dispersion bands enveloping the absorption lines. How the systematic displacements of the Fraunhofer lines toward the red, the obliquity of the lines in the spectra of sun-spots, and some other phenomena, may be explained from this point of view, has been shown in former publications [1]).

Anatomy. — "*Notes on the trochlear and oculomotor nuclei and the trochlear root in the lower vertebrates*". By Dr. W. G. HUET. (Communicated by Prof. L. BOLK).

(Communicated in the meeting of January 28, 1911).

In the course of the past year I made several observations regarding the oculomotor and trochlear nuclei and their roots, in Petromyzon, Lophius, Gadus, Hippoglossus, Rhombus, Pleuronectes, Selache maxima and Scyllium Canicula. The results of my researches can be best demonstrated by comparing the relations of the said nuclei in Petromyzon, Selache, and Lophius.

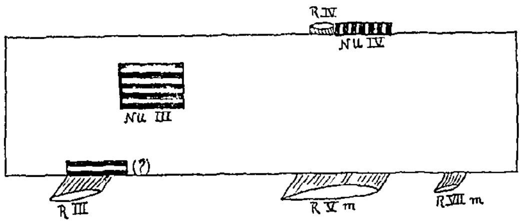

Fig. 1. Petromyzon.

Fig. 1 shows the topographic relation of the oculomotor nucleus and root, the trochlear nucleus and root and the motor V and VII root in Petromyzon.

As will be seen from this figure, the oculomotor nucleus in this animal lies partly on the level of its root-entrance, partly behind. The principal nucleus (Fig. 7), the only III nucleus according to some investigators, lies with its dorsal edge not far from the aquaeduct. Whether the so-called "ventral III nucleus" be a III nucleus or not, I will not state positively. Its topography speaks strongly for this view, as can be seen in Figs. 1 and 6. The cell-type is, however, somewhat smaller than that of the dorsal nucleus. I have not been able to obtain sufficient certainty about the course of its axis-cylinders to enable me to decide this question. [2])

[1]) Proc. Roy. Acad. Amsterdam, XII, p. 266 and 466 (1909); XIII, p. 2 (1910); Les raies de Fraunhofer et la dispersion anomale de la lumière. Le Radium, t. VII Oct. 1910.

[2]) This cellgroup is regarded by AHLBORN, JOHNSTON, and SCHILLING as being a part of the III nucleus, but by TRETJAKOFF, on the other hand, as a cell group independent of the oculomotor.

In the trochlear nucleus it is conspicuous that this lies very dorsally, *above* the aquaeduct in the velum (Fig. 8), as has been described by SCHILLING [1]) and observed by TRETJAKOFF [2]) in Ammocoetes.

The further topography of this nucleus shows that it lies nearer the trigeminus root and closer to the trigeminus nucleus than to the nucleus of the III nerve. Moreover the trochlear nucleus lies *in toto behind* its root-end (Fig. 1 and TRETJAKOFF l. c.).

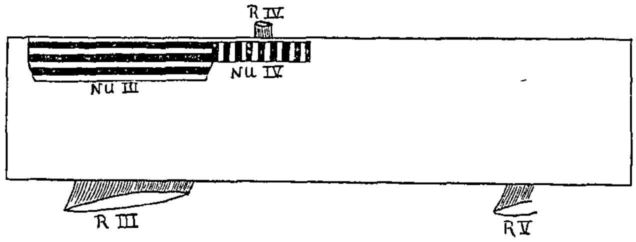

Fig. 2. Selache.

If we compare these relations with Fig. 2, which represents the topographic relations in Selache, we immediately find a difference in the position of the oculomotor nucleus, for the nucleus lies considerably farther frontally than in Petromyzon and surpasses the frontal boundary of its root (see also Scyllium, fig. 9). A ventral III nucleus does not appear here, all the cells lie in the upper third part of the mid-brain basis (fig. 10). Still greater are the topographical differences shown by the trochlear-nucleus and its root in comparison with Petromyzon. The trochlear nucleus no more lies *dorsally* from the aquaeduct *in* the velum, but to the side of the aquaeduct, practically under it, (fig 2). The nucleus is larger than in Petromyzon. A part of it still lies behind the root-entrance, another, much larger part lies in front. [3])

The distance from the IVth nucleus to the V root is greatly enlarged, and the shifting towards the III root is so pronounced that the III and IV nuclei partly overlap each other or pass into each other (Figs 2 and 9).

1) SCHILLING: Das Gehirn von Petromyzon fluviatilis. Abhandl. der Senckenbergischen Naturforschenden Gesellschaft, vol. 30 p. 441 1907.

2) TRETJAKOFF: Das Centralnervensystem von Ammocoetes. II. Das Gehirn. Archiv. f. Mikrosk. Anatomie vol. 74 p. 713 1909.

3) The topography of the IVth root and nucleus is not the same in all Selachii. Here I take Selache as object of demonstration because it seems more fit for comparison than Scyllium. Moreover our preparations of Scyllium did not allow us to fix the limits with so much certainty as those of Selache. (Added in the English translation).

I wish here to say that the great distance between IV nucleus and quintus-root is not to be attributed solely to the frontal shifting of the former nucleus. The isthmus in the Selachian is much more extended than in the more compressed brain of Petromyzon [1]) and likewise more than in the Teleosts. That, however, a considerable frontal shifting of the trochlear-nucleus has taken place is also apparent from the facts that a great part of the nucleus now lies in front of its root-entrance, and that the III and IV nuclei overlap each other for a part, while in Petromyzon there was a large gap between them.

Thus we find in these Selachii a strong frontal shifting of the IV nucleus as compared with Petromyzon.

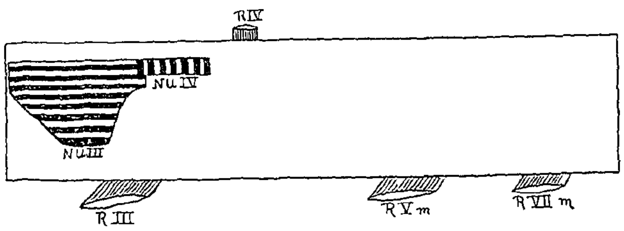

Fig. 3. Lophius.

Passing on to the relation in Teleosts, I refer to Fig. 3, in which the topographic relations of Lophius are given. Here in the oculomotor nucleus a great difference is noticeable as compared with Selache owing to a part of the III nucleus having undergone a strongly ventral shifting (Figs. 3, 11, and 12).

This ventral shifting should not surprise us, for it is known that the abducens nucleus in these animals also occupies a ventral position. It is highly probable that here too, the strong development of the ventral tecto-bulbar (optic) reflex tract is the cause of this displacement which, for the decussated reflexes also, may perhaps find support in the fact that the place of the lowest point of the nucleus agrees with the ventral decussation level of the above-mentioned reflex-tract, which lies (as we know from DE LANGE's [3]) researches) principally *before*, partly on the level of the III root entrance and

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1) The compressing of the Petromyzon-brain is also conspicuous in the fore-brain to which SCOTT has already referred. (Journal of Morphologie Vol. I, p. 253).

2) KAPPERS. The migrations of the V, VI, and VII nuclei etc. Verhand. der Kon. Akad. v. Wetensch. Vol. 16, 2de Sectie.

3) DE LANGE. The descending tracts of the corpora quadrigemina. Folia Neuro biologica. Vol. III, p. 644.

there sends out a series of fibres to the III nucleus (compare also EDINGER and WALLENBERG [1])).

In connection with the more frontal migration of the dorsal nucleus which was found in all Teleosts, I may recall here the fact that DE LANGE found the decussation of the dorsal tecto-bulbar fibres also more frontal than the decussation of the ventral set.

Regarding the III root I will mention that a great number of decussating fibres originate from the posterior part of the III nucleus bordering on the trochlear nucleus, which is interesting in connection with the fact that the IV fibres have also a decussating character.

The trochlear nucleus shows us a further stadium in the process already indicated in the shark, viz. the frontal shifting of its cells which here lie entirely in front of their root-entrance. Although this may partly result from a backward displacement of the root in some Teleosts, a more frontal shifting of the IV cells is also very probable, as is seen from the fact that the IV nucleus in Lophius has also a more frontal position in regard to the III root and V root and therefore, with regard to these points also, the shifting of the IV nucleus can be affirmed, equally in all Teleosts. (Figs. 3 and 11).

The position, which the IV nucleus occupies with respect to its root-entrance in the bony fishes is strongly suggestive of that in human beings (cf. MARBURG [2]) where the nucleus also lies entirely frontad thereof. It has been found by VAN VALKENBURG [3]) that this secondarily produced relation is sometimes shown by a *caudal* remnant of the IV nucleus, which he designates *"nucl. IV posterior"* (cf. JACOBSOHN[4]).

With regard to the trochlear-root the following point may be mentioned.

Earlier investigators had already observed that the trochlear-root traverses the brain-stem with 2 roots (Salmo, HALLER [5]) Gadus, KAPPERS [6])) in some bony-fishes in contrast to other bony-fishes (e. g.

[1]) Vorlesungen 7te Auflage. — Beiträge zur Kenntnis des Gehirns der Teleostier und Selachier. Anat. Anzeiger, Vol. 31, P. 369.

[2]) MARBURG, Mikroskopisch-topographischer Atlas des menschlichen Zentralnervensystems.

[3]) C. T. VAN VALKENBURG: These Proc. June 25, 1910.

[4]) JACOBSOHN, Verhandl. Preuss. Akad. 1909.

[5]) HALLER. Vom Bau des Wirbeltier-gehirnes. Morphologisches Jahrbuch Bnd. 26, 1898, p. 508. I cannot affirm however HALLER's statement that a part of the IV root originates from the Purkinje-cells of the cerebellum. Nor did I see a "kontinuierliche Zusammenhang dieses Kernes (IV) mit dem rostralwärtigen Ende des oberen motorischen Trigeminuskernes" (l. c. p. 505).

[6]) KAPPERS. The structure of the Teleostean and Selachian brain. Journal of Comparative Neurology. Vol. XVI, 1906, p. 62.

Fig. 6. Petromyzon fluviatilis.

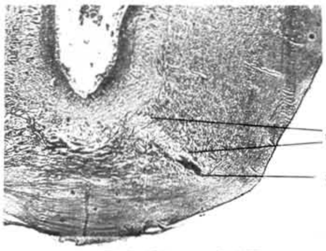

Fig. 7. Petromyzon fluviatilis.

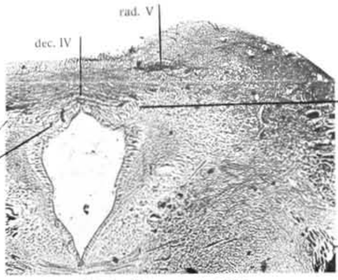

Fig. 8. Petromyzon fluviatilis.

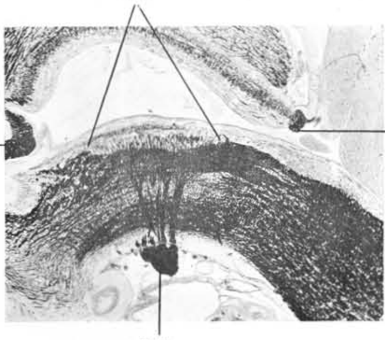

Fig. 9. Sagittal Section through the brain of Scyllium Canicula.

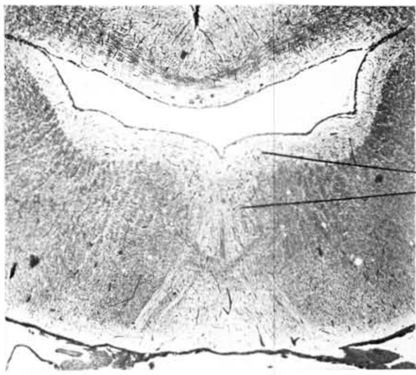

Fig 10. Selache maxima.

Fig. 11. Sagittal Section through the brain of Tinca tinca.

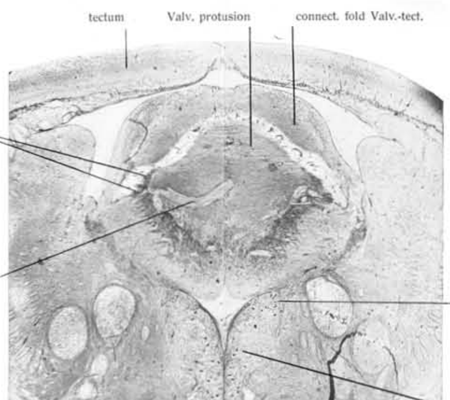

Fig. 12. Gadus morrhua.

Lophius). The exact course of both these roots was, however, never clear before.

As I had at my disposal some frontal and horizontal series of Gadus and other fishes, I was able to trace the whole system with fairly great exactness and arrived at the following conclusion.

In Lophius piscatorius the decussation of the trochlear root-fibres takes place in a fairly simple way. After their origin in the trochlear nucleus, the fibres pass in the form of one compact bundle closely round the aquaeduct upwards, and cross *in toto* on one and the same vertical level, the decussation occupying about 6 sections of 25 μ, but not more; a difference can only be observed between the fibres mutually in so far as some decussate closer to the aquaeduct, others closer to the surface of the velum, a few even after the exit (somewhat as in Scheme *b* fig. 4).

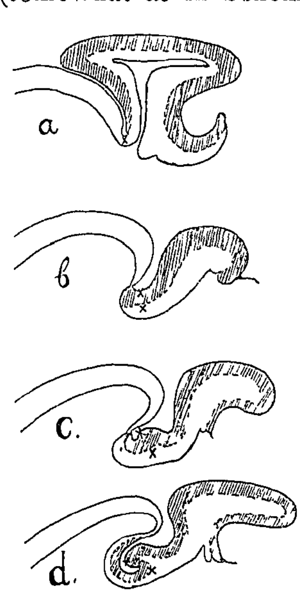

Fig. 4.

In Hippoglossus this relation is rather more complicated, owing to some of the fibres following a pathway separated from the others. Before proceeding to decussation, these fibres (about half of the total number) pass frontally into the valvula cerebelli; then only do they decussate and after the decussation they turn laterally, run again caudally between the valvula cerebelli and its connection with the tectum, to appear at the height of the original velum out of the groove between mesencephalon and cerebellum simultaneously with the other root-bundle which has decussated on the original level (somewhat as in Scheme *c*, fig. 4).

The impression is conveyed as if the anterior part of the trochlear-root and its decussation were drawn frontally by the growth of the valvula into the optic ventricle under fixation of the point of exit.

This dislocation is the most conspicuous in the case of the anterior root-half in Gadus, where the valvula protrudes somewhat farther forward under the tectum (cf. Scheme *d* fig. 12).

Besides by the peculiar dispersion of decussations, the anterior part of the IV root of this animal is also distinguished from the posterior by the fact that it does not run directly round the aquaeduct medially from the tr. cerebello-mesencephalicus, but runs outside that tract (Fig. 11) as has also been observed by Kappers (l. c. p. 62).

That the frontal shifting of a part of the decussation is caused by the frontal growth of the valvula is clear. It does not occur in animals without valvula (e. g. sharks), and in Lophius, where the

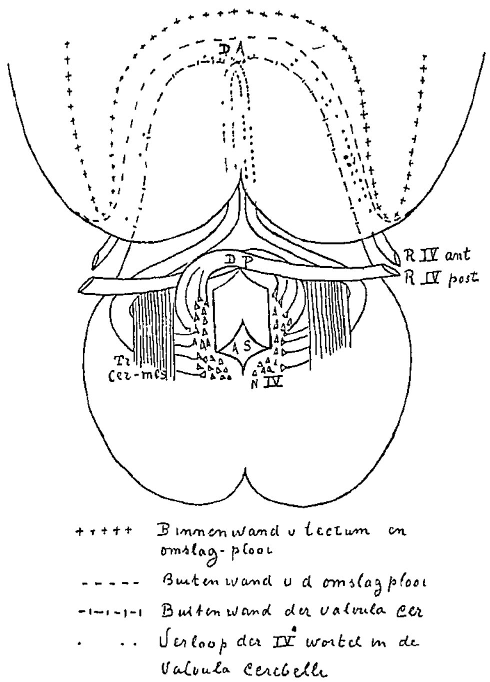

Fig. 5. Gadus.

valvula cerebelli is extremely small, there is neither any question of a frontal shifting of a part of the trochlear fibres. Nevertheless the conditions in this animal furnish us with the explanation.

The diagrams given here show how the said root dispersion is to be deduced from the simple position. In type *a* (shark) the decussation of the fibres occupies but a small space. As the velum is very thin there is only one decussation. In *b* the velum is considerably thickened, principally by the growth of the molecular and Purkinje layer over it. (Type Lophius).

Although the decussation remains on one vertical level, a distinction can nevertheless be made between the fibres which decussate close to the aquaeduct, and those which decussate more or entirely on the surface of the molecular layer.

In *c* the molecular and Purkinje-layer has grown still considerably further under the tectum opticum and exhibits more folds; a consequence of this is the enlargement of the distance between the fibres with a more peripheral and with a more central decussation, which attains its maximum in *d*, practically agreeing with the conditions as shown in Gadus.

This diagram, at the same time, demonstrates clearly that the space in which the frontal root decussates and runs back in a caudal direction, does not lie *in* the cerebellum but between the valvula and the fold connecting it with the tectum.

Summing up my results, I can state the following :

Oculomotor nucleus.

The III nucleus in the lower vertebrates occupies a more constant place in the longitudinal-axis of the brain than IV nucleus. Nevertheless it certainly undergoes a distinct frontal shifting. In a dorso-ventral direction the oculomotor nucleus of the Teleosts undergoes a considerable displacement, which agrees with the ventral displacement of the abducens nucleus in these animals.

Trochlear nucleus and root.

The trochlear nucleus in the lower vertebrates exhibits still greater differences in its position with regard to the longitudinal-axis of the brain. In Petromyzon it lies at a great distance behind the III nucleus even behind its own root-entrance, on the level of the trigeminus root-entrance, as has also been proved by TRETJAKOFF for Ammocoetes.

Moreover it lies more dorsally, above the aquaeduct in the velum.

In the Selachii the nucleus lies at a great distance from the trigeminus root and close to the III nucleus, passing into the latter. In Selache it extends partly behind, though for the greater part in front of the IV root-entrance. Moreover, it has come to lie under the aquaeduct. In Teleosts the frontal shifting has reached its maximum. The nucleus lies entirely in front of the IV root-entrance.

In some Teleosts the trochlear root undergoes a peculiar spreading in bundles, e. g. Gadidae and Pleuronectidae, owing firstly to the root being split into two parts before decussation by the passing through of the tr. cerebello-mesencephalicus; secondly, the part which runs round outside that bundle is drawn forward by the frontal growth of the velum that grows out to valvula cerebelli, in consequence of which it decussates more frontally, and then again runs caudally between valvula and its connection with the tectum.

This severing of the decussation levels also explains the splitting of the trochlear root into two roots at the exit, which until now has not been found in fishes without valvula (sharks) nor in those bony fishes where the valvula is very small (Lophius).