, I have observed a very remarkable circumstance. When I first observed that the ratio of the diameter to the thickness of the whole lens in its natural state, was different from the ratio of the diameter to the thickness of the nucleus, I examined a great number of lenses for the sake of ascertaining whether the fact was universal or only accidental. The result was, that the central part of the nucleus was always decidedly more spherical than the whole lens; but in some old lenses, I observed that the external laminæ of the nucleus approached nearer and nearer to the figure of the whole lens; from which it follows, that in advanced age, the force by which the figure of the nucleus is determined, is, *cæteris paribus*, less than in youth. This fact,

* *Physiologia*, lib. xvi. sect. 2.

therefore, is important in connexion with the well known decrease of the power of adjustment observed to occur in old age.

Having thus endeavoured to deduce, in the best manner I have been able with the limited means in my power, a knowledge of the functions of the capsule of the lens from its structure and from the phænomena, I shall conclude with a summary of the results to which the induction appears to lead.

- 1st. The lens of animals, in its original state, consists of a peculiar gelatinous fluid, which admits of being moulded into various degrees of sphericity, and condensed towards the centre by the functional action of its capsule.
- 2nd. The capsule of the lens is provided, around its circumference, with a muscular belt, by the contraction of which the two surfaces of the lens are made more convex, and the eye adapted to near objects.
- 3rd. The radiated zone, to which the capsule is firmly attached all round, is provided with a muscular structure, by the contraction of which, and simultaneous relaxation of the capsular belt, the figure of the lens is flattened, and the eye adapted to distant objects.

III. *Experiment on the Electro-magnetism of Metalliferous Veins made in a Copper Mine in Ireland.* By Mr. THOMAS PETHERICK.

To the Editors of the Philosophical Magazine and Journal.

Gentlemen,

THE following experiment, illustrative of the electro-magnetic properties of metalliferous veins, so ably developed by Mr. R. W. Fox, you will probably deem worthy of insertion in your Journal; not only from its being the first of the kind made in Ireland, but from the different character of the veins of the mine in which it was made, from those of the mines in the West of England, to which, I apprehend, the experiments made on this interesting subject have till now been confined.

The Connoree copper-mine, to which this notice refers, is situated near the summit of the Cronebane mountain, in the county of Wicklow. The mountain consists principally of compact clay-slate, and the metallic veins that occur in this and other mines on the same range appear to be of contemporaneous formation; the veins being interstratified with the laminæ composing the rock, and conformable with it in dip and direction. Immense masses of granite appear on the sur-