Thesis.

On the Asymmetry of the Pleuronectidae

by

Ramsay H Traquair.

Preface-

The principal Object of the following Essay is to demonstrate the morphological nature of the Asymmetry, so perceptible in the Flat fish family (Pleuronectidae); my observations being based on a consideration of the Skeleton of these animals. I had originally intended to have made this essay a monograph of the entire subject of the asymmetry of the Flat fishes but such an essay would have been far too long to be suitable for a Graduation Thesis, and also too long for the time at the disposal of the Medical Student. I have therefore confined myself to the Osseous System of these animals making however reference to other systems whenever necessary to the more complete elucidation of the subject and indeed when treated in this way an Essay on the Skeleton of the Pleuronectidae will certainly include all that can be said on the Morphology of their want of Lateral Symmetry-

I have endeavoured to illustrate this essay by a series of drawings, which, whatever be their merits or demerits I hope will serve to make my meaning clear.

In conclusion I must humbly apologise to the Medical Faculty for the hurried & apparently careless manner in which the written part of this Thesis has been got up. My excuse is that this

being the first paper of the kind I ever wrote I did not foresee the great difficulty I afterwards found in committing my ideas to paper - and consequently most unfortunately delayed too long the writing & composition of the following pages. And my time for writing was still further abridged by the great care I spent in the execution of the Plates.

31st March 1862

R. H. Tragueair

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Chapter I

That both eyes of a Turbot, or of any of its congeners (Pleuronectidae) are situated on one side of its head is a fact long interesting to naturalists in connection with the peculiar habits of these animals. It has also afforded a field for the labors of the Comparative Anatomist to ascertain what relation this Asymmetry bears to the Morphological Plan of the Fish-head in general.

And indeed if we look merely at the exterior of such a fish as a Turbot, the manner in which the transposition of the eyes has been effected is not very apparent. It is, it is true easy to imagine that the mesial line of the top of the head has been simply twisted to 1 side carrying with it the eye of the opposite. But the Dorsal Fin which stretches all along the back, in what is most assuredly the mesial line of the fish, extends also uninterruptedly in the same straight line, on to the head, beyond the eyes & between the nostrils & nearly the end of the snout. If the middle line of the top of the head has been twisted, why has such a distinctly median structure as the Dorsal fin not undergone the same process?

In our own language next to nothing has ever been said

about this curious subject - It has however been investigated by various continental observers, but as far as I am aware not to the extent it deserves. Accordingly before giving the results of my own observations, I will lay before the reader a brief account of the Bibliography of the subject as far as I have been able to collect it -

Autenrieth is the oldest writer I have found to allude to the subject anatomically. In a paper published in the year 1800 * he enters into the anatomy of the Plaice (Platessa vulgaris) and also makes many theoretical remarks on the structure of osseous fishes in general - His remarks on the osteology of the Plaice are however meagre, and his theoretical conclusion absurd - for he accounts for the transference of both eyes to the right side of the head, by supposing that the left eye has been removed from its place & stuck into the right cheek! I cannot do better than quote his own words - "Die Untersuchung des Skelets zeigt dass die ganze linke Seite vorwarts am cranio wirklich fehlt und die Natur um ein Auge nicht zu verlieren, genöthigt war es unter die einzige übriggebliebene rechte Orbita in die Wangenhöhle dieser anderen Seite zu setzen † It is then evident that he believes the middle line of the head to be unaltered, that the upper eye is the Right eye in its normal position, & that the lower eye is in effect the

* Wiedemanns Archiv für Zoologie und Zootomie - Thl. I 1800 - S 47 et seq. Bemerkungen ueber den Bau der Scholle (Pleuronectes Platessa) insbesondere und den Bau der Fische hauptsächlich ihres skelets im Allgemeinen. Von Dr J H F Autenrieth Professor der Anatomie in Tübingen.

† Page 52 -

left eye put into the Right cheek and that the bony ridge separating the eyes is a kind of zygomatic arch which has not been developed on the other side of the head. In this paper then it is needless to allude further seeing that it proceeds upon an entire misconception of the subject as will soon be apparent.

Rosenthal * has figured very neatly skeletons of Platessa flesus + of Pleuronectes maximus - the latter a foreign species which I have of course never seen. His ideas on the subject although a little more rational than those of Autenrieth are yet wholly untenable. He correctly enough holds the upper + lower eyes of the Flounder to be those of the Left + Right sides respectively, but accounts for the left one getting to the right side, by its being thrust through the head, + being placed "between the long processes of the Frontal bones after the manner of Cyclopean Malformations". It is easy enough to imagine how a superficial observer examining merely the skull of a Flounder or other Platessa might come to such a conclusion but I cannot well see how he could retain such an idea did he ever compare it with the disarticulated skull of a Turbot or Sole. Rosenthal has also figured the disarticulated bones of the Flounder's skull, but has entirely omitted the Petrous bone + does not seem to recognise the 2 prefrontals as fellows at all:- calling the Right one "Supra ciliar schuppe für das rechte auge", + the left "Nasentheil des Oberkiefers". As to Pleuronectes maximus he speaks of the upper eye being

* Ichthyotomische Tafeln. Berlin 1812-1822.

placed where the great fontanelle of the higher Vertebrata is. But it is to the great Meckel that we owe almost all our previous knowledge of the subject. His earliest remarks* on the asymmetry of the Pleuronectidae I have never seen, the work in which they are contained being very scarce; but his views are well given in the second volume of his comparative anatomy†, where he not only describes the asymmetrical condition of the bones of the head, but enters into the osteology of the entire trunk. He recognises correctly the homologies of the various Cranial bones with those of the symmetrical type - and notices the fact, that the asymmetry in the various species of Flatfishes shews gradual differences; the Turbot being the most & the Sole the least symmetrical in the order. How this opinion with regard to the sole must be modified I will explain hereafter (§) As to the bones of the face he says nothing but that the superior & Intermaxillary bones are larger on the Left side‡ - & calls especial attention to the very unsymmetrical condition of the latter pair of bones in the Sole.

The only thing in his description of the rest of the skeleton of the Flatfishes of which we must take special note, is what he says about the interspinous bones and fin-rays which extend over the upper surface of the head. He says

* "Ueber die Seitliche Asymmetrie in Thierischen Körper" in Meckels Anatomisch-physiologische Untersuchungen Halle 1822

† System der Vergleichenden Anatomie Bd II Halle 1824 - Translated into French by Riester & Dawson - Paris 1828 -

‡ Or rather in the "eyeless" side.

"This disposition is extremely interesting, it helps to establish the analogy of the Cranial bones with the Vertebrae: these accessory rays are placed in fact on the occipital and Parietal crests in the same way as those of the trunk are situated over the superior spinous processes".* But the untenableness of the idea that the interspinous bones & rays of the cephalic part of the Dorsal fin have anything morphologically to do with the bones of the head, I will endeavor to shew in Chap VI of this essay.

In fine, although Meckel has left room for considerably more to be said on the subject, he was undoubtedly the first anatomist who saw clearly that the 2 eyes of the Flatfish are brought over to one side by the twisting or twisting round of the original middle line of the head.

Cuvier in his Leçons d'Anatomie Comparée Tome II p 643 describes briefly the anterior part of the skull in the Turbot, especially the contour of the Frontal Bones & the manner in which the Orbit containing the upper eye is bounded by the Right Frontal & Prefrontal. So far as he goes all that he says is quite correct but he has not added anything to the information supplied us by Meckel.

Gottsche has described minutely the structure of the Brain in the Pleuronectidae† and has shewn how it also is to some extent unsymmetrical. Into this part of the sub-

* Op. cit. French edition page 312. vol II

† Müllers archiv. 1835

ject however I do not enter in the present essay.

Wagner*, in his Icones Zootomicae, has figured the cranium of a Turbot (Rhombus maximus) but not with sufficient clearness. In example for want of proper expression of the sutures the contour of the Frontal bones, the most important in the head, is not at all shewn. The palato tympanic apparatus also figured by him & stated in the text to be that of Pleuronectes Platessa (Platessa vulgaris) belongs also to Rhombus maximus

Köstlin alludes to the subject† But in the brief passage in the work referred to at the foot of this page he really tells us nothing but what we have already learned from Meckel.

Stannius in his work on the Peripheral nervous system of Fishes refers abundantly to the structure of the nervous system in the Pleuronectidae. But, as he is rather silent on the subject of the Assymetry, the most important passage in the work for us to consider, is that at page 123 where he states that the Dorsal branches of several of the first spinal nerves bend forward to supply the fin rays which are continued along the top of the head, & in Plate IV he gives a figure of this arrangement in the Plaice. The importance of this fact will be discussed in Chapter VI of this essay.

Van Beneden is the only author who has said anything a-

* Icones Zootomicae (Leipsig 1841) Tab. XVIII fig 8 & 11

† Der Bau des Knochernen Kopf in den vier Classen der Wirbelthiere (Stuttgardt 1844-8)

† Das Peripherische Nervensystem der Fische (Rostock 1849)

bout the state of the Pleuronectidae in embryo - and has taken the main step towards answering the question propounded at the beginning of this chapter, viz how the 2 eyes come to be found on 1 side of the head while the direction over the head of the Dorsal fin, a median structure, is unaltered. He has described an embryo Turbot in which the 2 eyes are still one on each side of the head & the rays of the Dorsal fin only yet descended to the middle of the cranium - and he also mentions having seen an adult specimen in which a somewhat similar condition was persistent. To this paper of M. Van Beneden* & to other notices of similarly formed or "malformed" adult Pleuronects I will have occasion again to refer to in Chap. VI

In our own language I have already said that next to nothing has ever been written on the subject. — and what has is not very edifying. Thus Professor Owen usually considered the greatest of English comparative anatomists thus expresses himself with regard to the Frontal "Bone" in the Halibut - "The mid frontal is single in the Pleuronectidae & has undergone more modification than any of the preceding bones in connection with the general distortion and loss of symmetry of the head - In the Halibut the Right posterior angle is truncated & the rest of that side scooped out as it were to form the large orbit of the Right side - The left side of the bone retains its normal form - a median

* Note sur la symmetrie des Poissons Pleuronectes dans le jeune age. Ann. des Sciences naturelles - 3e series XX p. 340 - 342 - (Paris 1853)

crest, a continuation of that on the supra-occipital divides the 2 sides" * He thus seems to think that the Left Frontal bone in the Halibut is homologous with the single Frontal in the cod. but if that be the case what are we to make of the other frontal bone which lies side by side with it behind the orbit? There must be a bone too many in the halibuts cranium if his view be correct.

In other parts of the same work from which the above quotation is taken we meet with stray remarks on the asymmetry of other bones in the Pleuronectidae but nothing very important or connected.

Rhymer Jones † alludes to the asymmetry of the head in the Pleuronectidae & gives a figure of the skull of Platessa flesus evidently copied from Rosenthal. He contents himself with saying that the 2 sides of the cranium are unequally developed & the head distorted in consequence but does not enter into any particulars.

And thus ends the list of authorities I have been able to obtain. In the next chapter I shall commence the subject itself & give the results of my own observations and dissections.

* Lectures on Comparative anatomy of the Vertebrate Animals London 1848.

† "Animal Kingdom"

Chapter II.

On the Cranium of the Pleuronectidae.

Before we proceed to consider the cranium of the Flatfish, let us look at the general plan of the osseous fish head. I have selected as standard of comparison the cranium of the common Cod as being the best known in this country, and it will do very well, the differences between its plan of structure & that in the Pleuronectidae being really immaterial.

We find three principal parts, each connected with one of the 3 great organs of special sense in the fish -

1 A posterior cavity containing the brain & the organ of hearing with a "foramen magnum" posteriorly, & in the macerated skull this cavity is widely open in front. Into its composition enter the Basilar, Exoccipital, Par occipital, supra occipital, Petrous, mastoid, alisphenoid, orbitsphenoid, postfrontal part of the Basipresphenoid, & part of the mid- or Great Frontal bones - and also a considerable quantity of primordial cartilage

2 A middle or Interorbital part consisting of a fibrous membrane extending from the Frontal bone above to the Basipresphenoid below forming a vertical "septum interorbitale". This septum is formed by the coalescence of 2 fibrous laminae which close to a considerable extent the anterior opening of the brain cavity

and also complete a groove on the under surface of the Frontal bone into a canal which contains the crura of the Olfactory bulbs & which continues the brain cavity as far forwards as the Nose - far as

3 An anterior or Nasal part, which contains no cavity, but presents 2 openings for the exit of the Olfactory nerves. It consists of 4 bones, the Vomer below, the nasal above & the Prefrontals 1 on each side - all of which bones are supported by a central mass of Preinordial cartilage -

The only differences worthy of note between the general plan of the Cod's skull as given above & that of the Pleuronectidae is that the 2 halves of the single frontal bone in the Cod are represented by 2 distinct bones in the Flatfish, & that in the latter the inter-orbital septum contains no tubular prolongation of the Posterior or Brain cavity.

I shall commence now to describe the simplest cranium to be met with among the Pleuronectidae -

The cranium of the Turbot (Rhombus maximus) truncated behind & somewhat pointed in front - presents superiorly a longitudinal ridge (α) which though commencing posteriorly in the middle line does not divide the head into 2 equal parts as it advances - On the contrary the anterior part of the cranium is broader to the Left than to the Right of this ocular non ocular ridge or of its supposed continuation forward in a straight line, and this happens, both because the skull anteriorly is actually considerably broader on the Left than on the Right Plate I fig: 1, 2

side, and because the ridge itself deviates a little though very slightly towards the Right side. This ridge supports the cephalic continuation of the Dorsal fin. Posteriorly we at once recognise the Brain cavity with its foramen magnum for the entrance of the spinal cord, & various other foramina for the exit of nerves. In front of the Brain cavity and to the Left side is an oval orbit (B), lodging the upper eye - in the macerated skull open both above & below - and in front of this orbit we recognise the nasal part of the cranium with its 2 foramina (C C) one for each Olfactory nerve -

On comparing this cranium with that of the Cod, we observe that while in the latter the anterior & posterior parts of the skull are connected by 2 bars of bone - an inferior (Basi presphenoid) & a superior flat & arch shaped (Frontal) we have here 3 bars, the 2 upper bounding between them the orbit for the upper eye. To the left those bars which forms the lower boundary of the orbit & lies between the 2 eyes I shall give the name Interocular and to the Right which bounds the orbit on the other side & lies in the same direction as the ridge supporting the end of the Dorsal fin I give the name "Pseudo nasial".

Proceeding now to disarticulate the Turbots cranium, we shall find that posteriorly the bones are very little altered in their symmetry.

The Basioccipital (1) The long axis of the bone is somewhat obliquely placed in regard to the transverse plane of

the disk on its posterior surface for articulating with the 1st vertebra — it points a little towards the left side. 1

Exoccipitals (2) Very symmetrical.

Par-occipitals (4) The posterior projecting process is longer on the Right side.

Alisphenoids (6) Very symmetrical.

Mastoids (8) Very nearly equal in size & conformation. That of the Right side however is generally longer than that of the Left.

Petrosal (10) These bones are much smaller than in the Cod but larger than in the Carp — and lie quite superficially That of the Right side is in the Turbot always larger than that of the left, and accordingly on the outside of the skull covers up more of the Mastoid and Exoccipital bones from view.

Post-Frontal (12) is longer on the Right side, & the process (B) from which the Levator tympani muscle arises is also more marked on that side.

Parietals (7) Like the Right Post Frontal the Right Parietal is considerably longer than the left. This is well shewn in fig 3 of Plate 1 where the 2 Frontal bones are removed from the rest of the cranium.

IV The bones enumerated in the last paragraph shew but little in regard to the symmetry of the head. In those next to be noticed, the indications are more decided.

Basi-pre-sphenoid (5) This bone is slightly bent towards the Right side a little behind its middle. To descrip-

tion we may divide it into 3 parts. The posterior flattened part which overlaps the basioccipital is symmetrical. The middle part presents on each side above an ascending lamniar process which bounds laterally a channel lodging the origin of the Eyemuscles* this channel passes obliquely accross the long axis of the bone from the Eyeless side (Right) towards the Eyed side (Left). The anterior part which receives the pointed end of the vomer is twisted on its long axis up towards the right (eyeless) side.

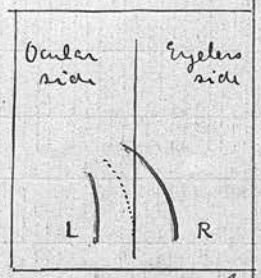
Orbito sphenoid (10) On the Right (eyeless) side this bone is longer than on the left, its direction also aggrees with that of the Eyemuscle canal of the B. pre-sphenoid, in pointing obliquely accross the head. This is shewn in fig 3 Pl I where the blue indicates the cartilaginous tip of the bone.

The Supra-occipital (3) presents a scale shaped "body" forming part of the roof of the cranial cavity surmounted by a very prominent ridge or spine (á). This "body" is pretty symmetrical its long axis often slightly curved points however to the eyed side (Left) but the spine though commencing posteriorly on the middle line passes forwards to the Right side, impinges on the Right Frontal bone + if continued further forward would pass quite by the Right side of the orbit. The supra-occipital bone is thus very unequally divided, the largest moiety being on the Left (eyed) side.

V If now before we proceed further we turn to Plate I figures

* This Eyemuscle channel is only separated from the anterior part of the braincavity which lies above it by fibrous membrane.

1 - 2 & 3 we shall see that although the basal keel of the cranial cavity is continued forwards in nearly a straight line the long axis of that cavity which the keel underlies is at unquestionably points round to the left side, anteriorly crossing that keel at an angle. This is well illustrated by the structure of the Basipresphenoid bone itself & IV where the eyemuscle channel, which is simply the lower part of the cranial cavity, crosses the long axis of the bone. This also explains the reason why several of the cranial bones as the Parietal, Mastoid, Postfrontal, & Orbitosphenoid are longer on the Right or eyeless side, simply because they have a longer extent to traverse as will be seen by the accompanying diagram.



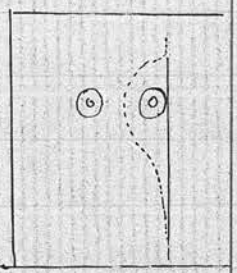
Notice also that although the long axis of the supra-occipital bone follows the general twist of the cranial cavity towards the Left side (indicated by the dotted line in the diagram) the spine of the bone continues forwards nearly in the same straight line as the middle line of the entire fish (indicated by the straight line in the diagram). To the line continuing forward the axis of the body of the supra occipital bone I give the name "morphological middle line", and the line of the Dorsal fin & spine of the Supraoccipital I will call the "Pseudo medial" line.

VI In advance of the orbito sphenoid - Post frontal, Parietal & supra occipital bones are two bones (11) which from their position must be the Frontals - Each consists of

of a posterior somewhat square shaped part - forming part of the roof of the Brain cavity & of an anterior more slender curved part which with its fellow of the opposite side forms the Interocular bony ridge or bar - The anterior part of the left bone Pl. I fig 5 is strongly curved the concavity looking upwards & to the Right at its extremity it is articulated to the Left prefrontal, touches the nasal, & rests likewise on a portion of primordial cartilage to be presently described (§ VII) The Right bone Pl I fig 5 is distinguished by having its posterior part larger the right anterior angle projecting forwards so as to take a slight part in the formation of the Pseudo mesial bar of the cranium which bounds the orbit on the R. side - This process I will call "External Angular" The anterior part ("Interocular process") is much more slender than the corresponding part of the Left bone & to which it is closely applied - at its extremity it likewise rests on a portion of primordial cartilage but does not touch the Right Prefrontal It forms the entire left or lower boundary of the Orbit -

VII We see now that the morphological mesial line continued from the supra-occipital bone in the line separating the 2 Frontal bones from each other, at first deviating but slightly from the left side now curves round the orbit along the interocular bar till anteriorly it tends to return again to coincide with the apparent mesial line - See diagram Plate XI fig 15 - and

also the under diagram accompanying.



That this is the true morphological middle line and that the Interocular bar is the only & complete homologue of the Frontal arch in the cod, is proved simply by the fact that between this interocular bar & the Basi presphenoid bone, there extends a fibrous membrane having imbedded in it the olfactory nerves as they proceed to the nasal fossae in front; similar to the interorbital septum extending from the Frontal bone to the Basi presphenoid in the cod, - but by the twisting over of the mesial plane to 1 side this septum in the Turbot instead of being vertical has become nearly horizontal *; and instead of coinciding with the mesial plane of the rest of the fish has become set nearly at right angles to it. In the Turbot & in all the other Pleuronectidae, the olfactory nerves are not contained in a distinct tubular prolongation of the Brain cavity at the top of the interorbital septum as in the cod, but are simply imbedded in its substance.

The ophthalmic branches of the 5th nerve on each side which in the cod lie beneath the Frontal arch here likewise curve round between the eyes along the inter-ocular processes of the Frontal bones till they end in the nostrils & front of the snout.

* Of course it is "vertical" when the flatfish is swimming in its side in the usual position.

But what then is the "Pseudo-mesial" bar or bridge in the Turbot's cranium, if the Interocular bar is the complete representative of the Frontal arch in the Cod? This we shall see presently.

VII. We now come to the anterior or Nasal part of the cranium characterised by 2 olfactory foramina of which, that of the Left or eyed side is more anterior than the other. As in the cod this part of the cranium consists of a central piece of cartilage supporting 4 bones – the Vomer below the Nasal above & the 2 prefrontals, one on each side.

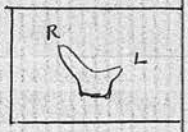
The cartilage. This portion of cartilage more extensive than the corresponding remnant in the Cod, appears as a very rudely quadrangular plate, with a very large hole through its middle, connected to bones all round its edges, save the concave posterior one which is continuous with the fibrous septum between the eyes already referred to (¶ VI). On each side of it, an olfactory nerve passes to its corresponding olfactory foramen, in the directions indicated by the bristles in Pl. I fig 4. It therefore indicates the morphological mesial plane of the anterior part of the head & would be vertical were it not for the twisting over to one side which has occurred. Beneath it rests on the Basi-presphenoid & Vomer – in front it supports the nasal bone (15), & laterally round its antero-inferior an- Plate I A

gle it is intimately connected to the Prefrontals on each side (14) Above the anterior extremities of the interocular process of the Frontal bones rest on it as follows. A longitudinal notch divides the upper edge of the cartilage into 2 unequal pointed processes (g & h Pl 1 fig 4) of these the left (g) by far the largest is lodged in a hollow on the under surface of the stout interocular process of the Left Frontal, & supports also the posteriorly directed process (a) of the left Prefrontal (14); the Right h is similarly related to the end of the slender interocular process of the Right Frontal bone, but is not touched by the Right prefrontal save at its base.

Now this notch as it indicates the line of separation between the 2 interocular processes of the Frontal bones, likewise must indicate the morphological middle line of the cartilage: so that here we have a mesial cartilage, not only unsymmetrical in its position but in the development of its two sides. that being much greater on the left or ocular side of the fish.

Vomer. (13) The posterior part of the Vomer which fits into a groove on the lower aspect of the Basi presphenoid, is more developed on the Right than on the left or ocular side; also the Right lateral ala for articulating with the Prefrontal is larger & projects more vertically upwards than its fellow of the opposite side; so that

like the anterior part of the Basipresphenoid the vomer has slightly the appearance appears as if twisted up on its long axis towards the right or eyeless side. In outward form the head of the bone however does not participate much in this twisting -



Nasal (15) This bone is tolerably symmetrical as regards the development of its two sides. In front it presents a deep transverse notch at which point it is slightly bent on itself the concavity being towards the left (ocular) side. We have then the nasal prominence divided in 2 parts the upper (i fig I Pl I) giving attachment to ligaments connected with the maxillary bones, & continuing forward the direction of the still oblique morphological middle line; the lower and anterior (k) forming an articular surface on which the intermaxillary nodule of cartilage glides up & down and backwards & forwards as the jaws shut & open, coincides in its direction with the pseudo middle line also - So that the notch between these 2 prominences in the nasal bone is the point where the morphological middle line again returns to the apparent or Pseudo middle line.

The two Prefrontals (14), are at once known by the notch borne by each & which is completed into an olfactory foramen (C C), by the contiguous nasal bone

The Left Prefrontal is somewhat triangular in shape Plate I
anteriorly & to the inner side it presents the notch 14 in all
already spoken of, articulates with the nasal bone (15) & touches the Primordial cartilage - Below the notch it is extensively continuous with the primordial cartilage & also sends down a process (c) which articulates with the left ala of the vomer - opposite the olfactory notch is a prominence e to which the 1st suborbital bone of the side is attached - & posteriorly it sends back a pointed process a which articulates with the interocular process of the Left Frontal, and rests internally on the primordial cartilage which forms the anterior part of the interocular septum (see page 19)

The Right Prefrontal is much larger & of a nudely quadrangular shape. Anteriorly it is similarly related to the nasal bone & presents the same olfactory notch beneath which the bone is more extensively connected to the primordial cartilage than it is above it. The same process (c) is sent downwards & forwards to articulate with the vomer, and in addition one b is sent downwards and backwards to articulate with the basipresphenoid. But the great mass of the bone projects back in a large flat quadrangular process & which instead of articulating with the interocular process of the Right frontal bone as the posteriorly

directed process of the L. Prefrontal does with its corresponding Left frontal, passes round the other side of the orbit, & joining the external angular process of the Right frontal forms with it the "pseudo mesial" bar of the cranium, which bounds the orbit to the Right side.

The orbit containing the upper eye is then bounded posteriorly & on the left side by the interocular process of the Right Frontal bone - at the anterior angle by a small portion of primordial cartilage (s) - on the Right side by the posteriorly directed process of the Right prefrontal & slightly by the external angular process of the Right Frontal.

VIII Now let us look at the Prefrontals in the bird (the lateral aspect of this bone I have figured Pl I fig 7) We observe Pl I fig 7

(1) 2 processes d d going towards the nasal bone with an Olfactory notch C between them

(2) An anteriorly directed process c for the ala of the vomer.

(3) A posterior inferior process b for the Basipresphenoid.

(4) A posterior superior process a going upwards & backwards to the frontal bone.

(5) A lateral process e opposite the Olfactory notch and to which the 1st Suborbital bone is suspended.

Now comparing the Left Prefrontal in the Turbot with this, we find everything to correspond exactly save that the inferior process for the Basi presphenoid is wanting; the interval being filled up by mere cartilage (Pl 1 fig 2)

The Right bone although it presents a large process b for articulation with the Basi presphenoid, shews no trace of the process a for articulating with the interocular part of the Frontal - it does not even touch it - But what then is the large process f ? That it is not homologous with the process a projecting posteriorly in the Cod & in the Left prefrontal of the Turbot is evident from its bearing no relation to the olfactory nerve of its side, nor to the interocular septum - On the Left side however the olfactory nerve runs close beneath the process a . See Pl I fig 4

It follows then that this process f in the Prefrontal bone of the ~~Left~~ Right or eyeless side is a new process, having no homologue either in the Cod or in the bone of the opposite side. I shall call it "External angular" corresponding with that process of the Right Frontal which with it completes the Right wall of the Orbit, & which also has no homologue in the Cod.

And now we see what is the nature of that bar of bone I have called Pseudo mesial (§ II page 12

and which some people have supposed homologous with the Frontal arch in the Cod - & other symmetrical fishes. Seeing that the true homologue of the interorbital arch in the cod's head has been reduced to a narrow bar & twisted over to one side we have here a secondary formation destined to supply the place of that arch in forming a strong & efficient bridge of connection between the anterior & posterior parts of the cranium and also to support the cephalic continuation of the Dorsal Fin.

IX The cranium we have just considered is the least asymmetrical & most easily understood in the whole Pleuronectidae. We shall now proceed to examine and compare with it the crania of some of the other Pleuronectidae & note to what further steps the process of distortion proceeds before finally generalising on the changes which have taken place.

X The cranium of the Brill (Rhombus vulgaris) is nearly identical with that of the Turbot. But we must remark that the Inter-ocular process of the Right Frontal bone is proportionally more slender than in the Turbot, while the external angular process of the same bone is more pronounced & forms more of the right wall of the orbit than in the last-named fish. To this I will again refer (Ch

Chap II page 30

XI We now come to a group of Flatfishes characterized zoologically by the rays of the Dorsal fin advancing only as far as the middle of the orbit, by the eyes being normally on the Right side of the body - and by a marked tendency little more than indicated in the last genus for the mouth eyes to become twisted towards the opposite side of the body from that on which the eyes are placed.

Under this head we will consider the crania of the Halibut (Hippoglossus) and of the Flounders (Platessa) And I would specially beg of the reader to remember that as in these 2 genera the eyes are normally placed on the Right side - the terms Right & Left, in regard to the general symmetry of the head, will mean exactly the converse of what they did when we were talking of the cranium of the Turbot (Rhombus) where the eyes normally are on the Left side - The import of such terms as "Ocular" side, or "eyed" or "eyeless" side will of course always remain the same.

XII On looking at the under surface of the Halibuts cranium we find the basal keel pretty straight in itself, but, when the head is in situ on the end of the Vertebral column, it tends strongly to point to the eyeless (left) side. In the occipital region the skull is apparently broader on the ocular side than on the left - this is due to a greater projection in that direction of the Mastoid (8) & Exoccipi

Plate II bis 2

tal bones (2) - the Petrous (16) is also larger - The middle line of the posterior aspect of the skull is also strangely curved the convexity being towards the ocular side (right) and corresponds in this way with a curve I will afterwards describe in the spinous processes of the anterior abdominal vertebrae. The corresponding curve on the posterior aspect of the cranium of the Plaice is slightly represented in Pl. IV fig 8.

The Basioccipital (1) is unsymmetrical - the middle line of the inferior surface pointing to the eyeless (left) side in the direction of the keel of the cranium, while the middle line of the superior surface, indicating the twist of the cranial cavity, diverges towards the ocular (Right) side. The mesial vertical plane of the bone is therefore pushed over to the right side anteriorly. Pl. II fig 2

Basipresphenoid (5) This bone presents in a much more exaggerated form than in the Turbot the twisting upwards of its anterior part on its long axis towards the eyeless side; here indeed the groove, in which the end of the Vomer is inserted, looks quite to that side (left). The axis of the entire bone points to the left side as I have already noticed -

The Right Postfrontal has the semilunar excavation completed by a similar one in the alisphenoid into a cotyloid cavity (D) for the head of the Epitympanic bone placed further forward on its surface than on the left side - so that the tympanic apparatus for the suspension of

the lower jaw is attached further forward on the ocular side of the head. To this I will again allude in speaking of the bones of the face.

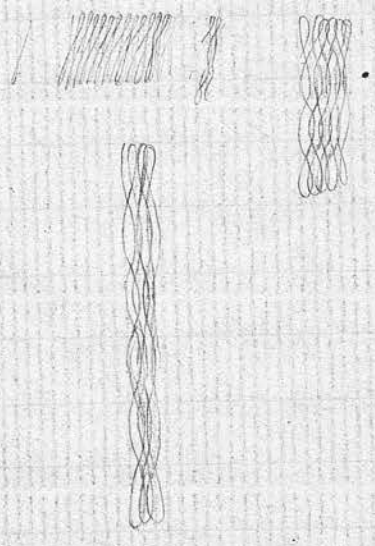
The orbito sphenoid (10) is larger on the Left than on the Right side & points considerably over towards the Right. Owing to this its real size is not apparent in Plate II fig 2 (10)

XIII On the upper surface of the skull

The supra occipital (3) shews in a more marked manner than in the Turbot. the divergence of the morphological from the apparent middle line at the back of the head I have indicated its direction by a dotted line. (Pl II fig 1)

The left parietal (7) is broader than the Right, having more room to develop itself in consequence of the turning of the supra occipital towards the Right side. The right parietal is often however a little longer.

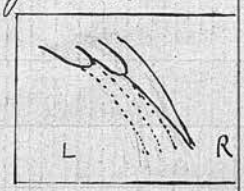
The Right Frontal bone corresponds very much in shape with that of the ocular side in the Turbot. But the Left bone (eyeless side) has its external angular proces much more developed forming more than one ½ of the left wall of the orbit while the Interocular proces is reduced to a mere curved spiculum, passing round all along the lower & Right border of the orbit closely applied to the stouter interocular proces of the Right Frontal. See Pl. II fig 1 (11, 11) & figures 4 & 5. A ridge continued from the supra occipital passes over the left frontal & on to its external angular proces - the ridge which Professor Owen has described



as the median ridge of the "single" frontal bone in the habitat.*

XIV Anterior part of the head

The Cartilage (Pl. 2 fig 3 A) This is thinner & smaller than in the Turbot but its relations & conformation are analogous. Its upper border is divided by 2 notches into 3 very unequal processes, of which that on the right side by far the largest extends posteriorly & supports the process a of the Right prefrontal. Into the Right and larger notch g is inserted the extremity of the intero-ocular process of the Right Frontal bone and into the smaller notch h on the left side is inserted the end of the intero-ocular process of the Left Frontal. in the manner represented in Plate II fig 1. This cartilage then as in the Turbot is very unequally developed on its 2 sides, the left side being quite atrophied, corresponding with the atrophy of the intero-ocular process m o fig 4 of the Left Frontal & the complete non development of the process a ≠ of the Prefrontal. See page 23. The above diagram exhibits the manner in which the left side of the cartilage A in Plate II is atrophied

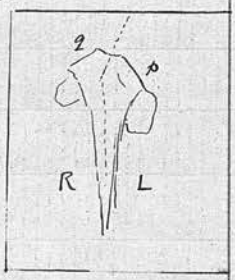


Pl. II fig 4

Vomer. This bone is inverted on its long axis up towards the eyeless side as in Turbot, but in a more exaggerated form see pl II fig 8 which represents a view of the anterior aspect of the head of the Vomer surmounted by the plate

* See page 8

of primordial cartilage last described. anteriorly it presents 2 facets p. & q. of which the left p is larger & looks more laterally than the Right q. : a line bisecting the angle formed by these 2 facets would pass obliquely towards the left side as in the accompanying diagram The left lateral ala of the vomer besides being larger is also directed more posteriorly than the right. so that the bone besides being twisted upwards to the left side on its own long axis has that axis turned to the left at its extremity as indicated by the dotted line in the diagram. The full import of this will be seen in next chapter when we come to treat of the bones of the face.



Nasal Bone This is a little bent on itself as in the Turbot (page) but the prominence k on which the intermaxillary cartilage glides is still obliquely directed to the left side. The nasal bone is more expanded transversely than in the Turbot & thus comes to enter into the boundary of the orbit Pl I fig 1 – (15). It is also apparent that this increase in size transversely is chiefly due to development on its left side.

Prefrontals. These are more nearly of the same size than in the Turbot. though that of the eyeless side is still a good deal larger than that of the eyed (right) side. I have already alluded to the fact that in the Turbot (page 20) the process a of the Prefrontal of the ocular side which articulates with the interocular process

of the corresponding Frontal is not at all developed on the prefrontal of the eyeless side an interval (s Pl I fig 1) being left between the frontal & prefrontal anteriorly on that side. In the Halibut, the prefrontal of the eyeless side at the place where the process a should be given off is still less developed, and the primordial cartilage being less in this region than in the Turbot a space is left in the anterior wall of the orbit which is filled up by a development from the left side of the nasal bone. Compare the boundaries of the orbit in Plate I fig 1 & in Pl II fig 1.

The principal reason why the Left Pre-frontal of the Halibut is smaller proportionally than the corresponding prefrontal of the eyeless side in the Turbot, is that the external angular process (of the left frontal) n fig 4 Pl II being more developed, & completes the left wall of the orbit there is less space left for the left Prefrontal.

XV We have seen (p 24) that the cranium of the Brill is more unsymmetrical than that of the Turbot in this respect that the external angular process of the Frontal bone of the Eyeless side is more pronounced while the corresponding interocular process is more slender. We now find that in the Halibut the interocular process of the corresponding bone (Pl II fig 4 m) has become very much more slender; the nasal bone by an increased development of its left side has entered into the formation of the orbit; that the anterior part of the cra-

nium is more twisted bodily on its long axis, upwards to the left and downwards to the right or ocular side - and that that long axis itself is now considerably directed to the eyeless side - (See diagram bis 16 plate XI)

XVI In the cranium of Platessa Pola the interocular process of the left frontal bone presents a form intermediate between its form in the Halibut & that in the Plaice next to be described. It is continued along between the eyes as a very slender spiculum, much more delicate than the corresponding part in the Halibut & very apt to be broken off in disarticulating the skull. The external angular process is very largely developed and with the corresponding part of the Left prefrontal forms the pseudo nasal bar of the cranium into an expanded vertical plate chiefly designed to support the curious series of ampullated mucous canals on the Left side of the head - (On this subject see chapter IV page 58 & Pl VII.) Plate XI bis 5

VII The Plaice - Platessa vulgaris. The general form of the Plaice's cranium is much the same as that of the Halibut, but some of the points of Asymmetry indicated in the latter have run to much greater excess.

In Plate IV I have figured the cranium of the Plaice, seen from various points of view, & also several of the individual disarticulated bone.

The keel of the cranium is strongly bent towards the

left side and its anterior part also strongly twisted upwards on its long axis towards the same side.

The external angular process of the Left frontal is similar to that in the Halibut but the intero-cular process is almost completely atrophied or rather non developed so that the great part of the lower or right boundary of the orbit is formed by the Right Frontal bone - a great part of the left boundary by the Left, and this might easily lead a superficial observer to imagine that the Interocular process of the Right bone & the external angular process of the Left were homologous with each other - This seems to have been Rosenthals idea when he talks of the upper eye being placed between the 2 long processes of the Frontal bones after the manner of cyclopian malformations. But the untenableness of this idea will be at once apparent if the reader will simply refer to the series of bones figured in Pl XI & to the relations of the interorbital fibrous septum & olfactory nerves already referred to in the description of the corresponding part of the cranium in the Turbot (page 17)

The Prefrontals (14) are fashioned much as in the Halibut - that of the ocular side is pushed forward much in advance of the other -

The Nasal bone forms a large part of the orbital wall anteriorly - it is much more developed on its left side

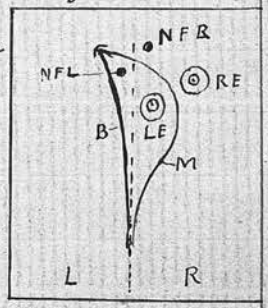
apparently occupying to a great extent the part which should have been taken in the formation of the orbit by the Left Prefrontal The ridge on its anterior surface for the intermaxillary cartilage is very obliquely directed towards the left side. Compare this with the direction of the analogous part in the Turbot (page)

Vomer The 2 facets (p. q) on the end of this bone for the heads of the superior maxillary bone are so placed that the line bisecting the angle which they form with each other passes very obliquely to the left side in the same direction as the ridge above on the nasal bone. Plate IV fig 6.

This conformation of the Nasal bone & Vomer so arranges matters that the long axis of the oral apparatus points obliquely to the left side & when the mouth opens it is protruded in the same direction. See chapter III page 46.

XVIII The cranium of the Plaice is then more unsymmetrical than that of the Halibut in the almost complete non-development of the interocular process of the Frontal bone of the eyeless side - & in consequence the interocular process of the Right frontal forms almost the whole right & lower boundary of the orbit. The nasal bone enters more largely into the boundary of the orbit in front - and the process of twisting of the anterior part of the skull, upwards towards the eyeless side and downwards towards the eyed side, as well as the bending of that axis itself toward

the eyeless side have proceeded to a greater extent. The principal points for us to note however are the non development of the intero-ocular process of the Frontal bone of the eyeless side and the increased degree in which the axis of the entire front of the cranium has turned toward the eyeless side, as evinced by the curve of the Basi-sphenoid & by the nasal foramen or fossa of the eyed side being so much more anteriorly placed than that of the opposite side. See the accompanying diagram and also Plate IV with the accompanying explanations.



In the diagram adjoining the dotted line represents the apparent middle line of the head of a Plaice: RE the right eye LE the left eye: NFR right nasal fossa: NFL Left nasal fossa: B keel of cranium: M morphological middle line of top of head.

XIX I have omitted considering the cranium of the sole up to this time, principally because I consider the Turbot to be a much more typical Pleuronect, and on the whole the most symmetrical of the order. And if we commence with the Turbot the Sole cannot be interpolated into the series which leads from it to the Plaice.

But the cranium of the Sole being a very interesting and curious one in many respects, I cannot afford to leave it out of consideration, and will according-

by point out rapidly the more important points in its construction.

Meckel has characterised the Sole as being the most unsymmetrical of all the Pleuronectidae, and certainly it is so, if the fantastic irregularity of the contour of its skeleton, & especially of the bones of its face be taken as our guide. But in the structure of its Cranium morphologically it is in many respects the most symmetrical of the order. and in the concluding chapter of this essay in my generalisations on the laws followed by the loss of lateral symmetry in the Pleuronectidae, I will place it as the first of the gradational series - not as the last as Meckel has done.

XX As in Hippoglossus & Platessa the eyes in Solea & the allied genera are normally situated on the Right side of the head.

In the cranium of Solea vulgaris the Basipresphenoid bone forming the keel of the cranium is at first turned a little towards the eyeless or left side and then a little behind its middle turns again and proceeds pretty straightforwards to the front. We have thus a concavity towards its ocular side - a circumstance we have not seen in any of the other Pleuronectidae - Its anterior extremity follows the universal rule of being ~~twisted~~ more developed on, & twisted up

towards the eyeless side (left)

The Vomer is likewise twisted on its long axis towards the eyeless side & on that side its lateral ala is alone developed.

The nasal bone shews in front a prominent curved proces projecting over the maxillary apparatus & very slightly turned towards the eyeless side. Behind it shews 2 proceses - the one on the ocular side projecting back between the Right prefrontal & the intero-cular proces of the corresponding Frontal. - the other one projects nearly at a right angle upwards & to the eyeless side, pushing aside as it were the left Prefrontal. It thus represents that part of the nasal bone which in the Halibut & Plaice enters into the boundary of the orbit.

The two prefrontals are very unequal in size - that of the left or eyeless side being 2 or 3 times the size of the other. Notice also that the great bulk of the left bone is formed of bone developed external and poste-rior to the olfactory notch - parts of which on the right side the only trace is a little half-ring (3) surrounding the external aspect of the olfactory nerve. The bulk of the right bone being formed of a proces (a) lying be-neath the extremity of the Right Frontal bone, and contributing to the formation of the intero-cular bar of the cranium. Compare this with what is said (page 20-23) about the prefrontals in the Turbot - always

Plate XL fig 7

keeping in mind that in the latter fish it is the Left not the right which is the ocular side. The only part common to the 2 prefrontals in the Sole is that a, in front of the olfactory notch on each side. This part on the left side, sends up a curved process a', overhanging the orbit, & which is probably the homologue of the process a of the Right bone but pushed aside from its Frontal bone by the process developed from the left side of the nasal.

The two Frontals are much more symmetrical than in any of the other Pleuronectidae. The interocular process of the Left bone extends all the way along to the nasal bone and is even longer than its fellow though considerably more slender - its external angular process is very slightly developed, the greater part of the left wall of the orbit being formed by the very long external angular process (f) of the left Prefrontal. Plate XI fig 1 fig 7

XXI The cranium of the sole agrees then with that of the other Pleuronectidae in having the anterior part twisted much up on its long axis towards the eyeless side and in the manner in which the interocular bar is turned down so as to make the original mesial plane between the eyes to become nearly horizontal. It differs, in having the long axis itself very slightly indeed tending to point towards the eyeless side.

As in the other Pleuronectidae the olfactory foramen of the eyeless side is much higher up on the eyeless than on the eyed side.

As is not the case in the other Pleuronectidae the olfactory foramen of the ocular side is not further advanced in the cranium than on the eyeless side

See diagram Pl XI by 14

——"——

XXII. I will now state in a series of 4 Propositions the changes which have occurred in the original axis mesial plane & mesial lines of the cranium in all the Pleuronectidae-

1 The anterior half of the cranium has, in all the Pleuronectidae without exception, become twisted on its long axis, up towards the eyeless & down towards the ocular side-

2 The mesial plane of the cranium has become twisted over towards the ocular side (including in the ocular region) - very slightly in the posterior part of the cranium - very much in the interocular part so as to become nearly horizontal instead of vertical; and at the front of the nasal part returns nearly to its original vertical position in the turbot, but never does so in the Halibut or Plaice.

3 In consequence of this - the original or morphological middle line of the top of the cranium diverges from the apparent or pseudo-middle line, curves round between the eyes (which the turning

over of the mesial plane has of course brought to one side) and returns again to the middle in front. Having got in front of the eyes and nasal fossae, in the Turbot & Sole it now again coincides or nearly so with the apparent middle line, but in the Halibut & still more so in the Plaices, the morphological & apparent middle lines, if produced would cross each other.

4 The axis of the entire anterior part of the cranium tends to become turned over towards the eyeless side & thus the keel of the cranium is seen to be bent over towards that side in the Plaice & the Prefrontal bone, & olfactory notch of the Ocular side considerably in advance of the other.

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Explanation of the diagrams figures 14, 15, 16, 17

PL Apparent middle line ML Morphological middle line. K Keel of cranium. NF Nasal fossa.

Chapter III

On the Bones of the Face

XXIII The bones of the Face are likewise more or less asymmetrical in all the Pleuronectidae, but as their asymmetry is very simple compared with that of the cranium, the subject need not detain us long. I will in fact confine myself to the elucidation of the most typical asymmetry presented by the facial bones in the genera Hippoglossus & Platessa.

XXIV 1 In this group the eyes are twisted downwards & towards the Right, while the mouth is twisted more or less upwards & to the left - as if the anterior part of the head had turned to some extent bodily on its own axis. This indeed has taken place, as I have shewn in last chapter,

2 The mouth is also pushed from behind forwards from the right over towards the left side, so that when the fish gapes the mouth points more or less obliquely to that side which is of course "downwards" when the fish is swimming in its natural position.

3 From these circumstances it happens that

A The opercular & tympanic apparatus* is larger & more arched on the right side while the Palatal apparatus is more slender, & the jaws shorter & flatter than on the Left side.

B On the Left side the tympanic & opercular apparatus (except the hypotympanic bone) are smaller & flatter; while the palatal apparatus is stouter, flatter & attached to the nasal part of the cranium higher up, & farther back, than the corresponding part on the other side. The jaws are also stouter longer & armed generally with a greater number of teeth than on the Right side.

Let us now substantiate these propositions by an examination of the individual bones

XXV First in the Halibut (Hippoglossus vulgaris)

In Plate III the opercular apparatus & jaws in the Halibut are indicated. The manner in which the mouth looks to the left side is also shewn in fig. 2

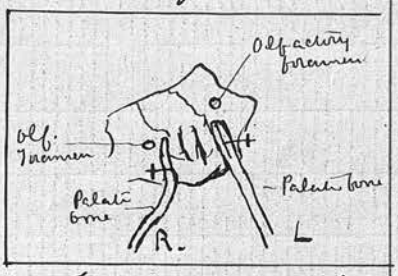
Opercular & tympanic apparatus. The opercular (35) the Subopercular (36) the Preopercular (34) & Interopercular (37) bones are larger & more arched on the Right than on the left side. Also the Epitympanic bone is larger on the Right side – the Right & Left Meso-tympanic bones are about the same in size, the Pretympanic & Hypotympanic are longer but

* Except the Hypotympanic bone, which though longer is not stouter than on the left side.

not so stout and broad as on the Left side. I have alluded (page 26) to the fact that the cotyloid cavity for the head of the Epitympanic bone is placed further forward on the side of the skull on the Right than on the left side. This leaves room to be covered by a large opercule, and, with the greater length of the opercular and tympanic bones above noticed aids in pushing the mouth over towards the Left side as stated in proposition 2.

Palatal Apparatus. The Pterygoid bone is shorter and more slender on the Right side - the Entopterygoids of both sides are of the same length - that of the Right is broader, while that of the left is much stouter. The Palate bone is smaller on the right side & differs somewhat in shape from that of the Left which is very stout. Each palate bone consists of 2 parts - of a palate plate proper & of an anterior process which projects over the heads of the upper jaw bones - On the right side these 2 parts are set at an angle to each other as in the Cod; but on the left, the anterior process, being inclined over towards the right side, comes to be nearly in the same plane with the body of the bone. The bone of the Left side is also attached much higher up on the side of the head than on the ~~Left~~ Right - because of the twisting up of the anterior part of the head on its long axis, & of the greater length of the left side of the vomer; while

that of the Right side is attached further forward because of the more anterior position of the Prefrontal on that side.



The Palatal arch is much flatter on the Left side as represented in the diagram. I have marked by a cross the point at which the palate bones are articulated to the sides of the cranium.

We have now seen what part in the biting of the mouth to the Left or eyeless side is taken by the palatal apparatus - we must now & lastly consider the jaws.

Lower Jaw. The lower jaw is longer - stouter more arched - and armed with a somewhat greater number of teeth on the Left side than on the right.

Upper jaw.

The superior maxillary bone (21) of the Right side is about the same in length as that of the left, but not so stout - the process, for the attachment of the ligament, which is joined by the tendon of the Retractor maxillae muscle, is much smaller & situated nearer the head of the bone. Plate III

The Intermaxillary bones (22) of the 2 sides are very nearly equal in size & development - that of the left side is generally a little more arched.

These 4 bones of the upper jaw are supported on a central nodule of cartilage, in especial connection with the intermaxillary bones, between the contiguous

ascending processes of which it is placed. This cartilage glides forwards* & downwards, as the mouth opens, on an articular ridge or prominence on the anterior aspect of the nasal bone; and as this ridge is directed rather obliquely to the left side, the whole upper jaw apparatus which moves "en masse" with the cartilage is protruded to the left side when the mouth opens.

Besides this, notice the manner in which the superior maxillary bones are articulated to & move on the front of the cranium.

I have already described the 2 facets on the end of the vomer (page 33); how by the twist of the axis of the bone the left is higher than the right. how it is also larger & how it looks more laterally — so that a line, bisecting the angle formed by the 2, will pass obliquely to the left side. On these 2 facets the heads of the 2 superior maxillary bones glide (an interarticular fibro-cartilage being as usual interposed) & their form & position coincides exactly with those of the ridge on the nasal bone in directing the axis of the oral apparatus to the left side, especially when the mouth is opened.

XXVI The facial bones of the Plaice are constructed & arranged on exactly the same principles as those of the Halibut last described, but the con-

* In the Halibut the movement is principally downwards.

ditions of asymmetry are considerably exaggerated.
Indeed when a plaice gapes its mouth screws round to the left side in a most remarkable manner, & that side being uppermost when the fish is swimming in its natural position, I suppose it is thereby better enabled to pick up from the bottom of the water the small shells crustacea & sandstars which form most of its food. This is effected by the very oblique direction of the articular ridge (A fig 1 Pl IV) in front of the nasal bone, by the great obliquity of the axis of the 2 facets on the front of the vomer - the Right of which facets looks anteriorly rather than laterally - by the articulation of the lower jaw being considerably further forward on the Right than on the left side, and by the conformation of the jaws themselves.
In Plate VI fig 1 represents the bones of the Right side of the face & fig 2 those of the left: the suborbitals - supra temporals & ossa terminalia are colored in red. (these latter will be described in next chapter)
The Right superior maxillary bone is smaller than the left to some extent.
But the Right intermaxillary bone is very much smaller than the Left - its ascending process is set at at obtuse angle to the rest of the bone, and

it bears only 4 – 7 teeth: while the left bone stout and strong with its ascending process set at nearly a right angle to its well arched body is set with 25 – 30 or more

The lower jaw of the Right side, rather flat is shorter than that of the left, its dentary part bears like the corresponding intermaxillary only 4 – 7 teeth. That of the Left side has its dentary bone much curved & set with 25 – 35 teeth.

So not only does the mouth when opened point to the left side, but its left side is more arched & prominent and contains almost all the teeth.

The same general arrangement prevails in a more or less marked form in almost all the species of the genus Platessa.

VII In the genus Rhombus some slight asymmetry is observable in the bones of the face on much the same principles as what I have just described in Platessa. On the ocular side the tympanic apparatus is longer & more arched – the palatal more arched but weaker, & the lower jaw shorter than on the eyeless side – But the mouth when opened looks straight forwards, & in the Turbot at least the Intermaxillary bones is longer & armed with a greater number of teeth on the ocular side, – exactly the converse of what is seen in the Plaice.

XXVIII In Solea the maxillary bones are very strangely & unsymmetrically conformed, there being no teeth at all on the ocular side of the mouth. On this subject however I cannot enter at present, suffice it to say that the long axis of the oral apparatus does not point to the eyeless side in any appreciable manner, & that the arrangements for rendering the mouth most available on the eyeless side are entirely furnished by the peculiar conformation of the jaw bones themselves on that side.

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XXIX As regards lateral symmetry I have been able to remark nothing marked in the Hyoïd & Branchial apparatus in the Pleuronectidae. The 2 sides are conformed just as in other fishes.

Chapter IV

On the Superficial Facebones and on the distribution of the Dermal Mucus Canals.

XIX We have still to consider whether in the Pleuronectidae there be any representatives of the Supra temporal and Suborbital ranges of bones and of those bones called by Cuvier "Nasal" but by Owen "Turbinal." In osseous fishes generally these bones are intimately connected with a system of tubular organs the "Mucus" or "Slime-canals" and hence it will be necessary for us to study also the relations & arrangement of these canals in the Pleuronectidae.

At first I thought I would not be able to make anything morphological out of these canals, but a more careful examination has enabled me not only to make out exactly the ranges of small bones aforesaid but has also shewn me how completely the plan of the arrangement of the mucus canals in the Pleuronectidae corresponds with that of the same organs in the bod, - how that plan has been modified entirely in accordance with the theory of the Pleuronect Cranium already given, shew com-

pletely that theory is corroborated thereby.

XXX And first as to the symmetrical arrangement in the cod. The mucus canal of the lateral (a) line, supported all the way along by peculiarly modified scales, extends on to the head, runs along the mastoid, post frontal, and Frontal bones, & then, lodged in the grooved os terminale *, terminates near the end of the snout and to the inner side of the nostril. On the surface of the Frontal bone it forms a commissure (e) with its fellow of the opposite side. On its way it gives off the following branches

Plate X figure 1

1 The supra temporal branch (β) at the back of the head supported by the supra temporal bones. (indicated on the diagram Pl X fig 1 in red outline)

2 The operculo mandibular, (c) running in a groove first along the Preoperculum and then along the lower jaw where it ends.

3 The Suborbital (α) supported by the suborbital bones (also indicated in red) running along beneath the eye and terminating near the end of the snout close to the end of the main canal but to the outer side of the nostril.

These canals I have shewn diagrammatically in Plate X fig 1. The outlines of the Terminal, supra-temporal & Suborbital bones I have indicated in red.

* Turbinal of Owen. Nasal of Cuvier. I prefer calling it os terminale as this word implies nothing about its homologies with bones in the higher vertebrates.

What is the arrangement in the Pleuronectidae?

XXI In the genus Rhombus (Diagram fig 2 pl. X) the lateral canal (a), of the Left side pierces the supra scapular bone, (50) then enters the 1st supra temporal bone which bifurcates. The canal coming from the lower branch of that bone then enters the mastoid, passes from it to the frontal, and, arrived at the posterior margin of the orbit, gives upwards & to the Right a branch (c) to communicate with the canal of the right side: it then pursues its way in the stout intervenular process of the Left Frontal bone, emerges from it at the anterior margin of the orbit, and ends to the inner or Right side of the Left nasal fossa (L N F) in a curved tubular ossicle which we at once recognise as the os terminale (L O T.)

On its way the following branches have been given off as in the cod.

1 The supra-temporal branch, (3) issuing from the upper limit of the tubular bifurcated 1st supra temporal bone, proceeds supported by a series of little tubular ossicles, constituting the rest of the supra temporal range, towards and along the base of the cephalic end of the Dorsal fin, to beyond the middle of the upper eye where it ends. These little bones have been indicated in red in the diagram

2 The operculo-mandibular branch, (c) given off while the main canal is still in the mastoid, runs in a

tube hollowed out in the preopercalum and lower jaw bones and ends near the symphysis -

3 The Suborbital branch, (a a) given off opposite the origin of the commissural branch already referred to, runs in a series of minute tubular ossicles under the left or lower eye, and ends to the outer side of the nasal fossa, in a much larger anterior suborbital bone, which is suspended to the prefrontal of the same side. This anterior suborbital bone is of an elongated triangular shape, the acute angle directed posteriorly - on its surface is a tube which receives the end of the mucas canal.

On this side the arrangement is very plain, the main canal curving round between the eyes following the morphological middle line; while the Supra Temporal canal proceeds forwards according to the apparent or Pseudo-middle line along with the Dorsal fin.

XXXII. On the Right or eyeless side, the lateral canal, (a') is similarly related to the supra scapular & 1st supra temporal bones, & to the mastoid. The supra-temporal branch proceeds forwards with the Dorsal fin in the Pseudo middle line, & the opercalo mandibular branch is given off & pursues its course exactly as on the left side - But the main canal having entered the frontal bone curves across the head, to the posterior margin of the orbit

where it gives off a commissural branch (c') to join that of the left side (c) already mentioned. It then passes between the eyes following the curve of the slender interocular process of the Right Frontal bone till it ends in front of the orbit and to the inner side of the Right nasal fossa (RNF.) in an os terminale (R.O.T.) which is longer than that of the opposite side.

We have thus the main stem of the Right mucus canal following exactly the curve of the morphological middle line of the top of the cranium and crossing the pseudomerial line, beneath the cephalic part of the Dorsal fin, & beneath the supra-temporal canals of both sides, passing between the eyes side by side with its fellow of the opposite side and with which as in the cod it is connected by transverse commissure. And thus we have afforded us additional & conclusive evidence that the "interocular bar" in the Pleuronect Cranium is the only and entire homologue of the arch of the Frontal bone in the cod.

XXIII But where is the Right Sub-Orbital range?

We have seen that a mucus canal contained in a range of minute bones lies alongside the upper eye, but we have also seen that this is the Left supra temporal range. We must then look for some other.

From the point behind the orbit where the main stem gives off its commissural branch is given off in the opposite direction, a branch (ddd') at first running a little backwards till it emerges from the Frontal bone when it turns forwards and proceeds in the skin of the Right cheek pretty closely alongside the pseudo-mesial bar of the cranium till it ends on the outer side of the Right nostril (RNF) This canal, enclosed in six tubular ossicles of which the anterior is the largest is undoubtedly the Right suborbital but situated on the other side of the body from its eye: and not only so but between it & its eye we find the pseudo-mesial bar of the cranium - the cephalic end of the Dorsal fin + both supra temporal canals + ranges of bones. In fact the Right eye has passed over to the Left side leaving its suborbital range behind it while the other structures just mentioned, proceeding forward from behind, have got interpolated between them. This latter circumstance will be discussed fully in chapter VI - meanwhile let us notice that although the Right suborbital canal with its chain of bones still remains on the right side although its eye has got over to the left it is situated much higher on the side of the head than the corresponding canal on the opposite side: indeed the process of turning has proceeded so far & then become arrested.

Pl X
fig 2

XXXIV In the Halibut (Hippoglossus vulgaris) in which I have examined the system with considerable care, the arrangement is much the same. We find the two mucus Canals curving round between the eyes in the same manner as represented in the diagram of the Turbot (Pl X fig 2) bearing in mind that in the present fish the eyes are situated on the right side while in the Turbot they are on the Left.

In Plate III fig. 1 represents the superficial facebones on the Right side of a Halibuts head - fig 2 those on the left.

On the Right side observe the suborbital range (73) extending along in direct relation to its eye but with this peculiarity not noticed in the Turbot that the first suborbital a stout oblong bone (73a) pointed at both ends is separated from the rest by an interval and that the mucus canal does not extend on to it, but stops short at the last of the rest of the range. Observe also the supra temporal range (72) following the direction of the Dorsal fin and extending along the upper side of the other eye like a pseudo-suborbital range for it. The os terminale (19) is also seen - on this (right) side in the specimen figured it is divided into two - and above it, lying on the top of the head is seen the os terminale (19a) of the left side.

On the Left side observe the Left supratempo- Pl. {ral Fig 2

range (72) following the direction of the Dorsal fin. Pl. III fig 2
and the Left suborbital range (73) lying on the cheek higher up than the corresponding range on the other side; but with no eye in relation to it. On the top of front of the snout is again seen the Left Os terminale.

The 1st Suborbital on the Right side is a stout oblong bone pointed at both ends and articulated to a process (Pl II fig 1 e) of the Right prefrontal opposite the Spactory foramen + closely related to the anteriorly projecting process of the palate bone. (Pl III fig 1 - 73a) That of the left side is smaller but flattened + is perforated by the mucus canal - similarly articulated to a process of the left Prefrontal (14) + to the anterior process of the palate bone. (20) The os terminale (19) of the Right side is larger than the left, it is considerably curved + flattened + contains a branching canal. In the specimen figured, I have already remarked that it is represented by 2 distinct pieces.

All the rest of the superficial face bones of the Halibut are very delicate tubules, often shewing lateral branchlets, through which little ducts pass to ramify in + open upon the external surface of the skin. As they get smaller towards the ends of the several ranges they often cease to be closed in above + appear like little scales, with the edges a little folded up.

As to number these little bones are apt to be irregular The supra temporal ranges generally consist of from 22 to 25 ossicles each, and the Right sub-orbital of from 17 to 19 - Two however often supply the place of one. The left suborbital range however consists pretty constantly of nine bones - scarcely one half the number on the opposite side - *

XXXV In the Plaice (Platessa vulgaris) the arrangement has undergone a little modification The canal of the Right side as usual extends between the eyes & ends in its os terminale - The opercular mandibular branches - the suborbital & supra temporal branches & bones of both sides are similar to those in the Halibut - & so is also the cross commissure - But as the intervenular process of the left frontal bone is atrophied or rather non developed (page 32) the main canal of the left side no longer extends between the eyes but stops short at the commissure - Anteriorly we find to the inner side of the left nasal fossa a minute os terminale so small that it may escaped my attention and containing as it were a little follicle with 2 openings on the skin, being

* I have omitted to state that the main canal of the left side which traverses the slender intervenular process of the Left frontal bone pierces the nasal bone as shewn by the 2 little openings in the bone 15 in Pl II fig 1 And this confirms what I have stated page 29 that the part of the nasal bone entering into the boundary of the orbit is a development from the left side of the bone -

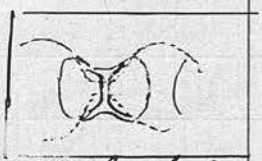
in fact the remnant of the main stem of the left mucus canal detached altogether from the rest. For more details I refer the reader to Plates V + VI & to Plate X fig 3 with the accompanying explanatory remarks.

This arrangement prevails in the genus Platessa - the interocular portion of the Left mucus canal having completely disappeared in all the species I have examined. In Platessa limanda the Left nasal bone is about as small as in the Plaice. In Platessa flesus it is somewhat larger.

XXXVI But the most remarkable condition of the mucus canals in the genus Platessa & indeed in the whole Pleuronectidae is that seen in Platessa Polaris. Here on the Right side we have nothing very peculiar to notice - the arrangement seems to be just as in the Plaice - there is however no cross commissure or a mere abortive attempt at one. Pl VII fig 1

The suborbital and supra temporal bones are very small and delicate and generally have not closed over so as to form complete tubules. But on the Left side the mucus canals are dilated into large round ampullae, the outline of which I have also given in Pl VII fig 2. There ampullae are 26 in number and of these 6 are situated on the main stem, 2 in the detached nasal portion, 4 on the supra temporal branch, 8 on the operculomandibular and Pl VII fig 2

6 in the Suborbital. The supporting bones of this system are also peculiarly modified - I have represented them in figure 3. The supra temporal bones (72) are 5 in number - very delicate laminae of bone, pierced with many minute holes, folded upon themselves and constructed about the middle where the 2 sides are bridged accross. The hollow of each bone is therefore hour glass shaped and takes part in the support of 2 ampullae, which communicate by the narrow port passing beneath the little bridge aforesaid, as in the adjoining diagram.



The left os terminale has the same structure and the 5 suborbitals are also similarly constructed except the anterior one which is somewhat trigonal and takes part in the support of 3 ampullae. I have already said that there is no cross comissure - the branch (c fig 1) on the right side, analogous to the commissural in the Plaice, ends almost immediately in a blind point; + on the Left side, the anterior ampulla on the main stem, indicated in dotted outline in fig 2, - situated more deeply than the rest + partially overlapped by the ampulla behind and by the 2 last supra-temporal ones in front, seems to indicate an attempt if we may so speak at a commissure but it is not effected.

See Plate VII + the explanations attached.

This is certainly a very remarkable arrangement, & one as to the function of which I am not prepared at present to offer any suggestion - Whether these canals be simply mucus-secreting, or be organs of special sense as Leidig supposes, it is evident that this curious and most asymmetrical modification of their form in Platessa Pola must refer to some peculiar habit of the animal with which we are at present unacquainted. Microscopic research must also be brought to bear on the subject - but this forms no part of the business of the present essay.

Chapter V

On the Vertebral Column & on the Fins

XXXVII The Vertebral column in the Pleuronectidæ is usually supposed to be symmetrical. It is not however quite so - as I will presently point out.

The vertebral column of the Plaice Platessa vulgaris displays the following peculiarities

XXXVIII 1 The mesial vertical plane of the vertebrae is curved the convexity being towards the ocular side. the concavity towards the eyeless. This is most strikingly shewn in the anterior vertebrae & especially in the first which in Plate IV fig 1 I have represented seen in front.

The spinous process is seen to be strongly bent over towards the eyeless side. a similar curve is seen in the middle line of the posterior aspect of the cranium fig 8 - & see also page 26 -

This gradually diminishes posteriorly - but throughout the entire series of caudal vertebrae the superior and inferior spinous processes are set at a slight angle to each other. And in consequence the entire skeleton of a plaice is convex on the ocular - concave on

the eyeless side.

2 The transverse processes of most of the abdominal vertebrae are unsymmetrical, slightly in their place of origin from the bodies of their vertebrae, considerably in the direction in which they proceed.

Seen from above or below, those processes on the eyeless side arise a little further forwards on the bodies of the vertebrae and project nearly directly outwards, if not a little anteriorly - while those on the ocular side are directed considerably backwards. The 4 anterior vertebrae & the 13th (last abdominal) are pretty exempt from this - but it affects those intermediate pretty strongly. Pl. IV fig 8 shews the under aspect of the series of abdominal vertebrae in the Plaice - & shows a line joining the tips of the transverse processes of such a vertebra as the 7th passes very obliquely across the long axis of the column

Again seen from in front or behind, the transverse processes of the abdominal vertebrae project more vertically downwards on the eyeless than on the ocular side This is shewn in Pl. IV fig 9.

XXXIX In the Brill (Rhombus vulgaris) - asymmetry is chiefly to be seen in the transverse processes.

When seen from above or below, those of the abdominal vertebrae on the ocular side point a little anteriorly: those of the eyeless side posteriorly - exactly the converse of what we found in the Plaice: but those of the

eyeless side agree with what we see in the Plaice in being directed more vertically downwards.

The transverse processes of the caudal vertebrae are much more prominent on the ocular than on the eyeless side.

Dorsal Fin.

XL The Dorsal fin, it is well known, extends in all the Pleuronectidae all along the back, & advances forwards on the top of the head.

Its advance on the head is effected in two ways

1 By a more & more oblique direction forwards of the anterior interspinous bones, till the first one is horizontal, or nearly so, & carries the first rays of the fin to opposite the middle of the upper eye (Hippoglossus, Platessa) or beyond both. (Rhombus, Solea.)

2 By a bodily advance forwards of these interspinous bones themselves on the top of the head.

XLI In the Sole only about 5 interspinous bones arise on the top of the head, & these go no farther than the supra-occipital bone. But the first of these is of enormous length and directed forwards & also curving downwards a little, carries the anterior rays of the fin to in front of the eyes & even of the mouth.

In Hippoglossus & Platessa there are 6-7—8 of these bones on the top of the head. In their

origin they have advanced from the supra occipital on to the Frontal bone of the eyeless side, but the anterior one is not nearly so long as in the Sole, and only carries the fin-rays of the fin to opposite the middle of the upper eye. This arrangement I have figured in the Plaice (Pl VI) where there are 7 interspinous bones on the top of the head, and in the Pole (Pl. VII fig 3) where there are only 6.

In the Brill (Rhombus vulgaris) 10 interspinous bones have advanced on the head, and not only on to the supra occipital & Frontal bones but we also find one of them taking its origin from the Prefrontal bone of the eyeless side. The anterior one carries the origin of the fin to beyond the eyes but not so far as in the Sole.

We thus find that in Rhombus & Solea, ~~in which genera~~, the fin has advanced over the head further than in Hippoglossus or Platessa; in Solea this has been effected by an excess of the 1st method of advance in Rhombus by an excess of the 2nd.

The direction in which this fin advances is nearly straight forwards in the same straight line as the middle line of the back, turning however a very little towards the eyeless side. It thus disregards the morphological mesial line of the top of the head & is supported anteriorly on the Pseudomesial bar of the cranium. And herein consists the mo-

portance of its relations, as regards our subject, & which I will discuss more fully in Chapter VI.

Pectoral fins.

XLII In all the Pleuronectidae the Pectoral fin of the ocular side tends to be larger than its fellow, & in one genus of soles (Achirus monochirus) of which I have never seen a specimen; the fin of the eyeless side is said to be altogether wanting. In the Halibut & in most of the Flounder genus this asymmetry is well marked, see plates III V VI & VII; but in the Turbot & Brill the 2 fins are very nearly equal in size. The scapular arch is always more arched on the ocular side of the fish & the coracoid bone broader. The Epicoracoid bone is very slender. & consists in fact of 2 bones, the bevilled ends of which overlap each other.

XLIII I have noticed nothing peculiar about the ventral fins - and will not dwell longer on these topics as they bear no relation to the morphology of the subject.

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Chapter VI

Embryology. Conclusion.

XLIV We have still to settle the question propounded in the first chapter, of how the middle line of the back, indicated by the Dorsal Fin, comes to be continued over the head in the same direction, while the eyes are found to 1 side of it. Had we accepted Antennelli's theory that the one eye was removed from its place & stuck into the cheek of the opposite side, or Rosenthal's that it was forced through the head to that side there would have been no great difficulty for us to contend with. But as we have clearly seen that the morphological middle line of the top of the head is simply twisted round to 1 side we must account for the presence of another middle line (pseudomerial) which is directly continuous with the middle line of the rest of the animal. & to which the arrangement of the cephalic part of the Dorsal fin, the anterior part of the body muscles, & other contiguous structures conform.

XLV For this we must refer to Embryology, and as I myself have seen no embryo Pleuronect, I must in

consequence quote from the only paper which has yet appeared on the subject.

Van Beneden in 1853 published a paper* in which he described an embryo Turbot taken soon after its eclosion & in which the vitellus was not yet entirely consumed a remnant still remaining in a pyriform vesicle attached to the intestine. For a complete description of the specimen I must refer the reader to the original paper as it is the state of the symmetry which now alone concerns us.

"In this young fish the mouth is perfectly symmetrical, the eyes are still on the 2 sides of the head, but the Left is about to pass over to the Right side, the nostrils are still symmetrical. The rays of the superior lophioderm only yet descend to the middle of the cranium, afterwards they stretch to in front of the eyes, but it is necessary first that the twisting of the head should have taken place on the vertebral column."

To these observations he adds the result of some made "on a Turbot of nearly adult size, in which the process of Torsion is arrested, when the eye has arrived at the middle line. The rays of the superior Lophioderm have not descended to more than in the Embryo described, the 2 sides are equally colored.

In remarking upon this paper, I may commence

* Referred to on page 7

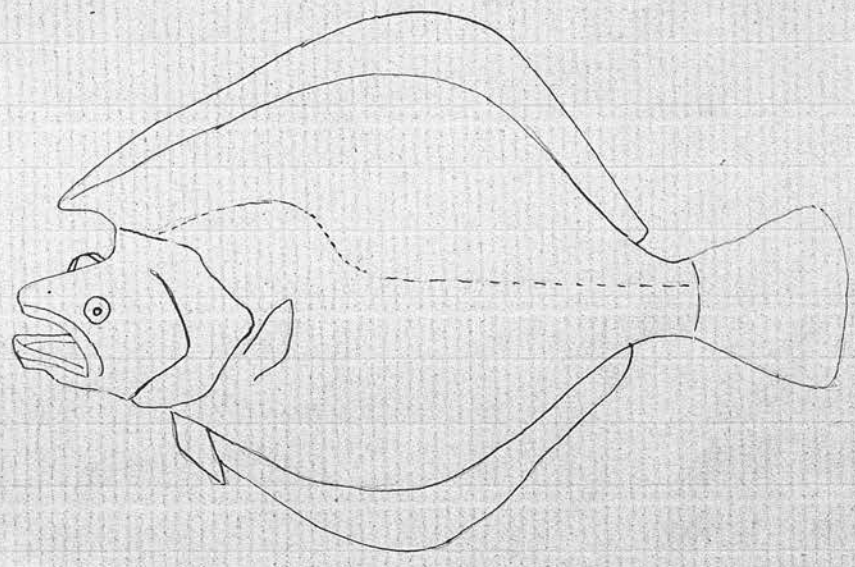
by saying that here for the first time we find distinctly announced the fact & doctrine, that the Dorsal fin is not primarily advanced so far forward on the head as we find it in the fully developed Flatfish, but that it advances after the eyes have turned round. The head does not however turn round "on the vertebral column" - it is the anterior part of the head which is twisted round on itself.

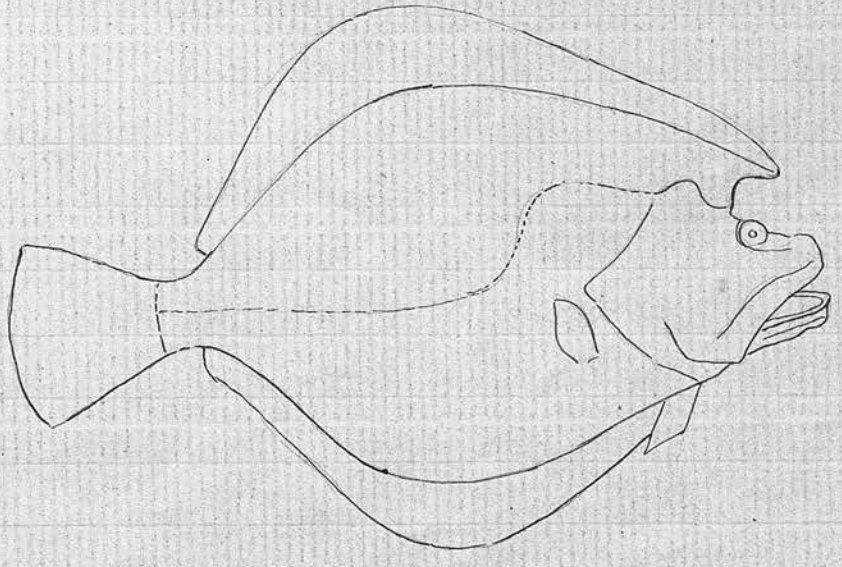
I may also remark that if his specimen was really an embryo of the Turbot, it must have been an exception to the general rule in the genus Rhombus in which the Right eye turns over to the left side. Such exceptions do however frequently occur.

Van Beneden is however not the first to notice an occasional condition of the adult flatfish somewhat similar to what he has described in his embryo, but he seems to me to be the first properly to appreciate the morphological value of such phenomena.

Schleep, in Oken's Isis for 1829 S. 1047, has described and figured an adult Turbot similar to the one referred to by Van Beneden, & to which he gives the name of "Pleuronectes maximus duplex". The 2 eyes are still, each on one side of the head, the upper is just about to make the turn - and the anterior part of the Dorsal fin has not yet advanced beyond the eyes but projects over them in a free pointed process.

.vi Schleep seemed to have a little doubt whether to consider this specimen a distinct species or merely a variety or monstrosity, but is more inclined to believe in the latter solution of the question. He merely describes the outside of the animal & makes no remarks on the morphological significance of its conformation.
The figures below are copied from his paper.





Yarrell in the second volume of his "British Fishes" has figured the head of a Brill (Rhombus vulgaris) with a similar condition of the anterior end of the dorsal fin. The upper eye is set nearly on the top of the head. He mentions also that he has seen similar specimens of the Turbot.

Donovan is said to have mistaken one of these abnormally developed specimens for a new species and to have called it "Pleuronectes cyclops."

Pl. VII Now although I have never seen an <u>embryo</u> Flat-fish, by the kindness of Professor Goodsir I have been enabled to examine, figure, & dissect one of these monstrosities or Embryoniform adults in his possession. The specimen is one of Platessa flesus, the common Flounder — 7¼ inches long & colored of a chocolate brown hue equally on both sides. In the conformation of its body it is a perfect Flounder except in what relates to the eyes & to the anterior part of the Dorsal Fin. The upper or left eye set on the top of the head has we may say just turned the corner and no more: while the anterior extremity of the Dorsal fin, which should have been tied down by the left side of that eye projects above it, supported on a free pointed process. The head thus seems to have a deep notch cut in the front of it.

In Plate VIII fig 1, I have represented the Right side

of this fish and in fig 2 the left. See also the explanation of the Plates at the end of this essay.

LVIII Osseous System - There is little to be noticed in this specimen.

1 The frontal bones are made much as usual in the genus Platessa - the interorbital part of the Right forming the lower boundary of the orbit - the corresponding part of the Left being atrophied to a mere point. The left bone also as usual shews a well developed external angular process. The Pseudomesial ridge, supporting the Interspinous bones of the cephalic part of the D. fin, which in an ordinary flounder passes by the side of the orbit on to the external angular process of the Left Frontal, here stops short at the posterior aspect of the orbit and if produced further would divide the eye in two. Here then the morphological and Pseudomesial lines of the top of the head do not diverge from each other quite so much as in an ordinary flounder.

2 The Interspinous bones on the top of the head advance forward nearly as far as in the typically developed Flounder, at least in respect to the attachment of their base or proximal ends. The direction of the bones themselves is worthy of note, In an ordinarily developed Flounder or Plaice (see Plate VI) the interspinous bones of the cephalic part of the Dorsal Fin project more & more obliquely forwards, till the anterior

one, nearly horizontal in its direction, is tied down by ligament to the Left Prefrontal bone by the side of the orbit. Here however they project much more upwards the anterior one instead of being tied down, carries the origin of the fin rays above the eyes on a projecting pointed process round which the skin is reflected.

Muscles.

Fig 1 Plate II represents the muscles on the right side of this specimen. They are just as in the genus Platessa in general, and the figure will accordingly serve to illustrate the muscles in normal as well as abnormal specimens. All that in this specimen can be said to be worthy of note is a circumstance not shewn in my drawing; viz that as here the Pseudomerial ridge divides the cranium more equally than in a perfect Flounder, the muscles on the top of the head arranged on each side of that ridge are also more symmetrical.

Mucus Canals Plate IX figures 2 & 3

On the Right side the canals are just as in an ordinary flounder or Plaice. Note how the supra-temporal canal (b) runs up on the pointed process which carries the fore end of the Dorsal Fin. On the Left side (fig. 3) the relation of the canal d to the upper eye (E) as in "Suborbital" is very obvious. The Dorsal fin not yet having

become interpolated between them. Note also the cross commissure (c) which here is not covered over by the Dorsal fin or by any other structure but skin, & the walls of the bony tube which contains it in the Frontal bones.

XLIX Now what is the inference which these phenomena in the Embryo & imperfectly developed Flatfish lead us when added to our knowledge of the structure of the adult & perfectly developed animal. Simply this that the rays & interspinous bones of the cephalic part of the Dorsal fin do not belong morphologically to the head at all but have advanced over it from some region posteriorly. The arguments in support of this doctrine I will now consider collectively in detail.

1 The mere fact that in the adult flatfish the Dorsal fin which is undoubtedly a mesial structure does not follow the morphological mesial line of the top of the head in its deviation towards the ocular side, and which deviation in most instances commences at the very posterior part of the cranium. And here we see wherein Meckel was wrong in that statement which I have quoted, (page 5) in which he says that the interspinous bones of the top of the head are placed on the occipital & "parietal" crests, in the same way as those of the trunk are placed over the superior spinous processes of the vertebrae: the fact being that

whilst the superior spinous processes of the vertebrae of the trunk are structures situated in the true original middle line of the animal: the occipital crest on the & frontal bones supporting the cephalic interspinous bones has nothing to do with the original middle line which has turned over to one side.

2 The other structures on the top of the head arrange themselves on each side of the line of the Dorsal Fin in equal disregard of the original & Morphological middle line - and all these structures shew unequivocal traces of having advanced from behind.

A That part of the Body muscle which is situated on the top of the head, consists of simply the anteriorly reflected portions of muscle segments lying posterior to the cranium. This is shewn in Plate IX fig 1, which represents a dissection of the muscles of Mr Goodsir's abnormal specimen, but which, as far as this circumstance is concerned, agrees exactly with any other Flounder.

B The nerves supplying these fin rays & muscles consist of the Dorsal branches of the first three & four spinal nerves which turn forwards over the head from behind. This was first noticed by Stannius who gives a figure of the arrangement in the work referred to (page 6 of this essay) This I have also myself verified.

C I have ascertained that the Vessels supplying

these parts are similarly arranged.

D The supra temporal mucus canals & bones which commence posteriorly also proceed forwards in defiance of the morphological mesial line. Compare what has been said on this subject in chapter VII page 54 and see also Plate X figures 2 & 3. They are supplied by branches of the Vagus nerve, which of course also must turn round from the back of the skull & run forwards.

3 We find the structures above enumerated covering over (anteriorly at least) undoubted dermal organs viz mucus canals, affording us strong reason to believe that the former, as they could not have been originally developed over the latter, must have advanced over them from some other region. In the Cod then Dermal mucus tubes are seen to run in grooves in the cranial bones: in other fishes the edges of the grooves seem to have closed over by a process of peripheral ossification, so as to include the mucus canals in complete bony tubes. In the Pleuronectidae we find not only this but on one part of the head, viz rays - muscle, & skin in many instances containing other mucus canals have advanced over the originally dermal organs.

In the Halibut the origin of the 1st Dorsal interspinous bone is immediately behind the cross commissure & the left mucus canal as it crosses the dorsal

to extend between the eyes on the Right side; but it extends over these tubes by its very oblique inclination forwards. The same is the case in the genus Platessa. But in the Turbot & Brill the 1st interspinous bone arises from the Prefrontal bone - quite in advance of the crossing of the mucus tubes. And in the Halibut & Brill the body-muscle advances on the external angular process of the Frontal bone of the eyeless side - above the position of the same canals.

L Those who hold the rays of the Azygos fins to be dermal, as well as the mucus canals may say there is nothing very remarkable in what I have stated above. But is the body muscle dermal? And supposing (for the moment only) that the interspinous bones & rays of the Azygos fins are dermal, the mucus canals are at all events more superficial structures than they - for we find the canal of the lateral line extending over the rays of the caudal fin.

Let me also recall to the mind of the reader the fact already alluded to that another set of mucus canals & bones (Supra-temporal) pass from behind forward, in the Halibut & Turbot at least, right over the cross commissure & the main canal of the eyeless side. This is shewn in the diagram Pl. X fig 2.

4 Although no embryo or "monster" has yet been seen with no fin rays on the head, yet Van

Beneden has described an embryo, and he and others have also described imperfectly developed adults, in which the dorsal fin has not yet advanced beyond the eyes. And here I may exactly define what these "monsters" are, of which I also have described one in the present paper. They are Flatfishes, in which the turning round of the upper eye to the other side of the fish has become arrested when it has got about the middle of the top of the head, and in consequence the passage forward & lying down of the anterior part of the Dorsal fin has also been stopped, or obviously it would cross over the eye instead of passing by the side of it as it should do. It accordingly projects upwards & forwards in a free pointed process as already described & figured - pages 70-71 & Pl VIII figs 1 & 2. It is also worthy of remark that all these abnormal specimens are equally colored on both sides, as if the animal not having perfectly acquired the characteristics of a Flatfish - swam with either of its sides upwards & exposed to the light at pleasure.

L1 So much then for the relation of the Dorsal fin to the Eyes & to the morphological middle line of the top of the head.

But there is is a question arising out of the consideration of these finrays - a question connected with the general morphology of the fish skeleton, and on which I cannot at present refrain

from saying a few words, although hitherto I have carefully abstained from entering on such topics. I cannot with Professor Owen regard the interspinous bones + rays of the Azygos fins as dermal, but must agree with Prof. Goodsir + others in regarding them as portions of the Endoskeleton appendages of the neural arches of vertebrae - whether actinapophyseal or not*. We have already seen that Meckel imagined that the rays on the top of the head in the Pleuronectidae were appendages of the cranial vertebrae, in the same way as those more posteriorly situated are appendages of the vertebrae of the trunk. But we have just come to the conclusion that these rays + interspinous bones have nothing whatever to do with the head morphologically, but have advanced on it from some region posteriorly.

But whence have they come, and of what vertebrae are they the appendages? - all the vertebrae of the trunk being already very amply supplied. And here comes in the point in the general morphology of the skeleton, and a very disputed one it is.

We all know that the principal evidence for Professor Owen's doctrine, that the shoulder girdle is the haemal arch of the occipital vertebra is the fact that

* See Goodsir "On the morphological constitution of the Vertebrate Head" in Edinb New Philos. Journ. New Series Vol V Jan 1837 page 132

in osseous fishes it is attached to the posterior part of the cranium. But does this fact admit of no other explanation? Another and more feasible doctrine is that originated by Professor Goodsir, namely that the shoulder has become approximated to the occiput in the Osseous Fish, by a non-development & disappearance of those vertebrae, which in the higher Vertebrata constitute the neck.* And in the osteology of many fishes there are strange circumstances which seem to point to the truth of this theory — bodies of vertebrae without neural spines - neural spines without bodies, (salmon, pike) ribs attached to the occipital region of many fishes as the Tunny. But what more immediately concerns us just now is that Professor Goodsir, in his lectures on comparative anatomy, has also alluded to the probability that the cephalic fin-rays of Lophius, - of Chironectes, and of the Pleuronectidae, are in fact appendages of the neural arches of these lost vertebrae, and that the absence of these vertebrae, primarily intended by nature for a very different purpose has yet afforded provision for the extension of fin rays over the top of the head in these animals.

L11 For my own part my researches into the asymmetry of the Pleuronectidae fully confirm this doctrine.

* This has happened from teleological reasons which I have not time to enumerate at present.

I have already stated my reasons for believing that these fin rays have nothing morphologically to do with the head, that they have advanced on it from behind - & as all the vertebrae behind are well supplied - what can be more natural than to suppose that these rays are appendages of a series of cervical vertebrae which have themselves never become developed? The only other explanation is afforded by believing with Owen, that these rays are merely dermal & not appendages of any vertebrae at all, but this question it is not the business of the present essay at all to discuss.

Conclusion.

I must now bring this essay to a conclusion by endeavoring to lay down in connection with the facts we have been considering, some generalisations on the laws followed by the process of asymmetrical distortion in the Pleuronectidae. And in the course of these generalisations I hope to be able to bring out the manner in which these laws have operated by referring to a gradational series of typical forms of the animals under consideration.

In the following remarks, the Flatfish must be supposed to be placed erect with its 2 sides looking laterally like those of any other fish. I will also abandon the terms Right & Left altogether - substi-

tuting "ocular" + "Eyeless" as not only do different genera of Flatfishes normally have the eyes on different sides, but variations occur in this respect even in the same species.

LIII The principal object of the asymmetrical distortion of the head being to bring both eyes to 1 side we find that most change has occurred in those regions of the skull in front of the Brain cavity - And now as to the manner in which these changes have proceeded.

1 In the anterior part of the cranium, the parts on the eyeless side of the middle line of the base, are in all the Pleuronectidae more developed than on the ocular side. This is exemplified in the more strong development of the eyeless side of the anterior end of the Basipresphenoid, in the greater size of the ala of the Vomer on that side, in the greater breadth of the orbitosphenoid - & in the great development of the processes (a + b) sent down by the Prefrontal to articulate with the Vomer & Basipresphenoid. While on the ocular side the orbitosphenoid is narrower, the ala of the Vomer is smaller, & the Prefrontal does not articulate at all with the Basipresphenoid - the process (b) being undeveloped. There is in consequence a weakness on the ocular side of the middle line below - & preternatural strength on the opposite or eyeless side.

2 On the top of the head the parts on each side of the ocular

the original middle line are more developed - exactly the converse of what happens below. We have seen already that the anterior or interocular part of the Frontal bone of the ocular side is in all the Pleuronectidae without exception much stouter than that of the eyeless. And in the series of Frontal bones given in Plate XI remark how gradually the interocular proces of the eyeless side, has become atrophied from Solea - through Rhombus & Hippoglossus till in Platessa it has almost disappeared. Also the corresponding proces a of the Prefrontal bone is not developed on the eyeless side - it is indicated however in the sole - very slightly in the Turbot & in the Plaice & Halibut no trace of it can be seen at all. We have also seen how the mesial Plate of cartilage (A in Plates I II & IV)* where it it is in connection with the interocular parts of the Frontal & Prefrontal bones has been principally developed on its ocular side.

These 2 circumstances then, the weakness below on the ocular side of the middle line and above on the eyeless - the preternatural strength or proness of development below on the eyeless side & above on the ocular - render it natural that, in the proces of development, the anterior part of the skull should turn on its own axis up to the eyeless side down to the ocular, in the manner indicated in

* See pages

the Diagrams Pl XL figures 10 & 11.
And to shew that this has happened I refer to the structure of the Vomer & of the anterior end of the Basipresphenoid, & especially to the position of the Olfactory foramina that of the eyeless side being invariably higher than the other The palate bone of the eyeless side is also we have seen attached higher up on the side of the head.

Relation of olfactory foramina.

(3) I have shewn already how the parts in relation to the middle line of the intero-ocular part of the top of the cranium have become developed to 1 side, & how this state of matter increases from the sole to the Plaice, where the intero-ocular part of the Frontal bone is hardly developed at all on the eyeless side.

LIV We must now suppose the entire interocular part of the cranium to increase in length faster than the Basipresphenoidal part below. Consequently it must turn and form a convexity to one or other side, and the same circumstance which aided in the twisting of the entire anterior part of the cranium round its own axis, also determines this convexity to the ocular side. For as we have seen that this interocular bar is more sturdily developed on its ocular than on its other side it must of necessity curve round with its convexity towards that side, on the same principle as when we rivet 2 bars of metals of different expansibility to each

other & then heat the double bar so formed it always curves round with its convexity towards the side formed of the more expansible metal. As in the diagram annexed.

LV To this it may be objected that the interocular process of the Frontal bone of the eyeless side is actually longer than the other in the Sole & Turbot. See plate XI bis 1. But its much greater weakness quite precludes it from exercising any influence especially when coupled with the non development of the corresponding interocular process of the Prefrontal of the same side.

LVI Thus is the lower concave boundary of the orbit formed. And this curving outwards & downwards of the interocular bar of the cranium tends to alter the mesial plane of the head in the region of the eyes still more from the vertical towards the horizontal direction which circumstance in this region has now run to a much greater extent than either before or behind. See Plate XI figs 12 & 13

And thus the eyes, which in the Cod looked out one on each side of a vertical interorbital septum, now are placed on the same side of the head, one above & the other below the homologous but now nearly horizontal interorbital septum in the Flatfish.

But this third law has had more effect than merely curving the interocular bar of the cranium

and making a concave lower boundary to the orbit. We must suppose the compact posterior part of the cranium to form a fixed point, and then the more rapid increase of the interocular bar in length over that of the Basipresphenoid will tend to push round the axis of the anterior part of the skull towards the eyeless side. And the effect of this increases gradually as we proceed along our series. It is limited in the sole to a slight inclination towards the eyeless side of the anterior projecting process of the nasal bone. the two olfactory foramina being still exactly opposite each other in the transverse direction. In the Turbot the olfactory foramen of the ocular side is slightly in advance of that of the eyeless but the anterior prominence of the nasal bone on which the Intermaxillary cartilage glides still points pretty directly forwards. In the Halibut the keel of the cranium & the prominence on the nasal bone for the Intermaxillary cartilage, are considerably directed towards the eyeless side. But in the Plaice not only is the Prefrontal & consequently the olfactory foramen of the ocular side pushed quite in advance of the other, but the nasal ridge points quite across the apparent middle line at an angle of 45 while the keel of the cranium is also very strongly curved in the same direction.

Del. Plate XI. figures 14, 15, 16 17.

In Plates I, II, IV & XI (fig 13, 14, 15, 16, 17.)

LVII If the reader will now return to page 38 he will find an enumeration of the various changes which have thus been effected on the axis, mesial plane, & mesial lines of the cranium & which I need not here again copy out.

LVIII To allow space for the accommodation of the 2 eyes now brought over to 1 side, the interocular part of the Frontal bones always remains as a narrow bar, never expanding out into a broad arch as in the Cod and other fishes. Consequently the stability of the cranium is impaired, there being no efficient bridge of connection between the posterior brain cavity & the nasal part. To supply this deficiency a new bridge or bar which I have called "Pseudomesial" is developed, & formed by the union of two processes ("external angular") one sent forwards by the Frontal bone of the eyeless side, the other sent back by the corresponding Prefrontal. In Plate X fig 4 I have represented diagrammatically the top of the head of a Plaice. The red line represents the morphological middle line curving round between the eyes. The shaded parts represent what has been developed of the original plan of the osteology of the cranium, the dotted outline represents these interocular parts of the Frontal & Prefrontal of the "eyeless" side

which have not been developed, while the parts (n-f) in head outline represent the external angular processes of the same bones which, not found at all in the symmetrical fish have here become developed to form the Pseudomesial bar & complete the wall of the orbit. The dotted black line also represents the direction of the Dorsal Fin over the top of the head.

LIX All the parts originally in relation to the interocular part of the head, follow the turning over of the original mesial plane & line to 1 side. The Olfactory nerves lie imbedded in the now nearly horizontal "septum interorbitale". The eyemuscles & nerves lie ranged above & below it as might be expected. The ophthalmic branches of the 5th nerve, on their way to the nasal fossae, also curve round between the eyes alongside the "interocular bar" of the cranium. The main stems of the mucus canals of each side likewise pursue the same course. But the suborbital canal & chain of bones of the eyeless side, always remains on that side, its eye having turned over faster & left it behind.

LX When these changes have become well impressed on the cranium of the Embryo, the Dorsal fin accompanied by muscle, vessels & nerves advances from behind over the head in the same straight line which it followed in the rest of the body, & utterly regardless of the deviation of the middle line of the

head. It is likewise accompanied in its advance forwards by the supra temporal canals & chains of bones of each side. These circumstances I have already fully enough dwelt upon, let me only again repeat that thus is solved the great problem in the structure of the Pleuronectidae, of how the Dorsal Fin, a mesial structure comes in the region of the head to have the two eyes on one side of it.

— " —

And now, as the time for the giving in of this Thesis draws nigh with much more rapid steps than I had anticipated, must for the present be concluded my researches into the Asymmetry of the Pleuronectidae. I am aware that, compared with what it deserves the subject has received but sorry treatment at my hands, but, should Providence ever afford me opportunity of prosecuting the study of Comparative anatomy, I hope to be able to work up the subject in its relation to all the organic systems of the body, & more especially in its Teleological aspect.

Ramsay H. Traquair.

March 31st 1862

Appendix.

Explanation of the Plates.

In the entire series of Plates appended to this Thesis the same numbers apply to the same bones. They are also the same numbers as those by which Professor Owen has distinguished the various bones of the Fish's head in his "Lectures on Comparative Anatomy.

—o—

List of Bones of Fish Head
according to Owen's Nomenclature

1 Basioccipital	15 Nasal	30 Angular
2 Ex occipital	16 Petrosal	32 Dentary
3 Supra occipital	17 Sclerotal	34 Preopercular
4 Par-occipital	19 "Os terminale"	35 Opercular
5 Basipresphenoid	20 Palatine	36 Subopercular
6 Alisphenoid	21 Maxillary	37 Interopercular
7 Parietal	22 Premaxillary	38 Stylohyal
8 Mastoid	23 Entopterygoid	39 Epihyal
9 ———	24 Pterygoid	40 Ceratohyal
10 Orbitosphenoid	28 a Epitympanic	41 Basihyal
11 Frontal	28 b Mesotympanic	42 Glossohyal
12 Post Frontal	28 c Pretympanic	43 Urohyal
13 Vomer	28 e Hypotympanic	44 Branchiostegal
14 Prefrontal	29 Articular	50 Supra scapular

51 Scapula
52 Coracoid
53 Ulna
55 Radius
56 Carpal
58 Epicoracoid
72 Supra temporal
73 Suborbital.

Plate I

In all the figures the primordial cartilage is colored in blue. The numbers refer to the list above.

Fig. 1 Cranium of Turbot (Rhombus maximus) seen from above.

A The plate of primordial cartilage supporting the 4 bones of the nasal end of the cranium & forming the anterior part of the septum between the eyes.

B points to the orbit. bounded on one side by the intero-ocular process 11 R of the Right Frontal bone & on the other by the process f of the Right Prefrontal 14.

C C The 2 Olfactory foramina of which the left is the most anterior.

e A process on each Prefrontal to which the 1st Suborbital bone is attached.

f A process (external angular) of the Right prefrontal sent back to join the external angular process 12 of the Right Frontal. Thus is the "pseudo meniscal" bar formed, & the orbit bounded on the Right side.

α The ridge & spine of the supra occipital bone proceeding forwards in the Pseudo meniscal line

and a little towards the right side.

The faint red line represents the direction of the morphological mesial line, which is seen to return to the middle of the head in the anterior part of the nasal bone on which the Intermaxillary cartilage glides & on the Vomer (13)

Fig. 2 Under surface of the same cranium.

D The colyloid cavity for the head of the Epitympanic bone.

a A process of the ~~Big~~ Left Prefrontal sent between the eyes to articulate with the interocular process of the Left Frontal This process corresponds to the process a in the Cow fig 7 & does not exist on the Right side.

b A process sent downwards & backwards by the Right Prefrontal to articulate with the Basipresphenoid. This process does not exist on the left side any more than the process f already pointed out.

c. c See fig 1.

Fig. 3 Upper surface of the same cranium the 2 Frontal bones (11 R & 11 L of fig 1 removed). The cartilage A is seen in its posterior part at least to be more developed on the left side the process 2 for the Left Frontal being much larger than the process 1 for the Right.

Note the manner in which the anterior end of the brain cavity here uncovered points to the left side.

and how the Right Postfrontal (12) & the Right Parietal (7) are longer than the left & considerably directed across the cranium. Note also the direction of the Orbitosphenoid (10).

Fig 4 Anterior part of another cranium, the frontal bones removed, & the whole tilted round towards the right side. Two long curved black bristles are inserted into & through the olfactory foramina (CC)

Lettering explained by reference to fig 7.

Fig 5 Left Frontal bone of the same skull also tilted round so as to be seen a little "sideways"

m Interocular process, resting on the process g of the pituitordial cartilage & a of the Left prefrontal in figure 4 & the rest.

Fig 6 Right Frontal bone.

m Interocular process curved round to the left side & resting on the process h of the pituitordial cartilage.

n External angular process articulating with the process f of the Right prefrontal.

Fig 7 Prefrontal* of Common Cod seen sideways

a Process going upwards & backwards to join the Frontal bone.

b Ditto going backwards & downwards to join the Basipresphenoid

c Process to join the right ala of the Vomer.

d d 2 processes going towards the nasal bone

Right Prefrontal

with an olfactory notch C between them
The representatives of these processes are marked with the same letters in the previous figures. Note that in the Cod there is no representative of the process f in the Turbot.

Plate II

Fig 1 Upper surface of the cranium of the Halibut (Hippoglossus) The orbit is here seen to be on the Right instead of on the left as in the Turbot.
A Cartilage as in the Turbot Plate 1.
g A notch in this cartilage into which a laminar projection of the intermediate process f the Right frontal bone (II) is received
h. a smaller notch in advance of the other which receives a similar lamina developed on the end of the more slender intermediate process of the Left Frontal.
p. q Two facets on the end of the Vomer the left of which (p) is larger & looks more laterally than the right (q) On these facets move the heads of the corresponding superior maxillary bones.
k A prominence on the Nasal bone on which the intermaxillary cartilage glides. It is directed rather obliquely to the left side — compare this with the same part in the Turbot pl. I.
Fig. 2 Under surface of the same cranium. The Basisphenoidal keel of the cranium points to the

left side. Lettering as in the corresponding view of the Turbot skull

Fig 3 Anterior part of a larger cranium, the two frontals removed & the whole tilted to the left. Two bristles pass through the olfactory foramina in the direction taken by the olfactory nerves. The Right olfactory foramen is in advance of the left. Observe here what should have been noticed in fig 1 that the nasal bone is ~~here~~ enters into the boundary of the orbit by an increased development from its left side which seems to push aside the left prefrontal. The lettering on the Prefrontals corresponds to that on the Turbot skull pl. I

g - h - The 2 notches in the primordial cartilage already referred to - fig 1 -

Figure 4. Left ~~Pref~~ Frontal of the same cranium - Note the extreme slenderness of the interocular process m which at its end gives off a little lamina o which is received into the notch h in the plate of primordial cartilage A. fig 4. The external angular process n is very largely developed.

Figure 5 Right Frontal, with its stout interocular process m & no external angular process at all. Its extremity along with the process a of the Right Prefrontal (fig 3) fits into the great notch g in the primordial cartilage A.

Figure 6 Right side of the end of the Basipresphe-

noid (5) & Vomer 13 - surmounted by the primordial cartilage -

Fig 7 Left side of ditto.

Fig 8 Front view of end of Vomer surmounted by the cartilage. Note how the Vomer is twisted up to the left side -

Plate III

Opercular & Oral apparatus of the Halibut together with the "superficial Face bones".

Figure 1 Right or Ocular side:

a a Tubular scales of the Lateral line

72 Supra Temporal chain

73 Suborbitals of the Right or lower eye.

73 a Anterior Right suborbital very much larger than the rest & having no connection with the mucus canal

1q Right "Os terminale" - * ("Nasal" Cuvier - Turbinal Owen)

1q a Left os terminale - got to the top of the head by the twisting up with left side of the long axis of the anterior part of the cranium

A Retractor maxillae muscle.

B Masseter.

C Right Olfactory foramen.

D Crucial ligament of the upper jaw - on this side well developed, to keep in order the tendency which the mouth has to point to the left side.

* In this specimen divided into two.

c Point at which the supra temporal mucus canal sends down a branch to join the cross commissure.

Figure 2 Left side of the head.

a a Tubular scales of lateral line.

52 Supra Scapular.

72 Left supra temporal range.

73 Left Suborbital range - on the other side of the head from its eye (the upper one in fig 1) & having the Dorsal fin and both supra-temporal ranges interpolated between them. Of the bilateral bones - fewer in number than on the opposite side the anterior is largest - flat - & like all the others perforated by the mucus tube.

19 a Left os terminale

D Only one of the crucial ligaments - that going from the superior maxilla to the nasal bone is developed on this side.

Note the much smaller size of the Pectoral fin on the Left than on the Right side.

Plate IV

Fig 1 Upper surface of cranium of the Plaice (Platessa vulgaris) Lettering as in the figures of the Halibut Pl. III The faint red line indicates the morphological middle line. Observe how much more obliquely it passes across the front of the cranium than either in the Halibut or Turbot. The right Prefrontal

bone and olfactory foramen much in advance of the left, and the ridge (K) on the nasal bone for the intermaxillary cartilage is directed to the left side at an angle of 45.

Fig 2 Under surface of same cranium. Lettering as in Halibut Pl II fig 2.

Fig 3 Posterior aspect of same cranium. Note its greater breadth on the Right side, from the projection of the mastoid bone (8) The colored line shews the curve of the mesial vertical plane in this region.

H Foramen magnum

K K Condyles of the Exoccipital bones for articulating with the 1st vertebra.

L Disk, for body of 1st vertebra.

Figure 4. View of Left side of the same cranium.

Lettering as in previous Plates.

Figure 5 Cranium of Plaice - the 2 frontal bones and the supraoccipital removed, shewing the interior of the brain cavity. Two bristles are passed, one into each olfactory foramen in the direction of the olfactory nerves.

P Eyemuscle canal bridged over by the union of 2 processes 1 sent from each Orbitosphenoid bone 10.

Figure 6. Disarticulated bones of the Frontal & Nasal regions.

11, 11 The two frontal bones, the left shewing a well developed external angular process n & a very

atrophied interocular process m. The right bone shews a large much curved interocular process m which forms almost the entire lower boundary of the orbit - & no external angular process at all.

13 Vomer seen from above - its left ala is the most developed. The left facet p is larger & looks more laterally than the right q which looks almost right forwards.

14 L Left Prefrontal bone turned over & seen from its inner or right side - a bristle passed through its olfactory foramen.

14 R Right prefrontal seen from above - a bristle likewise passed through its olfactory foramen.

15 Nasal bone seen from its posterior or orbital aspect.

Figure 7 First vertebra of a Plaice seen from infront shewing how the neural plane is curved with its concavity towards the Right side (R)

Figure 8. Abdominal vertebrae in a Plaice seen from below & shewing the unsymmetrical obliquity of the ~~th~~ transverse processes from the 5th to the 12th inclusive.

Figure 8 7th abdominal vertebra seen from before - shewing the more vertical direction downwards of the left transverse process - This exists in all the abdominal vertebrae. In this figure - the spinous process ought to have been more directed to the left

side.

Plate V.

Figure 1. Sketch of the distribution of the mucus canals on the Right side of the head of Platessa vulgaris.

a a a a The main canal extending from the tail along the Lateral line + along the head, between the eyes till it ends, on the inner, or left side of the nostril - giving off to the skin little ducts.

b The Supra temporal canal, usually simple here bifurcated, but which is also not an unusual circumstance It gives off as in the figure, numerous little ducts on its upper + posterior aspect.

c c c Operculo-mandibular canal.

d d Right Suborbital canal.

e Indicates the cross commissure given off to join the mucus canal system of the opposite side. It gives off a little duct to the skin at the posterior margin of the orbit.

Figure 2 The same canals of the Left side.

ā ā ā ā The main canal as before, but stopping short at the cross commissure. (e)

b. Supra Temporal canal - not so long as on the right side.

c c c Operculo mandibular canal.

d d d Left Suborbital canal, still remaining

on this side while its eye E has been transferred to the Right side

a' A small follicle, the representative of the nasal extremity of the main canal of this side; the portion intervening between it & the cross commissure having disappeared. See also Pl. X figure 3 where this arrangement is represented diagrammatically.

Plate VI

Skeleton of the head of Platessa vulgaris. the "superficial facebones" indicated in red.

Figure 1 Right side.

72 Supra temporal chain of ossicles. In this specimen the canal & chain of bones are simple - not bifurcated as in Pl V fig 1. or in Plate IX fig 2.

73 Suborbital chain consisting of a range of about 17 little tubular ossicles containing a mucus canal. & of an anterior suborbital 73a, separated from the rest of the chain, & having no connection with the mucus canal.

14 Right Os terminale containg the end of the main mucus canal of this side.

C Right nasal fossa.

Figure 2 Left side

72 Supra temporal chain consisting of about 15 little tubes. the first as usual bifurcated.

73 Left suborbital range 8 in number the

anterior the largest but containing a continuation of the mucus canal unites the anterior suborbital of the other side.

19 The very minute "os terminale" of this side, which lodges the little follicle a' in Pl V fig 2.

Plate VII

Figure 1 Sketch of the distribution of the mucus canals on the Right side of the head of Platessa Pola- The same letters refer to the same canals as in the head of the Plaice Pl. V fig 1. The commissural branch c however ends in a blind point.

Figure 2 Sketch of the distribution of the mucus canals on the left side of the head of the same fish where they are seen to be dilated into large ampullae communicating with each other by small openings. Each ampulla opens to the external surface of the skin, by seldom more than one little duct.

a a a a a a The canal of the lateral line and the series of 6 ampullae on the main canal of the head.

a+ The ampulla detached from the rest & lodged in the left os terminale. It is the homologue of the little follicle marked a' in Pl V fig 2.

The ampulla a in dotted outline is the last on the main stem & is partially overlapped by the adjoining ones.

bbbb. The 4 ampullae into which the supra-temporal canal is dilated.

cccccccc The 8 ampullae of the operculo mandibular branch.

ddddddd The 6 ampullae of the Suborbital branch but here as in the Plaice, situated on the other side of the head from the corresponding eye.

Figure 3. Skeleton of the left side of the head in Platessa Pola shewing the "Superficial Facebones" which support the ampullae of the mucus canals. They are enlarged + dilated but fewer in number than on the other side.

50 The supra scapular bone perforated by the canal.

72 The 5 supra temporal bones.

73' The 5 Suborbitals of which the anterior one is somewhat trigonal and takes part in the support of 3 ampullae.

19 The os terminale of the same side.

34 The Preoperculum and —

29, 30 the lower jaw hollowed out to contain the 8 ampullae of the opercule mandibular canal.

5 The Mastoid, 11 the left Frontal also hollowed out to contain the ampullae of the main stem aaaa in fig 2. 7 Left Parietal. 12 Left Prefrontal.

Plate VIII

Figure 1. View of the Right side of Professor Goodsir's malformed Flounder; natural size.

Figure 2 View of the Left side of the same animal.

For the description see page 71.

Plate IX

Figure 1 Dissection of the muscles of the right side of Mr Goodsirs malformed Flounder. This figure will however illustrate also perfectly well the muscles in the normally developed animal as that "malformation" has not at all affected the muscles as seen in this view at least.

A. Body muscles consisting of zigzag flakes the anterior of which are reflected forwards on to the top of the head.

B The deep muscles of the azygos fin rays.

C Retractor maxillae.

D Masseter.

E Muscles of the Operculum.

F Protractor scapulae. G Muscles of the Pectoral fin.

H Muscles of the caudal fin.

This figure is principally introduced to shew the arrangement of the Bodymuscles.

Figure 2 Sketch of the mucus canals on the Right side of the head of the same fish. The letters refer to the same canals as in the Plaice Pl V. The supra-temporal canal b b is bifurcated. The cross com-

missure c is not yet covered over by the advance of the Dorsal fin K

F Nasal openings of Right side.

Figure 3 Sketch of the distribution of the mucus canals of the Left side. Letters on canals as in Plate V

E Left eye, not yet quite got round to the Right side. its relation to its Suborbital canal a a is very obvious; the dorsal fin K not yet having become interpolated.

F Nasal openings of left side.

Plate X

Figure 1 Diagrammatic view of the mucus canals & superficial Face bones on the head of the Common Cod. (Gadus Morrhua)

a a a a Mucus canal of lateral line extending along the top of the head & ending in O.T. "os terminale indicated in red.

b Supra temporal canal. S.T. bones indicated in red.

c Operculo mandibular canal - which in the cod has no communication with the main canal (Munro)

d Suborbital canal. S.O. bones indicated in red.

e Cross commissure.

Figure 2 Diagram of the analogous organs in the Turbot (Rhombus).

a Left lateral canal b Left supra temporal branch & bones indicated in red. c Left opercule mandibular.

d Left suborbital. c commissural branch.
a' Right lateral canal cropping the head beneath the Dorsal fin indicated by the line D F & beneath both supra temporal canals, & curving round between the eyes side by side with its fellow of the left.
b' Right supra temporal canal & range of bones.
c' Right operculo mandibular.
d' Right suborbital canal & bones, still remaining on this side while its eye has passed over to the left & from which it is separated by the dorsal fin D F & by both supra temporal canals.
L.O.T. Left os terminale. R.O.T Right os terminale.
L N F Left nasal fossa R N F Right nasal fossa.
D F indicates line of Dorsal fin.
50 - Supra scapular bone.
Figure 3 Diagram of the analogous structures in the Plaice (Platessa vulgaris) Here the eyes have turned over to the Right side.
a Right lateral canal extending all the way to the nose head passing between the eyes. It ends in a well marked os terminale outlined in red.
b Right supra temporal canal & range of bones.
c Right operculo mandibular branch
d Right suborbital branch & chain of bones.
d+ Anterior suborbital bone of the Right side separate from the rest & having no connection

with the mucus canal.
a' a' Left lateral canal apparently stopping short at the commissure c
a+ a small follicle lodged in a minute Left os terminale, & which is in fact the nasal extremity of the canal a'. Owing to, at least coincident with, the nondevelopment of the Interocular process of the Left Frontal bone (see plate IV fig 6) the part of the left mucus canal which should extend also round between the eyes has not been developed either.
b' Left Supra temporal canal
c' Left Operculo mandibular branch
d' Left suborbital branch here again found on the other side of the head from its eye.
D F Line of Dorsal fin.
R N F Right nasal Fossa L N F Left nasal fossa.
Figure 4 Diagram shewing the manner in which the orbit is formed in the plaice The red line indicates the morphological middle line - the dotted black line indicates the direction of the dorsal fin The shaded parts are those parts of the original & symmetrical plan of the cranium which have become developed, the parts in dotted outline have not become developed - while the parts in entire outline are parts not in connection with their original symmetrical plan.

11 Right Frontal - with its interocular process m
11' Left Frontal, its interocular process m' not developed
while a new process n has sprung out of its external
anterior angle. whence I have called it "External angular"
14 Right Prefrontal sending back a process (a) to arti-
culate with the interocular part m of the Right Frontal
14' Left Prefrontal, its process a' corresponding to
the process a of the Right bone has not been developed
while it sends back a process f, not found on the
other side + which articulating with the process
n of the Left frontal forms the Pseudomesial bar
of the cranium + bounds the orbit on the left side.
15 Nasal bone - the unshaded part indicates
a development from its left side which enters
into the anterior boundary of the orbit apparently
pushing aside the Left prefrontal (14')
C C Olfactory foramina.
R E Right eye: L E Left eye.

Plate XI

Figures 1—6 A series of Frontal bones showing the
gradual manner in which the external angular pro-
cess of the Frontal bone of the eyeless side becomes de-
veloped and its interocular process atrophied. I
have represented for the sake of uniformity the
bones in the Turbot + Brill as if they had the eye
on the right side like the rest, and such often

is really the case as everyone knows.

Figures 7–9 Series of Pre-Frontals In this series observe that in proportion as the external angular process of the Frontal bone of the eyeless side increases in length the process of the prefrontal diminishes because it is not so much required to complete the wall of the orbit.

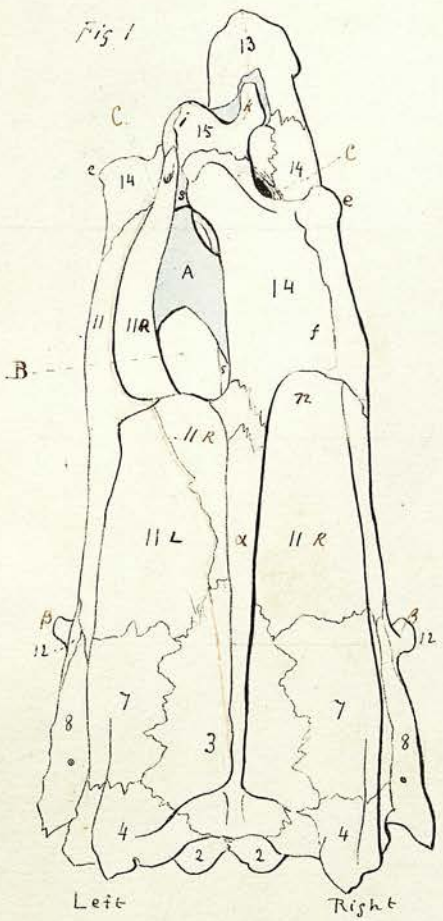
Figure 10 Diagram to illustrate the primary cause of the twisting over of the mesial vertical plane between the two sides, an increased development on one side of the mesial line below and on the other above.

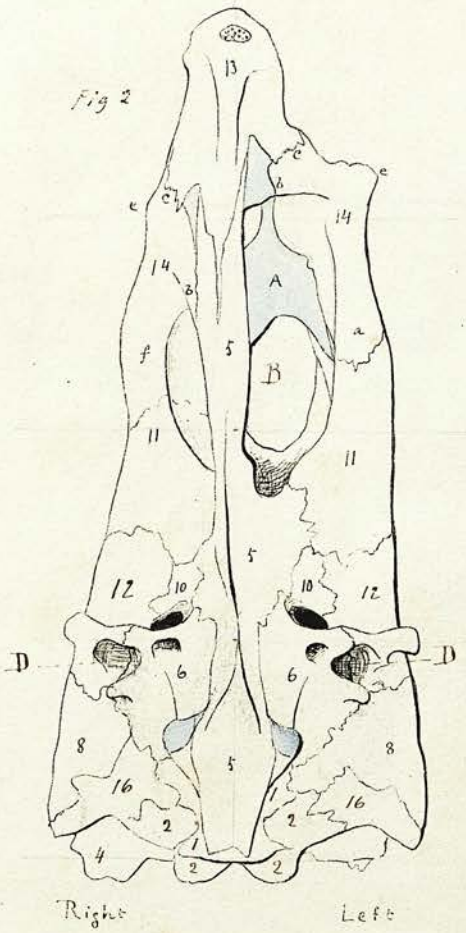
Figure 11 The 1st consequence of this - the fore part of the cranium turned somewhat on its own axis & one olfactory foramen higher than the other. The base of the cranium being more stable than the part above it turns much less up than the latter down.

Fig 12 The curving of the interocular bar of the cranium has come into play & brought the once vertical plane between the eyes to lie nearly horizontal or at least at a very low angle.

Figure 13 The elongation of the interocular bar has pushed the point of the cranium over to one side curving the long axis of the face of the cranium anteriorly as in the plaice.

Figures 14- 15 16, 17, For the explanation of these diagrams see the text page -39.





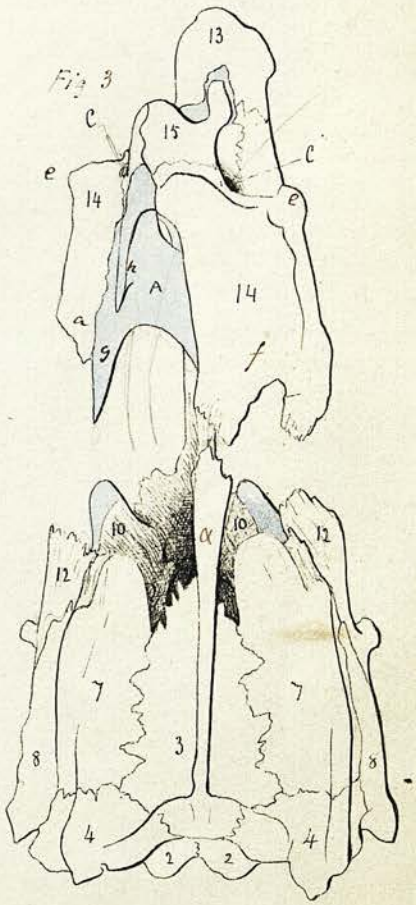



Fig 4


Fig 5

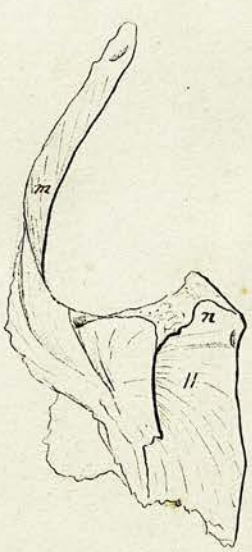


Fig 6


Pre frontal
of Common Cod.
Fig 7

R. H. Traquair delt.

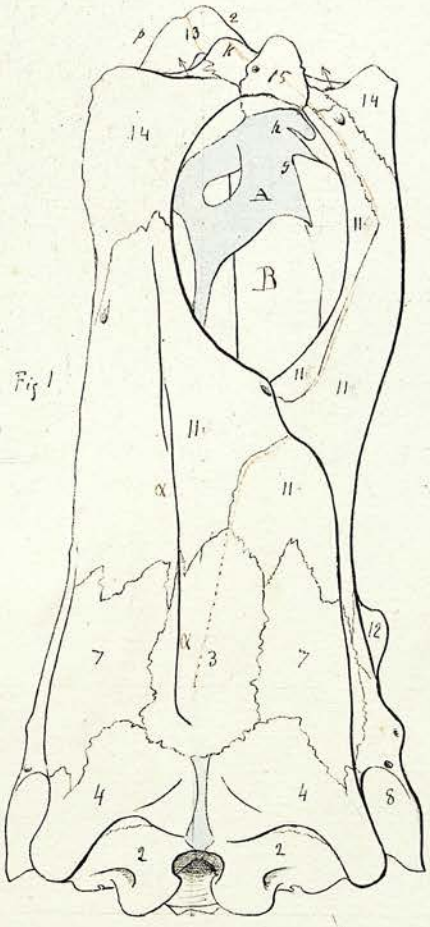


Fig 1

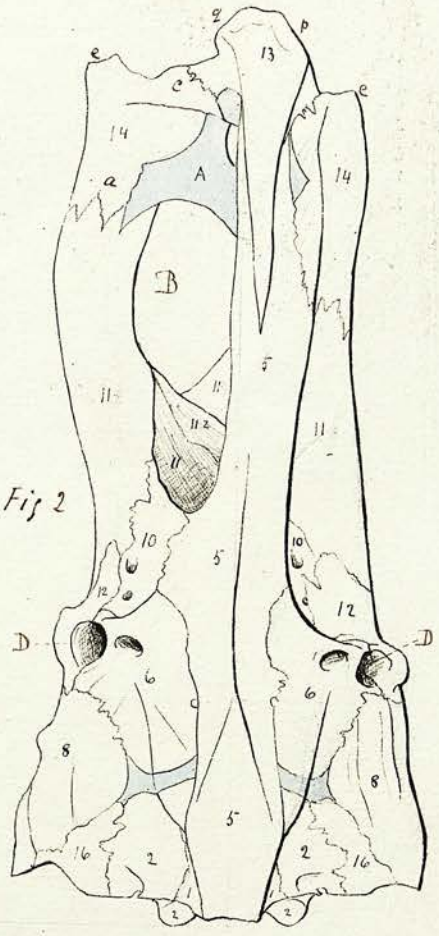


Fig 2

Fig 6

Fig 7

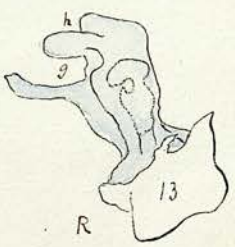


Fig 8

Fig 3

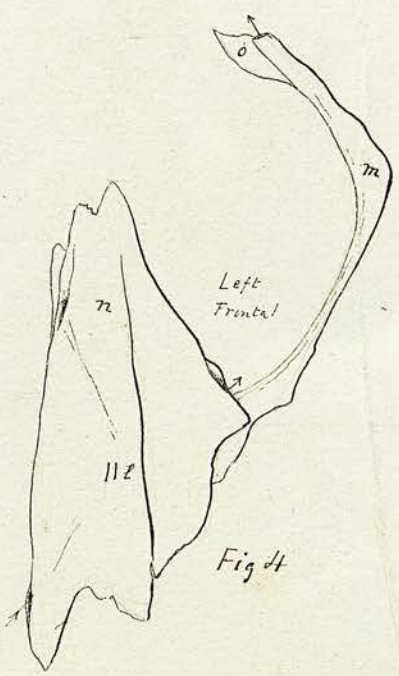


Fig 4

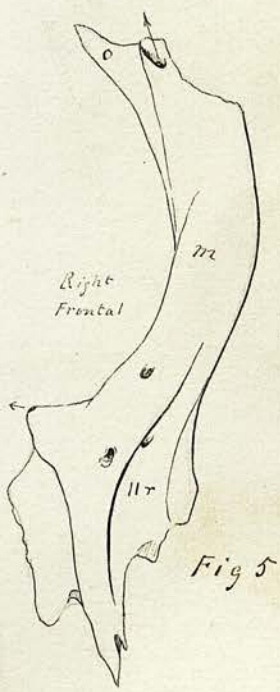


Fig 5

R. H. Traquair delt.

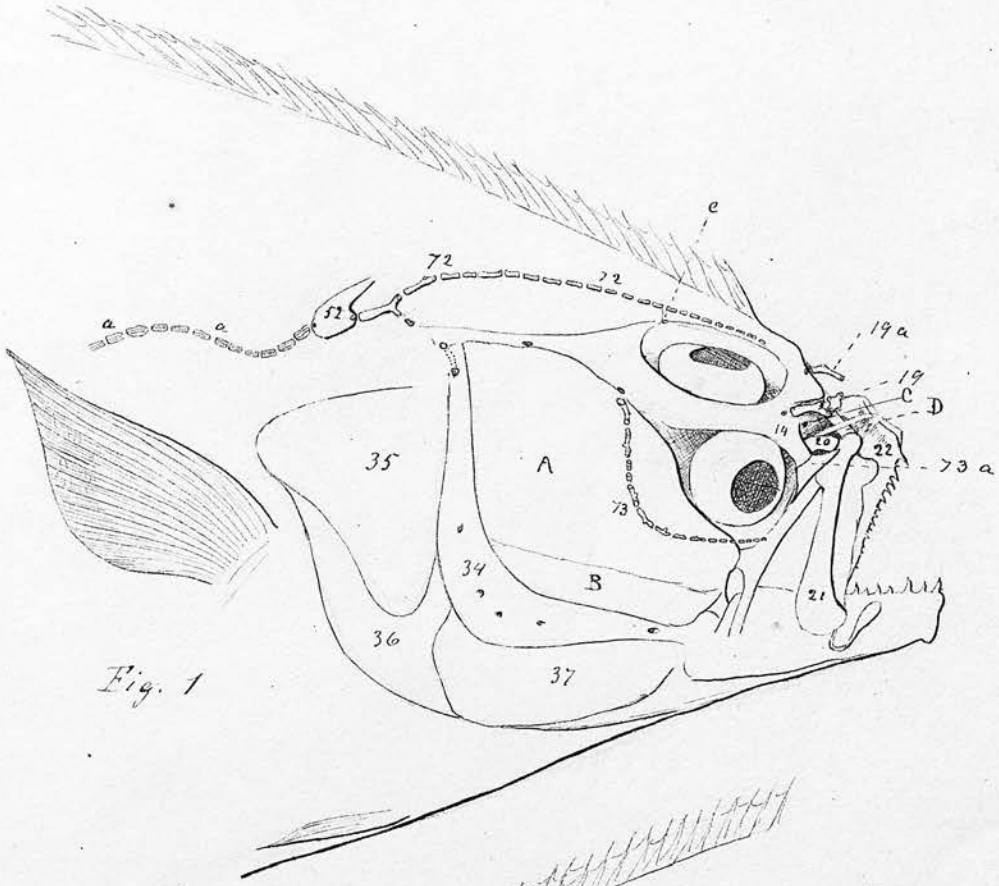


Fig. 1

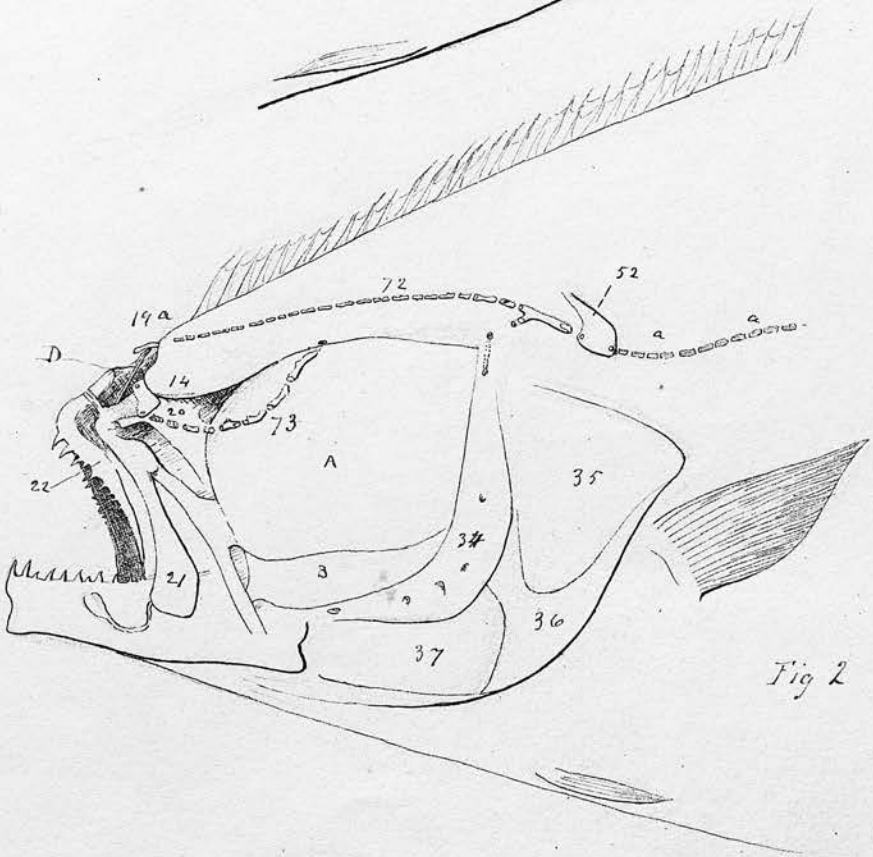
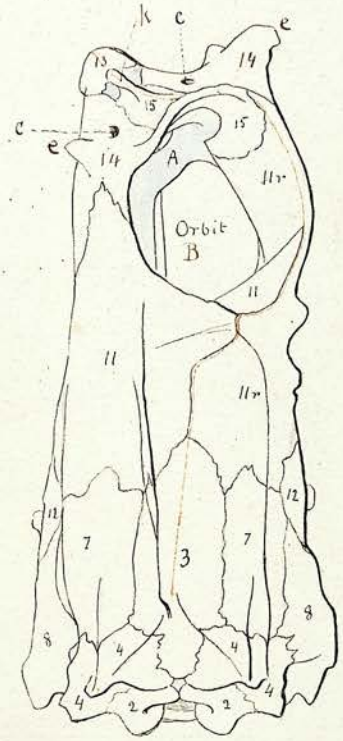


Fig 2

R. H. Traquair delt.

PLATESSA VULGARIS.



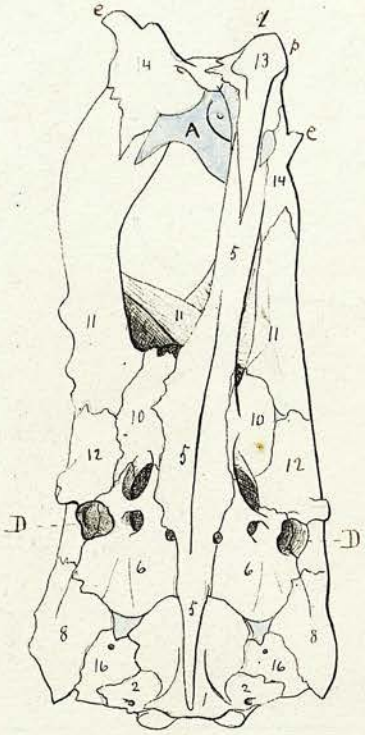


Fig 4

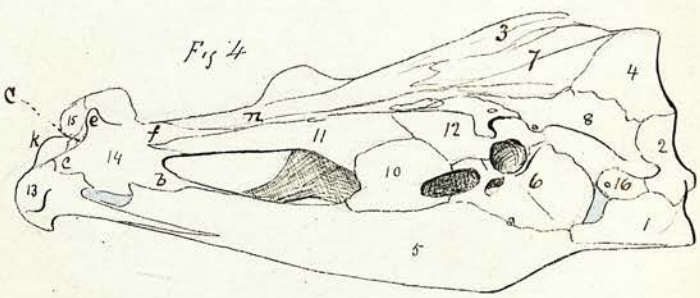


Fig 7

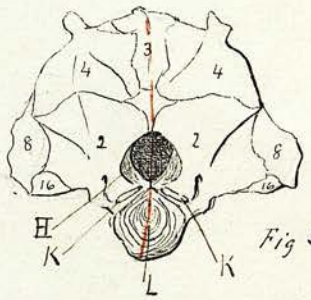


Fig 3

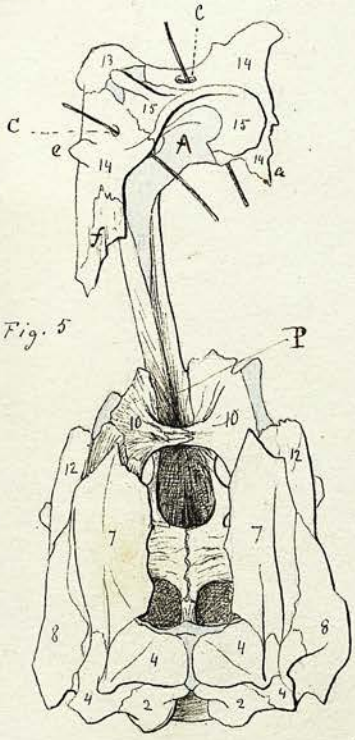
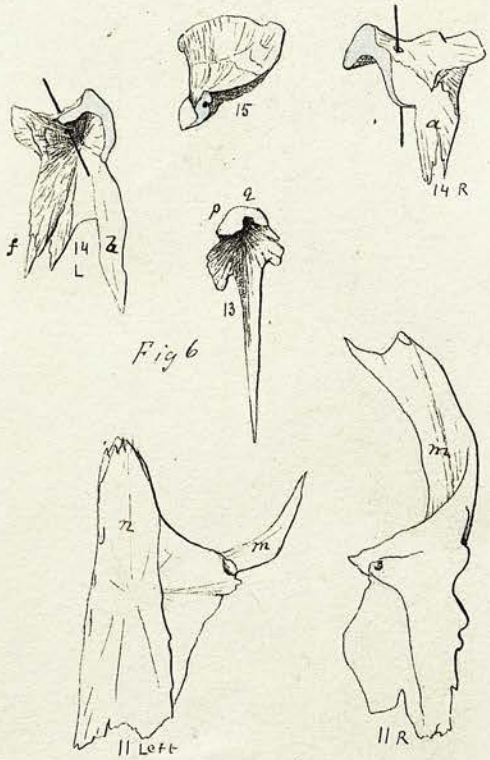


Fig. 5



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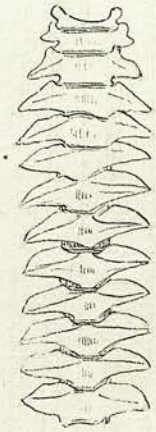

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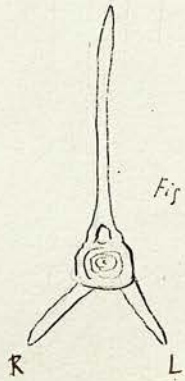

Fig 9.

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PLATESSA VULGARIS.

Plate V

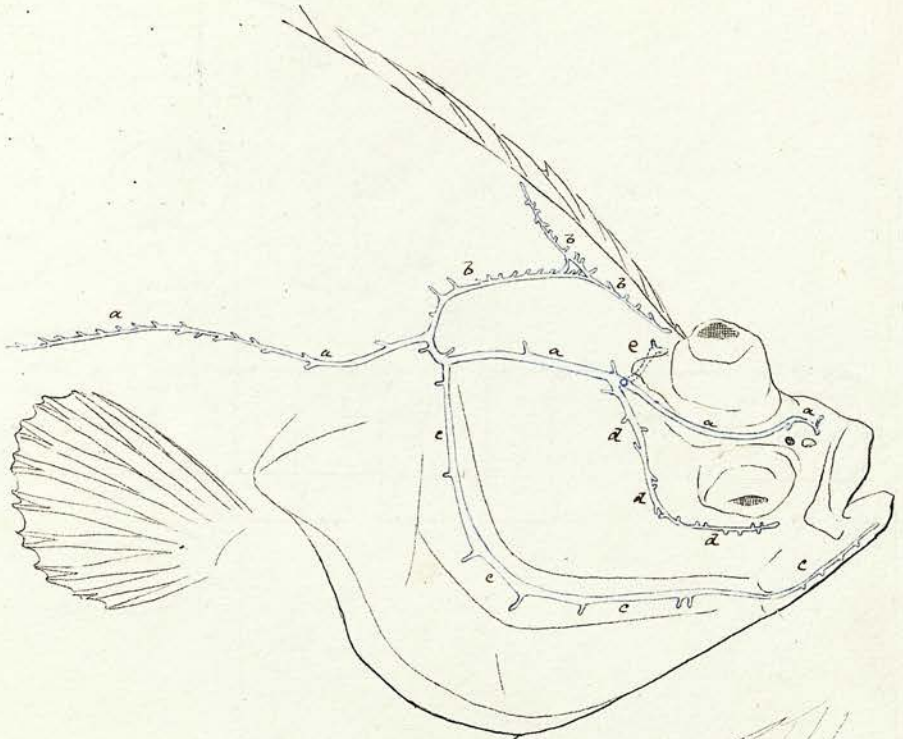
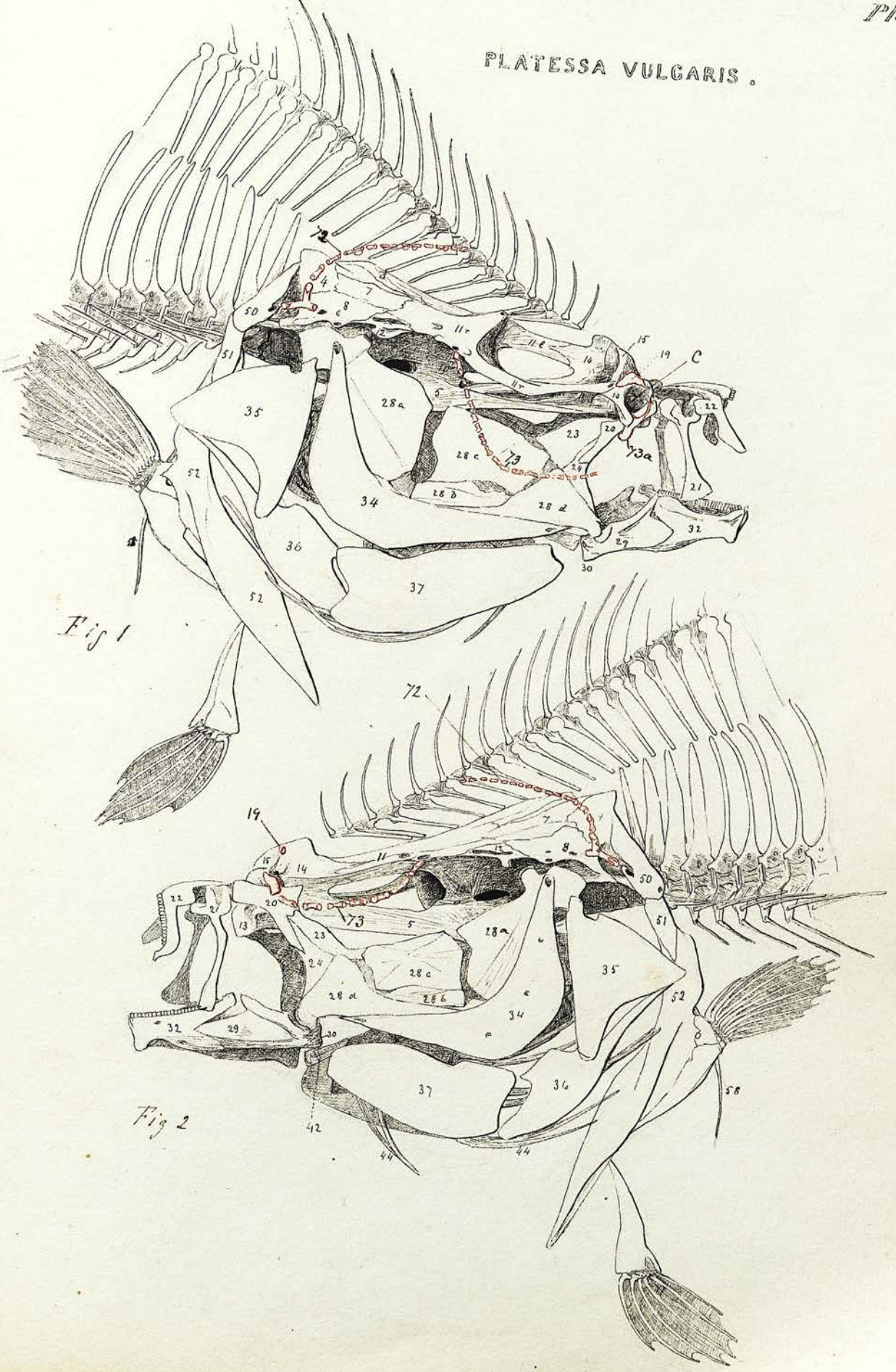


Fig 1

Fig 2

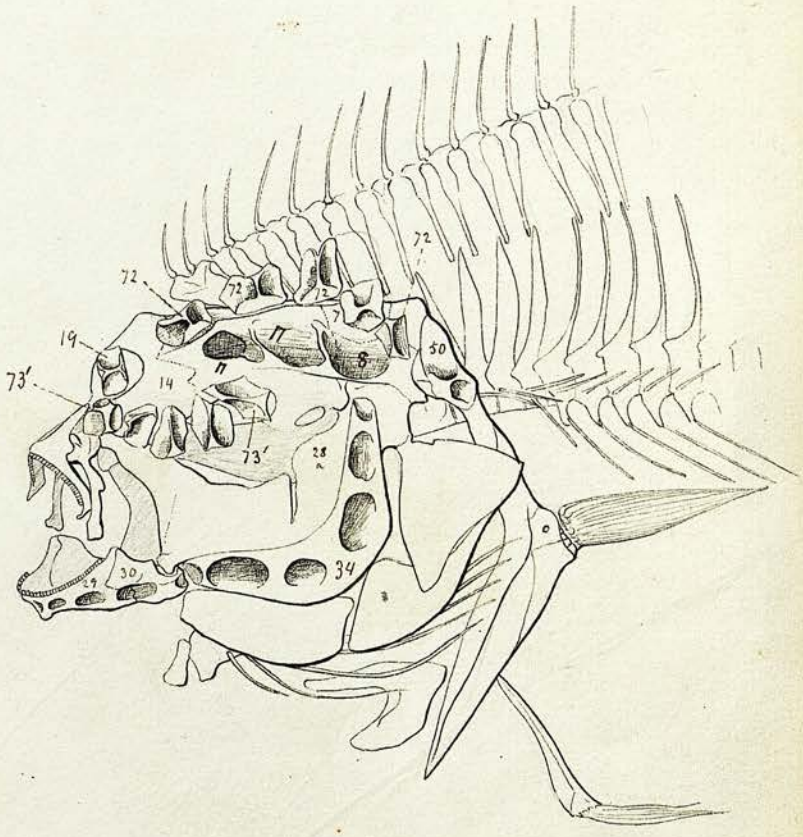
R. H. Traquair del.

PLATESSA VULGARIS.



PLATESSA POLA

Plate VII.



R H Traquair del

PLATESSA FLESUS.

Plate VIII

Mr Goodsir's Monstrosity.

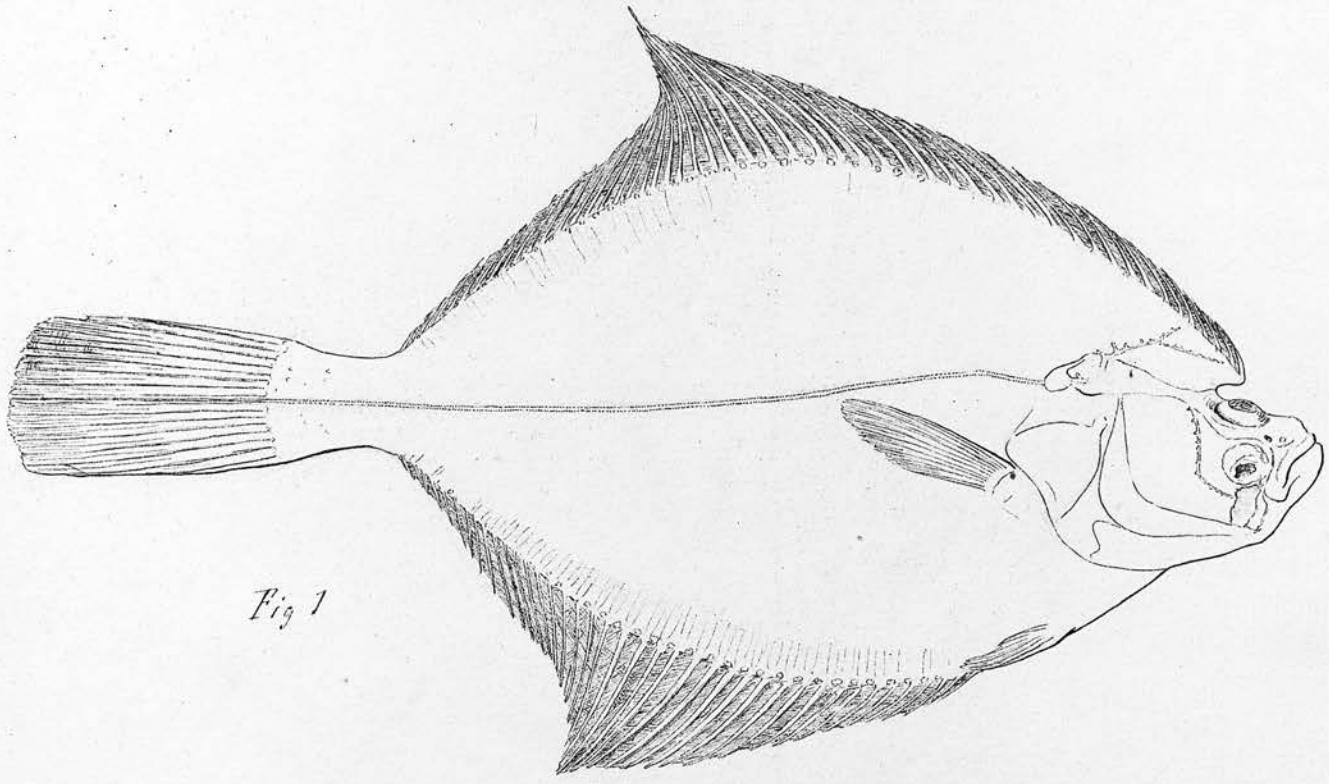


Fig 1

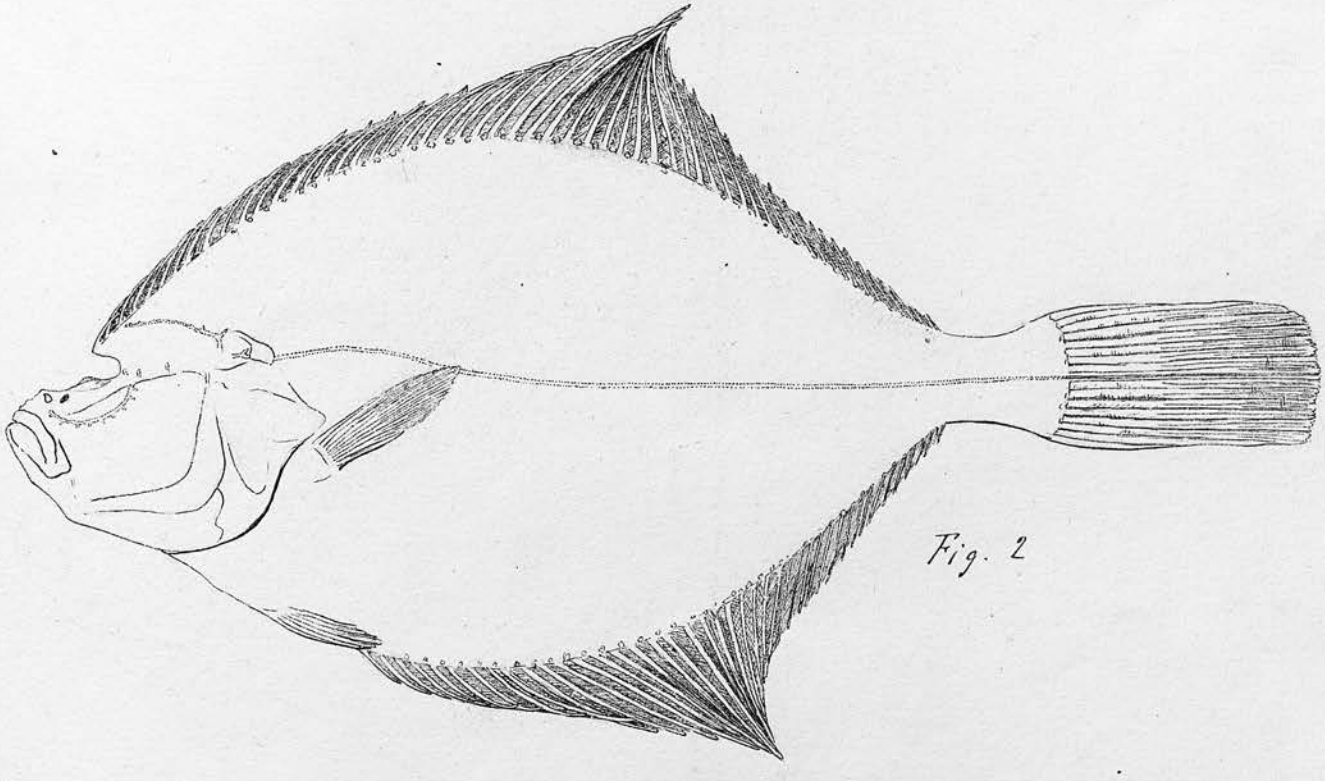


Fig. 2

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PLATESSA FLESUS

Plate IX.

Mr Goodsir's Specimen.

Muscles

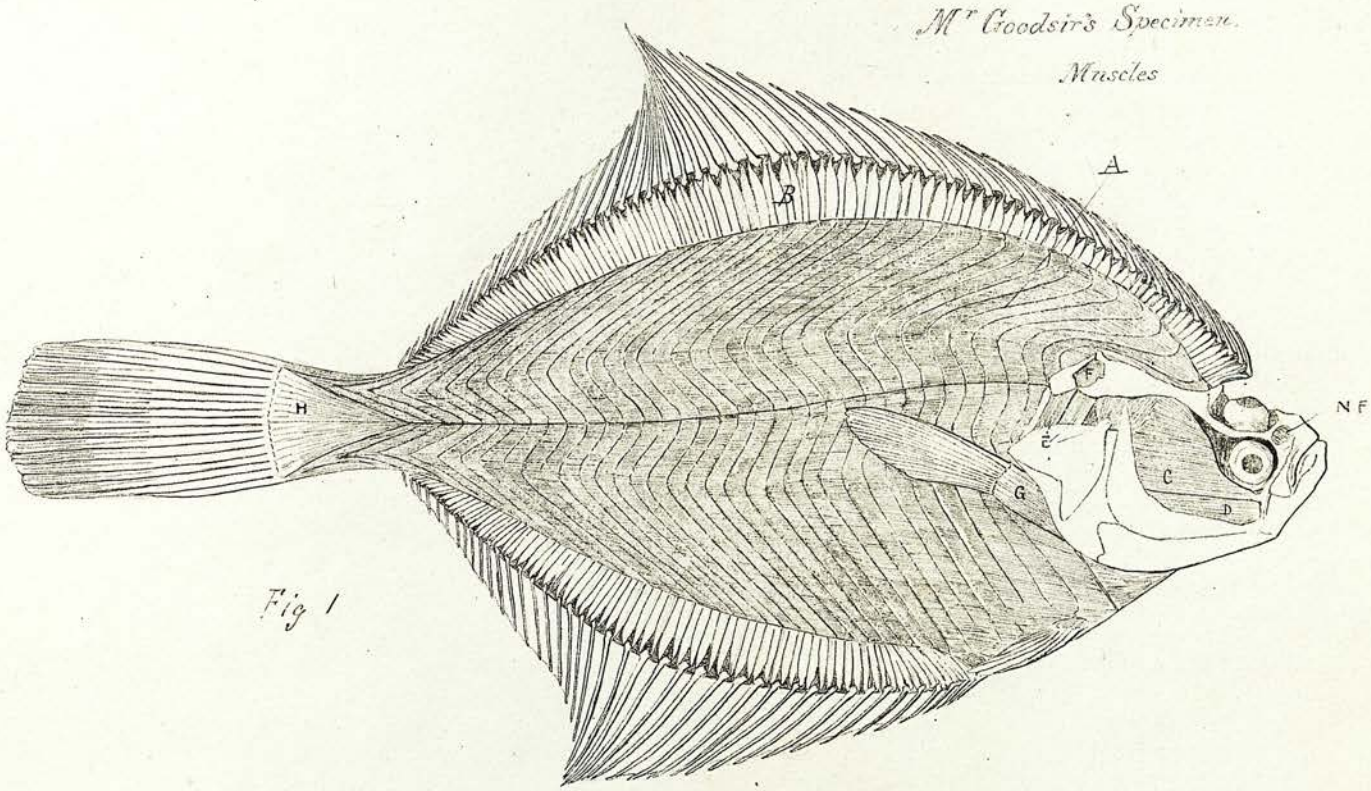
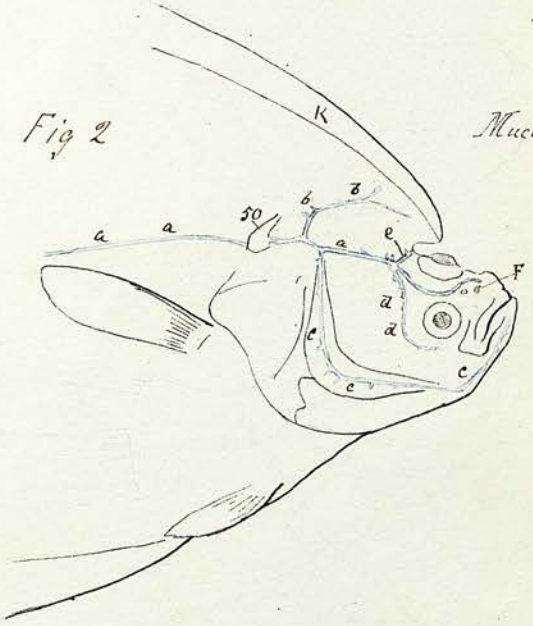


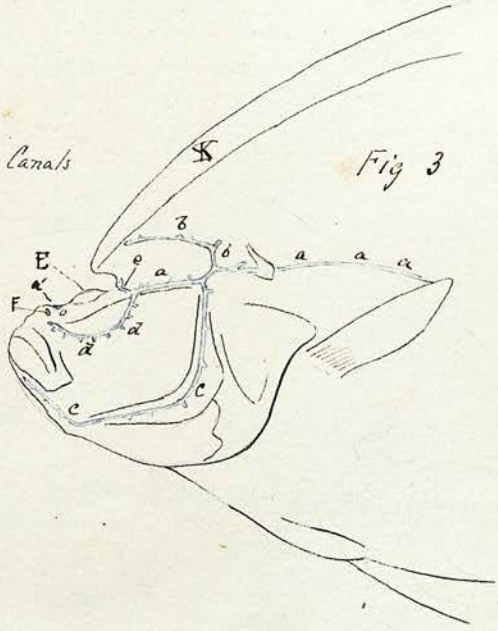
Fig 1

Fig 2



Mucus Canals

Fig 3



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DIAGRAMS.

Plate X.

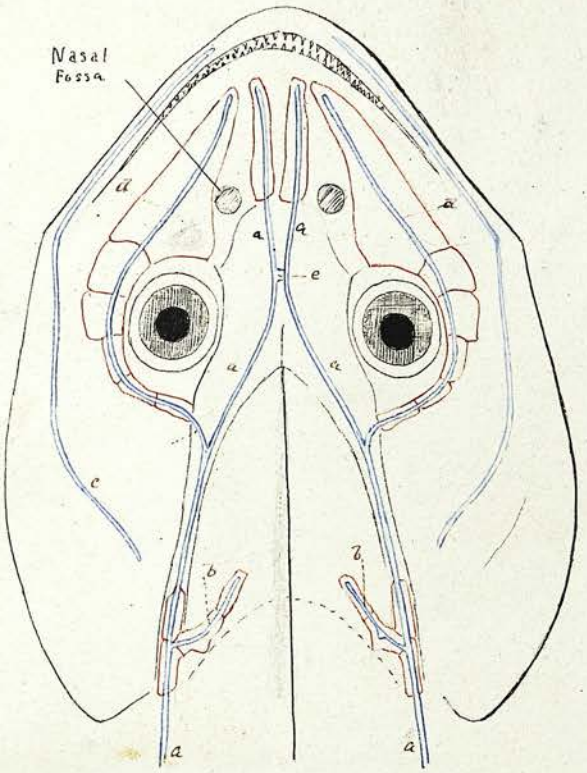
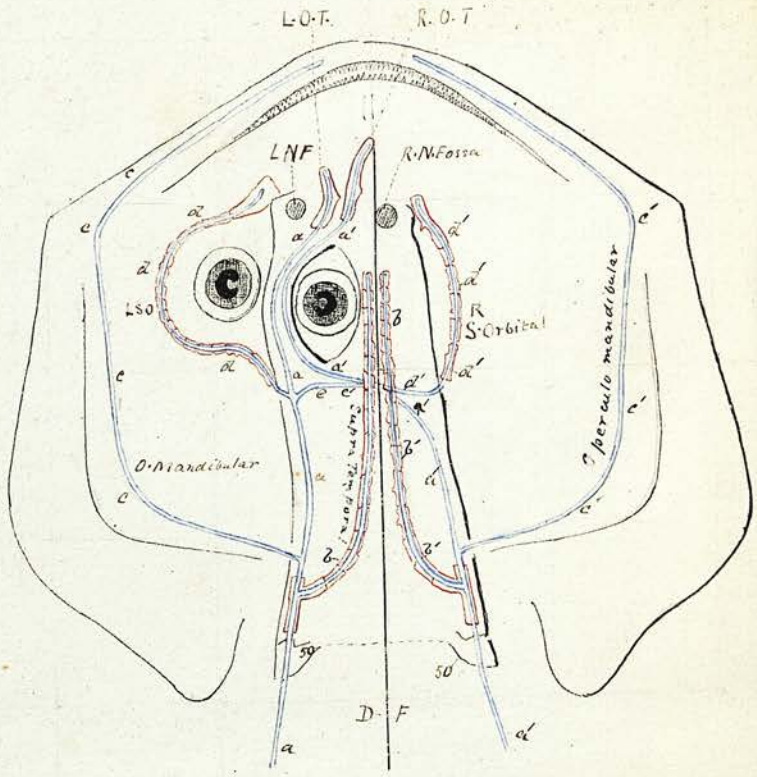


Fig 1



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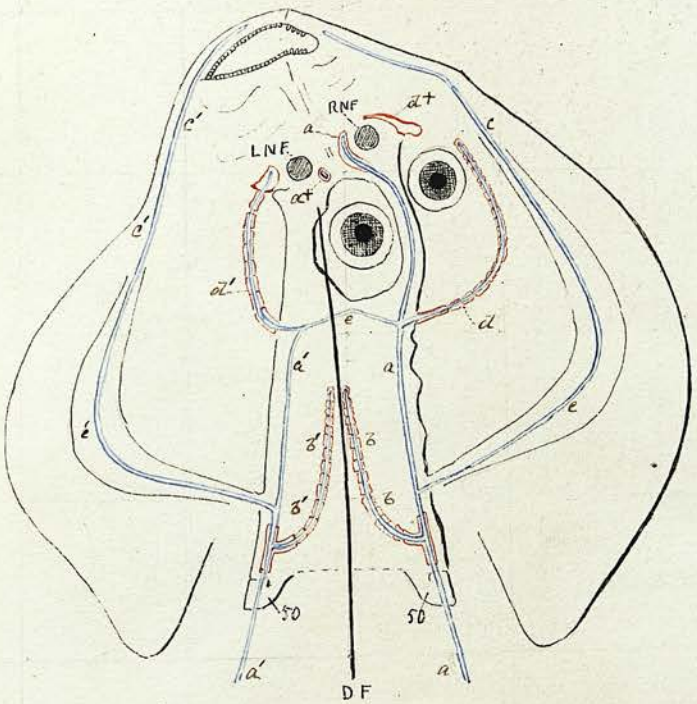

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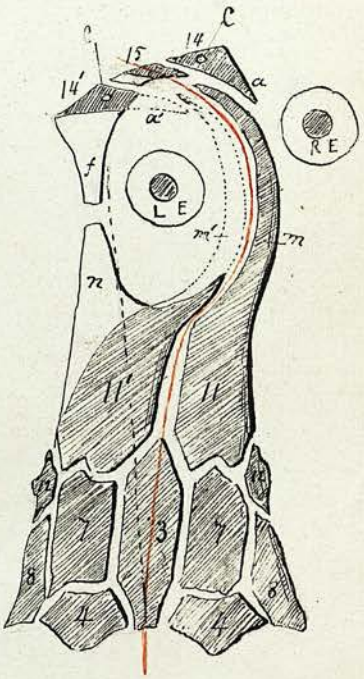

Fig 4

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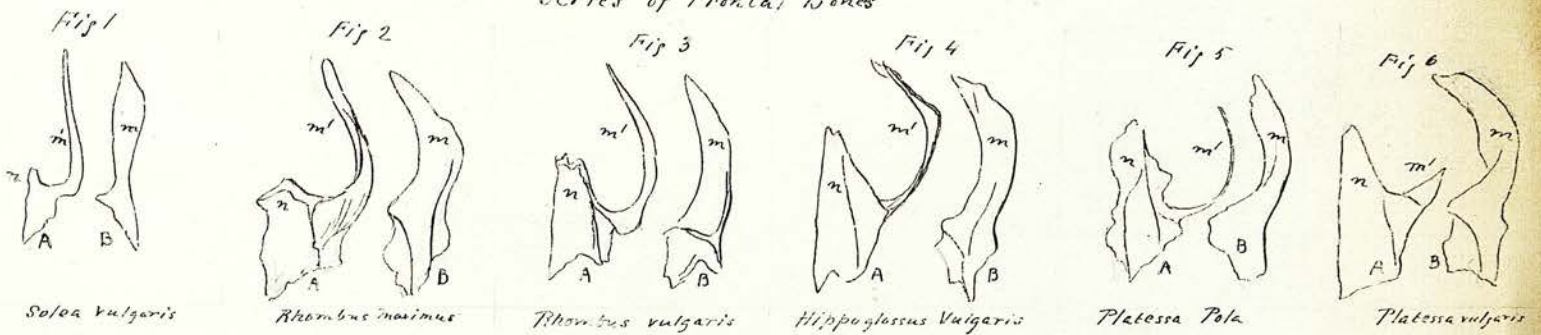
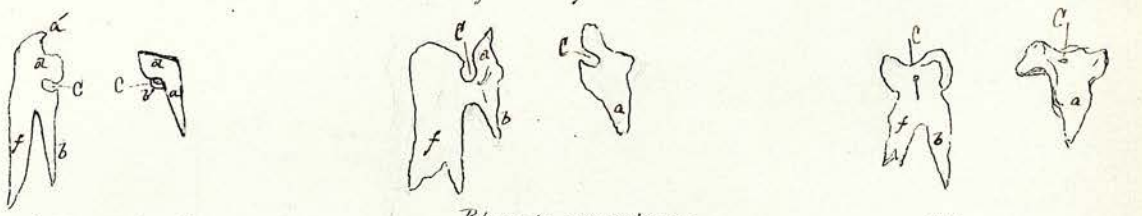
Series of Frontal Bones



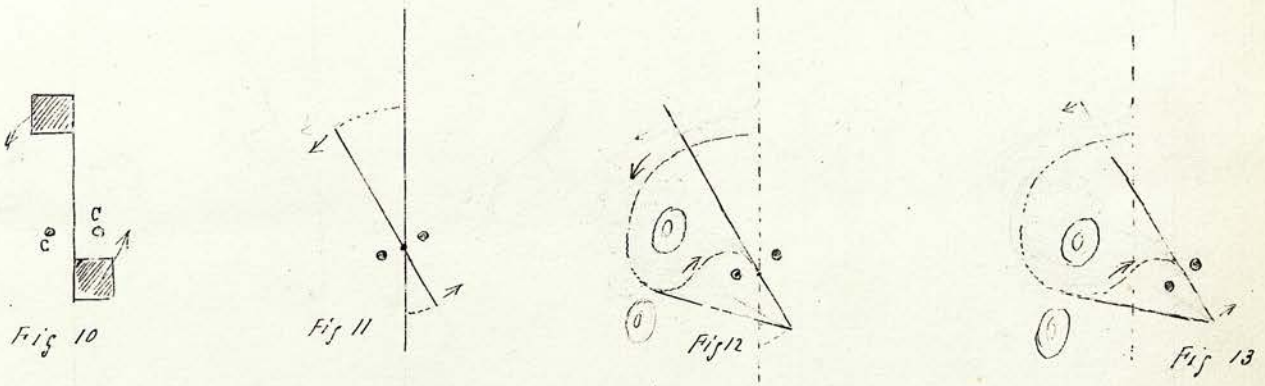
Solea vulgaris — Rhombus maximus — Rhombus vulgaris — Hippoglossus Vulgaris — Platessa Pola — Platessa vulgaris

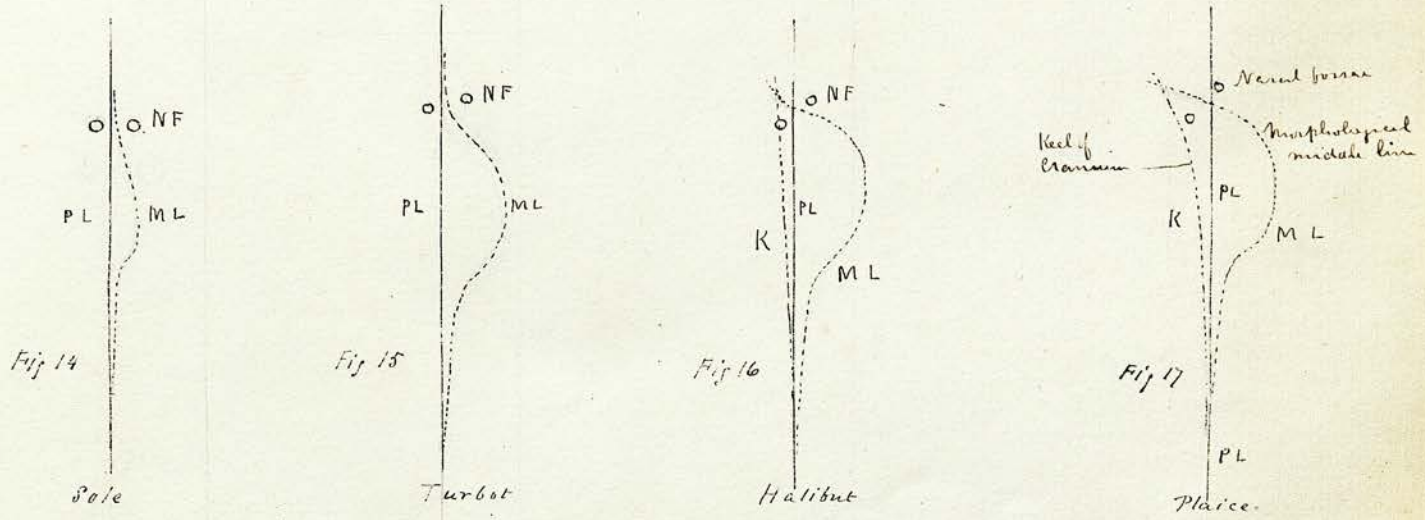
Series of Pre-frontals



Solea vulgaris — Rhombus maximus — Platessa vulgaris

Diagrams.





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