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VALENTIN

ON THE

FUNCTIONS OF THE NERVES

OF THE

ORBIT.

Translated from the Latin,

BY JOHN F. FRANCE,

ASSISTANT-SURGEON TO THE EYE INFIRMARY, GUY'S HOSPITAL.

From the London Medical Gazette.

LONDON:

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TRANSLATOR'S PREFACE.

THE opinions of Valentin, novel as they are in many respects—so novel, that from a less distinguished physiologist we should probably reject them at once as chimerical—must arrest attention, and certainly challenge careful examination. The presumed facts, upon which they rest, are, simultaneously with the peculiar theories deduced, laid before us in the following treatise; and it is but justice to its author to give, from his preface, the following extract, in testimony of the caution with which his observations have been recorded. "In the ensuing work," he says, "I have in no instance overlooked the necessity of specially mentioning what I have ascertained from one or a few experiments only, or have witnessed but once; on the other hand, whatever is announced in positive language, I have proved so frequently, as to be incapable of doubting its accuracy and truth."

Perhaps the most interesting subject discussed (that, at least, which first led me to peruse, and determined me to translate, so much of the original work, as relates to the nerves of the orbit), is that of the nervous endowment of the iris. This, as well as other debateable questions, I have, on the present occasion, studiously refrained from prejudicing by comment of my own, or by collating the observations of others. Hence, the reader may, with less bias, allow their due weight to the arguments and experiments of the author; and hence, too, with the highest estimation of Valentin's labours, I must disclaim credit, and decline responsibility, except for the faithfulness, with which the translation has been executed.

Cadogan Place, Feb. 1846.

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Translated from the Latin,

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The Optic Nerve—Modes of dividing the nerve, within the cranium and on its entrance into orbit—Effects of the operation as respects motion, sensation, vision, and state of the pupil—Circumstances under which pupil still acts—Destruction of globe as a consequence—Effects of long-continued blindness—Subjective vision; its various phenomena and their explanation—Muscæ.

After the brain of a body retaining its irritability is removed, no motion of any part ensues upon irritation of the optic nerve either by mechanical or chemical means; but in dogs or rabbits, if the nervous centres remain uninjured, the pupil becomes a little contracted all round while the optic nerve is being divided; and this we shall presently see is effected by the reflex action of the motor oculi, excited through the medium of the brain. In living rabbits the optic nerve may be divided in two places; viz. within the cranial cavity, before it reaches the optic foramen, or immediately after its entrance into the orbit. Since both operations have precisely the same effect on the function of vision, it is better to select that by the orbit, as the experiment is less disturbed by collateral circumstances; the attempt to divide the nerve within the skull frequently giving rise to fatal hæmorrhage.

In order to effect division within the cranium, the neurotome needle must be passed in the way we shall describe below for division of the motor oculi; with the single exception, that the posterior wall of the orbit must be carefully followed as far as the median line, and one or both optic nerves be there divided by a brisk and firm stroke.

To divide the nerve immediately it enters the orbit, the point of the neurotome is placed on the extremity of the orbital margin of the frontal bone, between the globe and superior lid; and, having pierced the conjunctiva, the instrument is advanced from behind forwards and inwards, guided by the bony wall of the orbit, until a softer substance, *i. e.* the nerve passing through the optic foramen, is touched. This being done, the section is completed by a few firm and forcible strokes.

During the operation, the animal, apparently on account of the subjective light arising from irritation of the optic nerve, is distressed, struggles with its feet, and stretches out its head; but gives no cry*, nor exhibits any convulsive motion. Upon the section of the nerve, the pupil, even if exceedingly dilated before, becomes immediately contracted to the utmost; while the globe itself, which is forced outwards on the entrance of the neurotome, being deprived of its posterior fixed point, prolapses; the prolapsus, however, in the course of a few days, disappears, little or no vestige of it remaining.

After destruction of the optic nerve, the sensation of the palpebræ, conjunctiva, and globe, remains fine and distinct, so that the least irritation of any kind is instantly communicated to the brain. It seems hardly worth mention that the motions also of the palpebræ and globe continue perfect; since in eyes deprived of vision for the longest period, or destroyed by suppuration, and transformed into shapeless tubercles, motion is still preserved. Whilst the pupil of the eye, the optic nerve of which, is irritated either chemically or mechanically, always contracts, that of the other eye, in the rabbit, sometimes contracts, and sometimes retains its usual size unaltered; a variableness the cause of which I have never been able to discover. It is quite clear, however, that contraction of the pupil is not by any means necessarily a sign of the optic nerve having been touched or divided, because the same effect (only more energetic and certain) constantly follows every irritation of the motor oculi. It may, in fact, be easily shown to arise from reflex action of the latter nerve, induced through the medium of the brain; for the pupil of a dead rabbit or dog contracts on irritation of the optic nerve only so long as the entire cerebrum, or its inferior half, remains uninjured in the cranium; and when the whole brain is removed, no irritation whatever, of nerve, causes the least motion of the pupil. In the living animal, as Mayo ascertained, the motion is produced by irritating that part of the divided optic nerve which is in connection with the brain,—not the peripheral portion detached from it.

Actual contraction of pupil soon disappears in the eye which is blinded; but the degree of expansion frequently does not for some time equal that which was habitual to it, and which the pupil of the uninjured eye retains. If prolapsus of the globe is produced by the operation, it most commonly subsides, as already observed, in a short time after; but should the ophthalmic artery have been wounded, and great hæmorrhage ensue, this is not the case; indeed, so much blood may escape as to cause apoplexy by entering the cranium through the optic foramen.

The eye, of which the optic nerve has been cut through, invariably remains permanently blind; and though the animals may have survived for months, I have never observed a restoration of the visual functions to their former state; notwithstanding that the optic nerve does not differ from other nerves, and admits of perfect regeneration. Thus, when the sound eye is bandaged, the creature runs against every thing put before it, provided the hairs round the mouth do not give intimation of the proximity of external objects; hence, to prevent the experiment becoming less definite, they too should be bound up with linen. Being thus suddenly blinded, the animal becomes distressed, and makes unusual movements; now rushes hurriedly straight to the opposite wall of the room; then striking the impediment with its head, stops; and again advances more rapidly than before, and so on. The blindness of the eye operated on continues unaltered for life.

That not the least sense of vision exists after division of the optic nerve is proved by another sufficiently delicate experiment. The palpebræ, which, when a strong light, especially that of the sun, falls suddenly upon the eye, are always closed immediately, remain unmoved under the same circumstances after division of the optic nerve. For this experiment, however, to succeed, it is essential that not the slightest perception of increased heat should be excited, which might evidently modify the result, if the branches of the fifth nerve were entire. I therefore employ one of two methods; either suddenly exposing the animal,

* That wounds of the retina are not attended with pain is easily observed in the lower animals, and in man is proved by the experience of Magendie, vide Fror. Notiz. v. xi.

previously kept in a dark place, to the sunshine; or throwing the solar rays concentrated by a magnifying glass quickly into the eye, a plan which is also the best for observing the action of the pupil.—Again, if the retina of an eye with the optic nerve cut is stimulated, as described, by the sun's rays, the pupil does not contract, unless, 1st, when the nerve has been only partially divided; thus, in men with imperfect amaurosis this change of pupil is still observed; or 2dly, the rays collected by a glass, before entering the pupil, touch the iris. In this case they may cause pupillary motion by means of reflex action propagated from the sentient to the motor fibres of the iris; and, in fact, the iris of the eye irritated by the wound of the optic nerve seemed much more excitable in this way, after, than before the injury. The opinion, however, must be cautiously expressed; since these experiments may be safely and with facility exhibited on men, but are not in them equally successful. 3. A third exception is, when the sun's rays fall on the eye for so long, that the heat becoming greatly increased, the sentient fibres of the iris are directly stimulated; reflex action taking place from them, not from the fibres of the optic nerve to the motor fibres of the iris. In this way, both in men and the lower animals, the pupils of perfectly amaurotic eyes often contract, if the flame of a candle is brought close to the organs; and that, whether the increased heat is perceived by the subject, or is appreciated by the nerves alone,* independently of true sensation.

4. Another exceptional case is, when the pupil of the sound eye alters. In like manner, the pupil of an amaurotic eye follows the variations of the healthy one; the reflected action being imparted from one motor oculi nerve to the other:† so also when one globe is extirpated, the pupil of the other eye, though covered with a bandage, is always, according to my observation, excessively contracted directly after the operation. This reflex action originating in the optic nerve is often not limited to the iris, but extends to the muscles of the lids. Thus the orbicularis palpebrarum closes the eyelids strongly and constantly when excessive irritability of retina is present, as we see daily in scrofulous ophthalmia; albinoes (leucopathici) keep the globe in continual motion, because the retina is over stimulated by ordinary light owing to deficiency of pigment in the choroid and iris;* and persons born with cataract are generally affected with the same morbid motion of the eye.† Again, nervous individuals with extreme myopia or excessive irritability of retina not uncommonly keep the globe in continual involuntary motion, (in a horizontal oftener than a vertical direction); and lastly, Walker‡ has observed, that the lids and iris are simultaneously affected with spasm. Photophobia (*e. g.* scrofulous), for example, almost always causes constant contraction of pupil; and thus in a man labouring under paralysis of the facial, auditory, and abducens nerves, and photophobia, all confined to the left side, from a wound of the head, I found the pupil of the affected eye, though mobile, yet less by above a third than that of the right. All these circumstances, occurring in man not unfrequently, are more rarely seen in animals, as there seems less direction of intelligence to the visual faculty in them, and the muscles of the globe and iris are less active. However, it is evident from what has been

* Guttentag relates an experiment in point:—The iris of a boy with amaurosis of both eyes following nervous fever, was immoveable, even if the rays of the sun at noon were concentrated by a lens upon it; yet it instantly contracted when the flame of a candle, or any other hot body, was approximated to the eye, so as to excite lacrymation and suffusion of the conjunctiva.

† Hæn, Richter, Janin, and more recently Swan and Walker, have denied that the pupil of amaurotic eyes is always (as commonly asserted) completely destitute of mobility. For though the motions of the pupil are most commonly absent, they are yet observable if a stronger irritant be applied (as on cauterizing the cornea with nitrate of silver, by which diminution of pupil is always produced in the most perfectly amaurotic eyes); or if the irritability of the iris itself be morbidly increased, as in young persons affected with congestion of the head and hæmorrhoids. I have never, however, seen the pupil of an amaurotic eye alter, merely in consequence of the light falling upon the retina; but when alteration has occurred, invariably, either abnormal irritability of the iris has been present, or the rays of light have touched the surface of the iris, or have necessarily, from long continuance, given rise to increased heat. It is obvious that increased heat, though the rays fall only on the amaurotic retina, might produce the change in the pupil through the ciliary nerves accompanying the vessels of the retina; and thus has been suggested by Troxler in Himly's Ophthal. Journ. vol. i. p. 42.

* Rudolphi, Berliner Encycl. Wært. vol. ii. A. Retzius, Fror. Not. vol. xv.

† Cecconi, Fror. Not. vol. xi.

‡ Schmidt, Jahrb. v. 3.

said that the motions of reflex action arising from the optic nerve are extensive; as when the eye is moved horizontally, both the motor oculi and abducens nerves are in action; and when the palpebræ are closed the power of the facial is exerted.

Destruction of the globe, after lesion of the optic nerve, ensues at a much later date, and I have seldomer noticed it than after division of the trigeminal; which causes it, in a day, more or less, as the case may be, but with absolute certainty. The eye of a rabbit thus destroyed, after division of the optic nerve in the orbit a month previously, had the lens turbid, and the cornea so opaque, that its lamellæ were, as they appear after immersion in hot water, yet free from exudation and pus. The pigment of the iris was somewhat diffluent and softer than natural; and from its internal edge, to the margin and posterior surface of the capsule of the lens, extended a soft effusion made up of numerous cellular fibres. The lens itself was rather softened; the cells and globules, indeed, of one layer remained; but the characters of the fibres, more advanced in destruction, were at one place indistinct, and at another altogether lost. The remaining parts of the globe were healthy. All this disease was caused by effusion of blood into the posterior part of the orbit, from the ophthalmic artery and vein having been injured in the operation, and the due nutrition of the eye being impeded in consequence.

In eyes, blind from disease, the nervous structures are variously altered according to the nature and duration of the complaint; in those in which the external portion is disordered or destroyed, so that light cannot enter to act on the retina, this membrane long escapes change, and for months or even years no very striking alteration may be found. Its laminæ, as also the limbus luteus, and foramen of Sœmmering (as Rudolphi correctly states*), remain. But if the anterior parts still admit some few and feeble rays of light, and a slight relic of vision is consequently preserved, the retina remains quite perfect; so at least I have myself found it, after the fifth year. When, however, complete blindness persists for years, the limbus luteus becomes paler, and at length disappears; and in place of the retina, an irregular fibrous membrane is seen, composed of white cylindrical threads, but affording no vestige of granules, nucleated globules, primitive nervous fibres or external verrucæ. The fibres of the optic nerve are supplanted by a congeries of cylindrical fibres; hence it becomes thinner, and grey or whitish, almost like a fresh soft nerve from the carotid plexus of ruminants. These fibres differ materially from those of the healthy nerve, by their greater softness and grey colour, and the union of their fasciculi; but whether or not they are produced by a morbid transformation of the healthy tubular fibres cannot be determined.* Never having had an opportunity of examining a recent amaurotic retina in an eye otherwise free from disease, I leave this subject to the observations of others.

Subjective vision is produced by irritation of the optic nerve or retina by external or internal agency; and objective vision, by the external light. As, however, the retina is indispensable to the latter, this structure must superadd some power not pertaining to mere subjective vision; and on comparing the two, this supplemental power proves to be one not limited to the general perception of certain things, but comprehending a capacity of distinguishing each particular external object. How this function is performed by the retina, but cannot be by the optic nerve alone, we shall endeavour to explain hereafter.

Subjective vision is always effected by internal irritation, directly or indirectly excited: either the central sentient fibres of the optic nerve being so stimulated by the mind, that from their peripheral force subjective vision arises, as in the phantoms of fever and superstition, and as Henle † has truly said,

* Berlin. Encycl. Wært. v. ii.

* That this is the nature of the morbid effects I have observed in the recent dog and horse; and have subsequently confirmed the observation on preparations from the human subject preserved in spirit.

† Casper, Medic. Wochens. 1838. We are, it is well known, so impressed with sights that delight and please us extremely, as to be capable of repeating them by subjective vision; and this takes place more easily in proportion to the mental and visual effort originally employed in beholding and enjoying them. Hence, continued gratifying inspection of microscopic objects most readily excites this reminiscent vision; and hundreds of times after having directed the eyes with deep attention for some

in reminiscent vision; or the peripheral portion of the optic nerve, or the retina, being directly or indirectly stimulated at a certain spot, and responding by its own peculiar sentient energy to that stimulation. Thus, sanguineous congestion, external or internal pressure, heat, cold, galvanism,* &c. acting on the optic nerve or retina, immediately produce the phenomena of subjective vision†; as does also over excitement of the retina: but not the least variation occurs, for certain definite phenomena always result under certain given conditions.‡

1. Light rapid pressure, caused either by the finger or sudden motion of the globe, excites the appearance of a semilunar or circular flash; the component shining points of which are not separately distinguishable; a linear portion of the retina being stimulated for a moment, and imparting consciousness of the impression in a general manner only.

2. If the external prominent surface of my presbyopic eye is steadily pressed with the finger, a large greyish black circular spot is beheld in the centre of the field of vision; and the space immediately surrounding the darkest point is filled with distinct and brilliant circular sparks, or with regularly arranged rhombic bodies: a complete rhombic figure, however, such as Purkinje§ has delineated, seldom appears. The circular sparks nearly correspond in size‖ with the globules of the innermost layer of the retina; and the rhombuli arise from the rhomboid cells, in which these are contained, also appearing, under greater irritation, subjectively luminous.*

3. When the same pressure is exerted upon the myopic and more irritable eye, after the central grey spot of the rhombus, there appears most commonly a perfect rhomboid figure: the irritability of the retina is here so great that its entire internal stratum seems luminous.

4. On the application of too great heat or cold, and particularly when the temperature is suddenly changed, less defined scintillations are not unfrequently observed.

5. Galvanism excites the appearance of arched or circular flashes, the component points of which are not seen separately; in this respect, therefore, its spectrum corresponds with that produced by rapid pressure, and cannot be referred to the particular structures of the retina.

6. Excessive irritation of the retina acts in two ways: either its subjective phenomena, first mentioned, take place; or some internal portions of the globe, not otherwise perceptible, are plainly seen. I have often a variety of phenomena in my own person, after too close and protracted microscopical examinations;—such as grey threads, sometimes knotted like necklaces, sometimes intertwined, and always retaining a certain fixed position in the globe, and following all its motions with accuracy.† I have, however, failed to discover what parts in the eye they represent; and have found by microscopical examination nothing which could be compared with them; though, indeed, their minuteness

hours to a particular microscopic object, I have seen it again immediately on closing the eyes. Not unfrequently these spectra have recurred on my falling asleep, but never as far as I recollect in dreams. Pictures of ciliary motion, of the terminal plexuses of nerves, of crystals, &c. have in this way appeared so perfect as to correspond exactly with nature, and surpass in delicacy and fidelity every attempt at delineation.

* There is this peculiarity with respect to galvinism; that if its action be too strong, the spectrum becomes coloured in accordance with the complementary law of colours, as is shown by the experiments of Purkinje, which I have repeated with the same results. See Bullet. der schles. Gesell. 1824, and Fror. Not. vol. x. Beiträge, vol. ii.

† On this subject see Purkinje in Berlin. Encycl. Wært. vol. iv. where works relating to it are cited.

‡ I describe what follows as observed in my own person; and have specially mentioned, where necessary, that my right eye is presbyopic, and my left, which I always employ in microscopic examinations, myopic.

§ Beitr. zur Kenntniss des Sehens in subject. Hinsicht, vol. 1, plate i. fig. iv.

‖ If anything can demonstrate that the retina, as its action is projected towards external objects, sees them in a way the reverse of that in which they are depicted on it, it is subjective vision; the appearances of which are always seen in the opposite direction; and these microscopic portions of the retina, from the same cause, appear so magnified, that they would be easily perceived with the naked eye, were they really of the size they seem.

* I see these shining rhombic figures divided by straight linear black interspaces; which seems to indicate that the actual parietes of the cells are not luminous; but that at first their nuclei only, and subsequently their whole contents, glow in subjective brightness.

† Joh. Muller clearly observes the same, habitually, in himself; but speaks of their independent motion, which I have never noticed. See his Physiology, vol. ii.

is such that, taking their size into consideration, they could hardly be recognised distinctly with our microscopes: possibly they may be external portions of the hyaloid membrane.

I see the blood-vessels in front of the retina subjectively in two ways; as the figure of a vein, in the manner described by Purkinje; or, by the motion of the blood. The venous figure* arises immediately in my left myopic eye; and its ramifications extending to the smallest offsets, are so clear and perfect, that no one, who has ever seen an injection of the central vein, could have the least doubt of their identity. The point of entrance of the optic nerve and the foramen centrale appear round and grey; and on continuing the experiment longer, I see the elevated fold in which the limbus luteus foramen centrale are situated; it appears raised, and of a milky grey, but I have never perceived any trace of the limbus luteus itself.

In the subjective phenomenon of the circulation, circular molecules, like the corpuscles of the blood, appear; and their motion resembles to a certain extent that of the blood as seen beneath the microscope; yet I have never distinguished a nucleus, and they can scarcely be regarded as blood-corpuscles, since they are not pale, or black, like other parts lying upon the retina, seen in subjective vision, but luminous†. I know no means of exciting this appearance voluntarily, in my own person; but it takes place, at certain times, if I throw the flame of a candle suddenly on the eyes; or, if after having been some time in a room lighted by a single candle only, I purposely and fixedly regard the flame. Then, on the grey ground surrounding the flame, these molecules appear, floating and moving rapidly from place to place, shining grey in colour, circular and flat in form; so that they resemble to a certain extent the molecules of the blood; but their motion is neither altered nor disturbed by movement of the eye itself.

I have never noticed the caudate sparks said to be seen on bending the head downwards too long; but separate, straight, or curved lines, have made their appearance, which might not inaptly be compared to portions of the papillary stratum of the retina. Not uncommonly, after sudden compression of the eye with the fingers or lids, or on keeping the latter too long closed, I see a luminous stellate figure: this is no doubt the expansion of the fibres of the optic nerve into the retina; for there is a dark round centre —corresponding with the point of entrance of the nerve—encompassed by a circular rim, from which the rays proceed, and which answers to its margin. The light, however, of the circle and rays varies in intensity.

On closing the eyelids forcibly, I often see a most delicate capillary network, at first black, and placed on a feebly illuminated ground; then itself illuminated feebly; and this phenomenon is often succeeded by a palely luminous venous figure: but, on such occasions, at the moment of re-opening the eye, there appears a network of capillaries of the utmost splendour and delicacy.

High stimulation of the retina causes the perception of brilliant light; and a stimulus less in degree*, that of colour; the reaction of the retina, however, is so constituted, that the subjective image, following the development of the latter, exhibits the complementary colour†. For, being prepared to perform its full function, and act with the force ‖ of complete light, the retina makes up, so to speak, with its complementary subjective image, what in objective vision was deficient, in consequence of the impression being coloured, and consequently in a certain

* In the "Repertorium," vol. i. I have communicated the fact that the tortuous course of the vena centralis retina can be observed in this way in the living subject. If this venous figure appears luminous sometimes, as on immersing the head suddenly in cold water, according to the observations of Purkinje and Muller, it is because the over-distended blood vessels compress the retina, each in form of its own outline.

† It is difficult, and, indeed, impossible, to suppose that each molecule of the blood can, by pressure, stimulate the retina to luminous subjective action, as the over-distended vessels do.

* This is not the proper place for discussing the causes and phenomena of colour; yet it is manifest from the experiments of Smith (Fror. Not. vol. xv.) and others, that its diversities arise from variety of light in respect of quantity, not of quality.

† The fact that white bodies, under certain circumstances, are followed by white secondary images, and black ones by black, does not invalidate this law; the circumstance arises from the retina, previously too active or too passive, prolonging its action after perfect closure of the eyes, and so producing continued, rather than secondary, complementary images.

sense imperfect. As a great difference is distinguished easily, and a less one with more difficulty, it often happens that individuals are unable to discriminate every colour with accuracy.*

There are two kinds of so-called muscæ volitantes; the fixed, or those destitute of absolute motion, though moving relatively as the globe moves; and the moveable, which possess absolute independent motion as well.†

The fixed musca is caused by a certain point of the retina being either paralysed, or covered by a local effusion, or a varix of the vena centralis retinæ: these differ from one another, in the latter disappearing in a bright subjective image, and the former remaining in it unchanged as a yellow spot. Of the moveable muscæ volitantes there are also two sorts; one excited by over-irritation of the retina, and the other by over-repletion of the vessels. The diagnosis between them is more difficult; but they are distinguishable by the former exciting very slight subjective images, or none at all; while with the latter, the entire surface of the retina may be luminous. The latter also sometimes annoys the patients,—probably hypochondriacal or hysterical, or labouring under hæmorrhoids, dysmenorrhœa, plethora or congestion of the head,—with other shining spectra. Of how great importance this diagnosis is in ophthalmic medicine it is needless to speak.

Whether integral parts of the retina are seen as luminous at the irritated points, or other structures within the globe are perceived, these subjective phenomena of vision all depend upon the nervous tunic. It is therefore evident that, during its persistence, though blindness have arisen from destruction of other parts of the eye, yet these phenomena may appear; and equally obvious is the impossibility of the subjective phenomena, which proceed from the retina, being developed, where blindness has lasted so long that this nervous membrane is absorbed or changed; or when it is destroyed in the first instance. The primitive fibres of the optic nerve, exerting exclusively an optic power, can of themselves, when irritated, undoubtedly induce subjective spectra; but they do not seem to possess the certainty, and (so to speak) excellence of the spectra arising from irritation of the retina itself. No elucidation of this subject of course can be drawn from the lower animals; but there are some circumstances which seem to prove the above opinion on man. Thus when, in extirpating the globe, the optic nerve is divided, there is sometimes no sense of subjective vision. The eye of a girl was extirpated by Demme, which had the anterior parts destroyed by an osteo-sarcoma of the lacrymal bone; but the retina and optic nerve, as I found by microscopical examination directly after the operation, were perfectly sound; in fact, she had seen well with this eye two weeks before. When all but the optic nerve was divided, the patient perceiving and describing other circumstances well, was desired by the operator to observe whether she saw any thing or not; and on this nerve being immediately cut through, denied, and persisted in doing so, that she saw any thing*. Since, however, on the other hand, the subjective phenomena of light do sometimes occur on section of the optic nerve, a difference must exist; which seems to depend on the phenomena in question not having sufficient definiteness†, or duration, to be certainly recognized by every one.

At first sight, indeed, our opinion seems controverted by the fact, that irritation of the portion of the optic

* Consult on this subject Goethe, Farben. vol. ii.; Colquhoun, Fror. Not. vol. xxiv.; Seebeck, Poggendorff's Annal. vol. xlii. In a pupil who saw the light of the finest threads not red but milky yellow, and seemed to belong to the first of Seebeck's proposed classes, I observed that this defect remains the same when colours, produced by the refraction of light are beheld under the microscope.

† Willis, in his Anatomy of the Brain, has well explained his doctrine, that muscæ arise from the subjective action of the retina or optic nerve.

* J. Müller, in his Physiology, vol. ii., relates two cases in which no subjective phenomena of vision followed the section of the optic nerve; but he speaks of the degeneration of the nerve in such a way as to leave it doubtful whether the degeneration were sufficient to have abolished perception or not. Jourteral remarked a strong subjective light.

† That the primitive fibres of the optic nerve as I have elsewhere shewn (Repert. vol. ii.), alone are not sufficient for objective vision, is manifest; as the experiment devised by Mariotte proves, that the place of entrance of the nerve cannot possibly receive a perception of external things; and this place, as we have already stated, is void in all subjective spectra. Hence it follows that the nervous fibres possess such subjective visual energy only, as either is not appreciable, or very slightly so indeed.

nerve concealed in the cranium, or of the fibres included in the brain itself, from inflammation, congestion, or any other cause, will produce subjective spectra; but it is hardly necessary to remind the reader how much may, under such circumstances, be added by the mind to some indistinct subjective perception. All these cases do but prove, that a certain power of subjective vision exists, which admits of being so dressed up by the imagination, as for its phenomena to become connected and confounded with external objects. But what the extent of this power is, and what the amount of exaggeration it may thus undergo, can not be determined.

Admitting, then, that the man observed by Lincke*, whose globe had been removed for a fungous excrescence, beheld numbers of dancing men, besides flashes and luminous circles; it only establishes, that the irritated trunk of the divided optic nerve excited some degree of subjective vision, which was invested in ideal forms by the imagination.

* On Fung. Medull. Leipsic. Müller's Phys. vol. ii.

We can scarcely form a judgment of the subjective impression of blind persons; for if, as far as can be traced externally, atrophy of the optic nerve has taken place, we cannot tell with certainty notwithstanding, whether those fibres contained within the cerebrum are all healthy* or destroyed; and indefinite subjective phenomena arising from them may be aided, as before, by the imagination and memory. That the memory acts a most important part in the matter is proved by the fact that patients, who have remained blind for a long series of years, fancy, even when not dreaming, that they can see†; while persons blind from birth never even dream they are otherwise than blind‡.

* That after long-continued, and in congenital blindness, no fibres endued with perceptive visual power exist may be inferred, according to Zrune, (Belisar. 1833), if no sense of light is produced by the application of galvanism. But when the optic nerve and retina, or the former alone, are still sound, the phenomena of subjective vision may be still excited; for patients often make pressure on the eyes, and say they thus cause a sense of flames and colours.

† Herrman, Amm. Zeitsch. 1838.

‡ Zeune, Belisar.

Part II.

The motor oculi, or third cerebral nerve—Two modes of dividing it within the cranium—Danger of wounding the carotid, and effects of the accident—Severe suffering on division of the nerve—Its effects on pupil—Effects of irritating the nerve on a dead subject—Pathological illustrations—Muscles supplied by the nerve, voluntary and automatic—Their actions and association—Associated contraction of pupil—Question of its voluntary contractility — Sympathy of motor oculi with retina in disease.

The experiments hitherto made respecting the motor oculi in living animals by Mayo† and Fari‡ were such, that a decided judgment as to its sensitive power could scarcely be formed from them; it being no matter of surprise, that a bird like the pigeon (which does not evince pain by cries, but by motions) should, after denudation and partial removal of its brain, indicate but doubtfully, the reaction of a nerve, by no means large, and not of sentient endowments only. In order, therefore, to be more satisfied respecting it, I reached the nerves, as may be done in rabbits, with a less amount of injury.

To divide the motor oculi at the base of the skull, the neurotome, with its cutting edge horizontal, is made to pierce the integuments and bone, immediately in front of the external ear, in the plane of a horizontal line dividing the orbit into superior and inferior halves; and having entered the cavity of the cranium, and being so turned, to the extent of 90°, that the point is directed downwards, it is advanced within the base of the skull, as far as the body of the sphenoid bone; which arrests it, and therefore is readily felt. The instrument being then slightly withdrawn, is gently thrust inwards from a quarter to half a line, and thus one motor oculi nerve is cut through, or both. Another mode of performing the operation is to enter the cavity of the cranium at the posterior margin of the orbit; follow closely the posterior and internal face of the external wall of the orbit; and, on nearly reaching the longitudinal median line of the base of skull, to incline the instrument somewhat inferiorly and posteriorly, so as to touch and divide the third pair.

Each of these methods has several advantages and inconveniences: the former is the surer way of hitting the desired nerve only, (though the internal carotid may very easily be injured, and apoplexy result); but the latter often fails, from the optic nerve, being wounded as well; and hence the former plan is the more eligible, the number of animals used for the experiments not being considered. If the carotid artery is opened in this operation, the animal is directly seized with convulsions, affecting most strongly the posterior extremities. As the effused blood approaches nearer and nearer the crus cerebri, the body is turned continually with increasing force, in a circle; the direction of rotation being to the opposite side to that of the wound, provided the extravasation does not spread across the median line; in which event this symptom is either imperfect, or altogether absent. The head is also not unfrequently retracted by tetanic spasms; then paralysis of the respiratory muscles of the chest, laboured abdominal respiration, and local or general convulsions of the muscles of the body supervene, which are sooner or later followed by death. I have never witnessed involuntary discharge of the urine and fæces in these cases; but from the commencement of the hæmorrhage to the period of death, the irritability of the skin, and the reflex muscular contractions in consequence, are such, that the lightest touch of the integuments immediately excites spasms, particularly in the muscles of the extremities. All portions of the cutis, however, under these circumstances, are not equally irritable; but it exhibits exalted sensibility of parts, in the following ascending scale, viz.; the skin of the extremities; of the back;

* "De functionibus nervorum cerebralium" 4to. Berne.

† Majendie, Journ. de Phys. Vol. iii.; Fror. Not. Vol. x.

‡ Behrend's Rep. Vol. v.

the abdomen; the posterior, and finally the anterior part of the face.

Whichever operation is adopted, the animals are perfectly silent, except on the wound of the skin, until the motor oculi is touched, when they directly moan most vehemently and piteously; and their cries increase during the division of the nerve, though still, less than those excited by irritation and section of the fifth. At the moment the motor oculi is cut through, the pupil of the affected eye, and frequently that of the sound one, becomes excessively contracted: if death ensue from the operation, it expands a little during the agony, but does not reach its original size; whereas if the animal survive, it becomes absolutely dilated, and continues in this state paralyzed. The sun's rays concentrated with a magnifying glass, and thrown either upon the iris or retina, now cause no change in the pupil; nor,—though the sound eye, if the rays of light are thrown upon it, exhibits the usual motion of the iris,—does the pupil of the injured one consentaneously vary its diameter, or undergo any alteration through reflex action. It is obvious from all this, that the third nerve is a motor of the iris; but, that it is not the only source of its motive power, we shall explain more at large hereafter.

The other motor functions of the third pair can best be ascertained on the dead bodies of mammalia retaining their irritability; the trunks of these nerves, where they lie in the base of the cranium, being stimulated by chemical or mechanical means after the brain is removed. The changes of the pupil may be observed in dogs, cats, rabbits, horses, or birds; but I prefer the carnivora for this experiment, on account of a successful issue to it being in them more frequent; and the motions of the muscles supplied by the motor oculi are most easily produced in dogs and cats. On either mechanical or chemical stimulation of the third nerve the pupil of the same side contracts; and although it increases again in a little while, yet it never, or only after a very long time, attains its original and wonted size*; and this law holds good in all cases, whether the iris be readily or with difficulty moved. But in the bodies of dogs and cats just dead, and preserving their irritability almost unimpaired, the globe is often at the same time rotated quickly inwards; more rarely, inwards and upwards; and least frequently of all, downwards; —a phenomenon very seldom observed in rabbits, and especially unusual in birds and horses. The motor oculi is thus proved to govern the motions of the superior, internal, and inferior recti, and inferior oblique, as well as of the iris. I have seen contraction of the levator palpebræ superioris only in the cat, and that, indeed, but feeble; and the reason is no doubt to be looked for, not so much in the formation of the parts, as in the circumstauce of the cranium and orbit being rapidly opened, and greater injury being consequently inflicted on the most adjacent structures. The fibres of the retractor muscle are now and then convulsed.

These motor powers of the third nerve are not uncommonly traceable in men, and in some respects, indeed, more clearly than in animals. Thus, paralysis of the branch of the superior division of the nerve which goes to the levator palpebræ, produces ptosis: and when the whole nerve is paralysed there is abduction of globe in addition; for the sixth nerve being unaffected, the external rectus, liberated from the opposition of other muscles, exerts its function to the full. Under excessive action of the motor oculi, on the contrary, the globe is drawn inwards, as we see in strabismus following division of the vagus and sympathetic in the neck.

The motor fibres of the iris are contained in the ciliary nerves*; some of which emerge from the lenticular ganglion, while the internal long ciliaries come from the nasociliary, and the external long ciliary from the lachrymal branch of the ophthalmic division of the fifth: and, on the yet irritable body, the pupil is found contracted in every eye, separated by the forceps from all that lies

* The contraction, though moderately quick, is not so rapid as that of the muscles of the extremities; but the augmentation of diameter is effected gradually. We shall speak subsequently of spontaneous changes of the pupil after death.

* The internal ciliary filaments are continued into the iris; but the external, as Schlemm (Berlin. Encycl. Wært. vol. ii.) states, enter the marginal substance of the cornea, as I have met self unequivocally seen; and unless I have been altogether deceived, after piercing the cornea, they unite by anastomosis with the nerves of the conjunctiva.

near to, or enters it, except the optic nerve; and extirpation or irritation* of the ophthalmic ganglion, on a recent subject, (or in † living animals, according to Brachet,) produces a similar effect. After division of the motor oculi, reflex action of the pupil of the same side no longer arises from irritation of either optic nerve: the pupil, however, contracts, if the portion of the third nerve remaining attached to the globe (but not if that connected with the brain) be stimulated. Light entering the injured eye causes no change of the pupil; and that which falls upon the other excites contraction of the corresponding pupil alone.‡ It clearly follows from all this, that the contraction of the iris, produced by light, is effected by a reflex influence acting upon the inferior division of the motor oculi, and the ciliary branches more especially. We shall speak below of the long ciliary nerves.

In examining the distribution of the branches of the third nerve, another circumstance presents itself, which though not absolutely demonstrable, has the strongest presumption in its favour, and is, therefore, well worth mentioning. Both divisions of the nerve are sent to the muscles of the globe; but these are various in nature and character. The superior division,—which, as we have seen, originally contains fibres of sensation, and receives new ones by anastomosis with the naso-ciliary branch of the ophthalmic division of the fifth, or with a branch of the long root of, the ciliary ganglion, supplies the superior rectus and levator palpebræ. The latter is a well-known voluntary muscle; and the former is proved by an experiment of Bell's to be the voluntary agent in directing the globe upwards; for after its division in an ape, the animal was quite unable to raise the eye voluntarily, but raised it immediately when the surface of the globe was irritated with a feather; and this result has been confirmed by experiment on a rabbit.

The superior division of the motor oculi, then, is evidently expended on voluntary muscles: the inferior, however, is for the most part, if not entirely, employed in supplying the internal and inferior recti, together with the inferior oblique and the iris. That the iris is only moved automatically, is incontestible; for we shall prove the motions, termed voluntary, to be merely reflex actions in conjunction and connection with actions of the muscles of the globe. The remaining muscles have either principally or exclusively automatic power, as the obliquus inferior; or both automatic and voluntary, as the rectus internus and rectus inferior; and by far the most remarkable automatic motion, being that which exists during sleep, is performed by them; as the eye is then drawn upwards and inwards from contraction of the inferior oblique, and rectus internus. During this action, the pupil becomes contracted: and this likewise occurs, if, as in strabismus convergens, we direct both corneæ to the inner canthus;—a movement either executed in an arc, the globe being first directed inwards, and then downwards or upwards; or directly, when it is at once drawn straight inwards. In the former case, the rectus internus, is in action, together with the inferior rectus or superior oblique; or with the inferior oblique; in the latter, the rectus internus alone contracts; while the rectus inferior, and inferior oblique, are so balanced, that the eye is not directed either upwards or downwards.* Hence we see that the principal automatic motions of the globe

* As the preparation of the ganglion by itself occupies a longer time than the irritability of the subject lasts, and cannot be effected without irritating, in some degree, the inferior division of the motor oculi, the only resource is to take it away together with the surrounding parts: but the experiment becomes in consequence less delicate and more open to fallacy on account of the other branches of this nerve. In the horse, after drawing back the skin of the head, the neurotome may without much trouble be introduced into the orbit, which is naturally half open; and the motor oculi, if its position is well known, may in this way be irritated or divided at the point where it forms the ciliary ganglion near the optic nerve. The iris of the horse is, however, so sluggish, that in numerous experiments on this plan, I have only once noticed the effect.

† Rech. exper. sur les fonct. du syst. nerv. gangl. 1837. p. 420.

‡ We have reason to believe, that these phenomena are developed in the same manner, after excision of the lenticular ganglion; and Brachet's experiments prove them to be so, though, from causes already explained, this operation is defective in strict and perfect demonstration.

* It is difficult to move both eyes inwards by contraction of the recti interni alone, or in conjunction with the inferior oblique muscles. But the movement can be easily performed if the globe is first either raised, or moved downwards and inwards; for the first impulse of the former of these motions is, we believe, manifested in the superior rectus, that of the latter in the superior oblique,—that is to say, in simply voluntary muscles; and it then is communicated secondarily to the internal rectus, a muscle partly automatic.

are effected by parts supplied from the inferior division of the motor oculi nerve; and this proposition is countenanced apparently both by human and comparative anatomy. We have elsewhere proved that the nucleated globules of the ganglia especially assist in automatic motion*.

The motions of the iris, as we shall hereafter show more fully, are governed by nervous influence from two sources, the motor oculi, and the vagus and cervical sympathetic nerves. We have already said that contraction of pupil results from irritation of those fibres of the former which influence the iris; and if these are paralyzed or impeded in their action, remarkable dilatation takes place. Diminution of the pupil arises from various causes; thus it ensues if the iris is mechanically irritated, as by escape of the aqueous humor, or lesion with a needle; and the circumstance hardly needs further explanation, the sensitive obviously exciting the motor ciliary fibres to reflex action. The pupil also contracts if both eyes are directed inwards, or inwards and downwards, or inwards and upwards; in other words, if the internal rectus, or internal and inferior recti, or internal rectus and inferior oblique, of both sides; or, which is the same thing, if the motor fibres of the inferior divisions of the third pair are simultaneously in action. But it does not contract when the eye is voluntarily turned straight upwards; and it actually enlarges upon strong exertion of the levator palpebræ superioris: so that the remarkable contraction of this aperture, which is produced directly by the motor ciliary nerves, and indirectly by certain motor fibres of the third nerve, does not follow when the superior division of this nerve is in action.

* Muck has observed in some beasts a branch sent from the ciliary ganglion to the inferior oblique and inferior rectus (De Gangl. Oph. &c. 1815): in the dog and cat it is distributed to the inferior oblique only; in the weasel (mustela foina et putoria) to the rectus inferior likewise. I have myself always found in the sheep a large branch going from the ciliary ganglion to be united with the branches of the inferior division distributed to the inferior oblique and inferior rectus. The superior division, on the other hand, receives a twig from the long root before it enters the ciliary gangilon, a fact observed also by Fæsbeck (Müller's Archiv. 1839). It is evident, therefore, that the superior division of the motor oculi is augmented by branches of sensation only, and the inferior by filaments which have passed through the ganglion.

The effect, however, is quite different when the motions of the eyes are harmonious instead of symmetrical:—I term harmonious motion of the two eyes, that which takes place in an analogous direction (as to the right or left); and symmetrical, that which is effected by analogous and similar muscles of opposite sides. The right eye being then directed outwards, and the left simultaneously inwards, or *vice versâ*; that is, the external rectus of the right eye contracting, with the internal rectus of the left;—or again, the motor fibres of the sixth nerve of the right eye exerting their influence, together with those given to the internal rectus from the inferior division of the third nerve of the left,—no sympathetic contraction of the pupil occurs. J. Müller states the cause of this remarkable difference to be, the contrariety of the conditions; but I confess myself unable to perceive the force of his explanation. We have already shown that the inferior division of the motor oculi chiefly directs automatic, and the superior, voluntary movements. Now there is this law, as we shall see below, respecting all automatic motions; that different automatic parts, which receive branches either from the same nerve, or nerves close to one another at the nervous centre, and which I call synergetic, move very readily in combination. Another law is, that if an automatic part is primarily moved, the synergetic automatic parts are moved also; but if a voluntary part and a single automatic one are moved together in the first instance, the automatic synergetic ones remain passive. Hence, when both eyes move in harmony, the voluntary external rectus of one, and the automatic internal rectus of the other, are exerted without any synergetic effect resulting: whereas if both internal recti contract at the same time (either in conjunction with the inferior recti, or inferior oblique, or not), the synergetic automatic parts are likewise moved; that is to say, the iris is called into action and the pupil diminished.

All the movements of the iris are automatic. Authors, indeed, speak of its voluntary motion; but I have, by personal observation, obtained such acquaintance with this supposed power, as to be led to the foregoing conclusion on the subject. So-called voluntary

contraction of pupil takes place: first, if both eyes are turned inwards; and of this we have already spoken: secondly, if, the eyes being open, one, *e. g.* the right, remains stationary, while the left is turned inwards. In this case the left internal rectus is in action with or without the inferior rectus and inferior oblique; the pupil of the same eye is therefore contracted; and the experiments before adduced have taught us, that the action of the motor fibres of one iris excites those of the other to contraction. The grand experimental argument in favour of the voluntary motion of the iris is, thirdly, that if the palpebræ of one eye, for example, the left, be shut, the pupil of the right (remaining open and unmoved) contracts. This, however, only occurs when the left eye is moved inwards; and never when it is kept still, or, as can be done very little, is attempted to be directed outwards. The last is* therefore evidently identical with the second case; and it becomes clear that the exertion of volition only affects the iris secondarily, *i. e.* through the medium of the muscles of the globe.

Finally, the action of the muscles supplied by the inferior division of the motor oculi is intimately connected with irritability of the retina and optic nerve†; for if the third nerve is overstimulated, so that the eye is involuntarily turned inwards, such irritability of retina supervenes that the subject shuns ordinary daylight. Thus, a man, after receiving a blow on the head which caused internal strabismus of the left eye, with diplopia, became affected with photophebia on the same side, and the least daylight was insupportable; yet the retina was so far healthy that he recognised both remote and near objects with facility. On the contrary, when the retina is paralytic, not only the motions of the pupil, but those of the muscles which turn the eye inwards, are impaired, and the external rectus consequently everts the organ. An outward squint then becomes occasionally an earlier symptom of amblyopia, amaurosis, or extreme morbid myopia, than paralysis or even sluggishness of the iridal movements. Two cases of this kind have occurred to myself, in which, relying upon this symptom only, I pointed out their disease to men previously ignorant of it. In another case, that of a female, the outward-squinting eye was totally amaurotic; and in a girl of eight years old it was morbidly myopic. Yet external, like internal squint, is also sometimes caused by long-continued habit, as in a man of my acquaintance, aged 40, who enjoys perfect use of both eyes, but squints outwards with the left. The complaint arose from his labouring, when five years old, under a tumor of the internal wall of the orbit, thrusting the globe outwards; the tumor was, however, so successfully extirpated at that period that not a trace of it remained, though the morbid condition of the external rectus muscle was permanent.

The foregoing theory,—that the superior division of the motor oculi governs the voluntary motions of the globe; and the inferior, the involuntary,—is easily deducible from the systematic arrangement of the muscles. The muscles chiefly voluntary (and I use the expression because every muscle of the body may, under certain conditions, exhibit automatic action, whilst the automatic muscles are either altogether independent of, or from exceedingly unusual causes only, are subjected to volition), are: the external rectus, directed by the abducens nerve; the superior oblique, by the pathetic; and the superior rectus, by the superior division of the motor oculi. Those chiefly automatic are:—the internal and inferior recti, and inferior oblique governed by of the inferior division of the motor oculi. The whole globe, in respect of the points at which the muscles* are attached to it, is then, as it were, surrounded by a circle; of which the upper and outer portion is made up of muscles chiefly voluntary, and the lower and inner portion of those chiefly automatic. The two mainly voluntary recti, the superior and the external, are antagonized by the two, chiefly automatic, the inferior and the internal; while the voluntary superior oblique is

* Roget no doubt used this method; for he states that iridal motion took place upon the mere voluntary adaptation of the eye for vision of near and remote objects. See Graefe and Walther's Journal, vol. iii.

† Stromeyer very properly adverts to this fact. See Goettinger gelehrte Anzeigen, 1836.

* The external part of the retractor or suspensory muscle in the horse is supplied by branches of the abducens nerve; the internal, by some from the inferior division of the motor oculi; so that this same difference exists, and holds good of all the muscles of the globe.

in the same way opposed to the automatic inferior.

The fact that the eye is readily moved inwards voluntarily, seems at first sight to militate against our theory; but not so. For on comparing the automatic muscles of the globe, we shall find the internal rectus is the one most under the influence of the will; and next the inferior rectus; while the inferior oblique seems exclusively automatic. We shall have another opportunity of proving that this inequality of automatic disposition exists in other muscles of the body also; and that the principally automatic muscles represent flexors and the voluntary, extensors.

The automatic action of the ocular muscles is intimately connected with that of the iris and retina; indeed, throughout the body automatic actions in no instances stand alone, but are always harmoniously combined, so as to promote one determinate function of an organ or system of organs. It cannot, indeed, be questioned, admitting the phenomena we have described, that the action of the muscles supplied by the inferior division of the motor oculi is closely connected with contraction of the pupil. Palmedo* contends that it is the sole cause, on the ground that we habitually contract the pupil in inspecting near objects; but if so, we naturally inquire why the same occurs when we look at a distant object,—during sleep,—and if we fix the eyes on no external point.

The pathetic or fourth cerebral nerve—mode of dividing it in the living animal—effect of irritating it in the recent subject—Nature of branch to tentorium cerebelli.

The pathetic nerve is so slender and concealed in the base of the skull, that it is scarcely possible to institute a satisfactory physiological examination of it. To divide it within the skull of a living rabbit, the neurotome is inserted through the integuments and bone immediately in front of the ear, in the plane of a horizontal line bisecting the orbit equally; and the edge being turned back, it is advanced to the median line of the base of the cranium. At this point, when the fold of the dura mater is recognized by its softness to the finger, the instrument being somewhat elevated, the nerve is cut through at one stroke. The animal, which previously lies quiet, cries vehemently on the fold of dura mater being touched; but whether this is in consequence of sentient power in the pathetic nerve; or from the fifth, covered as it is by the fold in question, being compressed, cannot be ascertained.

The bodies of dogs and cats, while irritable, clearly demonstrate the motor power of the fourth nerve; for after removal of the brain, the globe is rotated downwards if the nerve is irritated; and this action of the superior oblique muscle may be actually seen, if the upper wall of the orbit is very quickly removed after death. The experiment succeeds best in the rabbit. As to the combined action of the two superior oblique muscles, the reader is referred to what is stated, under the head of the abducens nerve.

The branch to the tentorium, which Arnold, at first*, considered to come from the pathetic; and afterwards,† from the first division of the fifth; and Bidder‡ attributed to the pathetic, must be classed with those, by no means infrequent filaments, which ramify upon the parietes of various sinuses of the dura mater; and, like all the nerves of vessels, is of compound origin; one portion coming from the soft nerves accompanying the vessels, and the other from the trigeminal and pathetic. Chassaignac§, who agrees in vindicating the compound origin of the nerves of the dura mater, derives the ramus tentorii more particularly from the ophthalmic division.

* De Iride. 1837.

* Diss. de Parte Cephal. Nervi Symp. 1826.
† Der Kopftheil des Veget. Nervensyst. 1832; and Icones Nerv. Capitis. 1834.
‡ Neurolog. Brobacht. 1836.
§ French Trans. of Swan on the Nerves. 1838.

Part III.

The Trigeminal or fifth cerebral nerve—Mode of dividing it within the cranium—Effects of its partial or entire division, particularly as respects the eye—Anæsthesia of face and conjunctiva—Alteration of pupil—Destruction of globe—Pathological indications of its function.

In order to divide the trigeminal nerve in the living rabbit with the cranium entire—an operation I have myself seen Magendie perform* with the utmost dexterity in two instances—the neurotome should pierce the integuments and bone in a horizontal direction at the same point, immediately in front of the ear, indicated for the division of the motor oculi; and having done this the handle of the instrument is raised 90°, so that its point becomes directed towards the base of the skull. It is then pushed on in a straight line, as far as the soft obstruction of the fold of dura mater: this is passed by withdrawing the instrument a little, and inclining it inwards; and the nerve is then divided by a few horizontal strokes. Except on the wound of the skin, the animal is perfectly quiet throughout the operation until the trigeminal is compressed or cut, when it cries piteously, and the pupil becomes excessively contracted. As soon, however, as the nerve is completely divided the cries cease; and an imperfect division, and irritation of the remaining sensitive fibres, may be pretty certainly inferred from their continuance. The chief danger of the operation consists in the likelihood of injuring the carotid artery, which is in the immediate neighbourhood,—an accident giving rise to much the same symptoms as those before described, as its consequences; and on this account, the precaution must be used of directing the instrument while within the fold of dura mater, somewhat backwards. This is also necessary to avoid making a section of the two anterior divisions of the nerve only, with the omission of the third.

A very sanguinary experiment, and not more instructive, than that just described, is to divide the fifth nerve in the base of the skull, after opening the cranium and lifting up the brain with the fingers, or some blunt instrument. In doing this, the hæmorrhage, arising mainly from the wound of the transverse sinus, is often so great as only to be restrained by the actual cautery; and, owing to the quantity of coagula, the several nerves cannot be satisfactorily seen. In rabbits, upon the trigeminal being touched, there are the same cries; and, upon its compression or division the same contraction of pupil, the same vehement complaints, and insensibility of corresponding parts, as in the former experiment; but the sequelæ of the destruction of the nerve cannot be determined, as the miserable rabbit soon expires. In pigeons subjected to the same experiment, the

* See also Eschricht, de funct. nerv. faciei et lof. org.

extreme pain produced by irritation of this nerve is manifested by violent motions of the whole body, especially the wings; the pupil, however, does not contract, but becomes dilated, as, according to the statement of Magendie and Eschricht*, happens also in cats and dogs.

When the entire trigeminal nerve of rabbits is divided, in the manner first mentioned, the face, nose, eyeball, teeth, upper and nether lip, and tongue, on the same side, are totally deprived of sensation. The lower jaw is somewhat relaxed, but does not drop, as the muscles of mastication of the opposite side are unaffected; yet it seems to a close observer to be moved rather more obliquely: if, however, both nerves are cut across, the jaw drops, and the animal holds its head, now devoid of feeling, in a peculiar and hesitating manner, as though carrying a foreign substance before it. When only the two anterior divisions of the trigeminal are divided, loss of sensation occurs in the eye, nose, and anterior and middle parts of the face, but not in the tongue and ear. The hairs surrounding the mouth of course touch things which come in their way as before,* but the animal does not perceive the contact; so that if both eyes and the cilia of the opposite side are bound up, it ceases to be aware of the presence of external objects, and runs unconsciously against them. The lids are opened and shut properly; but the surface of the globe, the conjunctiva, and palpebræ, are utterly insensible to either slight irritation or the severest lesion; and the animal does not avoid a wire or needle passed through the nostril into the nose. The skin of the face and subjacent muscles are so insensible as to experience no pain when touched, pinched, cut, or even burnt to the bone; while the motions of the palpebræ, face, eyeball, ear, nose, mouth, and tongue, are as perfectly executed as if no operation had been performed. From all this it is evident that the function of sensation, not that of motion, is abolished in these parts by section of the two anterior divisions of the fifth; and that as regards motion, the muscles of mastication only are in addition paralyzed by section of the whole nerve. The extinction of sensibility, however, only affects the side on which the nerve has been divided; and even here, towards the median line of the forehead, nose, and mouth, an inferior degree of sensation still remains, whence it appears that this part is supplied with sentient fibres from both sides; and either in man or the horse accurate examination of the nerves proceeding from the infraorbital branch of the superior maxillary nerve and from the mental branch of the inferior, tends to confirm this statement; for though many filaments terminate in the cutis, without reaching the other side, yet in the median line there do exist extremely minute anastomotic branches connecting opposite analogous filaments.

In the operation first described, especially if the precaution I added be neglected, the third division of the fifth, from lying more posteriorly and immediately becoming deeply seated, is frequently left untouched. When it is completely divided, however, the lower jaw, as Bell first observed on the ass, and Magendie* again proved by experiment, becomes more or less relaxed; so that, guided by this sign, one may form a determinate judgment of the success of the operation; though nearly perfect mastication is still practicable by means of the sound muscles of the unaffected side. The motor function of this division may be more satisfactorily observed on a body retaining its irritability: in this way, Bell has seen convulsions of the muscles of mastication ensue upon its irritation on the ass; and I have myself witnessed the same in the cat, dog, and rabbit.

Upon the whole trigeminal nerve, or both its anterior divisions being divided or irritated in the rabbit, the pupil, as Magendie and Eschricht† have correctly stated, becomes contracted to a very small size, and continues immoveably in that state; while in dogs and cats, according to Magendie, and in pigeons, according to my own experiments, it dilates. Whether this results from a reflex influence, transmitted through the brain to the motor oculi,

* Eschricht, de funct. &c.
† Magendie, Journ. de Phys. 1824; Eschricht, loc. cit.; Lund, Vivisec. Fodera Journ. de Phys. vol. ii.

* Journ. de Phys. vol. iv.
† Loc. cit.

or from some motor fibres to the iris being directly injured, we shall i quire hereafter; the effect, however, is either not communicated to the opposite globe, or so slightly, that it shortly disappears. Hence, on the sound side, the pupil is very often unaltered; and if increased or diminished in diameter, it soon regains its usual character; while the irritability of the iris remains from the first in the wonted degree.

After a complete section of the fifth nerve in rabbits, disease of the globe on the affected side so rapidly supervenes that in sixteen or twenty-four hours it is cognisable with the naked eye. The cornea loses its brilliance, and becomes turbid and white,—a change beginning at the centre and spreading with considerable rapidity to the circumference. The delicate lamella of conjunctiva covering the cornea, in the commencement, undergoes little morbid change; though the blood-vessels of its palpebral and ocular portions are dilated and gorged; and the membrane becomes covered with more copious mucous secretion, soon assuming a decidedly puriform character. A section of the eye exhibits the layers of the cornea opaque and milky, like coagulated white of egg, but without any proper exudation corpuscles between them;—ecchymosis of the external surface of the globe;—and dilatation and congestion of the blood-vessels. The lens, as far as I have seen, is always transparent; the anterior capsule, however, is here and there turbid; and fibrous effusion exists between it and the pupillary margin: the remaining structures are free from disease. The foregoing description is drawn from my own observations on rabbits: but, in dogs, according to Magendie, suppuration occasionally extends, so that true hypopyon takes place; and the globe, bursting in consequence, is evacuated, and becomes converted into a small shapeless mass, which continues to be acted on by the muscles.

The consequences of disease of the trunk of the fifth nerve in man, hitherto observed, are few and incomplete; yet symptoms, such as have been ascertained by physiological experiment, are more or less given by physicians. Thus, Wishart* noticed impeded mastication in a person who had this nerve compressed by fungoid tumors; but the case proves little, as the facial and accessory were similarly affected, and other parts of the brain were diseased. The same may be said of Serres'* case of an epileptic, who had inflammation of the globe, opacity of the cornea, and coarctation of the pupil for six months previously. There was likewise anæsthesia of the conjunctiva and nostril of the same side, with loss of taste from one half of the tongue, scorbutic gums, and dulness of hearing; but the power of mastication remained entire. The trigeminal nerve was found in a state of pulpy degeneration, with the exception of its muscular portion; but,—not to mention loss of taste,—other symptoms, as dulness of hearing, sufficiently show that the disease was not confined to that nerve. There is the same ambiguity about the case related by Montault;† in which a woman with a tumor pressing on the fifth nerve, had redness of the conjunctiva and exsiccation of the cornea ten days before death: the history of the disease and post-mortem examination, however, displayed such extensive and great morbid changes, that the ocular affection could only in part be attributed to compreision of the nerve. The same observation holds good with respect to Bell's‡ case, though paralysis of the trigeminal nerve was well ascertained; and with those narrated by Montault and Romberg. The case noted by Abercrombie, however, exhibits more decisive indications. No power of sensation remained on the left side of the face, including the eye and nostril (from which there was occasional epistaxis), and half the tongue. The left globe, of which the cornea was nebulous, became frequently attacked with inflammation, mitigated at first by antiphlogistic remedies, but in the course of two months a linear portion of the circumference of the cornea was destroyed by ulceration, and the humours escaped. There was also complete paralysis of the masticatory muscles of the left side, which were quite relaxed during the acts of mastication and closing the mouth; and these paralytic symptoms remained unrelieved more than a year after de-

* Burdach, Gehirn, vol. iii.

* Fror. Not. vol. x.; and Bell, loc. cit.
† Fror. Not. vol. xxv.
‡ Mayo's Outlines of Hum. Path.

struction of the eye. There then came on severe pain in the head, with fever and coma, eventually terminating in death. The necropsy displayed softening of the central parts of the brain, and atrophy of the left trigeminal nerve, the portion near the Gasserian ganglion was particularly firm, but the remainder extremely small, and its adhesion to the pons varolii so slight that it seemed only attached by the neurilema:—this was no doubt from the same morbid affection that we find in the optic nerve when the globe has been destroyed for years, and has degenerated into a mere tubercle: we have already spoken of it.

In now following the branches of the fifth we commence with the proposition, that, as explained before, its two anterior divisions are endued with functions of sensation only. There is no difficulty in reaching the ophthalmic division as it enters the orbit (indeed, I have sometimes unintentionally injured it, when attempting to divide the optic nerve in the same situation); and on cutting through it in rabbits, no loss of motion ensues. The naso-ciliary branch has the same endowments; for though in the long root of the ciliary ganglion and the long ciliary branches, there are some fibres not exclusively for sensation, yet these are added from another source, and do not originally form part of that nerve.

The internal and external branches of the ethmoidal nerve regulate the common sensation of the mucous membrane of the nasal cavity, especially in the middle and inferior parts; for on destruction of the nerve, this only, and neither special sensation, nor motion in the ducts of the glands contained within the mucous membrane, is lost. No olfactory power resides in these branches; but I have not yet seen branches of the nasal nerves of common and of special sensation ever become united together in actual plexus; and, indeed, the structure of their primitive fibres is different. Those of the plexus of the olfactory are inclosed in thick remarkably soft sheaths composed of most minute filaments; and, from this circumstance, they have some resemblance to other soft nerves; while the primitive fibres of the branches of the trigeminal do not in any way differ, either as respects size or the character of their sheaths, from motor or sentient fibres in other parts of the body. Experience on the human subject proves that the external twig of the lateral branch of the ethmoidal nerve does not produce motion in any muscle of the nose: nor are the movements of the palpebræ governed directly by the infra-trochlear nerve, though besides being in part distributed to the muscular structure of the lacrymal sac, and to the caruncula lacrymalis, it supplies the orbicularis muscle and the skin of the forehead and root of the nose.

Some branches of the supra-orbital nerve enter the orbicularis, occipito-frontalis, corrugator supercilii, and there become intermixed with branches of the facial, yet they do not in man and mammiferous animals cause the motion of those muscles; for Bell observed neither spasm nor loss of motion upon division of the supra-orbital nerve in the human subject; nor does true neuralgia of this nerve interfere with the action of the muscles in question. Experiments on the lower animals support this conclusion.

The diseases of the ophthalmic nerve, which occur in the human subject, uniformly confirm the theory of its function being that of sensation. Bell relates several cases of the kind. A woman with typhus had lost the feeling of the surface of the eye and of the forehead, lips, and cheek; but the motions of these parts remained unimpaired. The nose was entirely destroyed, the ethmoidal cells and antrum maxillare were laid open; and the disease had attacked the orbit through ulceration of the lacrymal bone, whence the paralysis of the ophthalmic and infra-orbital nerves. A girl affected with dimness of sight in one eye, following an injury, after various diseases of this organ and the ear, had at the end of four years anæsthesia of the globe, lids, and skin of the forehead and cheeks, without any deterioration of motor power.* Another female, besides other paralytic affections of the trunk, and of the optic and motor oculi nerves, had the eye-balls, internal canthus, and forehead insensible.† These morbid

* Loc. cit. † Loc. cit.

conditions are not unfrequently seen.*

That the function of the superior maxillary nerve is that of sensation is proved by the experiments already mentioned. The inferior branch of the snbcutaneus malæ gives filaments to the orbicularis palpebrarum, as well as the skin; yet the action of this muscle is not impaired by division of the nerve immediately after it emerges from the zygomatic foramen or foramina; the junction of these fibres of sensation with motor twigs of the facial upon the cheek mnst therefore be of the same nature as in the case of the snpra-orbital nerve.

No certain conclusions respecting the minute filaments which go towards the optic nerve, and as to the middle root (so to speak) of the ophthalmic ganglion, can be deduced from experiment.

The branch of communication with the abducens nerve, described by Bock, which I have found for the most part proceeding from the spheno palatine ganglion, probably serves to impart some fibres of sensation to that nerve.

* * * *

The abducens, or sixth cerebral nerve—Its motor function, as proved by experiment, confirmed by disease—Its sensibility negatived by experiment—Comparison of the motor nerves of the eye—The various movements of the globes—Their mechanism and laws.

The abducens nerve governs the motions of the external rectus muscle of the eye; and this is readily proved: for, on the rabbit, or any other domesticated mammiferous animal, after the brain and upper wall of the orbit have been removed, the trunk of the nerve may be irritated in the base of the skull, or in the orbit; and while the body remains irritable, this muscle is thereupon remarkably convulsed. The motion is comparatively feeble in rabbits; but in dogs and cats is such, that the globe forcibly drawn outwards.

This experiment tallies with the observation of Yelloly,† who describes a man's eye to have been drawn inwards, in consequence of paralysis of the external rectus muscle from a tumor compressing the sixth nerve. The same phenomenon is occasionally seen in persons labouring under hemiplegia, when the external rectus only has lost its power; and the internal rectus, either alone, or aided by the inferior oblique, directs the globe inwards, or inwards and upwards, respectively, so that diplopia is at first produced. This contrast between the actions of the internal and external rectus affords a diagnostic symptom apparently too much neglected hitherto by medical men.

We have already stated that the integrity of the inferior division of the motor oculi is intimately connected with that of the retina; it therefore often happens that the internal rectus and inferior oblique of an eye the subject of amblyopia or amaurosis, become feeble in their action; so that the external rectus, owing to the abducens nerve being sound, contracts disproportionately, and draws the globe outwards. Hence strabismus divergens is frequently seen in persons with the diseases just mentioned. If, on the contrary, the retina is sound, and objects can no longer be seen merely from opacity of the cornea, the internal rectus, with or without the inferior oblique (they being the more automatic) overcomes the action of the external rectus (in accordance with the law by which, in paralytic affections, other involuntary muscles easily overcome voluntary ones, as the flexors do the extensors), and a squint inwards, or inwards and upwards, is produced. This twofold form of asymmetrical position of the globe indicates with accuracy the sound or diseased condition of the retina respectively.

Whether or not, however, the abducens nerve contains fibres of sensation in addition to those of motor power, can only be determined by a difficult experiment; for whichever way of dividing it with the neurotome we select, the operation is such as to preclude a decided judgment upon its sensibility. Thus, when the instrument is introduced behind the temporal bone, it is impossible to avoid lesion of the medulla oblongata, or the injury of so many blood-vessels that great hæmor-

* See, for example, Montault in Fror. Not., vol. xlviii.

† Quoted by Burdach, Gehirn. vol. iii.

rhage takes place: or again, if we enter the skull in front of the temporal bone, part of the fifth nerve is invariably touched during the operation, and extreme pain produced from this cause. Hence there is no alternative, but to divide the latter nerve at once, and then enter upon the inquiry respecting the abducens. The division of the trigeminal, therefore, in the base of the skull, in the manner previously described, must be first performed on a living rabbit; an assistant ascertaining the perfect success of the operation by the sensibility of the corresponding parts being totally extinguished, and the pupil of the same side becoming very contracted. During the examination of these points, the instrument is retained within the cavity of the cranium in the fold of dura mater inclosing the fifth nerve: it is then advanced inwards and downwards, so that its edge, placed perpendicularly in the base of the skull may strike the abducens nerve, which, in fact, it can hardly miss. Through this period of the operation the animal utters no cry, and seldom even moves. The experiment, however, very easily fails, since the medulla oblongata, or the portion of the trigeminal in connection with the brain, is often more or less irritated. To establish the insensibility of the abducens nerve, indicated by the experiment just described, the calvarium of a rabbit was removed, and the nerve divided in the open base of the skull. The globe was quickly turned outwards; but, though a cry instantly ensues upon the least touch of the motor oculi or trigeminal nerve,—in this case there was none. All this, then, fairly proves that the abducens is, in all probability, quite devoid of fibres of sensation; but, unquestinably, does not contain many.

On comparison, then, of the various cerebral nerves distributed to the muscles of the globe, we find one, the motor oculi, both highly sentient and motor; another, the pathetic, endowed with preponderating motor powers; and a third, the abducens, probably, exclusively motor. The fibres of sensation in these trunks are, therefore, the less numerous, and those of motion more abundant, in proportion as they take their origins more posteriorly from the nervous centre; and we may remark the same law in respect of those nerves which proceed from the medulla oblongata. Of the pathetic and abducens, each goes to its own muscle, which is, in both cases, altogether under the command of the will: but the motor oculi divides into a superior portion under the influence of volition, and an inferior, more or less automatic; so that, to a certain extent, it differs from the others.

The regular movements of the globes are harmonious, not symmetrical, and are reducible to the following classes:—1. One eye may be turned outwards, the other inwards; in which case, the external rectus of the former, and the internal of the latter, are in a state of contraction. 2. Both globes may be raised by the two superior recti. 3. Both may be depressed: this motion is in the commencement effected by the two inferior recti; but if it exceed a certain degree, mere depression is not continued, but the eyes are directed inwards also; hence it is evident the internal rectus is likewise in action. 4. Both eyes may be, at first, turned downwards and inwards; a motion resulting from the simultaneous action either of the internal and inferior recti, or of the superior oblique and internal rectus. When produced in the latter way, the superior oblique originating the movement, it is probably voluntary; when in the former, automatic;—so that this effect, which may be traced to two sources, is available for a double purpose. 5. One eye may be turned upwards and outwards, the other upwards and inwards; the superior and external recti, and the superior and internal recti respectively acting together. 6. The one may be directed outwards and downwards by the external and inferior recti, and the other inwards and downwards by the internal and inferior.

All the movements hitherto described may be performed voluntarily; but there are two more, of which the former is produced in every person during sleep, and the latter takes place when too near an object is looked at. 7. Both globes may be rotated upwards and inwards by the inferior obliqui, aided by the internal recti muscles. 8. Both may be turned inwards; the internal recti acting alone, or in conjunction with the inferior or supe-

rior recti; the latter combination being the more difficult, and less complete.

From what has now been stated the following are deductions:—

1. Among the movements of the two eyes there is one, both harmonious and symmetrical; namely, that caused by the simultaneous contraction of the superior recti. The effect of the combined action of the inferior recti is of the same character, to a certain point; but their contraction beyond this produces inharmonious, though symmetrical, automatic movements.

2. All the regular motions of the globe, which are harmonious and asymmetrical, are performed in such a manner, that a voluntary muscle of one eye (either the superior or external rectus, or the superior oblique), acts in harmony with a muscle of the other eye, more or less automatic in habit; but it is my own decided opinion that the first impulse to action is produced in the former.

3. Two voluntary muscles, upon the simultaneous action of which want of harmony of the eyes would ensue,—as, the two external recti, or the two superior oblique,—cannot be so employed.

4. Yet automatic muscles may act together under these circumstances; as the internal recti, when we regard too near an object; and the inferior obliqui during sleep. The simultaneous action of the inferior obliqui, however, is always involuntary, for they are entirely automatic muscles; but that of the internal recti is induced voluntarily by many persons, and as an automatic phenomenon in all; and for the reason now stated greater and more firm contraction is possible when the inferior, than when the superior recti are combined in action with the internal.

5. Voluntary squinting is performed by those muscles only, which are chiefly automatic: and squinting from disease, when unaccompanied by any affection of the iris or retina, is most commonly produced by muscles of the same class; namely, the internal rectus alone, or with the inferior rectus; less frequently, however, it is caused by the inferior oblique, which is entirely automatic.

Voluntary internal squinting with one eye, while the other remains stationary, is extremely difficult of accomplishment; for it requires such a power over the internal rectus, as may effect its contraction separately and alone; and hence very few persons, and they only after long practice, are capable of performing it. The whole active effort of the will is, in this case, directed to the mainly automatic internal rectus; while its influence is preventing the contraction of the external or internal rectus of the other eye. I have never known a person capable of keeping one eye stationary, while the other is directed simply outwards; for the internal rectus, like every automatic muscle, possesses such very high contractile energy, as to be insuperable, except in harmonious action; and for the same reason the superior oblique muscle can never be exerted alone, while the opposite eye is unmoved.

The foregoing remarks appear to throw light upon the nature of the muscles of the globe; for as respects the two eyes both of man and of animals, there are, as it were, two conflicting principles. On the one hand, in accordance with the system obtaining throughout the body, symmetrical muscles exist; on the other, the movements of the two eyes are not symmetrical, but harmonious. Again, on the one hand, the eye is moved voluntarily; yet, on the other, it is controlled by various affections of the retina. For the involuntary actions nature has destined the internal circle of muscles, that is to say, the internal and inferior recti and the inferior oblique; and to the voluntary, she has adapted the external circle, consisting of the external and superior recti and the superior oblique: upon the action of the voluntary circle, the pupil dilates; upon that of the automatic one, it contracts: the former may be compared to an extensor muscle; the latter, which accordingly is more easily exerted both in health and disease, to a flexor. Even the individual constituents of these circles are opposed—the superior, to the inferior; the external, to the internal rectus; and the superior, to the inferior oblique.

Harmonious motion is produced by the action of a portion of the voluntary circle of one eye, exciting the involuntary contraction of the opposed portion of the automatic circle of the other.

The preceding observations sufficiently explain the constantly uniform arrangement of the muscles of the globe, and the disposition of the

nerves supplying them. It is scarcely necessary to point out more fully, that the automatic circle derives its nervous influence from the same source as the iris.

That the external rectus and superior oblique have each their own peculiar nerve, seems to depend upon the same cause—their voluntary nature. That a separate cerebral nerve is not given to the superior rectus, but the superior division of the motor oculi is sent to it in common with the levator palpebræ, may be from the circumstance, that these two are the only muscles of the voluntary circle, the action of which is connected with dilatation of the pupil; hence the nervous fibrils going to them seem to emerge from the brain closest to those of the iris.

To the entire theory, for explaining the various actions of the muscles of the globe, given above, there is one circumstance which at first sight seems opposed; viz. that we can simultaneously employ the external rectus of one eye and the internal of the other, but not the superior rectus of one and the inferior of the other. There is, however, this difference between these two kinds of movement; that, in the former, harmonious has the advantage over symmetrical action; but in the latter neither harmony nor symmetry; it would not correspond with anatomical conformation, or contribute to any physiological object.

The consequences of division or paralysis of the facial nerves upon the eye.

When the facial branches of this nerve are cut through, the motions and in some degree the sensation of the face are destroyed. The eye cannot be shut; but the upper lid can be normally raised, as the superior division of the motor oculi which supplies the levator palpebræ remains sound. * * * * *

The effect of paralysis of the facial nerve in man is nearly the same as we observe in mammalia. The eye is moved properly within the orbit; but the motions of the palpebræ are not normal. The person being unable to close the eyelids, if he wishes to do so, lets the superior palpebra drop, and rotates the globe upwards and inwards, or upwards only; but the lower lid continues motionless, so that an uncovered white stripe of sclerotic of some breadth is exposed to view. The globe thus insufficiently protected by the palpebræ, and either too copiously or too sparingly bedewed with tears, becomes constantly affected with inflammation.

Part IV.

THE RETINA AND CILIARY NERVES, AND THE MOTIONS OF THE IRIS.

Structure and evolution of the retina.— Constituents of the organs of sense, preparatory and sentient—Laminæ of the retina — their endowments. — Nervous supply of the palpebræ, and of the lacrymal and Meibomian glands—Position of the globes in sleep—Origin and nature of the ciliary nerves.—Importance of the contractility of the pupil—its contraction not voluntary—conditions under which it contracts—former observers of pupillary contraction upon division of the vagus and sympathetic nerves—detail of the author's experiments upon this subject—review of their results, and the inference—dilatation of pupil regulated by filaments of cervico-spinal, conducted through carotid and ciliary nerves—General antagonism of the nerves of the orbit.

Every nerve of sense* exhibits a peculiar ganglionic structure at some part; and the optic nerve is not an exception to the rule; for, although no such character is apparent either in the chiasma, or the further course of the nerve through the cranium, it is nevertheless developed in the retina itself, a particular stratum of the membrane being produced in consequence. The history of embryonic evolution explains this peculiarity. The optic nerve is at first hollow, with a tumid sac at its extremity; which subsequently, upon the formation of the lens and vitreous body, has its anterior wall depressed, and so comes to surround these structures as a reduplicate membrane, with a space between its layers,—in the same way as the pericardium encloses the heart. The cineritious bulb of the olfactory nerve, which also has originally a saccular construction, is secondarily filled up entirely or in great measure; and in the same way, this cavity of the optic nerve (being much smaller on account of its inversion) becomes occupied by a substance of ganglionic nature.

Every organ of sense is supplied with a ganglion, which facilitates the motions of its external parts, and assists their performance harmoniously with the action of the corresponding nerve of sense. Thus, the spheno-palatine ganglion belongs to the organ of smell, the otic to that of hearing, the maxillary or lingual to that of taste, and the ophthalmic or ciliary to that of sight.* Yet it is pretty certain, from microscopic examination, that none of the ciliary nerves unite with the primitive fibres of the optic nerve and retina; but such of them as most closely approach the latter must be considered either as nerves of the vessels, or as going to certain parts of the globe, and merely running in proximity to the other nervous fibres.†

The organs of sense agree with the agents of common sensation, in consisting of a portion truly sentient, by which the impression, when perfected, is conveyed to the brain; and a 'preparatory' portion, which arranges and aids the impression to be received by the former: but as the powers of these organs are peculiarly delicate in nature and extent, both of their constituent portions are proportionately complicated; and the more so, the greater

* Vide §§ 190 et 184, textus Latini.

* § 185 text. Lat.
† §§ 240, et seq. text. Lat.

the importance of the particular organ. Thus, as respects the eye, the parts which direct and modify the external impression, and are therefore immediately 'preparatory,' are the vitreous body, the lens, aqueous humour, and cornea; but there are besides other parts the actions of which favour its progress and perception, and which may be termed mediately preparatory,—as the iris, Crampton's muscle in birds, the muscles of the globe, and the eye-lids.

The sentient or nervous portion of the eye constituting the retina is similarly complex, being composed of four laminæ; viz. a globulose stratum, most internal,—next a stratum of nucleated globules,—then one of primitive nervous fibres,—and externally a verrucous layer, or Jacob's membrane. The nature and powers of these are apparent in the evolution of the embryo. The internal granular and the external verrucous laminæ seem analogous; for they form the parietes of the original cavity of the retina already described, which contains a fluid, and may be compared to the ventricles of the brain. When this cavity becomes obliterated, there are found in its place the primitive nervous fibrils and the nucleated globules; and its parietes, the most external and internal strata of the retina, then diminish greatly in thickness. The primitive nervous fibres, as we have previously stated, are possessed of but an indefinite visual energy: the remaining laminæ must therefore be devoted to purely objective vision, or objective and subjective vision conjointly; and this is proved by the fact, that in cases of blindness these laminæ are destroyed, if the retina is paralyzed, so that objective vision is totally lost; but still remain, when there is disease of the preparatory parts only, preventing access of light to the retina.

As it is of course impossible to ascertain by experiment in what manner each particular stratum acts, I may be permitted perhaps to offer an hypothesis on the subject. Now the nucleated globules of the retina are so disposed, that impressions of light from without, received by the inner stratum, before reaching the primitive nervous fibres, must traverse these globules; it seems probable, therefore, that they promote the centripetal progress of such impressions, and contribute to the diversity of the resulting objective phenomena.* The globulose internal lamina, and the verrucous external one, stand in relation to the fibres of the optic nerve somewhat as muscular to nervous fibres; they receive the optical stimulus upon the minute individual points of their structure, and impart an impression of the whole to the primitive nervous fibres; the globulose lamina receiving the direct rays of light, and the verrucous those reflected from the choroid. Both the globules, therefore, and the verrucous bodies, as it were touch the light, and examine it by touch; just as the cutaneous papillæ of the fingers are compressed by contact with external objects, and communicate to the nervous fibres of sensation the excitement thereby occasioned; and hence the size of the globules and verrucous bodies of the retina may be determined by that of objects which are just visible. It may be that their action has reference to the quality of the images; and that the distinction of colour is assisted, or partly effected by them; and if so, we can readily explain how persons of otherwise excellent sight sometimes driscriminate colours imperfectly, or are quite incapable of distinguishing them.

It is clear from Magendie's observations on the human subject and animals, and my own made on rabbits, that the retina is not sensible of pain. The ciliary branches accompanying the central artery, though probably containing some fibres of sensation, are so minute, that no effect is perceptible from them; nor do they affect the retina, except remotely. It is likewise evident that the retina does not produce any motion directly; for no alteration of pupil occurs, after the optic nerve is separated from the brain, upon irritation of its peripheral portion or of the retina: we shall presently, however, find, that this nerve does excite reflex motion of the iris.

The external parts of the globe influence vision more or less indirectly in two ways, either contributing to the integrity of parts indispensable for objective vision or preparing the eye for various degrees of light and distance. The lacrymal, like every

* § 227 text. Lat.

other conglomerate gland, receives fibres both of sensation and motion, contained principally in the internal branch of the lacrymal nerve; for by the junction of this nerve with the ciliary ganglion, motor fibres from the third are in all probability guided to it. These filaments of sensation and motion serve for the normal secreting action; and for the reflex motion of the ducts of the gland, and discharge of the secreted product. Thus Magendie* noticed excessive lacrymation in men, the fibrils of whose lacrymal nerve he pricked with a needle; and so, on the other hand, after division of the fifth, or its lacrymal branch, the surface of the eye becomes drier, because the sentient fibres of the lacrymal gland being paralyzed, the reflex motion of the ducts is prevented, and the excretion, as well as the secretion, diminished. The lacrymal, or tensor tarsi muscle, which draws the puncta lacrymalia nearer the sac, receives fibres of sensation from the infra-trochlear branch of the naso-ciliary nerve, and motor fibres principally from the zygomatic branches of the facial. Some fibres of sensation likewise come off from the infra-trochlear nerve for the lacrymal sac; and perhaps motor fibres are also conveyed to it by the free junction of the inferior branch of this nerve with the pathetic.

The palpebræ possess a double supply of nerves and means of motion: the orbicularis muscle having motor fibres from the facial nerve, by the temporal and zygomatic branches; and fibres of sensation from the fifth, by the lacrymal, supra- and infra-trochlear, frontal, and supraorbital branches of the ophthalmic nerve, and by the subcutanous malæ of the superior maxillary: but the levator palpebræ superioris is supplied by the long branch of the superior division of the motor oculi, which originally contains both motor and sensitive fibres. This diversity of nervous supply is rendered conspicuous in the varying symptoms of diseases; for ptosis takes place when the superior division of the third nerve is paralyzed; yet the patient, though unable to raise the superior palpebra, closes and covers the eye perfectly; and performs properly all the functions which depend on the orbicularis muscle. On the contrary, when the facial is paralytic, the lids cannot be completely closed; for though the superior palpebra descends, yet every endeavour to close the lids, still leaves a transverse portion of the globe, at the inferior part, uncovered. Lastly, as the sensibility of the conjunctiva and palpebræ is given chiefly if not altogether by fibres of the trigeminal nerve, if this latter or its two anterior divisions be cut through or paralyzed, all or nearly all sensation in these parts is extinguished.

The Meibomian glands receive fibres of sensation from the fifth, and motor filaments principally from the facial; so that they are closely concerned in the integrity, and diminution of their secretion follows the lesion of these nerves. Since, then, on the division of the fifth, both the Meibomian and lacrymal glands secrete more sparingly, the dryness of the surface of the globe and arid state of the epithelium of the conjnnctiva genenerally after this operation, are intelligible phenomena.

It has been already stated that the muscles of the globe are briefly divisible into two sets, or as it were semicircles;—a superior and external one, consisting of the superior and external recti, and the superior oblique; and an inferior and internal, comprising the inferior and internal recti, and the inferior oblique;—that the former is supplied by the superior division of the motor oculi with the abducens and pathetic nerves, and the latter by the inferior division of the motor oculi;—and that dilatation of pupil is connected with the action of the superior and external circle, and diminution with that of the inferior and internal. It has also been explained how the various motions and directions of the globes are determined: it now therefore only remains to speak of the remarkable position of the eyes during sleep. Whilst the eyes are being closed for sleep, the globes are directed involuntarily upwards and inwards, so as to converge upwards; and the pupil is contracted. In a little while, however, a very different position of the eyes is found, to which Tortual* has very properly drawn attention in

* Physiol. vol. i.

* Ammon's Monatsschrift, 1838.

some men, both globes being moved upwards and outwards; not, however, to the external canthus, but stopping, as it were, midway: in others, one eye obeying this outward and upward impulse more than the other. Now in the former class of persons an upward divergence of the eyes takes place, which if not extreme, (though it may be so), yet is such, as is never produced voluntarily; nor does it correspond with any movement of the eyes during their employment in vision. While the palpebræ are being reopened, or the person is awaking, oscillation of the globe, first inwards, (or inwards and upwards), and then outwards, supervenes; and by this alternation, more or less frequently repeated, the eyes gain and preserve a position corresponding to the nature and distances of the objects beheld. Now these facts seem explicable upon the theory propounded above, for as the superior and external recti, and the superior oblique, are the more voluntary, and answer to extensors; the internal and inferior recti more involuntary, and analogous to flexors; and these muscles are in a certain degree of antagonism; so, whilst falling asleep, both globes at first converge upwards (by means of the two inferior oblique, with or without the internal recti), just as flexion of the extremities takes place, at the same period. As, however, the antagonism of the superior oblique is immediately excited, divergence takes place; but this is nevertheless always less marked than it would be if the superior oblique and external rectus were acting alone; and is always more or less overcome by the contractile force of the inferior oblique. It may well be supposed that this contest, so to speak, of antagonizing muscles, varies, accordingly as we dream or not; or, as in different individuals, the voluntary or involuntary action of the muscles of the globe prevails.

The ciliary nerves which enter the globe, being derived almost directly from the motor oculi and fifth, carry to it both motor and sentient fibres; but the former does not supply motor fibres only, nor the trigeminal exclusively fibres of sensation. Anatomical examination shows that some of both classes of these nerves go to the iris, (and in birds to Crampton's muscle), and some to the vessels and other structures contained in the globe; and comparative anatomy demonstrates that, where few motor filaments enter the iris, the ciliary ganglion is less developed,—a circumstance easily explained from what has been elsewhere stated, respecting the automatic motion of the iris, and the nature and powers of ganglionic structure. That the motion of the iris is of the highest consequence in objective vision, has not escaped any observer, and is evident from several circumstances:—1. The larger the pupil is, the greater is the number of luminous rays entering the interior of the globe, unintercepted and unreflected by the iris. 2. When the iris is not properly contractile, and the pupil is dilated, the eye becomes quite unfitted for seeing distinctly at different distances. The contraction of the pupil is intimately connected with the action of the retina, and inferior division of the motor oculi nerve. 3. The images become more distinct and defined in proportion to the narrowness of the pupillary aperture,—a fact directly demonstrated by the artificial apparatus of Walker* and Gerber:† on this account, when the pupil is dilated by belladonna or hyoscyamus, distant objects are seen indistinctly, and with coloured margins. 4. Lastly, the more the pupil is dilated, the more are the peripheral portions of the crystalline lens used in bending the rays of light; whence aberrant refraction ensues.

The movements of the iris produced by irritating it, like those of all other organic muscular fibres, take place but slowly‡; and they are involuntary alone,

* Schmidt's Jahrb. vol. ix.

† This consists of a paper bladder, perforated in the centre in front and behind, containing a glass bladder filled with alcohol: the anterior foramen may be converted into a larger or smaller pupil at pleasure. Now the smaller the pupil is, the smaller are the images, though proportionately delicate, well defined, and free from adventitious colouration; but the larger the pupil the more undefined and coloured are the images, though of greater magnitude.

‡ It is fair to infer that Crampton's muscle in birds contracts more quickly, because it is made up of compound muscular fibres. Whether the vacillation of iris observed in many birds, especially parrots, is partly or altogether produced by this muscle or not, vacillation of another kind, not unfrequently seen in dropsical eyes both of the human subject and horse, is certainly caused by too large a quantity of aqueous fluid being effused about the iris, which consequently vacillates, at its free pupillary margin, upon any motion of the globe, or other mechanical cause.

as we have already proved. A great many persons, indeed, as Zinn, Toracca, Fontana in some degree, Adams, Doemling, Magendie, and Palmedo, controvert this position; yet, except the arguments already related, nothing is adduced which in the least countenances the supposed voluntary power over the iris. Magendie, in the first volume of his Physiology, states that the pupil is capable of voluntary undulation, which, I candidly confess, I have never seen. Palmedo imagines he proves the truth of this opinion by the following circumstances:—"There are," says he, "two phenomena tending no little to establish the voluntary motions of the iris, because only explicable upon this supposition. We have already said, that when there are two pupils, the lateral one dilates in the light, whilst the central one contracts; and contracts in the dark, whilst the central one dilates. But if the central pupil is closed by synizesis, and the marginal pupil only remains, and if the preceding inflammation has not entirely destroyed the natural structure of the iris, it has oftener been observed that the marginal pupil no longer dilates, but contracts in the light, and dilates in the dark, like the original but destroyed central pupil. It is perfectly clear that these contrary effects of light can only be interpreted by admitting an intervening mental influence. There is another circumstance no longer questionable; namely, that the pupil of persons afflicted with central leucoma of the cornea (not exceeding the size of the pupil), gradually recedes from its natural situation, even its natural form (though the iris, as shewn by its unchanged aspect and healthy motion, is free from disease); and withdraws from its central to a lateral position in the iris, where it may more easily evade the impediment offered by the cornea to the transition of light." The opposite effects, displayed in the normal and marginal pupil, necessarily happen in the case of every muscle which contracts in the manner of a sphincter: but if the central pupil is obliterated, it then presents a fixed point, of which the margin of the lateral pupil was previously destitute; so that the latter becomes capable of more easy and regular contraction. The case of central leucoma prove still less, because the pupil is dilated by the shadow of the leucoma itself; and the person, in order that the rays of light may enter, turns the eye laterally; and thus, by moving the muscles of the globe, excites indirectly an alteration of pupil at first only momentary, but soon becoming habitual and permanent. But all these movements, in whatever way produced, are widely different from voluntary actions.

The iris is not a single muscle, but an aggregation of muscular fasciculi; on the action of certain of which the pupil is diminished, and by the others is dilated; while, when both are paralyzed, the state of dilatation prevails, yet does not nearly reach its utmost point. We shall presently shew that the fasciculi which contract the pupil are flexors, and those that dilate it extensors; and that the former derive most likely all their nervous fibres, but certainly all their motor ones, from the motor oculi, by means of the short root of the ciliary ganglion; and the latter theirs, from the spinal marrow through the long root.

The iris is moved, and the pupil undergoes alteration:—

1st. When the retina or optic nerve (maintaining its continuity with the brain) is irritated;—in which case, mechanical or chemical stimuli act in the same way as the stimulus of light does upon the retina.

2d. By strong irritation of the ophthalmic division of the trigeminal nerve, the pupil, as we shall see below, in the human subject, and have stated already with respect to rabbits, becomes greatly contracted*; but in cats and dogs, according to Magendie, dilates. This coarctation of the pupil in rabbits lasts until opacity of the cornea and effusion† into the anterior chamber impede the view of it.

3d. When the sentient fibres of the iris are slightly stimulated, they very frequently fail to excite reflex motion; which is produced, notwithstanding,

* Fario, in Behrend's Journal, vol. v. incorrectly affirms that it becomes dilated, in opposition to Magendie, who first observed this contraction.

† For these symptoms to ensue, division of the trunk of the trigeminal is not essential; but strong pressure, the actual continuity of the nerve not being destroyed, is sufficient. This experiment, which is easily performed with the neurotome, I have repeated several times, with the same result.

upon stronger stimulation being employed. The circumstance observed by Zinn* and Langenbeck†, that the iris becomes contracted upon escape of the aqueous humour, appears unconnected with this point; for every time I have repeated the experiment on the dog, though the pupil has contracted, yet the animal has become so strongly affected by moderate day-light as to be obliged to search for a dark place, and the pupil has again dilated when this has been gained. Hence it would seem that the contraction was not so much from a direct action upon the nerves of the iris, as from the excessive effect of light upon the subjects of the operation, and consequent reflex action flowing from the retina upon the motor fibres of the iris. According to Haller‡, Fontana§, and Magendie‖, mechanical irritaion of the iris has no effect upon the membrane: but the fact is, that in living animals the experiment is ambiguous, because morbid irritability of retina arises from the operation. The freshest¶ bodies of animals are alone fit for this experiment; and in them strong irritation of the iris, whether mechanical, chemical, or galvanic, excites an alteration of pupil; not rapidly, indeed, as in muscles with compound fibres, but slowly, as happens in organic muscles. Hence, however, it is evident that the sentient fibres contained in the ciliary branches are capable of exciting motion of the iris, by reflex action from the nervous centre.

4th. It has been fully explained already, that diminution of the pupil is connected with the action of the inferior division of the motor oculi; and that upon the action of the superior division of the same nerve, the pupil either remains unchanged or rather becomes dilated.

5th. We have also shewn that the motor fibres, whether contained in the ciliary nerves or ganglion, or in the inferior division or trunk of the motor oculi, cause motion of the iris directly.

Finally, the pupil contracts when the cervical portions of the vagus and sympathetic are divided, in dogs or horses, and in a less degree in rabbits.

Of this important fact, Petit* was the original observer, who instituted the first experiments relating to the subject in the years 1712 and 1725. Having persuaded himself that the sympathetic nerve sends the animal spirits upwards to the eye, he divided the conjoined cervical portions of the vagus and sympathetic in a dog; and always found after this, the cornea of the same side lessened in brilliance, dull, and flattened; the fold of conjunctiva drawn out, an increased flow of tears, and coarctation of pupil. These symptoms had, in one case, entirely subsided in two months; in another, to a certain extent, in twelve days. When the vagus and sympathetic were divided on both sides, the pupils were unequally dilated.

Molinelli†, who tied the sympathetic and vagus, confirms these statements; but Arnemann‡, though after division of the vagus in dogs, he observed increased lacrymation, and morbid sensibility and inflammation of the globe, with muddiness of the cornea and mucous discharge covering it, and extension of the fold of conjunctiva, yet, expressly denies any alteration of pupil. Dupuy§, together with Dupuytren and Breschet, found the pupil contracted and the blood-vessels of the conjunctiva distended, after division of the superior cervical ganglion of the sympathetic. Mayer‖, again, in so many words, asserts this influence of the cervical portions of the sympathetic and vagus upon the globe; but Brachet, who instituted a multitude of experiments upon the vagus and sympathetic, makes no separate mention of the state of the pupil. Lastly. Arnold¶, who observed diminution of pupil follow the operation of dividing the vagus and sympathetic nerves in dogs, and disappear again in four or five months, considers the latter phenomenon a certain indication of re-

* Observ. circa diff. oc. hum. et brutorum, Comm. reg. Soc. Gotting.
† According to Palmedo.
‡ Part. sens. et irrit.
§ Natur d. thier. Kœrpers.
‖ Phys. vol. i.
¶ Even these, however, are only avaiiable provided the pupil is not at all paralytic from death, and possesses a certain considerable degree of irritability.

* Hist. de l'Acad. Paris, 1727, 1729.
† Comment. Bonon. vol. iii.; and Burdach, Geh. vol. iii.
‡ Versuche üb. die Regen. vol. i.
§ Jour. de Méd. vol. xxxvii.—Lund, Vivis.
‖ De arter. regen. 1823.—Graefe and Walth. Journ. vol. x.
¶ Bemerkungen.

union of the nerves being accomplished: he, however, convinced himself that the symptoms were produced by the sympathetic, and not the vagus; because no change in the pupil occurs when the vagus is cut through in birds.

Now in order to explain this remarkable fact, which we shall presently see throws abundant light on the actions of the iris, I must give an account of my own experiments somewhat more fully.

1. In old or young dogs, when the common trunk of the cervical portions of the vagus and sympathetic is divided, the pupil always becomes contracted. On examining into this circumstance more closely, we find that this diminution of pupil is not observable directly and immediately after section of the nerve; but that the pupil is stationary for nearly a minute, when it contracts so quickly that the utmost remaining diminution is completed in another half minute.

2. This state of contraction continues some months, and, on its disappearance, examination of the body proves the vagus to have been regenerated. But if, as I have done in two young dogs, the extremity of both vagus and sympathetic, when divided, be placed in the wound with such obliquity and distortion that their regeneration is impossible, the contraction of the pupil continues permanent: thus Arnold's statement is correct, that this condition of pupil is a proof the vagus has not been reproduced. In a dog on which, more than nine months ago, I displaced the extremities of both vagi after dividing them, the same diminution of pupil is now present as existed directly after the operation.

3. The contracted pupil does not act at all, or much less than that of the unaffected eye, upon the influence of light stimulating the retina of either. Upon wounding the cornea of a dog, the vagus and sympathetic of which I had divided in the neck fourteen weeks previously (the pupil being still remarkably contracted), the aqueous humour escaped, and extreme photophobia ensued; yet no alteration of the pupil took place, though it occurred immediately when a similar wound was inflicted upon the other and unaffected eye. When regeneration is complete, and the pupil, though still contracted, has consequently become larger, evacuation of the aqueous humour through a wound of the cornea does not excite contraction as usual, but some enlargement of the pupil, which becomes elongated in the longitudinal direction. All these effects take place invariably, and with certainty, in dogs.

4. In rabbits, especially if black, or black and white (for the pupil of these has greater irritability than that of white rabbits), if the simple middle cervical portion of the vagus or sympathetic separately, or of both conjoined, be divided, no distinct alteration is commonly observed in the pupil*; but if the ganglia of these nerves be attacked, the result is different.

5. In this animal the ganglion of the vagus may, with care, be easily excised: with this end, a longitudinal incision is to be made from the angle of the lower jaw to the middle of the neck; the platysma myoides is then divided on the inner side of the external jugular vein, and the obtuse part of the knife, by dissecting upwards with the carotid, vagus, and sympathetic, are brought into view. The vagus is then surrounded with a loose thread and raised, and the submaxillary gland being drawn aside and upwards with a hook, the former is gradually separated with a blunt instrument up to the jugular foramen of the skull. The portion which lies above the ganglion is first divided, then that by which the vagus emerges from it to descend into the neck, and thus the whole ganglion is removed.

This operation, which I have frequently repeated, succeeds so well, if performed in the manner described, that the rabbit scarcely loses a drop of blood except on the division of the skin. Upon its completion, the change in the condition of the pupil is remarkable: it is rather smaller, oblong, and very often, especially at its superior margin, somewhat angular†.

6. Extirpation of the superior cervical ganglion of the sympathetic

* Arnold's opinion, that this influence over the pupil existed in the sympathetic alone, is thus disproved: we may add, that the vagus of birds cannot be divided so near the cranium as to allow a determinate judgment to be formed on this subject.

† For these phenomena to ensue properly, however, it is essential that the entire ganglion be taken away; for no alteration of pupil is observed either in black or white rabbits, if the lower third, or half only, be removed.

is far more difficult; as, although the carotid of the same side be tied, which I have never found necessary in extirpating the ganglion of the vagus, so great hæmorrhage often ensues from the inferior angle of the jaw, that the operation cannot be continued. It is effected by cautiously detaching the cervical portion of the sympathetic in an upward direction, by means of a blunt probe; and the ganglion having been disconnected from the neighbouring structures, is carefully cut away with fine scissars. The pupil of the same side then becomes remarkably contracted, oblong longitudinally, and angular; the angle being situated at the inferior termination of the ellipse, the superior extremity of which is rounded. The same experiment succeeds more easily on the dead subject, if quite fresh, and killed by bloodletting, not by a blow on the head. The head in this case is prepared as if for the purpose of dividing the glosso-pharyngeal nerve; that is to say, the cranium of the rabbit just killed*, is to be divided in half, from the occiput to the orifice of the nostrils, so that the upper part of the vertebral column remains on one side entire, and the lateral and posterior parietes of the pharynx are exposed freely to view. The pupil becomes somewhat contracted upon extirpation of the ganglion of the vagus, but more upon that of the sympathetic being removed: as, however, this effect quickly ceases, and the experiment, though on the living animal always successful, on the dead subject is often not so, it must be frequently repeated on the latter.

7. After the superior cervical ganglion of a rabbit has been laid bare, if a tight ligature be put round the soft nerves and internal carotid artery, the same alteration of pupil takes place as upon the superior cervical ganglion being cut through; namely, it becomes contracted, longitudinally elliptical, rounded at the superior margin, and sharply acuminate at the inferior. Not the slightest organic change in the globe ensues, at least, two months afterwards (for which period I have now had a rabbit under observation), the conjunctiva, cornea, and entire globe, remain sound; and differ, neither in brilliance nor any other respect, from the healthy state.

8. The diminished pupil of a rabbit on which the soft nerves have been tied three weeks, either remains unchanged or becomes slightly expanded on exposure to light; and contracts, instead of dilating, upon its withdrawal.

9. The pupil of the same rabbit becomes widely dilated upon evacuation of the aqueous humour through a section of the cornea, though, in the uninjured animal, the pupil contracts in a remarkable manner, under the same circumstances.

10. If a curved cataract needle is passed through the pupil, so as to make a linear wound on the posterior surface of the iris, parallel to its pupillary margin, the artificial pupil which results is, in a perfectly sound iris, circular; but in that of a rabbit, the soft nerves of which have been tied, it presents a slender longitudinal fissure, in form of an arch, parallel to the pupillary border.

11. The variations of pupil now enumerated, are all less decided in white than in black rabbits; in which latter the pigment of the iris is more abundant*.

12. With these alterations of the pupil, agree, more or less, the actions of the inferior division of the motor oculi; for the globe always becomes more or less rotated inwards, so as to appear deeper in the orbit, and (in rabbits particularly) somewhat flatter, than the other unaffected eye. The fold of conjunctiva becomes peculiarly extended in dogs, and an increased secretion of tears and mucus is observed, which is not equally, if at all, the case in rabbits†; but in both animals,

* Sec. 87, text Lat.

* As the size of pupil and the irritability of iris varies, in the lower animals, with the quantity of pigment, so is it also both in albinoes and in healthy men; for on comparing different persons together, we find the size of pupil various in relation to one and the same given object at the same distance; the irritability of the iris fluctuating as the pigment varies. Thus grey and greenish-blue irides have the least contractility; deep blue, and brown ones, the greatest; and hence bluish irides have the largest pupils, and brown, or dull green, the smallest.

† The sensibility of the iris seems to be somewhat increased; but I venture upon this statement with the greatest caution; for some dogs evidently disregard the contact of the needle with the iris, yet one, of which I had divided and displaced the vagus and sympathetic nerves eight months before, and the pupil of which had remained very contracted for the entire interval, cried out vehemently as often as I touched the iris.

when regeneration has taken place, all the symptoms vanish. The alteration of pupil is, during its existence, invariably confined to the side on which the lesion of the nerves has been produced.

I at first believed this alteration of pupil to be caused by reflex action; but as such an opinion was invalidated by the long duration of the pupillary contraction, and by its not being propagated from one globe to the other, I began a fresh series of experiments. After laying bare the ganglion of the vagus, with the utmost care and minuteness, I cut through those branches which enter the outer and posterior border of the ganglion from the superior cervical nerves; and upon this, the pupil (previously rather contracted) became elongated in the longitudinal direction, and angular at the upper part. The trunk of the vagus leaving the ganglion to descend the neck was then divided, but no alteration in the pupil resulted; nor was any observed when I cut through the same nerve where it enters the ganglion from above. From this, then, it is manifest, that the fibres entering the ganglion from the superior cervical nerves are really those which produce alteration in the pupil. The trunk of the sympathetic, nearly as far as the superior cervical ganglion, in like manner does not affect the pupil; yet the aperture undergoes a change immediately, if the posterior and external surface of the ganglion is cut; whence, it is obvious, the case is here the same as with the vagus. These phenomena are often observable on very recent subjects also; for if the spinal marrow of a rabbit is divided at the situation of the first vertebra, and its cervical portion destroyed, the pupil not uncommonly at the same instant becomes remarkably contracted. In dogs, however, there is some difference; the fibres capable of causing motion of the iris being in them contained within the cervical cord of the vagus and sympathetic, as well as in the ganglionic potion: it is fair to infer, therefore, that they enter the vagus and sympathetic lower down; and this conclusion is completely borne out by experiment. For oftentimes, if directly after the death of a dog, killed by hæmorrhage from the heart and aorta, the inferior cervical ganglion, or that part of the vagus and sympathetic immediately above it, is irritated, the pupil contracts, and again dilates upon removal of the irritation. The alteration of pupil is indeed greater, if the irritation be applied at a higher point; from which we may conclude that fresh motor fibres are there added.

Lastly, in horses as in rabbits, the motor fibres seem to proceed from the spinal marrow towards the head, at the higher point; since no diminution of pupil can be observed, when the lower cord of the vagus and sympathetic is divided, though Dupuy, Dupuytren, and Breschet, observed it after division of the superior cervical ganglion of the sympathetic.

From the foregoing facts the following deductions may be drawn :—

1. The iris is endowed with two sets of nerves, which are of cerebral and spinal origin, respectively; the filaments of the former being derived from the motor oculi nerve, and those of the latter from the cervico spinal nerves.

2. The cerebral fibres, passing through the inferior division of the motor oculi, enter the ciliary ganglion by its short root. The spinal fibres arising from the cervico-spinal nerves traverse, in the dog and horse, a portion of the vagus and sympathetic in the neck, and then enter the superior cervical ganglion of the latter: while in rabbits, and, as we shall presently see, in man, they scarcely touch the simple cords of those nerves; but on emerging from the superior cervical nerves enter, some the ganglion of the vagus; some, the superior cervical ganglion of the sympathetic. They all, however, proceed by means of the carotid plexus; and having passed on, through the ophthalmic division of the trigeminal, reach the ciliary ganglion by its long root.

3. As the motor oculi and the cervico-spinal nerves are of mixed nature, it is reasonable to suppose that both sets of the iridal nerves contain fibres of sensation as well as fibres of motion; though it is evident that the latter fibres alone admit of demonstration, the others can only be inferred. Be this as it may, the hypothesis hitherto received, that the motor nerves of the iris reach the membrane by means of the short root of the ciliary ganglion, and those of sensation through the long one, is incorrect; as

the filaments (of whatever kind) having a cerebral origin, penetrate the former root of the ganglion, and those of spinal origin the latter.

4. The muscular actions of the iris depending on the power of its cerebral nervous supply are opposed to those excited by its spinal nerves. Upon irritation of the motor fibres of the third nerve, the pupil diminishes to a very small circular area; when they are paralyzed it becomes widely dilated; for not only are the muscular fasciculi commanded by them passive, but by the operation of the spinal nervous current, which continues unaffected, other fasciculi greatly enlarge the pupil. Hence, the dilatation of pupil is not merely to the extent it would attain, if all the muscular fibres of the iris were paralyzed during life, or by death; but is greater, in proportion to the activity of the fibres which dilate the pupil and are supplied from the spinal nerves. Again, upon irritation of the spinal nerves of the iris, the pupil is somewhat enlarged; but upon their division, the cerebro-iridal nerves being no longer antagonized, the pupil becomes extremely contracted. These facts are demonstrated by the experiments mentioned above.

The iris, therefore,—as careful examination of it most clearly confirms,—is not a simple muscle, but an aggregation of muscular fibres of two systems, which respectively diminish and enlarge,—or, in other words, are contractors and extensors of the pupil.

6. The medium size of pupil is inconsistent with disproportionate action of either the extensor or contractor fibres: when both are paralytic, the size of the pupil is determined merely by the bulk of the iris.

7. When the contractor fibres altogether overcome the extensors, the pupil is exceedingly diminished; but when the latter are actively exerted, the pupil is expanded beyond the medium state.

8. Thus, if strong light fall upon the eye, or both eyes are turned inwards, or inwards and upwards, or objects in close proximity are looked at, the contractor fibres become especially active; and, on the other hand, the extensor fibres come into play in the dark, or when the upper lid is raised, or distant objects are regarded.

9. Now we have already shown that the former of the actions just particularized are more or less involuntary, and effected by the inferior division of the motor oculi; and the latter, comparatively voluntary and governed by the superior division of the same nerve, the pathetic and abducens; the contractors, therefore, of the pupil act in concert with the involuntary motions, regulated by the inferior division, while the extensors are in relation with the voluntary actions of the superior division of the motor oculi, the pathetic and abducens. The nerves of the contractors of the pupil are contained, as already stated, in the cerebral; those of the extensors in the spinal division of the iridal nerves.

10. In rabbits when the contractor fibres are paralyzed, the pupil is enlarged; when the extensors are so affected it is somewhat diminished, and made elliptic in the longitudinal direction.

11. There is also in rabbits an antagonism between individual filaments of the spino-iridal set of nerves supplying the extensors of the pupil. If the entire ganglion of the vagus and the branches entering its posterior and external border are divided, the superior margin of the longitudinally oblong pupil becomes pointed, and the inferior rounded; but if the superior cervical ganglion of the sympathetic be wounded, the inferior margin becomes pointed, while the superior is rounded. This experiment may be pushed even farther still. When excision of the ganglion of the vagus has been performed, although the pupil always obtains an oblong form, and is diminished in size, yet we often find its superior angle less acute, and not unfrequently inclined obliquely, especially backwards: but when the superior ganglion of the sympathetic or the soft nerves are divided, the inferior acumination of pupil is never absent, and very often, as just described, the aperture presents the rounded and acuminate form combined: finally, if both the ganglion of the vagus and that of the sympathetic with the soft nerves be cut away, the shape of the pupil becomes oblong, obliquely from the superior external to the inferior and internal part. When the

several experiments are compared together, it appears that the filaments coming from the ganglion of the sympathetic supply the muscular fibres of the iris at the inferior portion of the pupil; and those proceeding from the ganglion of the vagus, the fibres nearest its superior boundary; so that, by a mere operation successfully executed, the figure of the pupil is made oblong in the perpendicular direction. The more, however, we proceed upwards in operating upon the cervical ganglion of the sympathetic, the more does the effect upon the iris and pupil also become developed from below upwards and backwards; while the further we descend in the ganglion of the vagus, so much more is the effect from above, downwards and forwards. It is from this easily intelligible why the pupil becomes obliquely oblong (as it is not unfrequently observed in the human subject), when both these parts, together with their immediate branches, are cut away.

12. In proportion as the spinal nervous supply is destroyed, the cerebral one becomes more influential; as the flexors, in other cases, produce contraction of a limb, when the extensors are paralytic or divided: and as, when the extensors are enfeebled, the contraction of the flexors, though already great, admits of increase upon strong irritation of the nerves, so is it with the iris. This is demonstrated by the following experiment:—The ganglion of the vagus of a rabbit was removed on the left side, and the pupil was thereby rendered small, longitudinally oblong, acute at its superior extremity, and rounded at the inferior. The animal being now killed suddenly by a wound of the heart, the pupil became a little more contracted still; then, dividing the head as quickly as possible along the central line, I extirpated the superior cervical ganglion of the sympathetic; when the pupil became yet more contracted and almost circular, though slightly angular at its extremities and side. Every time I irritated mechanically the left motor oculi nerve, the pupil became so small as to be comparable only to the minutest granule; but when the irritation ceased the former condition of pupil returned. This experiment I have repeated three times with precisely the same result.

13. As the flexors occupy for the most part one surface of the extremities, and the extensors another, yet on one and the same surface, notwithstanding, both flexors and extensors exist; so, in the iris, though the circular fibres surrounding the pupillary margin comprise the great majority of those which contract the pupil, and its extensor fibres are chiefly situated at the periphery, yet neither set of muscular fasciculi appears strictly circumscribed within these limits.

14. The antagonism of the contractors and dilators is remarkably exemplified in artificial pupils. Thus, if a longitudinal fissure is made almost in the centre of the iris of a healthy rabbit, when both sets of fibres are acting, the wound becomes diminished in length, and circular: while, if the same operation is performed on a rabbit, of which the spino-iridal nervous supply is destroyed; the artificial pupil presents a persistent longitudinal fissure, more or less parallel to the pupillary margin.

15. Upon evacuation of the aqueous humour the pupil of a healthy rabbit becomes notably contracted; whereas in one, of which the spino-iridal nerves are divided, it expands under the same operation.

16. When the spinal source of supply is cut off, the pupil becomes contracted, and continues so, unaltered by the light. If, however, some time have elapsed; it occasionally happens in rabbits, that the pupil enlarges when the strong light of a candle falls upon the eye, and contracts in the dark.

These phenomena are explicable in the following manner. In a sound eye, upon the impression of light, or evacuation of the aqueous humour, the cerebro-iridal overcome the spino-iridal nerves, and diminution of pupil results. An extreme of this condition also ensues, and is persistent, owing to the unopposed action of the contractor, when the latter nerves are divided, and the former alone remain efficient. Now, as the light is a moderate stimulus, it still produces its ordinary effect, provided the contraction has not reached its utmost limit: this is now and then the case with rabbits, especially when a few weeks have elapsed after the operation, If, however, it has already reached its highest degree, and an irritation sufficient to overcome the power of the cerebro-

iridal nerves is applied, the contraction, being incapable of increase, is actually lessened,—as stronger irritation still would of necessity cause paralysis: in like manner, a certain given force of electricity, which produces convulsion of a healthy muscle, renders one employed in excessive or continual contraction paralytic. This peculiar dilatation of pupil upon the influx of light, is more rare in rabbits than in dogs; because the spino-iridal nervous supply is less energetic, and consequently less readily exhausted, in the former.

17. We have said that after section of the trigeminal nerve the pupil becomes much contracted in rabbits, but in dogs and cats is enlarged—a difference according with the diversity in the cerebro and spino-iridal nerves of dogs and of rabbits. For in dogs, where the cerebro-iridal nervous action is greatest, the excessive irritation produced by division of the fifth induces paralysis of the contractor, and consequently dilatation: in rabbits, where the excitability is less, the same irritation causes only extreme contraction of the muscle.

18. The alterations of pupil after death seem to depend on the antagonistic contractility of the iris; for, during cadaveric rigidity, according as the contractors or extensors are the more in action, the pupil becomes either exceedingly large or small, and continues the same throughout. When, however, rigidity has entirely disappeared, the pupil assumes a degree of expansion corresponding to the bulk of the iris.

19. Lastly, the antagonism of the cerebro- and spino-iridal nerves is borne out by the history of their evolution. The motor oculi at first represents an anterior motor root, and receives its fibres of sensation subsequently; the ophthalmic division of the fifth, on the contrary, is at first purely sensitive, and receives the motor spino-iridal fibres afterwards. The motor fibres, therefore, of the cerebro-iridal set, and the sentient fibres of the spino-iridal, are the first developed; and the sentient filaments of the former set, and the motor filaments of the latter, are secondary.

Before, however, proceeding further, we may well inquire whether this spinal supply of nerves to the iris exists in man; and if so, what is its nature. Legallois, jun. relates two cases in which a contracted pupil was combined with suffusion of the conjunctiva, ulceration of cornea, and wasting of the whole body; and relying on the experiments upon the superior cervical ganglion of the sympathetic, instituted by Dupuy, upon the horse; and those by Majendie, respecting nutrition by sugar, attributes all this mischief to disease of the nerve just mentioned. As, however, no necroscopic examinations are detailed, absolute demonstration is wanting. Among cases of disease given by other authors, I have found but three relating to this subject, which, however, illustrate two very remarkable facts: namely (1) that, as regards the alteration of pupil, produced by lesion of the spinal nerves of the iris, the human subject resembles the rabbit rather than the dog; and (2), that reaction of pupil, similar to that of which we have spoken above, under numbers 8 and 16, takes place upon influx of light afterwards. Andral* observed a man, who having twice suffered from syphilis and scabies a long time after had pain of the right knee for three weeks. On its removal the kidneys were affected painfully for four or five months; then pain arose in the anterior part of the chest; and, subsequently, in the left thigh, where it remained for eight months. Two weeks more having elapsed, the left side of the head, and shortly after, that of the face, became painful; and the neck, of which the motions also became impaired, afterwards partook in this affection. A large quantity of pus was now ejected as if by regurgitation; and emaciation, with inclination of the head and rotation of the face to the right shoulder, supervened; and four weeks after this, formication occurred in the fingers of the left hand, followed by paralysis of the left superior, and debility of the left inferior, extremity. The following were the symptoms at this period, being the fifth year from the commencement of the malady, when the patient was admitted into the Hôpital de la Charité of Paris:—Decubitus upon the back; inclination of the head and face to the right side; pains on the left side of the head; the

* Clinique Medicale, tom. v.

left pupil smaller than the right; the conjunctival vessels of the left globe excessively congested; some degree of ptosis on the same side; but no weakness of vision in either eye, nor hallucination of the senses, nor disturbance of the intellect; "loss of motor power in the left arm, but no contraction nor anæsthesia of the paralytic limb; movements of the left inferior extremity much impaired. Death occurred in sixteen days. On post-mortem examination, the brain was found healthy: but the arachnoid was injected; and the transverse ligament of the atlas, which separates the odontoid process of the axis from the medulla spinalis, totally destroyed; so that this apophysis, which was itself rough and irregular, compressed and produced softening of the medulla. The left superior articular surface of the atlas was not connected with the condyle of the occipital bone by either ligament or capsule, the left half of both bones being carious and surrounded with a quantity of pus; and disorganization of the same kind, but to a less extent, existed on the right side. The anterior surface of the bodies of these vertebræ was carious, and "there was a large collection of pus between them and the pharynx, which presented an aperture in lieu of a portion of one of the cervical vertebræ." The remainder of the spinal column and medulla, together with the thoracic and abdominal viscera, were free from morbid appearance.

As it is unquestionable that, in the foregoing case, the motor cords of the left side were paralyzed, so is it also clear that the motor spino-iridal fibres were similarly affected: and the pupil being described as smaller, we may perhaps assume that it was of oblong form. Man, therefore, in this particular, resembles the rabbit, which, like him, has the cervical vagus and sympathetic distinct, rather than the dog, in which the same nerves are united: so that in this respect anatomical conformation and physiological characters completely tally.

Himly* speaks of some cases of amaurosis and amblyopia in which the ordinary effect of light upon the pupil is reversed; and Hennen remarked the pupil expand upon increase of light, and contract with its diminution, in a person the examination of whose body subsequently disclosed extravasation of blood between the membranes of the brain. This phenomenon, at first sight, seems explicable in two ways: either, the spinal nerves of the iris being paralyzed, a condition was established, the effect of which, as exhibited in rabbits, has already been explained; or, the cerebro-iridal nerves being paralyzed, the extensors of the pupil only retained the power of contracting upon the action of light; and relaxed again on its removal. Since, however, the latter explanation is not supported by experiment on animals, the former claims preference. In conclusion, when, as is observed not unfrequently, both pupils of an individual are motionless; but one contracted and the other dilated; both classes of iridal nerves are paralyzed—the cerebro-iridal set; in the other in the last mentioned eye, the spino-iridal.*

By the preceding observations, other symptoms which ensue upon division of the carotid nerves emerging from the cervical ganglion and vagus are made intelligible.

* Ophthalm. Brobacht., Ophthalm. Bibliothek, vol. iii.

* Various anomalous distributions of the nerves will be now better understood: and among them, the case observed by Otto, to be found in Seltene Brebacht. zur Anat. &c., in which the nasal nerve, not proceeding from the ophthalmic division of the trigeminal, but from the abducens, supplied the long root of the ciliary ganglion, and two long ciliary branches. In this instance, undoubtedly, the spino-iridal nerves did not pass with the trigeminal and abducens, but with the latter alone. Again, if it happens occasionally, as Morgagni, Meckel senr., and Zinn (in his "Descrip. Oculi Hum.,") have observed, that both the long and the short roots of the ganglion are derived from the motor oculi; we must suppose that the spinal supply then passes either through the long ciliary branches, or the motor oculi. If, as Schlemm witnessed, and has noticed in his "Obs. Neurol.," the long root before entering the ciliary ganglion communicates by a branch with the lachrymal nerve, that which we shall presently state respecting the secretion and excretion of tears after section of the spinal nervous supply, will throw light upon the variety. Finally, the anomalies recently described by Hyrtl (Med. Jahrb. d. Oester. St., vol. xxviii.,) are perfectly explicable from his own observations; as in the case in which a branch came from the abducens nerve to the ciliary ganglion, this nerve had previously received it from the motor oculi. So, when fibres are added from the superior division of the last mentioned nerve, dilatation of pupil, in accordance with our previous statements, would perhaps occur more readily on elevating the upper lid. The inferior long root discovered by Hyrtl, as like the long root ordinarily described, it arises from the nasociliary nerve, does not affect the physiological inquiry.

1. The globe both in rabbits and dogs is drawn inwards; the external being overcome by the internal rectus, or the abducens nerve by the inferior division of the motor oculi. For if the primitive nervous fibres, which pass from the carotid branches to the abducens, exercise in part motor powers; when they are divided, the motor force of the abductor muscle must be diminished; and the greater is this diminution, the more easily will the internal rectus muscle over come the external.

2. From the same cause, the fold of conjunctiva is drawn out, and not unfrequently more or less suffused.

3. The excretion of the lacrymal gland being either excessive or scanty—a circumstance often observed after extirpation of the superior cervical ganglion—might seem at first explicable, from the motor oculi being over-exerted; just as tears flow when we adapt the eye for vision of very near objects, or look through glasses of too great convexity. Yet the disproportionate action of the internal rectus after the operation is not so great as to produce lacrymation; for this symptom does not occur upon one or both of the eyes being turned inwards: hence there must be another reason for the phenomenon, which is explained by the following theory, in perfect conformity with observation. If a portion of the motor fibres of the cervico-spinal nerves, accompanying the carotid branches, and joined with the ophthalmic nerve, is carried by means of the lacrymal branch of the latter to the lacrymal gland, the ducts of this gland, which derive motor fibres from the motor oculi nerve also, possess a double supply of nerves: filaments coming from the brain through the motor oculi, and from the spinal medulla through the cervico-spinal nerves. Upon division of the latter, the former will come into constant contractile action; and thus produce abnormal secretion and excretion of tears.

In conclusion, then, the muscles, together with the motor, and probably the sentient nervous fibrils of the globe, are all reducible into two opposed or antagonized classes, viz.:—

1st. The automatic set: consisting of the internal and inferior recti and inferior oblique muscles, supplied by the inferior division of the motor oculi; and the contractores pupillæ, deriving their power from the brain, through the same nerve.

2nd. The voluntary set: comprising the external rectus, supplied by the abducens nerve; and the superior rectus, supplied by the superior division of the motor oculi; the superior oblique, by the pathetic; and the dilators of the pupil, by the filaments from the spinal nerves. The muscles of the palpebræ are in similar antagonism; the levator palpebræ superioris contracting, and the orbicularis being relaxed, when the eyes are open; and when closed, the former being relaxed, and the latter active: the levator palpebræ is, therefore, to a certain extent, in analogy with the voluntary class and the dilators of the pupil, and the latter with the automatic set and the contractors of this aperture.

CORRIGENDA.

Page 8, line 2, *for* impression, *read* impressions.
,, 11, ,, 48, *after* contracts, *read* with effect.
,, 17, ,, 10, *omit* previously.
,, ,, ,, 28, *before* the history, *read* for.
,, ,, ,, 29, *omit* however.
,, 18, ,, 46, *for* but I have not, *read* nor have I.
,, 22, ,, 2, *after* symmetry, *read* would exist.
,, 27, ,, 44, *before* even, *read* and.
,, 29, ,, 27, *after* and, *read* by dissecting upwards with the obtuse, &c.
,, 35, ,, 25-26, *read* the cerebro-iridal set in the last-mentioned eye; in the other, the spino-iridal.

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