

### III. THE DISPOSITION OF MUSCLES ASSOCIATED WITH RESPIRATION IN CERTAIN TELEOSTS

While numerous papers have been published in India and elsewhere on the habitats of the air-breathing fishes, the morphology of the air-breathing organs etc., sufficient attention has not been paid to the study of the associated structures viz. the muscles which are helpful during inspiration and expiration.

Hora, however, has made a brief mention of some of the muscles in one of his papers (1933). It is desirable to know the disposition of these muscles not only, in order to understand the working of the respiratory mechanism but also to find out whether any differences with regard to musculature exist between the water-breathing teleosts and the air-breathing ones. A study of these muscles therefore has been made in the following Indian teleosts comprising both water-breathing and air-breathing forms:-

#### Water-breathers

1. Callichrous pabda (Ham.)
2. Barbus dobsoni (Day)

#### Occasional air-breathers

3. Macrones gulis (Ham.)
4. Notopterus notopterus (Lacep)

Habitual air-breathers

5. Ophichthys (Pisoodonophis) boro (Ham.)
6. Ophiocephalus punctatus (Bloch)
7. Osphronemus gourami (Lacep)
8. Boleophthalmus dussumieri (Cuv. & Val.)
9. Mastecembalus armatus (Lacep).

The inspiratory phase of respiration first consists in the opening of the mouth by the lowering of the lower jaw whereby the water enters the bucco-pharyngeal cavity. During this period, the gill arches are brought close together so that no water escapes into the gill chambers. In the act of respiration, first the sphincter muscles at the opening of the oesophagus close the oesophagus in order to prevent the water from entering the gullet. The mouth is now closed by the adductors of the lower jaw and the gill arches simultaneously diverge from one another. The pressure caused on the water as a result of this action, forces the water into the opercular chambers resulting in the exchange of gases. Almost at about the same time the opercular slits are opened and the expiration of water takes place.

The lowering down and the raising up of the lower jaw resulting in the opening of the closure of the mouth, the coming together as well as the separation of the gill arches and the opening or the closure of the opercular slits, are all brought about by the action of certain cranial muscles. These include the mandibular, the hyoid, the branchial and the hypobranchial muscles.

The mandibular muscles of teleosts are divided into Adductor mandibulae, Constrictor dorsalis and Intermandibularis. Usually the Adductor mandibulae is divided further into 2 to 3 parts while in others, each of these parts gets divided further. The Constrictor dorsalis is also divided into two parts viz. the Levator arcus palatini and the Dilatator operculi. The Intermandibularis remains single in a few forms. More usually however it is divided into an anterior and a posterior part.

The hyoid muscles comprise the Adductor arcus palatini, the Levator operculi, the Adductor operculi, the Interhyoideus and the Hyohyoideus muscles. Of these, the Interhyoideus and the Hyohyoideus show wide variations in different species of fishes.

The branchial muscles comprise the Levatores arcuum branchialium, the Attractores arcuum branchialium, the Coraco-branchiales, the Subarcuales recti (including the Subarcualis communis), and the Transversi ventrales. The sphinctor oesophagi group of muscles in the branchial region which are differentiated into the Transversi dorsales, the Obliqui dorsales, (superioris and inferioris), and the Retractores arcuum branchialium, are also helpful in moving the branchial bars.

The hypobranchial forms a single muscle known as the Coraco-hyoideus (the Rectus cervicis of Edgeworth-1935 and Sterno-hyoideus of Takahasi-1925).

(It may be mentioned here that there is considerable confusion in the terminology of muscles used by various workers who have investigated the cranial musculature of fishes. The terminology adopted here is that of Edgeworth (1935) with certain modifications.)

As far as the respiratory function of these muscles is concerned, it becomes necessary to divide them into three groups viz. (i) the mandibular group of muscles primarily associated with the closure and opening of the mouth, (ii) the opercular group associated with the closure or the opening of the opercular slits and (iii) the branchial group for the movements of the gill arches.

#### I. THE MANDIBULAR GROUP OF MUSCLES

In this group have been included all those muscles which are associated with the first two visceral arches except those directly concerned with the closure and the opening of the opercular slits. For the sake of convenience the hypobranchial muscle which takes a prominent part in the opening of the mouth besides effecting the movement of the gill arches - which is its main function - is described under the branchial group of muscles.

Functionally, these muscles may be divided under two main parts viz. the depressors and the levators of the jaw.

The depressors

The muscles which serve as depressors of the lower jaw consist mainly of the Intermandibularis and the Constrictor hyoideus ventralis. They depress the lower jaw and at the same time make the gill arches come close together, as a result of which the mouth opens wide and the gill slits become closed. Their origin is fleshy and they arise from the branchiostegal rays, the ventral hyoid bones and/or the opercular bones on the ventral side.

The Intermandibularis muscle remains single or more usually separated into an anterior and a posterior part. The former part which is present in most of the fishes examined in the present investigations, runs transversely behind the symphysis of the dentaries, while the latter which runs longitudinally, arises from the distal part of the hyoid arch and/or the bones of the operculum. In some fishes, this muscle meets its fellow of the opposite side anteriorly along the median line in a thin tendinous raphe and has a common insertion behind the symphysis of the dentaries. In other fishes, however, the insertion shows considerable variation.

The Constrictor hyoideus ventralis muscle separates into an anterior Interhyoideus and a posterior Hyohyoideus. In some fishes, the Interhyoideus runs along the outer surface of the Intermandibularis posterior with which it is closely associated,

while in others a part or whole of this Interhyoideus together with the Intermandibularis posterior forms a single Protractor hyoidei muscle.

The Hyohyoideus muscle is situated in the opercular fold behind the distal series of hyoid bones and passes downwards and forwards. Its upper end is attached to one or more of the opercular bones. It remains single or is divided into a Hyohyoideus superior and a Hyohyoideus inferior. The portion which extends in between the branchiostegal rays is known as Hyohyoideus superior and the portion extending anterior to the lowermost branchiostegal ray is known as the Hyohyoideus inferior.

In some, the Hyohyoideus superior is segmented further into a number of parts passing from ray to ray. The Hyohyoideus inferior arises from the anterior branchiostegal rays, the ceratohyal or the ceratohyal and the epihyal. It passes forwards and downwards and is inserted on the hypohyal of the same side or on that of the opposite side.

#### Innervation

The Intermandibularis : This muscle whether single or divided is innervated by the R. mandibularis inferior portion of the R. mandibularis nerve, which forms a branch of the Vth nerve.

The Interhyoideus : It is innervated partly by the Maxillo-mandibularis branch of the Vth nerve and partly by the Hyomandibularis branch of the VIIth nerve.

In those fishes where the Protractor hyoidei is formed as the result of the union of the Intermandibularis and the Interhyoideus, possesses the same respective sources of innervation as those of the two individual muscles.

The Hyohyoideus : It is innervated by the Hyomandibularis branch of the VIIth nerve.

The following is the disposition of the mandibular depressors in the fishes investigated.

#### Callichrous

The Intermandibularis : The Intermandibularis anterior (Fig.5) runs in between the dentaries immediately behind their symphysis, ventral in position to the Intermandibularis posterior and the inner fibres of the Interhyoideus and dorsal in position to the outer fibres of the latter. The Intermandibularis posterior muscle (Fig.5) arises from the ceratohyal and epihyal. It runs forwards and inwards and is inserted on the dentary towards the inner angle of the rami of the lower jaw.

The Interhyoideus : It (Fig.5) arises from the ceratohyal, epihyal and the uppermost branchiostegal rays. It runs forwards and inwards in close association with the Intermandibularis posterior muscle. The insertion is on the dentary external to that of the Intermandibularis posterior muscle.

The Hyohyoideus : The Hyohyoideus muscle consists of two parts (Fig.5). Of these, the Hyohyoideus superior passes

from ray to ray as usual. The portion of the Hyohyoideus below and in front of the lowest ray is known as Hyohyoideus inferior.

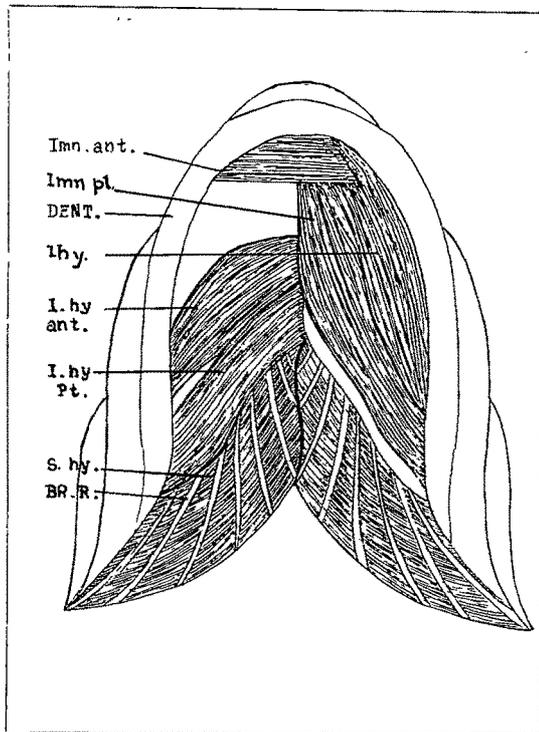


Fig. 5.

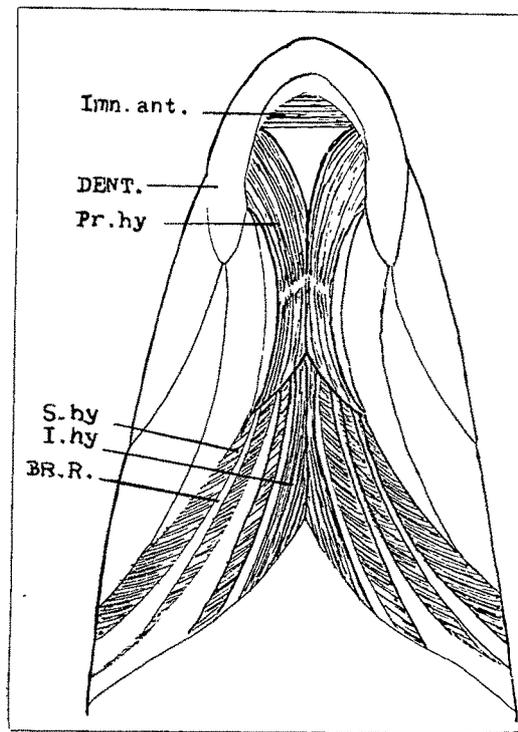


Fig. 6.

Fig. 5. Callichrous. Depressor muscles of the lower jaw (after removal of the Ihy. and Imm.pt. of the right side).

Fig. 6. Barbus. Depressor muscles of the lower jaw.

This muscle meets its fellow along the median line and is inserted on the hypohyal of the same side. Towards the origin, however, it consists of two parts, an upper i.e. anterior and

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Lettering for figures 5-13

BR. or BR.R. - Branchiostegal rays; DENT. - Dentary;  
 HY. - Hyohyoideus; Ihy. - Interhyoideus; I.hy. - Hyohyoideus inferior; I.hy.ant. - Hyohyoideus inferior anterior; I.hy.post. - Hyohyoideus inferior posterior; Imm.ant. - Intermandibularis anterior; Imm.pt. - Intermandibularis posterior; Pr.hy. - Protractor hyoidei; S.hy. - Hyohyoideus superior.

a lower i.e. posterior. The upper part which remains dorsal to the lower one, arises from the epihyal. The lower part arises from the first five branchiostegal rays and the ceratohyal. Both parts meet each other as they pass forwards to gain insertion on the hypohyal.

### Barbus

The Intermandibularis : The Intermandibularis anterior (Fig.6) is developed as usual immediately behind the symphysis of the dentaries and dorsal to and in front of the insertion of the Protractor hyoidei. In this fish the Intermandibularis posterior and the Interhyoideus form together a well developed Protractor hyoidei (Fig.6). The Intermandibularis part of the muscle lies anterior to the Interhyoideus one. The Protractor hyoidei arises from the ceratohyal and the inner branchiostegal rays. The insertion is as usual on the dentary behind and ventral to the insertion of the Intermandibularis anterior muscle.

The Hyohyoideus : It is divided into its usual two parts. Of these, the Hyohyoideus superior (Fig.6) is segmented into a number of parts passing from ray to ray. The Hyohyoideus inferior (Fig.6) arises from the lowermost branchiostegal ray, the ceratohyal and epihyal bones. It is inserted on the hypohyal.

### Macrones

The Intermandibularis : The Intermandibularis anterior (Fig.7) lies throughout ventral to the Intermandibularis posterior

and dorsal to the fibres of the Interhyoideus. While its anterior fibres are inserted behind the symphysis of the dentaries, some of the posterior ones get separated into two sets. The middle set of these runs in between the proximal end of the base of the anterior mandibular barbel, and the posterior one in between the anterior and the posterior barbels. The Intermandibularis posterior (Fig.7) arises from the distal hyoid bones viz. ceratohyal and epihyal. Dorsally it forms a continuous sheet of muscle, while its ventral fibres are separated into three parts due to the intervening bases of the

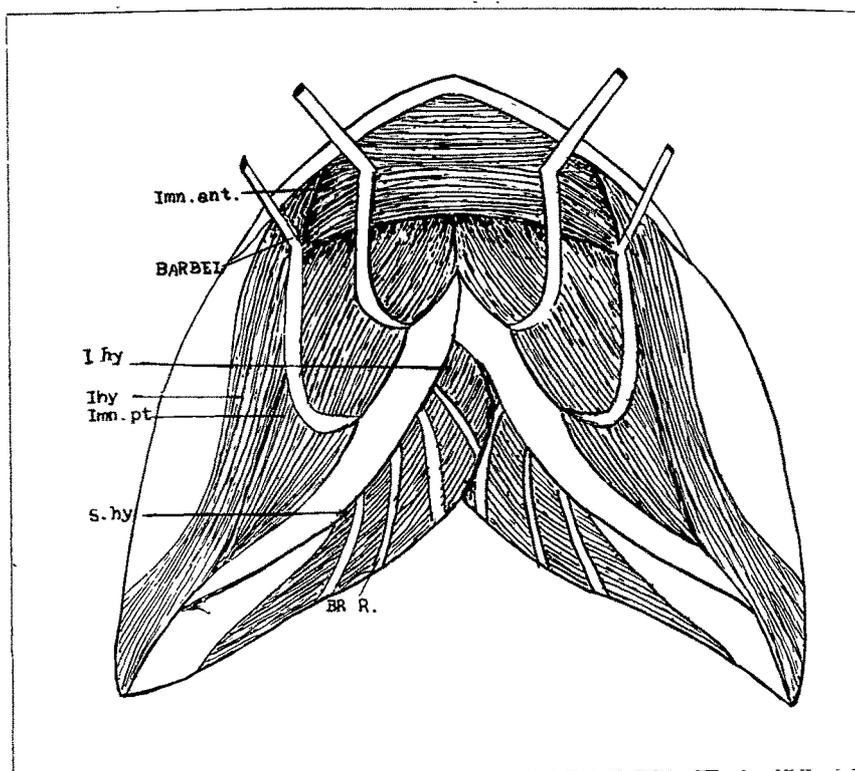


Fig.7. Macrones. Depressor muscles of the lower jaw.

barbels. The insertion is on the dentary by the side of the symphysis.

The Interhyoideus : It arises from the ceratohyal, passes forwards and is inserted on the dentary external to the insertion of the Intermandibularis posterior (Fig.7).

The Hyohyoideus : It is divided as usual into two parts (Fig.7). The superior part is, as in others, segmented into a number of parts passing from ray to ray. The Hyohyoideus inferior arises from the lowermost branchiostegal ray, the ceratohyal and the epihyal. The insertion is on the hypohyal.

#### Notopterus

The Intermandibularis : The Intermandibularis anterior (Fig.8) is practically reduced to a tendon with only a few fleshy fibres. It lies dorsal to the insertion of the Protractor hyoidei.

The Protractor hyoidei : The Intermandibularis posterior and the Interhyoideus, form a fully developed Protractor hyoidei. It (Fig.8) arises from the anterior end of the branchiostegal rays, the ceratohyal and the epihyal. It runs as usual forwards and inwards and unites with its fellow along the median line. The insertion is on the dentary ventral to the disposition of the Intermandibularis anterior.

The Hyohyoideus : This muscle is divided into two parts. Of these, the Hyohyoideus superior (Fig.8) is segmented as usual. The Hyohyoideus inferior (Fig.8) arises from the lower end of the lowermost branchiostegal ray and the ceratohyal. It passes forwards and inwards and crosses the median line in such a way

that the muscle on the left side lies ventral to its fellow of the opposite side. The insertion is consequently on the hypohyal of the opposite side.

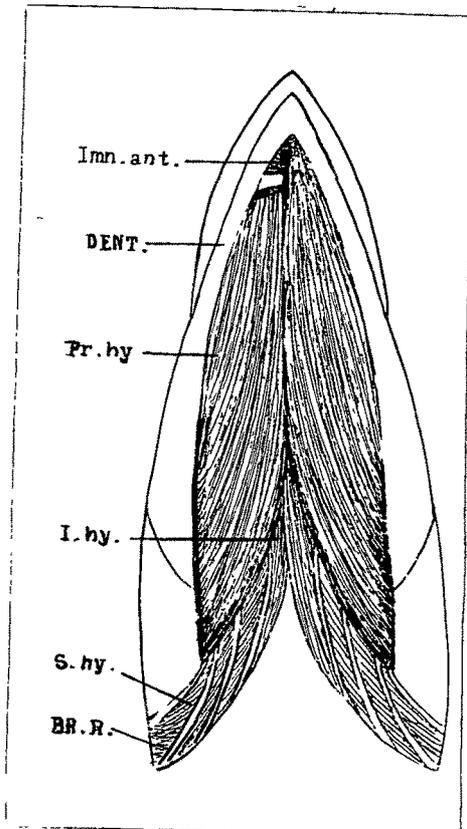


Fig. 8. Notopterus.

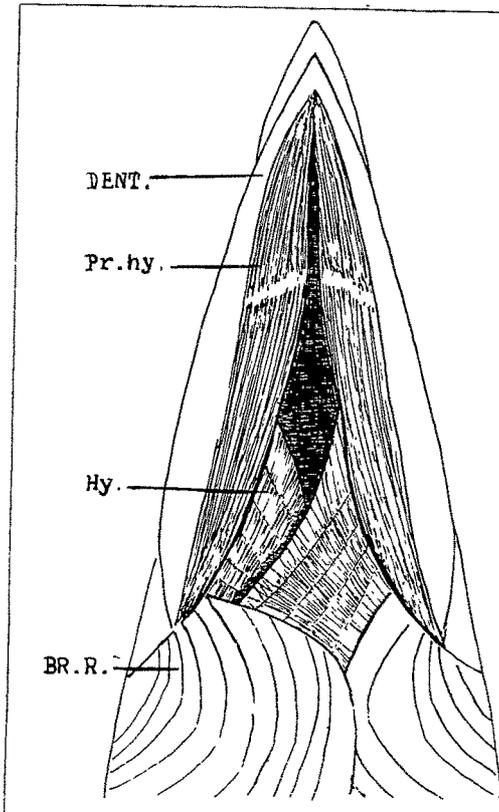


Fig. 9. Ophichthys.

Depressor muscles of the lower jaw.

### Ophichthys

The Intermandibularis : The Intermandibularis anterior part of this muscle is poorly developed and lies dorsal in position to the insertion of the Protractor hyoidei.

The Protractor hyoidei : It is well developed in this fish (Fig. 9). Its anterior portion consists of the Intermandibularis

posterior and the posterior portion of the Interhyoideus.

The origin of the Interhyoideus is from the tips of the lower series of branchiostegal rays as well as the lower hyoid bones with which they are attached. As the muscle runs forwards it is joined by the Intermandibularis posterior muscle to form a common Protractor hyoidei. The insertion is as usual on the dentary.

The Hyohyoideus : It remains single and runs as a continuous broad sheet of muscle covering the lower series of branchiostegal rays (Fig.9). Its anterior fibres extend upto the posterior portion of the hypohyal on which they are inserted.

#### Ophiocephalus

The Intermandibularis : The Intermandibularis anterior (Fig.10) is well developed and remains dorsal in position to the insertion of the Protractor hyoidei.

The Protractor hyoidei : The Intermandibularis posterior and the Interhyoideus together form the Protractor hyoidei. It (Fig.10) arises from the ceratohyal and epihyal in such a way that the fibres of the Intermandibularis lie anterior to those of the Interhyoideus. The insertion is on the dentary below that of the Intermandibularis anterior muscle.

The Hyohyoideus : The Hyohyoideus muscle is divided as usual into two parts. The Hyohyoideus superior of these (Fig.10), which arises from the opercular bones is segmented into portions

passing from ray to ray. The Hyohyoideus inferior (Fig.10) is well developed and is inserted on the hypohyal.

Osphronemus

The Intermandibularis : The Intermandibularis anterior (Fig.11) lies dorsal in position to the anterior fibres of the Protractor hyoidei.

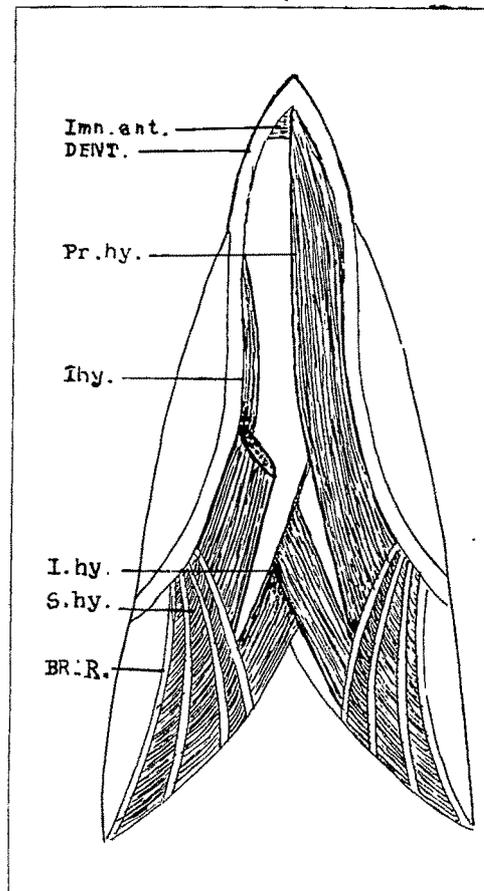
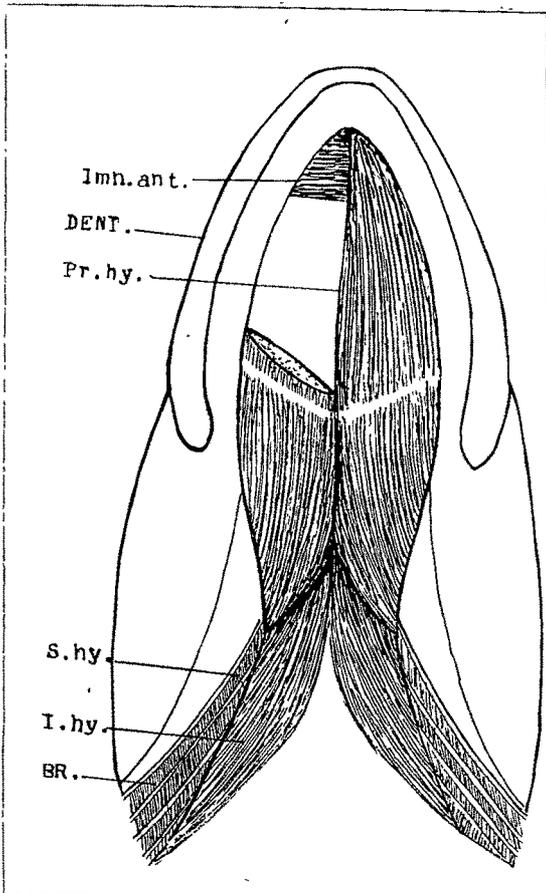


Fig.10. Ophiocephalus.

Fig.11. Osphronemus.

Depressor muscles of the lower jaw.

The Protractor hyoidei and the Interhyoideus : The Intermandibularis posterior and inner fibres of the Interhyoideus

unite to form the Protractor hyoidei (Fig.11). The outer fibres of the Interhyoideus (Fig.11) however remain separate from the Protractor hyoidei, pass forwards and are inserted on the dentary behind the insertion of the latter.

The Hyohyoideus : This muscle is divided as usual into a superior and an inferior part. The former part (Fig.11) is segmented as usual into portions passing from ray to ray. The latter part arises from the distal portion of the lowermost branchiostegal ray and the ceratohyal. It crosses its fellow anteriorly in such a way that the fellow of the left side becomes ventral in position. The insertion is consequently on the opposite hypohyal.

#### Boleopthalmus

The Intermandibularis : The Intermandibularis anterior is not represented in this fish.

The Protractor hyoidei : The Intermandibularis and Interhyoideus together form a Protractor hyoidei muscle (Fig.12). It arises from the ceratohyal and is inserted on the dentary as usual.

The Hyohyoideus : This muscle is divided into the usual superior and inferior parts (Fig.12). Of these, the superior part extends in between the branchiostegal rays. The inferior part is further divided into an anterior and a posterior segments. Of these, the anterior one arises, from the anterior portion of the lowermost branchiostegal ray, runs forwards and is inserted

on the hypohyal. The posterior segment runs forwards and downwards and meets its fellow of the opposite side in a median raphe.

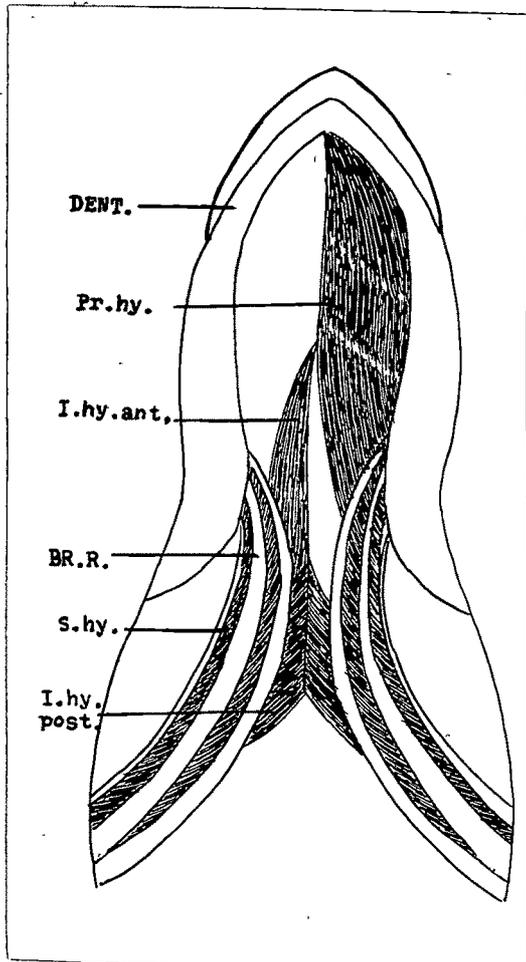


Fig. 12.

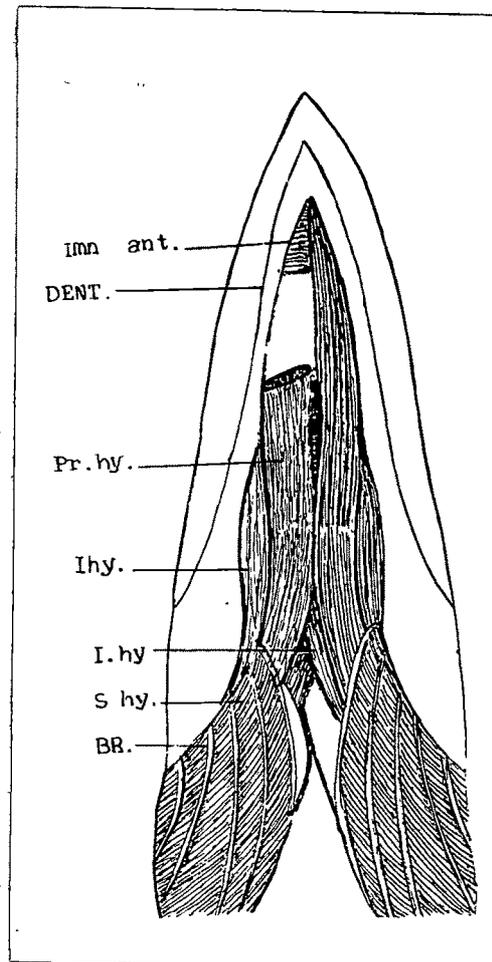


Fig. 13.

Fig.12. Boleopthalmus. Depressor muscles of the lower jaw (after removal of the I.hy.ant. of the left side and Pr.hy. of the right side).

Fig.13. Mastecembalus. Depressor muscles of the lower jaw.

Mastecembalus

The Intermandibularis : The Intermandibularis anterior

(Fig.13) remains dorsal to the Protractor hyoidei.

The Protractor hyoidei and the Interhyoideus muscles :  
The Intermandibularis posterior which forms the anterior portion and the inner fibres of the Interhyoideus which forms the posterior portion, together form the Protractor hyoidei (Fig.13). The outer fibres of the Interhyoideus however arise separately from the hyoid bones to gain insertion on the dentary behind that of the Protractor hyoidei.

The Hyohyoideus : The Hyohyoideus superior (Fig.13) is developed as usual and lies in between the opercular bones and the lowermost branchiostegal ray and segmented as usual. The hyohyoideus inferior (Fig.13) which arises from the middle portion of the lowermost branchiostegal ray and the lower hyoid bones crosses its fellow in such a way that the left muscle remains ventral in position. The insertion is consequently on the opposite hypohyal.

### Discussion

The Intermandibularis muscle : It consists of an anterior and a posterior part in almost all the fishes examined. In only one fish viz. Boleophthalmus the anterior part is not represented. In Callichrous and Macrones, the anterior part remains ventral in position to the posterior one, whereas in all the other fishes examined it remains dorsal in position. It is fairly well developed in all the fishes in which it is represented except

in Notopterus and Ophichthys. In Notopterus, it is practically reduced to a tendon and in Ophichthys, it is represented by a few muscle fibres only.

The posterior part is well developed in all the fishes examined. In Barbus, Notopterus, Ophichthys, Ophiocephalus, Osphronemus, Boleophthalmus and Mastecembalus, it is joined with the Interhyoideus to form a Protractor hyoidei. In other fishes, it remains separate. In Barbus, Ophichthys, Ophiocephalus and Mastecembalus, the Intermandibularis posterior and the Interhyoideus portions of the Protractor hyoidei can be easily distinguished. The fibres of the former, lie anterior to those of the latter. In Notopterus and Osphronemus, they are indistinguishable.

The Interhyoideus : It remains a separate muscle in Callichrous and Macrones and in all other fishes examined it is joined to form a Protractor hyoidei as stated earlier. In Barbus, Notopterus, Ophichthys and Ophiocephalus all the fibres of this muscle join to form the Protractor hyoidei. In Osphronemus and Mastecembalus however, the inner fibres alone take part in the formation of the Protractor hyoidei and the outer fibres remain separate.

The Hyohyoideus : In Ophichthys, it forms a broad sheet of muscle covering the lower series of the branchiostegal rays. In all other fishes examined it is divided into a superior and an inferior part. The former part is further divided into segments:

extending between one branchiostegal ray to the other. The Hyohyoideus inferior is inserted on the hypohyal of the same side in Barbus, Callichrous, Macrones and Ophiocephalus. In Notopterus, Osphronemus and Mastecembalus, the muscle passes obliquely forwards in such a way that the left muscle remains ventral in position to the right one. The insertion is consequently on the opposite hypohyal. In Callichrous and Boleopthalmus, this is further divided into an anterior and a posterior part. In Callichrous, both the parts are inserted on the hypohyal of the same side. In Boleopthalmus, the anterior part is inserted on the hypohyal, whereas the posterior part meets to join its fellow in a median raphe.

#### The levators

The levator muscles of the lower jaw are associated mainly with the elements formed by the first two visceral arches viz. the mandibular and the hyoid. These muscles include the Adductor mandibulae, the Levator arcus palatini and the Adductor hyomandibula. All these muscles have a fleshy origin and the insertion is either fleshy or tendinous. The Adductor mandibulae muscles act as adductors of the lower jaw bringing about the closure of the mouth and at the same time the separation of the gill arches effecting the widening of the gill slits. The Levator arcus palatini and the Adductor hyomandibula muscles are not normally associated with the movement of the jaws or any other part except the barbels in the siluroid fishes.

The Adductor mandibulae usually arises from the lateral bones of the cranium situated behind and also in some cases above the orbit, and some of the bony elements of the hyoid arch such as hyomandibula, the symplectic and elements formed by the palato-pterygo-quadrate bar such as the pterygoid series of bones and the quadrate. The muscle extends as far back, often including the preopercle bone. It may remain single or may be divided further into a Maxillaris and a Mandibularis. The Mandibularis of these is more usually divided further into a superficialis and a profundus part. In some teleosts these parts are divided further. (The nomenclature adopted by Edgeworth in naming the various parts of the Adductor mandibulae is that of Vetter (1878). The Maxillaris muscle is termed as  $A_1$ , the Mandibularis superficialis as  $A_2$  and the Mandibularis profundus as  $A_3$ . These muscles divide further as  $A_1\alpha$ ,  $A_1\beta$  etc. Takahasi, whose nomenclature is followed here with suitable modifications, names  $A_1$  as the Maxillaris and  $A_2$  and  $A_3$  together as the Mandibularis.)

The Levator arcus palatini is covered partly or entirely by the Adductor mandibulae or one or more of its parts. Usually it is situated behind the orbit and arises from the lateral bones of the cranium such as the postfrontal, sphenotic and pterotic. The insertion is usually on one or more of the following bones viz. hyomandibula, the quadrate and pterygoid.

The Adductor hyomandibula remains single in most of the fishes examined and is known as the Adductor arcus palatini.

It arises usually from the lateral and/or ventral series of cranial bones such as parasphenoid and prootic and runs forwards and downwards to gain insertion on the pterygoid and/or hyomandibula. In the two siluroid fishes examined here, the Adductor hyomandibula gives rise to another muscle or muscles known as the Extensor(es) tentaculi. This muscle remains completely separate from the Adductor arcus palatini. It arises from the cranial bones situated towards the antero-dorsal border of the latter muscle, passes forwards and is inserted on the base of the barbel or the barbels as the case may be.

#### Innervation

The Adductor mandibulae : All the parts of this muscle are innervated by the Maxillo-mandibularis branch of the Vth nerve. In addition to this, some branches arising from the Hyomandibularis of the VIIth nerve are also given off to this muscle or one or more of its parts.

The Levator arcus palatini : This muscle is innervated by the Maxillo-mandibularis branch of the Vth nerve.

The Adductor hyomandibula : Both the parts of this muscle viz. the Adductor arcus palatini and the Extensor(es) tentaculi when present, are innervated by the Hyomandibularis branch of the VIIth nerve.

The following is a description of the levator muscles of the lower jaw in the fishes investigated :

Callichrous

The Adductor mandibulae : The Maxillaris part of this muscle is not present in this fish and the Mandibularis (Fig.14) remains single as a thick mass. Besides its origin from the hyomandibula and preopercle bones, the origin also extends anteriorly on the frontal and pterotic bones of the cranium. It becomes narrow as it passes downwards and slightly forwards. It gains a slightly tendinous insertion on the hind portion of the mandible.

The Levator arcus palatini : This muscle (Fig.15) is almost completely covered by the Mandibularis. It arises from the pterotic and sphenotic bones. Towards the origin, it is broad and becomes narrow as it passes downwards to be inserted on the hyomandibula and pterygoid bones.

The Adductor hyomandibula : This muscle is differentiated into the Extensores tentaculi and the Adductor arcus palatini muscles. Of these, the Extensores tentaculi (Figs.14 & 15) arise from the ventral surface of the post-frontal and consist of a superior and an inferior part. They run forwards and their insertions are on the base of the barbel in such a way that the insertion of the former part is above that of the latter. The Adductor arcus palatini (Fig.15) muscle arises from the parasphenoid and prootic bones behind the Extensores tentaculi. It is a fan shaped muscle becoming narrow towards the insertion which is on the pterygoid extending as far as the upper border of the quadrate.



M.s.s. - M. superficialis superficialis; MX. - Maxilla; Mx. - Maxillaris; NAS. - Nasal; NPTG. - Endopterygoid; OP. - Opercle; OPS. - Opisthosphenoid; PAR. - Parietal; PAS. - Parasphenoid; PMX. - Premaxilla; POP. - Preopercle; PRO. - Prootic; PST. - Posttemporal; PTC. - Pterotic; PTFR. - Postfrontal; PTG. - Pterygoid; RART. - Retroarticular; Q. - Quadrate; SOC. - Supraoccipital; SOP. - Subopercle; SP. or SPH. - Sphenotic; STMP. - Supratemporal; SYM. - Symplectic; T. - Tendon.

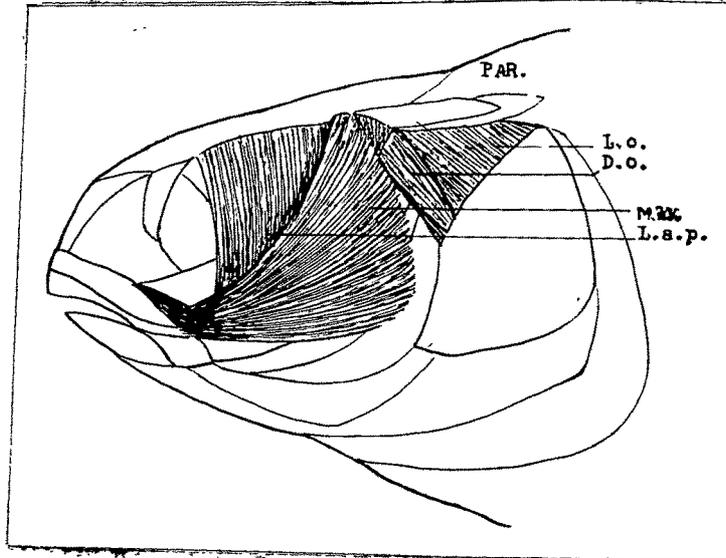


Fig. 16.  
Without A.o. muscle.

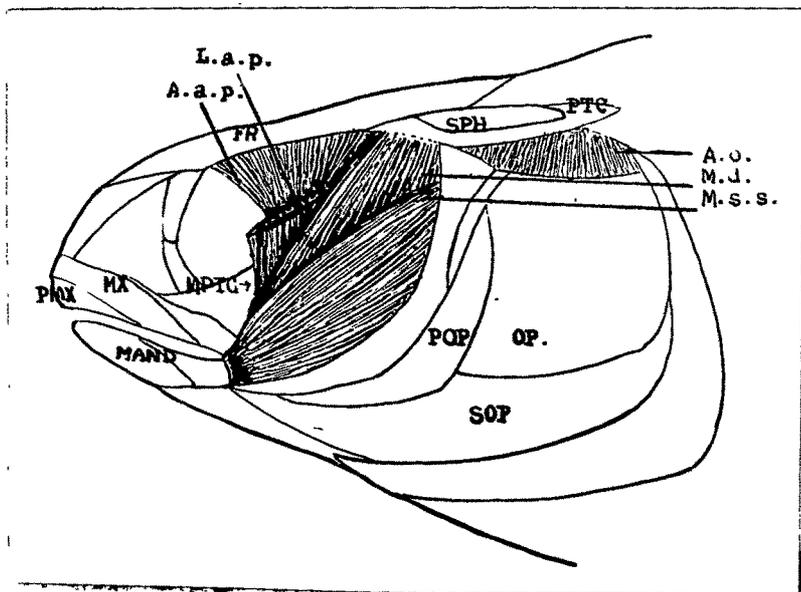


Fig. 17.  
After removal of superficially disposed muscles.

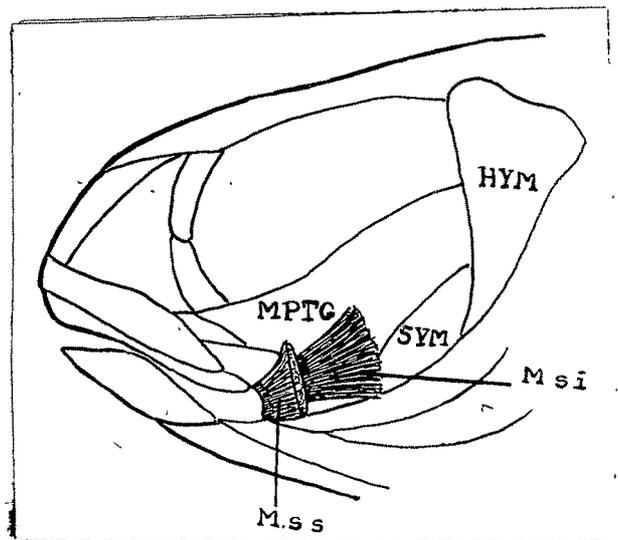


Fig. 18.  
Mandibular superficial muscles.

Figs. 16-18. Barbus. Levator muscles of the jaw and the opercular muscles.

Barbus

The Adductor mandibulae : The muscle is divided in this fish into three main parts viz. the Maxillaris, the Mandibularis superficialis and the Mandibularis profundus. The Maxillaris of these (Fig.16) arises from the hyomandibula, preopercle, symplectic, quadrate and metapterygoid bones and becomes narrow as it passes forwards and downwards to be inserted by a tendinous ribbon on the maxilla along the dorsal border and the inner surface. The Mandibularis superficialis muscle (Figs.17 & 18) is divided into a superficial and a deep part. The former forms the main mass of the muscle. It arises from the hyomandibula and symplectic bones. The latter arises from the metapterygoid, symplectic and quadrate and is covered by the superficialis. These two parts join anteriorly and gain a common tendinous insertion on the postero-dorsal margin of the inner surface of the mandible. The Mandibularis profundus muscle (Fig.18) extends dorsally upto the skull. Its origin is from the hyomandibula and metapterygoid bones. Its middle and lower portions are covered by the superior part of the Mandibularis superficialis muscle. Anteriorly it is provided with a ribbon shaped tendon which is inserted on postero-dorsal portion of the mandible viz. the articulare, internal to the insertion of the superficialis muscle.

The Levator arcus palatini : The postero-ventral portion of this muscle is covered by the Maxillaris and the Mandibularis

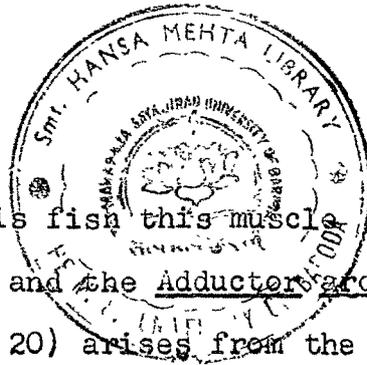
profundus muscles. It (Figs.16 & 17) arises from the frontal and hyomandibula, and descends downwards on the metapterygoid bone on which it is inserted.

The Adductor hyomandibula : This muscle is represented by the Adductor arcus palatini muscle (Fig.17). It arises from the parasphenoid and is inserted on the anterior surface of the hyomandibula and metapterygoid bones.

### Macrones

The Adductor mandibulae : The Maxillaris part of this muscle is not represented in this fish. Both the superficialis and profundus parts of the Mandibularis are however represented (Fig.19). Of these, the Mandibularis superficialis, arises from the hyomandibula, pterygoid and quadrate bones. It passes forwards and downwards and has a blunt tendinous insertion on the tip of the mandible. The Mandibularis profundus muscle arises from the postfrontal, hyomandibula and the preopercle bones internal to and internal and above the origin of the Mandibularis superficialis. Anteriorly it is provided with a quadrangular piece of tendon which is inserted on the mandible below and internal to the insertion of the M.superficialis muscle.

The Levator arcus palatini : This muscle (Fig.19) arises as usual behind the orbit from the postfrontal and hyomandibula bones. It becomes narrow towards the insertion which is well spread on the hyomandibula and inserted on the postero-dorsal portion of the pterygoid bones. This muscle is partly covered by the M.profundus.



The Adductor hyomandibula : In this fish this muscle is represented by the Extensor tentaculi and the Adductor arcus palatini. The former of these (Figs.19 & 20) arises from the

Fig.19. After removal of L.o. muscle.

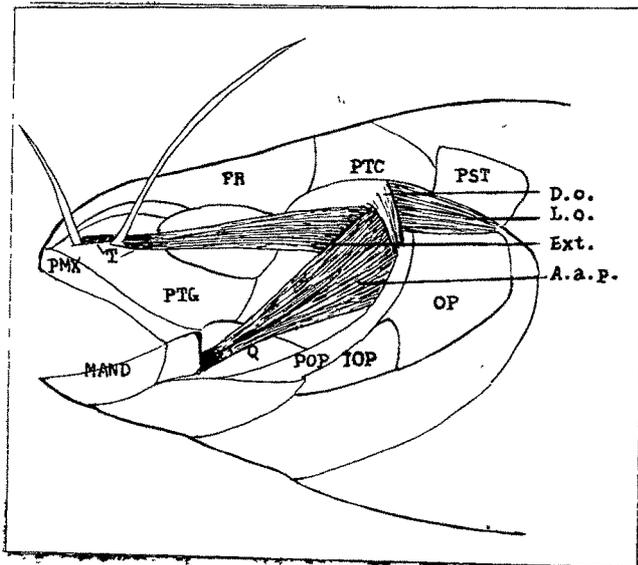
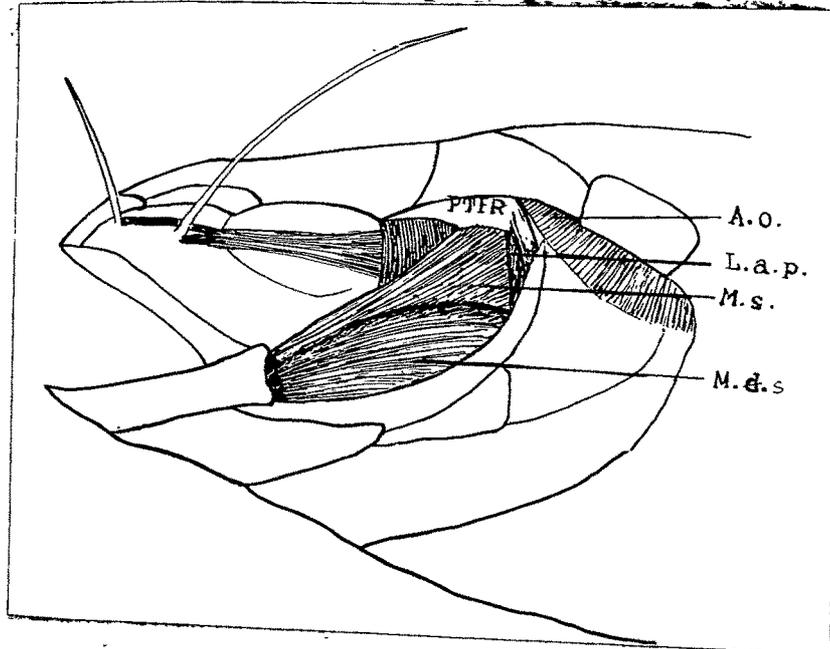


Fig.20. After removal of some superficially disposed muscles.

Figs.19-20. Macrones. Levator muscles of the jaw and the opercular muscles.

postfrontal and hyomandibula bones. It becomes narrow as it passes forwards and anteriorly it is provided with two tendinous ribbon-shaped structures. Each of these is inserted respectively on the base of one of the maxillary barbels. The Adductor arcus palatini muscle (Fig.20) is a triangular shaped muscle which arises from the prootic, hyomandibula and the preopercle bones. Towards the insertion it forms two fasciculi both of which are attached anteriorly with a thick tendinous ribbon, inserted on the quadrate bone.

Notopterus

The Adductor mandibulae is represented by a single Mandibularis muscle (Fig.21). It arises from a portion of the

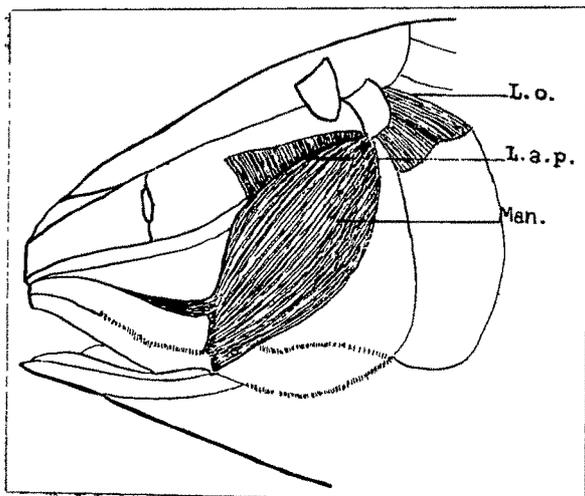


Fig.21.  
D.o. muscle not shown.

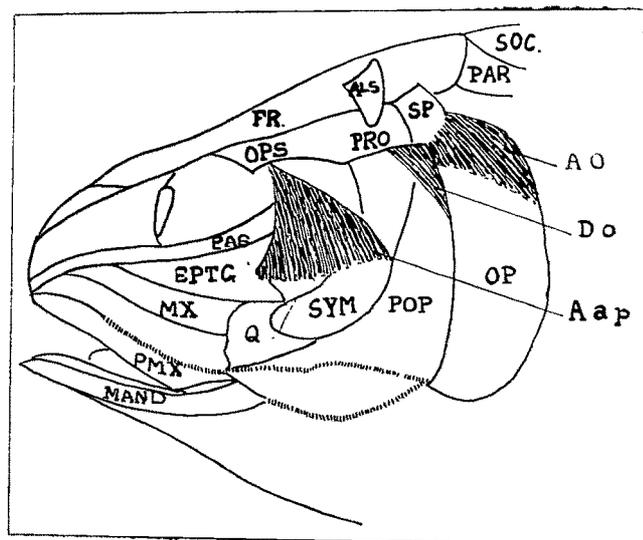


Fig.22.  
After removal of some superficially disposed muscles.

Figs.21-22. Notopterus. Levator muscles of the jaw and the opercular muscles.

prootic, hyomandibula, preopercle, symplectic, metapterygoid and ectopterygoid bones. It forms a thick sheet of muscle with a broad belly becoming slightly narrow as it passes forwards and downwards towards the insertion which is partly tendinous and partly fleshy. The dorsal portion which is tendinous, is inserted along the upper and inner border of the maxilla whereas the fleshy portion is inserted on the posterior edge of the mandible.

The Levator arcus palatini : This muscle (Fig.21) arises from the sphenotic, the lower edges of the opisthotic, prootic and hyomandibula bones. It has a fleshy insertion on the metapterygoid and ectopterygoid bones.

The Adductor hyomandibula : This muscle is represented by a single Adductor arcus palatini muscle (Fig.22). It has a fleshy origin from the parasphenoid, becomes broader as it passes downwards and backwards to be inserted on the ectopterygoid metapterygoid, symplectic and hyomandibula bones.

### Ophichthys

The Adductor mandibulae is divided in this fish into the Maxillaris and a single Mandibularis. The Maxillaris of these (Fig.23) is peculiar in the sense that it is practically devoid of muscle fibres. It is in the form of a thin rectangular tendinous ribbon. It arises from the inner angle of the preopercle bone, passes forwards and is inserted on the inner surface of the posterior edge of the maxilla. The Mandibularis

(Fig.23) is well developed and extends dorsally so as to meet its fellow of the opposite side. The main mass of the muscle

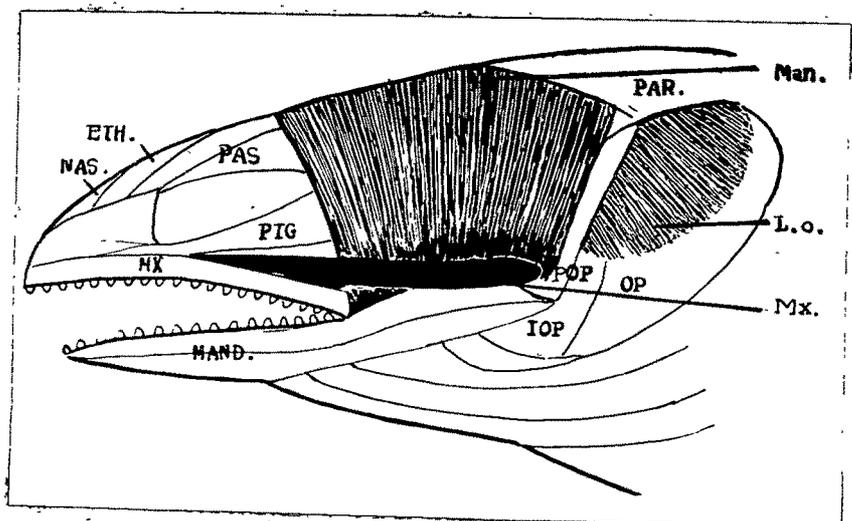
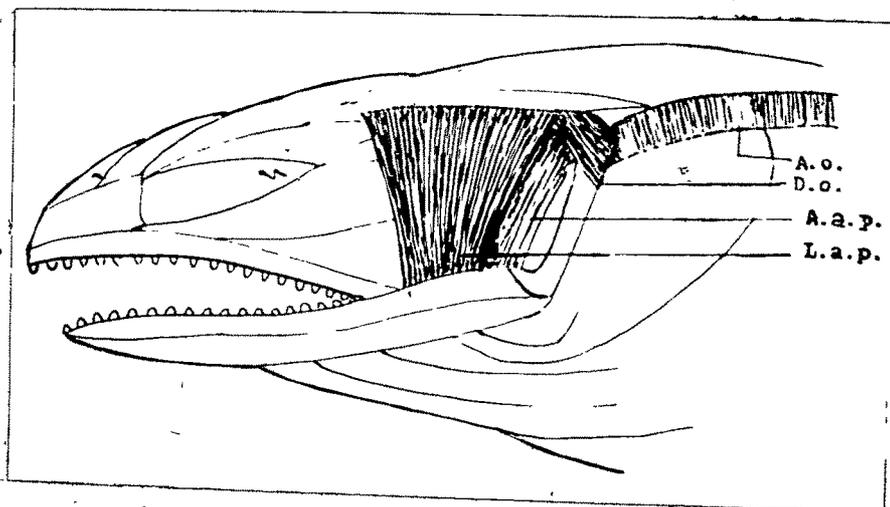


Fig.23.  
A.o. and D.o.  
muscles not shown.

Fig.24.  
After removal  
of some super-  
-ficially  
disposed muscles.



Figs.23-24. Ophichthys. Levator muscles of the jaw and the opercular muscles.

however, arises from preopercle, hyomandibula and quadrate bones and passes downwards and forwards to gain a tendinous insertion along the inner and upper surfaces of the mandible.

The Levator arcus palatini : This muscle (Fig.24) has

a thick fleshy origin from the postfrontal, parietal and pterotic bones, and running downwards as far as mandible to gain insertion on the pterygoid and hyomandibula.

The Adductor hyomandibula remains single and is represented by the Adductor arcus palatini. It arises (Fig.24) from the prootic internal to the origin of the Levator arcus palatini and the parasphenoid bones. It runs downwards and gains a fleshy insertion on the pterygoid.

#### Ophiocephalus

The Adductor mandibulae is divided into all its three usual parts. Of these, the Maxillaris is further divided into an upper Maxillaris superioris and a lower Maxillaris inferioris. This Maxillaris (Fig.25) arises from the sphenotic, pterotic, preopercle and hyomandibula bones. The superioris part is inserted on the postero-dorsal portion of the maxilla whereas the inferioris one on the posterior tip of the mandible. The Mandibularis superficialis (Figs.26 & 27) is also divided in this fish into a superioris and an inferioris part. Both the parts are situated below and the upper part also internal to the Maxillaris. The former arises from the preopercle, hyomandibula and metapterygoid bones and the latter from the hyomandibula and metapterygoid. They join anteriorly and have a common tendinous insertion on the hind tip of the mandible. The Mandibularis profundus which remains single (Fig.27) arises from the symplectic and quadrate bones and is inserted by a thin tendon on the posterior portion of the inner surface of the mandible.

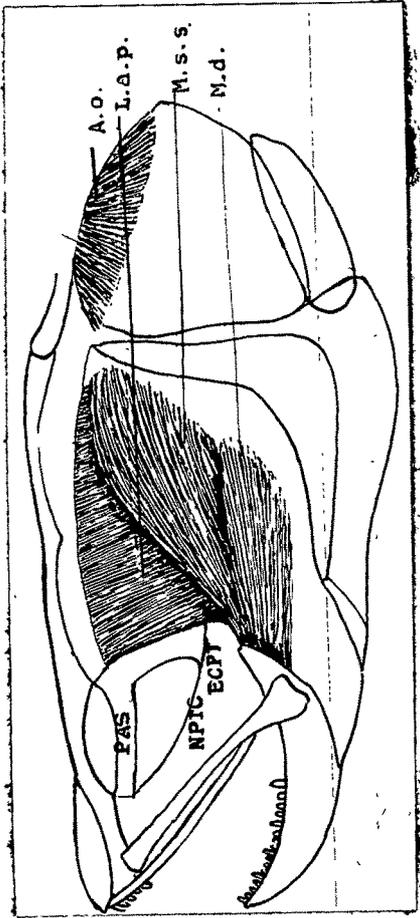


Fig.27. After removal of some superficial muscles.

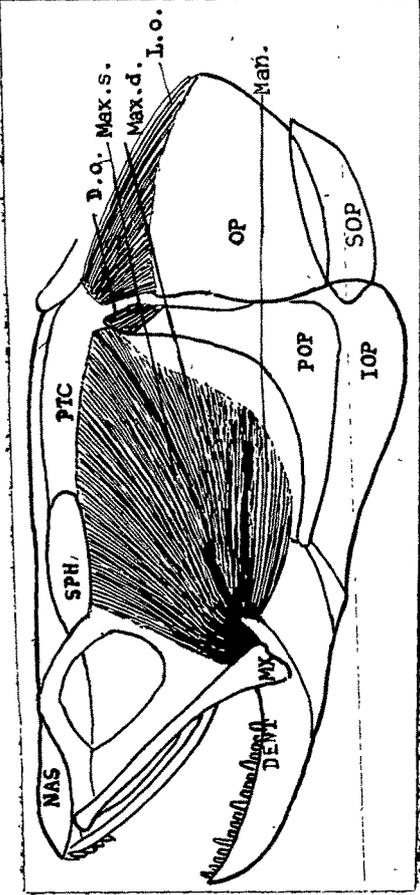


Fig.25.

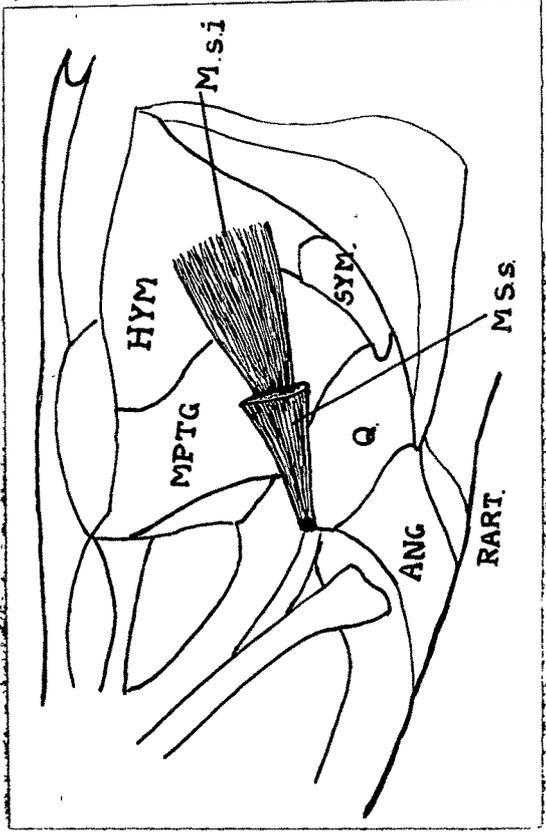


Fig.26. Mandibular superficial muscle.

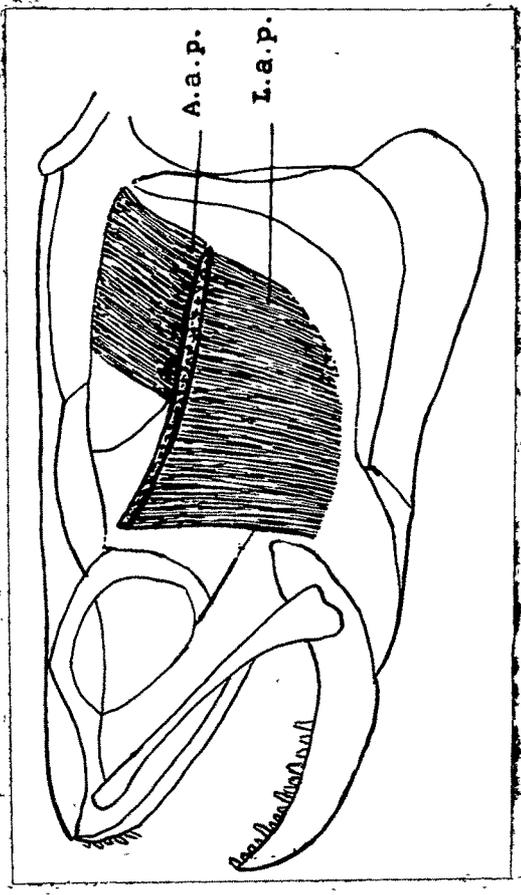


Fig.28. L.a.p. and A.a.p. muscles.

Figs.25-28. Ophiocephalus. Levator muscles of the jaw and the opercular muscles.

The Levator arcus palatini (Fig.28) which is completely covered by the Adductor mandibulae arises from the frontal, sphenotic and pterotic bones, extends downwards and is inserted on metapterygoid and hyomandibula bones.

The Adductor hyomandibula is represented by the Adductor arcus palatini (Fig.28) which arises internal to the origin of the Levator arcus palatini from the pterotic. Its insertion is situated on the hyomandibula, metapterygoid and quadrate bones internal to the insertion of the Levator arcus palatini.

#### Osphronemus

The Adductor mandibulae in this fish also is represented by all the three parts. The Maxillaris (Figs.29 & 30) of these is further divided into a superficialis and a profundus part. The superficialis part arises from the hyomandibula, symplectic and the basal portion of the preopercle bone. The Maxillaris profundus is the smaller of the two and arises from the symplectic. It is completely covered by the superficialis. These two parts join anteriorly to gain a common tendinous insertion on the premaxilla along the inner and dorsal portion of its surface. The Mandibularis superficialis (Fig.29) arises from the preopercle, hyomandibula, and metapterygoid bones, its lower border being covered by the Maxillaris. Towards the insertion it is joined by the Mandibularis profundus (Fig.31) which arises from the quadrate and the symplectic and gets inserted by a common ribbon like tendon. Another muscle known as the Intramandibularis

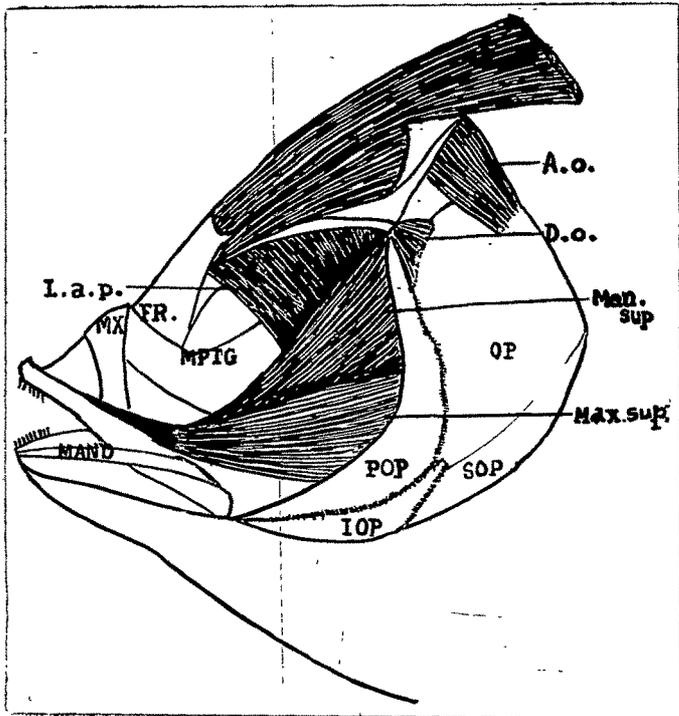


Fig.29. L.o. muscle not shown.

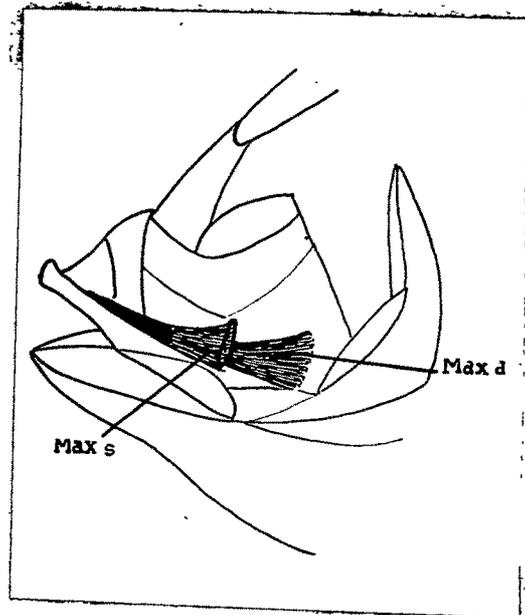


Fig.30. The Maxillaris muscle.

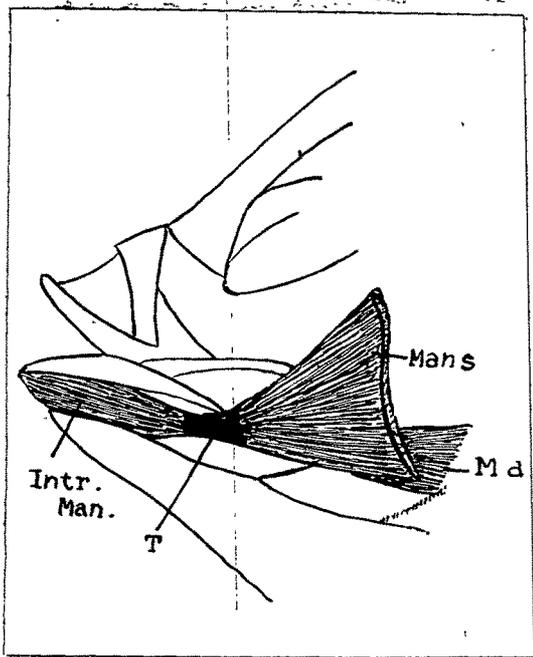


Fig.31. Mandibular and intra-mandibular muscles.

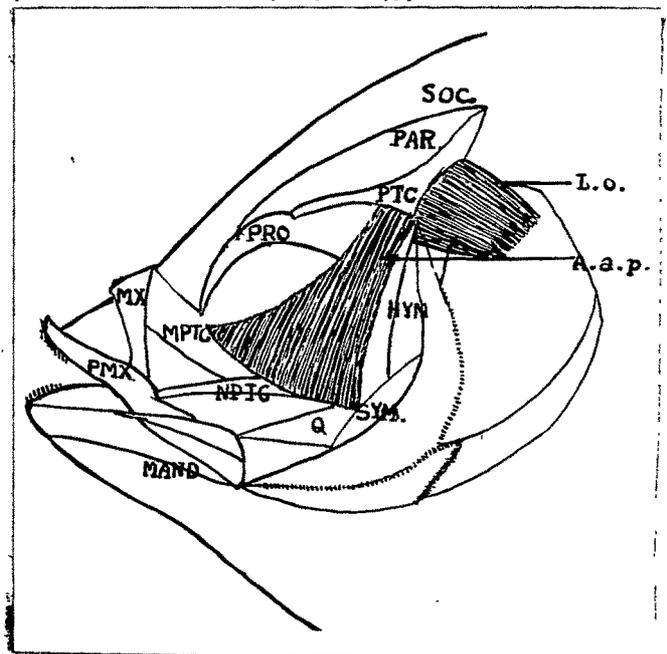


Fig.32. After removal of some superficial muscles.

Figs.29-32. Osphronemus. Levator muscles of the jaw and the opercular muscles.

(Fig.31) arises from the anterior end of this tendon. This muscle runs along the inner surface of the mandible on which it is finally inserted.

The Levator arcus palatini arises behind and above the orbit from frontal, prootic and pterotic bones (Fig.29). It becomes narrow as it passes downwards and backwards and has its insertion on the metapterygoid and hyomandibula bones.

The Adductor hyomandibula : It is represented by the Adductor arcus palatini (Fig.32) which arises from the pterotic and becomes broader as it passes downwards to be inserted on the hyomandibula, metapterygoid, endopterygoid and the quadrate.

#### Boleopthalmus

The Adductor mandibulae : This muscle is divided into a Maxillaris and a single Mandibularis. Of these, the Maxillaris (Fig.33) arises partly from the frontal just below its median ridge. Anteriorly the muscle arises immediately behind the supraorbital bones of the orbit. As it passes downwards it is split into two fasciculi, an anterior and a posterior. The anterior fasciculus has a broad base which is inserted on the upper border of the maxilla, while the posterior becomes narrow as it passes downwards to gain a tendinous cord-like insertion on the postero-dorsal portion of the mandible. The main mass of the Mandibularis (Fig.33) is situated immediately behind the Maxillaris. Its dorsal fibres extend as far as the frontal. Laterally it arises from the preopercle, hyomandibula, symplectic and the

quadrate. Its fibres pass downwards and forwards and the muscle becomes slightly narrow and tendinous to gain insertion on the mandible.

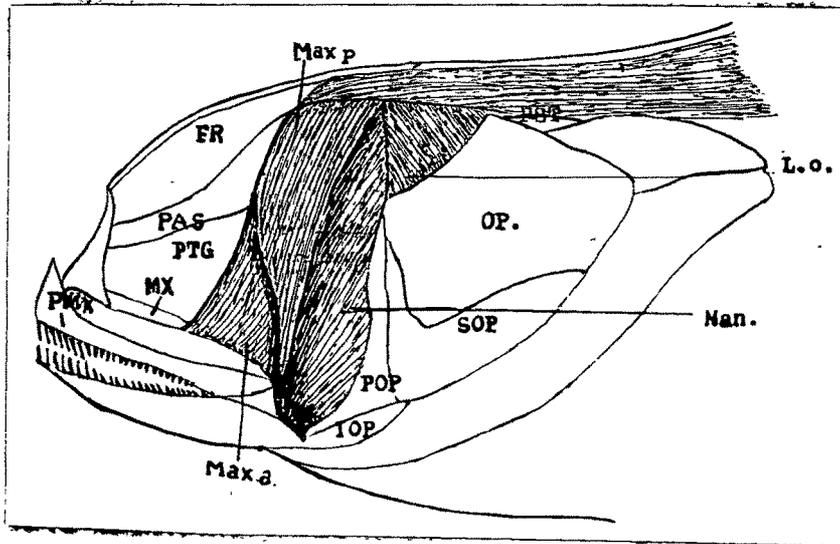
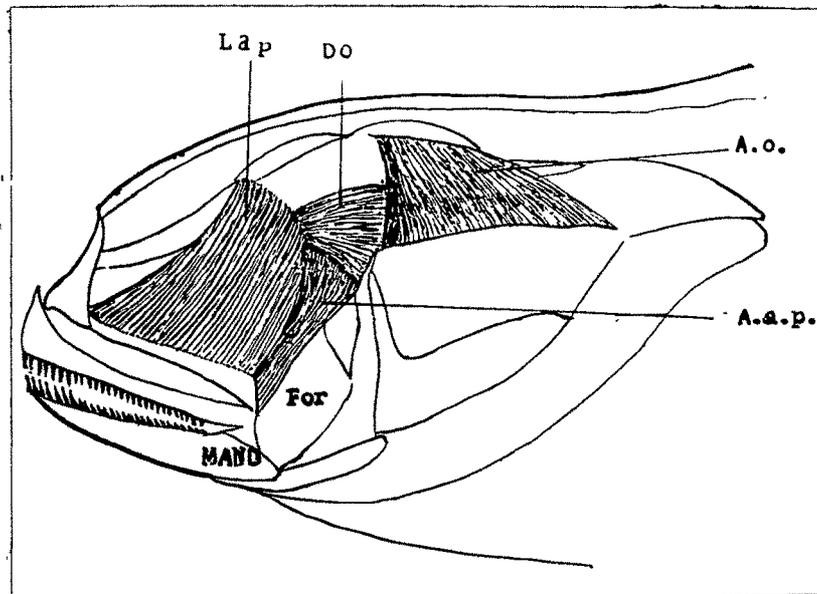


Fig. 33.  
A.o. muscle  
not shown.

Fig.34. After  
removal of super-  
ficially disposed  
muscles.



Figs.33-34. Boleopthalmus. Levator muscles of the jaw and the opercular muscles.

The Levator arcus palatini arises from the parasphenoid and the lower border of the sphenotic and hyomandibula (Fig.34).

It passes downwards and forwards towards the maxilla and premaxilla and is inserted on the pterygoid and quadrate bones.

The Adductor hyomandibula is represented by a single Adductor arcus palatini (Fig.34). It arises from parasphenoid, hyomandibula and symplectic in such a way that its anterior portion remains covered by the Levator arcus palatini. The insertion is on the pterygoid and the symplectic.

(It may be mentioned here that a muscle (Fig.33) hitherto unreported consisting of two fasciculi arises from the supraorbital bones, passes backwards and is inserted partly on the base of the first ray of the dorsal fin and partly on the myotomes with which it becomes continuous. However, it is in no way connected with respiratory movements of the fish.)

#### Mastecembalus

The Adductor mandibulae in this fish is represented by a Maxillaris and a single Mandibularis. The Maxillaris (Fig.35) arises from the inner angle of the preopercle, as well as the symplectic and quadrate bones. It passes forwards to become a thick tendon by which it is inserted practically along the entire inner surface of the maxilla and premaxilla. The Mandibularis (Fig.35) arises from the pterotic, sphenotic, hyomandibula and pterygoid bones. Its lower fibres are covered by the Maxillaris. The insertion is on the posterior portion of the mandible, just internal to the tendon of the Maxillaris.

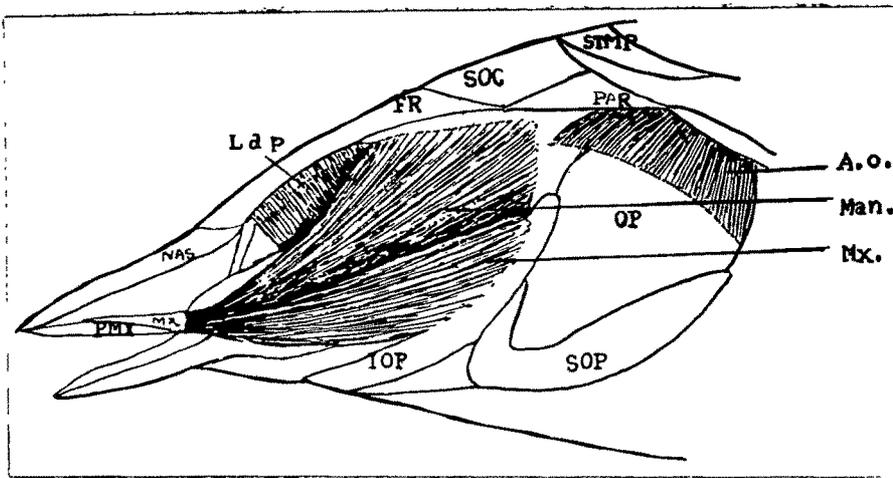


Fig. 35.  
D.o. and L.o.  
muscles not  
shown.

Fig. 36. After  
removal of some  
superficial  
muscles.

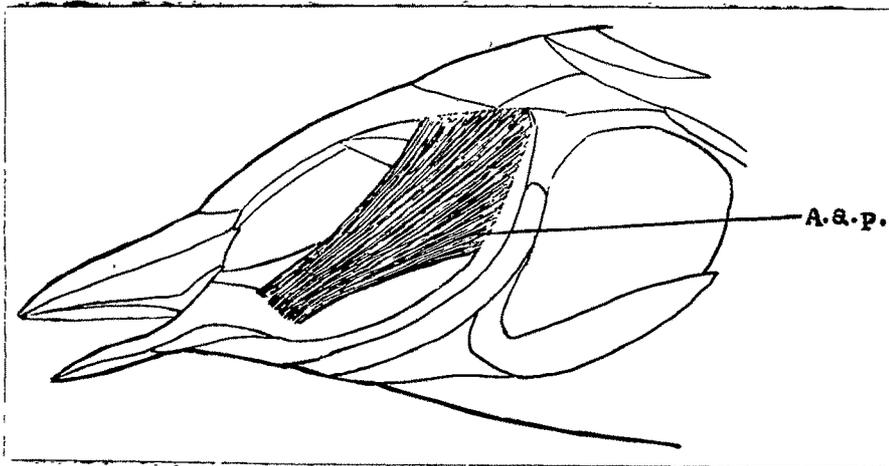
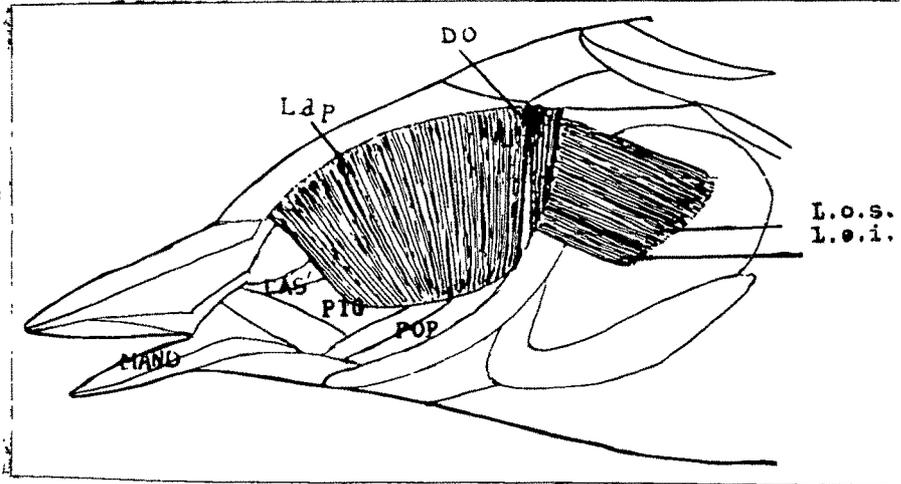


Fig. 37.  
A.a.p. muscle.

Figs. 35-37. Mastecembalus. Levator muscles of the jaw and the opercular muscles.

The Levator arcus palatini is a well developed muscle (Fig.36) and is practically covered by the Adductor mandibulae except its antero-dorsal portion. Its origin is from the frontal, pterotic, sphenotic, parasphenoid, and hyomandibula bones and the insertion on the quadrate, symplectic and preopercle bones.

The Adductor hyomandibula is represented by a single Adductor arcus palatini (Fig.37). Arising from the parasphenoid, hyomandibula and the pterotic, it gains insertion on the pterygoid and quadrate bones.

#### Discussion

The Adductor mandibulae : It is a single muscle in Callichrous and Notopterus. In these as well as Macrones, the Maxillaris part is not present. In all other fishes investigated both the Maxillaris and the Mandibularis parts are represented. The Maxillaris is further split into two parts in Ophiocephalus and Osphronemus. These parts develop as superior and inferior ones in the former, whereas in the latter they form a superficial and a deep part. In Boleopthalmus, the Maxillaris arises as a single muscle towards its origin. Towards the insertion however it is divided into two fasciculi, an anterior and a posterior. In Ophichthys it is represented by a ribbon shaped tendon. In Ophiocephalus and Boleopthalmus only one fasciculus is inserted on the maxilla, the other one being inserted on the mandible.

The Mandibularis remains single in Callichrous, Notopterus, Ophichthys, Boleopthalmus and Mastecembalus. In others, it is split into a superficialis part and a profundus one. In Ophiocephalus, the superficialis part is further split into a superficial and a deep part. In one fish viz. Osphronemus, both the parts of the Mandibularis possess anteriorly an intermediate tendon from which another muscle known as the Intramandibularis arises. The latter muscle passes forwards to be inserted on the mandible.

The Levator arcus palatini is present in all the fishes examined. The insertion of this muscle is usually on the elements formed by the palato-pterygo-quadrate bar in Barbus, Notopterus and Boleopthalmus. In others the insertion is on these elements as well as the hyomandibula. These elements are the immovable elements of the skull and as such the muscle does not take an active part in elevating the lower jaw.

The Adductor hyomandibula : In all the fishes examined except Callichrous and Macrones it is represented by a single Adductor arcus palatini. In the last two fishes, the muscle splits further to form the Extensor(es) tentaculi in addition to the Adductor arcus palatini. In Callichrous, the Extensores tentaculi consist throughout of two parts viz. an upper and a lower. In Macrones, the Extensor arises as a single muscle and towards insertion, is provided with two ribbon shaped tendons. The insertion of the Extensor(es) tentaculi is on the base of

the barbels. The Adductor arcus palatini is inserted internal to that of the Levator arcus palatini muscle on the elements formed by the palato-pterygo-quadrata bar in Macrones, Notopterus, Ophichthys, and Mastecembalus. In other fishes the insertion is on these elements as well as the hyomandibula.

## II. THE OPERCULARIS GROUP

The following are the muscles which comprise this group viz. (i) the Dilatator operculi, (ii) the Levator operculi and (iii) the Adductor operculi.

Like the Levator arcus palatini, the Dilatator operculi is also derived from the Constrictor mandibularis dorsalis and lies immediately behind the levator muscle. The Levator operculi and the Adductor operculi are formed by the division of the Hyoid operculi (Edgeworth-1935).

The Dilatator operculi arises usually immediately behind the Levator arcus palatini, from the lateral and/or ventral bones of the cranium. In some forms, it also arises from the hyomandibular bones. In only one form the origin was also from the preopercle.

It runs backwards and usually downwards and the insertion is on the dorsal and upper surface of the preopercle and/or the opercle bones of the operculum. The Levator operculi arises usually from one or more of the following bones viz. pterotic,

sphenotic, hyomandibula and in few forms also from frontal, parasphenoid and the preopercle. The insertion is usually on the opercle along its inner surface. The origin of the Adductor operculi is usually from the cranial bones situated above the operculum. The muscle runs downwards and the insertion is usually on the dorsal and inner surface of the opercle, internal to the insertion of the Levator operculi.

These muscles are developed in all the fishes examined and the origin as well as the insertion of all the muscles is fleshy.

Functionally these muscles can be divided into two groups, viz. the Dilators and the Constrictors of the opercular slits. The Dilatator and the Levator operculi belong to the former group. They raise up the operculum whereby the opercular slit widens. This enables the water and/or air that might have entered into the branchial chamber to escape to the outside. The Adductor operculi on the other hand serves as a constrictor muscle. By its contraction, the operculum comes in close contact with the body and the opercular slit is closed. This results in the water and/or air that might have entered from the pharyngeal chamber being retained there.

#### Innervation

The Dilatator operculi : The same branch which innervates the Levator arcus palatini (i.e. the Maxillo-mandibularis branch of the Vth nerve) innervates this muscle also.

Both the Levator and the Adductor operculi are innervated by the Hyomandibularis branch of the Vth nerve.

It might be mentioned here that some branchial muscles such as the Hyohyoideus superior and the Coracohyoideus also function to a certain extent as dilators or constrictors of the opercular slits. The role played by these muscles is discussed elsewhere.

#### The Dilatator operculi

In Callichrous, it is a poorly developed muscle arising partly from the pterotic and partly from the postero-dorsal border of the hyomandibula. The insertion is on the tip of the preopercle and the antero-dorsal corner of the opercle bone (Fig.14).

In Barbus : Dorsally it arises from the pterotic and laterally from the hyomandibula. It passes downwards and backwards and the insertion is on the dorsal tip of the preopercle and the antero-dorsal corner of the opercle bone (Fig.16).

In Macrones : It arises (Fig.20) from the postfrontal and the hyomandibula bones and the insertion is on the dorsal tip of the preopercle.

In Notopterus, it arises (Fig.22) from the ventral border of the prootic, sphenotic and also from a portion of the hyomandibula bone situated immediately below. The muscle runs

downwards and backwards and has an insertion on the dorsal and outer border of the preopercle.

In Ophichthys : The origin is from the antero-ventral edge of the parietal and the hyomandibula. The insertion is on the postero-dorsal tip of the preopercle (Fig.24).

In Ophiocephalus : It is poorly developed in this fish (Fig.25). The origin is from the postero-ventral edge of the pterotic and the hyomandibula. It runs backward to be inserted on the dorsal tip of the preopercle.

In Osphronemus : The muscle (Fig.29) arises mostly from the ventral extremity of the pterotic, the postero-dorsal border of the hyomandibula and the preopercle. The insertion is on a portion of the antero-dorsal border of the opercle situated immediately behind the origin.

In Boleophthalmus, it (Fig.34) is well developed and arises from the sphenotic and hyomandibula and becomes broader as it passes backwards. The insertion is on the antero-dorsal border of the preopercle and the adjoining portion of the opercle.

In Mastecembalus : It (Fig.36) arises from the pterotic, parasphenoid and hyomandibula from where it descends downwards. It is inserted along the antero-dorsal border of the preopercle.

The Levator operculi

In Callichrous : It (Fig.14) is poorly developed. Its origin is partly from the pterotic, the posttemporal and hyomandibula. It becomes narrow as it passes downwards and backwards and is inserted on the antero-dorsal angle of the opercle.

In Barbus : It (Fig.16) is well developed. Arising partly from the pterotic and partly from the hyomandibula, it is well spread on the opercle on which it is inserted. Dorsally the insertion extends along its entire upper border and anteriorly along the upper half of its border.

In Macrones : Here, the origin is similar to that in Barbus, but the insertion is only along the dorsal border of the opercle (Fig.20).

In Notopterus : Here the muscle (Fig.21) arises from the pterotic. As it passes downwards, however, it divides into two fasciculi. The upper fasciculus is inserted along the dorsal border of the opercle whereas the lower one also on the opercle immediately below the insertion of the former.

In Ophichthys : It arises anteriorly from the preopercle, whereas dorsally it arises partly from the parietal and partly from the ventral portion of the otic (Fig.23). The insertion is on the dorsal tip of the interopercle as well as most of the upper and inner surface of the opercle.

In Ophiocephalus : This muscle arises (Fig.25) from the posterior border of the pterotic and is inserted along the dorsal border of the opercle.

In Osphronemus, its upper fibres arise from the pterotic while the lower ones from the preopercle (Fig.32). It runs backwards and downwards and is inserted on the opercle.

In Boleophthalmus : Arising partly from the pterotic and partly from the hyomandibula (Fig.33), it is inserted along antero-dorsal surface of the opercle.

In Mastecembalus, this muscle (Fig.36) is divided into two fasciculi, a superior and an inferior one. The superior one arises partly from the pterotic, partly from the hyomandibula and partly from the preopercle. The insertion is along the antero-dorsal surface of the opercle. The inferior fasciculus arises from the preopercle. Its upper border is continuous with the lower border of the superior. The insertion is on the opercle.

#### The Adductor operculi

In Callichrous : Here the muscle (Fig.15) arises from the postfrontal and the posttemporal, runs downwards and is inserted on the upper portion of the opercle.

In Barbus, it arises (Fig.17) from the lower border of pterotic and opisthotic to gain insertion on the inner surface of the dorsal portion of the opercle.

In Macrones, the origin is similar to that in Callichrous, the insertion being on the inner surface of the dorsal border of the opercle and the adjoining membranous portion of the operculum (Fig.19).

In Notopterus, it arises from the sphenotic and the pterotic. It has the usual insertion on the opercle (Fig.22).

In Ophichthys, this muscle is best developed (Fig.24). Here the opercular bones support only the anterior quarter to one third of the operculum, whereas the rest of the portion is supported by the branchiostegal rays which extend upwards almost reaching the vertebral column. Consequently the origin is not only from the ventral surface of the hind portion of the cranium, but also from the vertebral column. The muscle fibres pass directly downwards and gain insertion on the upper surface of the opercle as well as the dorsal border of the membranous portion of the operculum which is supported by the branchiostegal rays.

In Ophiocephalus : Here the muscle (Fig.27) arises from the pterotic and supratemporal bones. Its fibres run downwards and the insertion is on the opercle as usual.

In Osphronemus : The origin of the muscle in this fish is from the pterotic above and internal to the origin of the Levator operculi. It runs downwards and backwards and is inserted on the postero-dorsal portion of the opercle (Fig.29).

In Boleopthalmus, it (Fig.34) is well represented. It arises from the pterotic and posttemporal bones and inserted on the upper half of the inner surface of the opercle.

In Mastecembalus : The muscle (Fig.35) arises from the parietal and the epiotic. It runs downwards and forwards and is inserted on the opercle and a posteró-dorsal portion of the hyomandibula.

### Discussion

The Dilatator operculi : This muscle is fairly developed in all the fishes examined and arises behind the Levator arcus palatini. Its origin is restricted to the cranial bones and hyomandibula in all the fishes except Osphronemus where it extends also on the dorsal tip of the preopercle. The insertion is on the preopercle only in Macrones, Notopterus, Ophichthys, Ophiocephalus and Mastecembalus. In Callichrous, Barbus and Boleopthalmus, the insertion is on the preopercle as well as the antero-dorsal border of the opercle. In Osphronemus, this insertion is on the opercle only.

The Levator operculi : In Callichrous, Barbus, Macrones, Boleopthalmus and Mastecembalus, this muscle arises from the cranial bones as well as the hyomandibula. In Mastecembalus, this muscle is further divided into a superior and an inferior fasciculus. In Notopterus, the origin is restricted to the cranial bones only. In other fishes viz. Ophichthys and Osphronemus,

the muscle arises from cranial bones as well as the dorsal tip of the preopercle. In Ophiocephalus, the origin is restricted to the cranium only. The insertion of this muscle is restricted to the antero-dorsal portion of the opercle bone in Callichrous, Osphronemus, Boleopthalmus and Mastecembalus. In other fishes i.e. Barbus, Macrones, Notopterus, Ophichthys and Ophiocephalus, the insertion is spread practically along the entire dorsal border of the opercle.

The Adductor operculi : This muscle arises from the cranial bones directly internal to, as well as behind the Levator operculi. The insertion is on the opercle extending along its entire dorsal border except in Osphronemus, where it occupies only the anterior portion of this border. In Ophichthys, the insertion also extends on to the membranous portion of the operculum behind the opercle, where the operculum is supported by the upwardly directed branchiostegal rays.

### III. THE BRANCHIALIS GROUP

These are the muscles associated with the branchial bars. They form two series of muscles viz. the dilators and the constrictors of the gill openings (branchial slits) and are situated in between the branchial bars. The constrictor series of muscles bring about the closure of the gill opening, the dilator series on the other hand bring about the dilation of the gill openings. Based on their position the branchial muscles could be divided into two main groups :

A. Dorsal series of muscles comprising:

1. The Transversi dorsales
2. The Levatores arcuum branchialium
3. The Obliqui dorsales superioris
4. The Obliqui dorsales inferioris
5. The Retractores arcuum branchialium
6. The Attractores arcuum branchialium.

B. Ventral series of muscles comprising:

1. The Transversi ventrales
2. The Subarcuales recti
3. The Coraco-branchialis
4. The Coraco-hyoideus of the Hypobranchial muscle.

Dorsal series of branchial muscles

The Transversi dorsales : These muscles are formed of the Sphinctor oesophagi. They are however closely associated with the dorsal portion of the branchial bars. If present, they run transversely and usually connect some or all the pharyngobranchials with their fellows of the opposite side. A single Transversus is usually present and it may remain single or is divided into an anterior and a posterior part. Posteriorly this muscle becomes partly or completely continuous with the antero-dorsal portion of the Sphinctor oesophagi.

By contraction the muscle pulls up the branchial bars resulting in the gill slits becoming narrow.

The Levatores arcuum branchialium : They are present in all the fishes examined, and more usually their number is four. In some fishes however only three of them are present and still in some others the number is five. Fifth muscle if present, is named as the Trapezius profundus by Takahasi (1925). The first two muscles are more or less completely divided into an external and an internal fasciculus. All these muscles have a fleshy origin usually from the otic region of the cranium one behind the other. In some, the origin may extend on hyomandibula also. The internal fasciculi however lie internal to their external counterparts. These muscles run downwards and backwards. The insertions of the external fasciculi of the 1st and the 2nd muscles and the insertions of the 3rd and the 4th muscles, all of which are fleshy, are situated usually on the dorsal surfaces of the 1st, 2nd, 3rd and the 4th branchial bars usually on the epibranchials or cerato-branchials. The insertion of the 5th muscle which, when present, is also fleshy, is on the dorsal side of the 5th ceratobranchial behind the insertion of the 4th muscle. The insertions of the internal fasciculi are usually on the pharyngobranchials. Mention may be made here of a muscle known as the cephalo-clavicularis which according to Edgeworth, is probably the 5th Levator arcus branchialis that has changed its insertion on to the pectoral girdle. Further, according to him the Cephalo-clavicularis is found only in those fishes where the 5th muscle is not observed.

Due to the contraction of these muscles the branchial arches tend to become straight as a result of which the gill openings are closed.

The Obliqui dorsales superioris : Only one muscle which may remain single or divided into two or more parts, is usually present. The origin which is fleshy is on the pharyngobranchials only or also on the pharyngeal wall immediately behind them. Each part runs backwards and outwards and is inserted variously usually on epibranchials. In either case the insertion is partly dorsal and partly internal to that of the Levatores arcuum branchialium.

The Obliquus dorsalis superioris serves as the constrictor of the gill openings.

The Obliqui dorsales inferioris : A single obliquus dorsalis inferioris consisting of one or more parts is usually present. The parts of this muscle connect the epibranchials usually with the posterior ones in their series. They run backwards and inwards and remain ventral in position to the Obliquus dorsalis superioris.

They serve as the constrictors of the gill openings.

The Retractores arcuum branchialium : These muscles are present in most of the fishes examined, and are represented by a single muscle which may be divided further into an anterior and a posterior part. The origin of this muscle is from the

ventro-lateral portion of the cranium such as the basioccipital and otic bones. In a few forms, the origin is from the centra of one of the anterior vertebrae. When it arises as a single muscle, its insertion is on the anterior pharyngobranchial. When the muscle is divided into two parts the anterior part is inserted variously and the posterior part is inserted on the last pharyngobranchial or the 5th ceratobranchial. In either case the muscle runs forwards, downwards and inwards.

The contraction of this muscle brings about the separation of the branchial bars resulting in widening of the gill openings.

The Attractores arcuum branchialium : Only a single muscle is present in the fishes examined. Usually however it is divided into two fasciculi. It runs downwards and connects the 4th epibranchial with the last ceratobranchial.

The contraction of this muscle brings the 4th branchial arch in close association with the 5th one whereby the last gill opening gets closed.

#### Innervation

All the dorsal series of branchial muscles are innervated by the branches arising from the post-trematic of the 5th nerve.

The following is the arrangement of the dorsal series of branchial muscles in the fishes investigated.

Callichrous

The Transversus dorsalis : This muscle which is well developed remains single and is posteriorly continuous with the Sphincter oesophagi (Fig.38).

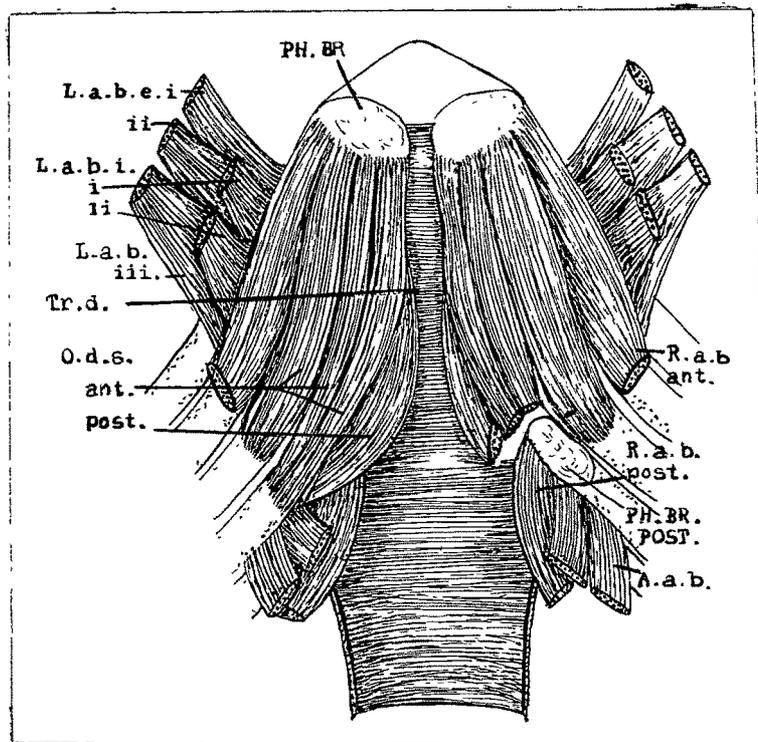


Fig.38. Callichrous. Dorsal series of branchial muscles.

Lettering for figures 38-46.

A.a.b. - Attractor arcus branchialis; L.a.b. - Levator arcus branchialis; L.a.b.e. - L.a.b.externus; L.a.b.i. - L.a.b.internus; O.d.i. - Obliquus dorsalis inferioris; O.d.i.ant. - O.d.i. anterior; O.d.i.post. - O.d.i.posterior; O.d.s. - Obliquus dorsalis superioris; O.d.s.ant. - O.d.s.anterior; O.d.s.med. - O.d.s.medial; O.d.s.post. - O.d.s.posterior; PH.BR. - Pharyngo-branchial; R.a.b. - Retractor arcus branchialis; R.a.b.ant. - R.a.b.anterior; R.a.b.post. - R.a.b.posterior; Sph.o. - Sphincter oesophagi; Tr.d. - Transversus dorsalis; Tr.d.ant. - Tr.d. anterior; Tr.d.post. - Tr.d.posterior.

The Levatores arcuum branchialium : Only the first three muscles are present in this fish (Fig.38) and the first two are divided as usual into two fasciculi each. The origin of the 1st muscle is partly from the hyomandibula and partly from the pterotic. The 2nd muscle arises from the hyomandibula and sphenotic and the 3rd muscle arises from the sphenotic alone. These muscles have the usual insertions, those of the internal fasciculi being situated on the median pharyngobranchial.

The Obliqui dorsales superioris : They comprise two parts viz. an anterior and a posterior (Fig.38). The anterior of these is divided into three fasciculi viz. an internal, a medial and an external one. All of them arise from the anterior pharyngobranchial from its inner and lateral surface. The insertion of the external fasciculus is on the 3rd epibranchial, and those of the other two fasciculi is on the 4th epibranchial. The O.d.s.posterior muscle arises from the median pharyngobranchial and runs immediately below the anterior muscle. Its insertion is on the 5th ceratobranchial.

The Obliqui dorsales inferioris : These muscles are not represented in this fish.

The Retractores arcuum branchialium : They are represented by two parts, The R.a.b.anterior and the R.a.b.posterior (Fig.38). Of these, the former arises from the junction of the pterotic with the occipital bones, and is inserted on the anterior pharyngobranchial, external to the origin of the Obliquus muscle.

The posterior part arises directly internal to the origin of the R.a.b.anterior and is inserted on the posterior pharyngobranchial.

The Attractores arcuum branchialium : A single muscle is present and is divided into two fasciculi (Fig.38).

### Barbus

The Transversus dorsalis is absent in this fish.

The Levatores arcuum branchialium : Five of these muscles are present (Fig.39). The first two of these are further divided into two fasciculi each as usual. The first three muscles arise from the prootic one behind the other, while the 4th and the 5th ones arise from the basioccipital. All the muscles have normal insertions, those of the internal fasciculi being on the anterior and median pharyngobranchials respectively.

The Obliqui dorsales superioris : It is represented by two parts on each side (Fig.39). The first Obliquus dorsalis superioris of these arises from the postero-lateral surface of the anterior pharyngobranchial, runs obliquely backwards and is inserted on the anterior margin of the 2nd epibranchial. The 2nd O.d.s. arises from the median pharyngobranchial and is inserted on the 2nd epibranchial dorsal and external to the insertion of the 1st. The 3rd O.d.s. arises from the last pharyngobranchial behind the origin of the second part and is

inserted on the 3rd epibranchial. The 4th O.d.s. arises from the posterior pharyngobranchial behind the origin of the 3rd and has an insertion on the 4th epibranchial.

The Obliqui dorsales inferioris : They are represented by three parts (Fig.39) in this fish. They arise from the epibranchials 1, 2 and 3 respectively and run forwards in such a way that the successive muscle lies ventral and internal in position to the former. The insertion is on the 2nd, 3rd and the 4th epibranchials respectively.

The Retractores arcuum branchialium : Two muscles (Fig.39) are present on each side. The anterior of these arises

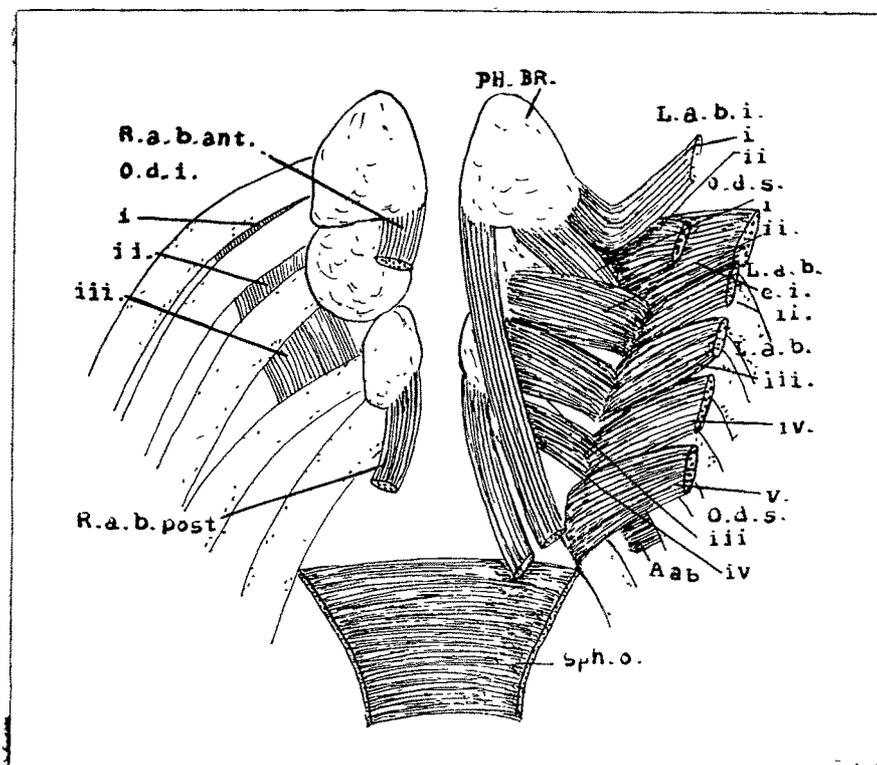


Fig.39. *Barbus*. Dorsal series of branchial muscles (after removal of superficially disposed muscles on the left side).

as usual from the basioccipital bone and has an insertion on the anterior pharyngobranchial. The R.a.b.posterior muscle which also arises from the basioccipital external to the origin of the anterior muscle, is inserted on the last pharyngobranchial.

The Attractores arcuum branchialium : They are represented by a single muscle. (Fig.39) divided into two fasciculi having the usual origin and insertion.

#### Macrones

The Transversi dorsales are represented by a poorly developed Transversus dorsalis divided into an anterior and a posterior part. (Fig.40). The anterior of these is stretched in between the anterior pharyngobranchials and the posterior one behind it in between the median pharyngobranchials.

The Levatores arcuum branchialium : Only three muscles are represented in this fish (Fig.40), and all remain single. Their insertions are on the 2nd, 3rd and 4th epibranchials respectively.

The Obliqui dorsales superioris : Two parts are present in this fish (Fig.40). The anterior of these arises from the median pharyngobranchial and is inserted on the 4th epibranchial. The O.d.s.posterior is however divided into two fasciculi. This muscle arises from the posterior pharyngobranchial and lies ventral in position to the anterior muscle. The external and

the internal fasciculi arise from the outer and inner portions respectively of the posterior edge of the posterior pharyngobranchial. They are inserted on the 4th epibranchial

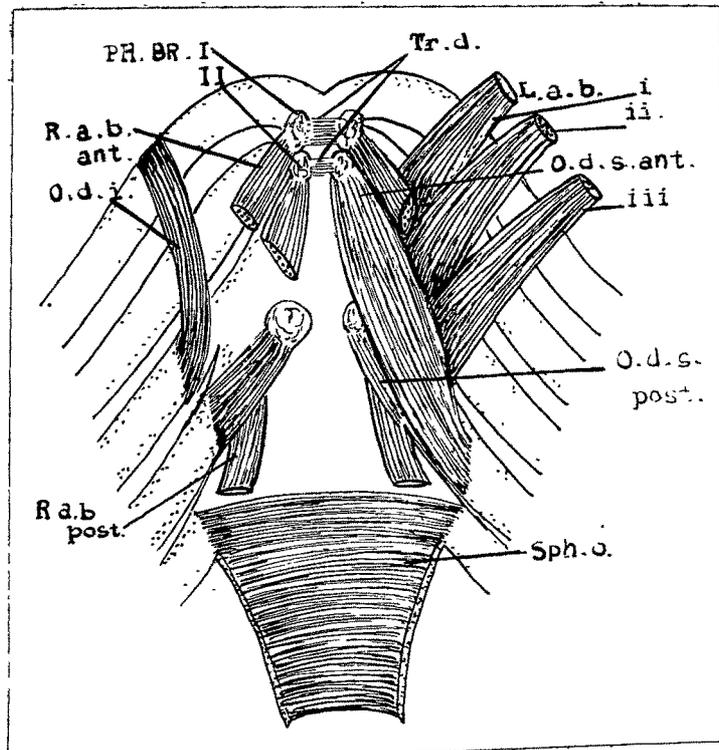


Fig.40. Macrones. Dorsal series of branchial muscles (after removal of superficially disposed muscles on the left side).

in front of and internal to the insertion of the anterior muscle in such a way that the insertion of the anterior fasciculus lies anterior to that of its external counterpart.

The Obliquus dorsalis inferioris : A single muscle is present (Fig.40). It lies ventral and external to the Obliqui dorsales superioris and connects the 1st epibranchial with the 3rd.

The Retractoress arcuum branchialium : The Retractor muscle is divided into an anterior and a posterior part (Fig.40). These parts arise from the basioccipital and are inserted on the anterior pharyngobranchial and the 5th ceratobranchial respectively.

The Attractores arcuum branchialium remain absent in this fish.

Notopterus

The Transversi dorsales : A single well developed Transversus dorsalis muscle (Fig.41) is present in this fish stretching anteriorly as far as and including the anterior pharyngobranchial and posteriorly continuous with the Sphinctor oesophagi.

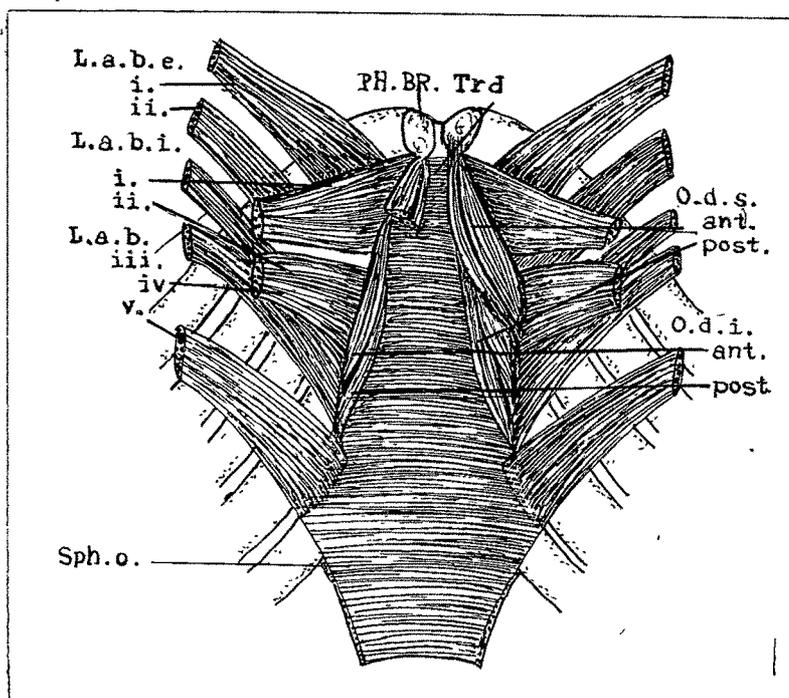


Fig.41. Notopterus. Dorsal series of branchial muscles.

The Levatores arcuum branchialium : Five muscles (Fig.41) are present in this fish and they arise from the epiotic, exoccipital and basioccipital. The first two are divided as usual into an external and an internal fasciculus. The internal fasciculus of the 1st Levator muscle lies internal to the 1st and anterior half of the external fasciculus of the 2nd muscle. The internal fasciculus of the 2nd muscle lies internal to the posterior half of its external counterpart and the 3rd muscle. The insertions are also situated as usual, those of the internal fasciculi being attached on the cartilaginous pad external to the anterior pharyngobranchial and behind it respectively.

The Obliquus dorsalis superioris : It consists of an anterior and a posterior part. (Fig.41). The anterior one arises from the anterior pharyngobranchial and is inserted on the 3rd epibranchial. The O.d.s.posterior which is comparatively thinner also arises from the anterior pharyngobranchial, immediately behind the anterior muscle. The muscle is spiral in nature and lies ventral to the former muscle towards the origin and becomes dorsal in position towards the insertion which is on the 4th epibranchial.

The Obliquus dorsalis inferioris : It consists of an anterior and a posterior part (Fig.41). The former part arises from the 2nd epibranchial and lies dorsal and anterior to the latter part. The insertion is on the 4th epibranchial. The posterior part arises behind the anterior one to gain insertion on the 4th epibranchial behind and external to the insertion of the anterior muscle.

The Retractoress arcuum branchialium and the Attractores arcuum branchialium are not present in this fish.

Ophichthys

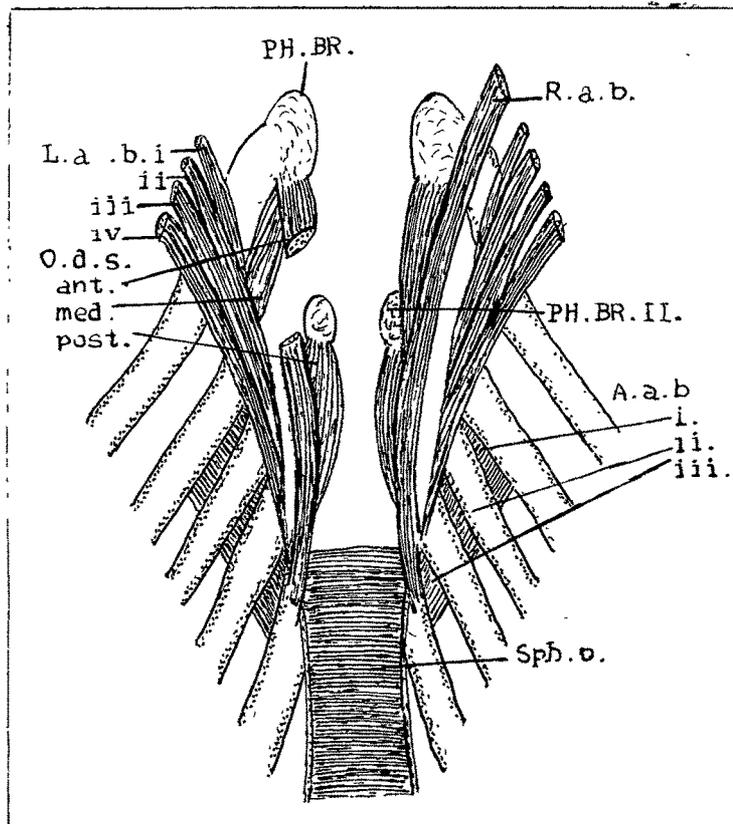


Fig.42. Ophichthys. Dorsal series of branchial muscles.

The Transversi dorsales are not represented in this fish.

The Levatoress arcuum branchialium : Four muscles (Fig.42) are present on each side and all of them remain single. They are all slender muscles and arise from the basioccipital bone of the cranium one behind the other. They pass downwards and

backwards and are inserted as usual on the respective epibranchials.

The Obliqui dorsales superioris : They are represented by three parts on either side viz. an anterior, a medial and a posterior (Fig.42). The anterior of these arises from the anterior pharyngobranchial, runs backwards and is inserted on the 2nd epibranchial. The median part also arises from the anterior pharyngobranchial ventral to and behind the origin of the anterior muscle. It runs backwards and the insertion is on the 2nd epibranchial. The posterior muscle arises from the posterior pharyngobranchial, passes backwards and slightly inwards and is inserted on the 4th epibranchial.

The Obliqui dorsales inferioris remain absent in this fish.

The Retractores arcuum branchialium are represented by a single muscle (Fig.42). It arises from the base of the otic capsule in front of, and external to the origin of the Levatores arcuum branchialium and runs backwards to be inserted on the 5th ceratobranchial.

The Attractores arcuum branchialium : They are represented by three parts of a single muscle (Fig.42). The first of these stretches in between the inner angle formed by the epibranchials 2 and 3. The 2nd is also similarly disposed in between the epibranchials 3 and 4. The 3rd is better developed and stretches in between the 4th epibranchial and the last ceratobranchial.

Ophiocephalus

The Transversi dorsales are absent in this fish.

The Levatores arcuum branchialium : This group consists of four muscles (Fig.43) the first two of which, unlike in many other fishes, are not divided further. The origins of the 1st and 2nd muscles are from the sphenotic situated one behind the other. The origins of the 3rd and 4th muscles which are also one behind the other are from the pterotic. The first one is inserted on the 1st ceratobranchial. The insertion of the 2nd muscle is on the 2nd ceratobranchial behind that of the 1st. The third one is having its insertion on the 3rd ceratobranchial

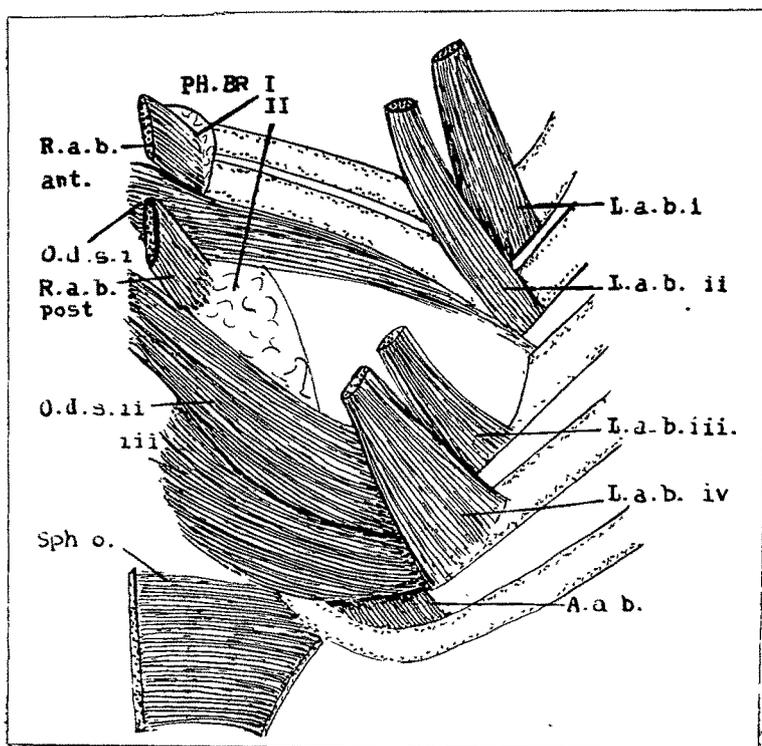


Fig.43. Ophiocephalus. Dorsal series of branchial muscles of the right side.

as usual. The fourth one is stout muscle and is inserted as usual on the 4th ceratobranchial behind the insertion of the third. Except the second, all others are narrow towards the origin becoming broader towards insertion.

The Obliqui dorsales superioris consist of three parts of a single muscle (Fig.43) all of which arise from the pharyngeal wall. The 1st arises internal to and in between the anterior and the median pharyngobranchials and is inserted on the 3rd epibranchial along its entire anterior surface. The 2nd muscle arises behind and dorsal to the median pharyngobranchial, becoming broader backwards and outwards to gain insertion on the 3rd epibranchial internal to that of the 3rd Levator arcus branchialis. The 3rd muscle arises behind and external to the origin of the 2nd and remains ventral to the latter along the anterior edge. This muscle also has the same disposition as the previous one. The insertion is on the 4th epibranchial.

The Obliqui dorsales inferioris are not represented in this fish.

The Retractoress arcuum branchialium : It consists of an anterior and a posterior part (Fig.43). The anterior one is inserted as usual on the anterior pharyngobranchial while the posterior one is inserted on the median pharyngobranchial instead of the 5th ceratobranchial which is the usual insertion for this muscle.

The Attractores arcuum branchialium though present, remains undivided (Fig.43). It has the usual origin and insertion.

#### Osphronemus

The Transversi dorsales remain: absent in this fish.

The Levatores arcuum branchialium : Four muscles are present and the first two are divided into two fasciculi (Fig.44). They arise from the basioccipitals of the cranium one behind the other. The insertion is on the distal ends of the ceratobranchials 1, 2, 3 and 4 respectively, those of the internal fasciculi being internal to their external counterparts.

The Obliqui dorsales superioris : It is a single muscle consisting of an anterior and a posterior part (Fig.44). The former part consists of three broad bellies broader towards the middle and narrow towards the ends. It arises from anterior pharyngobranchial passing backwards and outwards and is inserted on the 4th ceratobranchial. The latter arises from the median pharyngobranchial behind and ventral to the origin of the anterior muscle and turns slightly so as to occupy a dorsal position towards its insertion which is also on the 4th ceratobranchial a little behind that of the anterior muscle.

The Obliqui dorsales inferioris are absent in this fish.

The Retractores arcuum branchialium are represented by a single muscle (Fig.44), arising from the basioccipital in front of the origin of the Levatores arcuum branchialium and

inserted on the posterior pharyngobranchial.

The Attractor arcus branchialis is not represented in this fish.

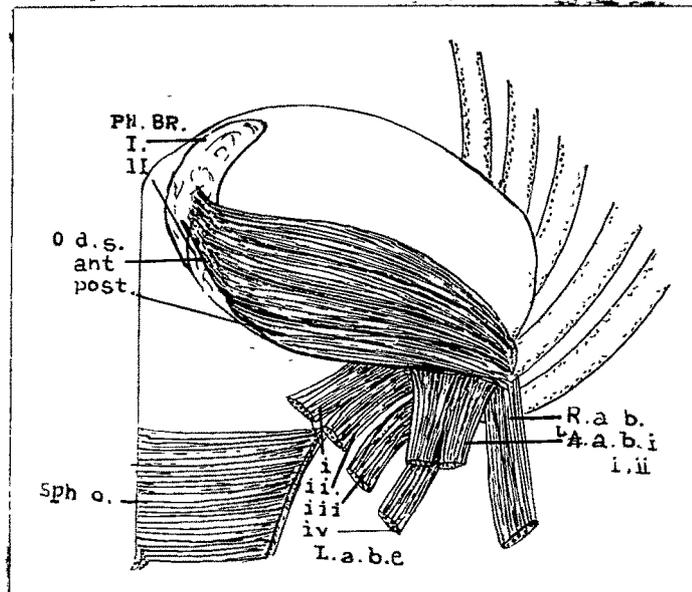


Fig.44. Osphronemus. Dorsal series of branchial muscles of the right side.

### Boleopthalmus

The Transversi dorsales are absent in this fish.

The Levatores arcuum branchialium : There are four of them and the first two are divided as usual into 2 fasciculi (Fig.45). The external fasciculi of the first two muscles are directed downwards and forwards, whereas the 3rd and 4th muscles are directed downwards and backwards. The 4th muscle is short and relatively broader towards insertion. All these muscles

arise as usual from the otic bones of the cranium and are inserted on the respective epibranchials except the internal fasciculi which are inserted on the pharyngeal wall.

The Obliquus dorsalis superioris consists of 4 parts (Fig.45). The 1st one which is divided into 3 fasciculi arises from the antero-lateral portion of the pharyngobranchial 1, 2, and remains broad towards the base. All the three fasciculi become narrow as they run outwards and are inserted on the 1st epibranchial one behind the other. The 2nd is a larger and longer than the 1st one and consists of two bellies. This muscle also arises from the pharyngobranchial 1, 2, behind and ventral to the origin of the 1st part. It first runs directly outwards and then outwards and backwards, the insertion being on the proximal end of the last pharyngobranchial. The 3rd muscle arises behind to the origin of the 1st and is divided

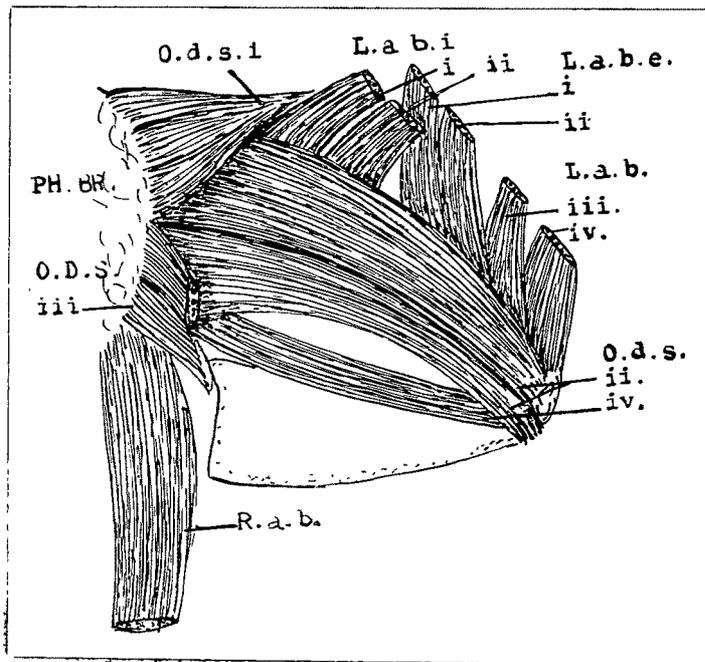


Fig.45. Boleopthalmus. Dorsal series of branchial muscles of the right side.

into 2 fasciculi. These fasciculi run obliquely backwards and are inserted on the proximal end of the 4th epibranchial. The 4th muscle which remains single arises from the pharyngobranchial behind the origin of the 2nd and ventral to the origin of the 3rd and runs backwards to gain its insertion on the distal end of the 4th epibranchial.

The Obliqui dorsales inferioris are not represented in this fish.

The Retractor arcus branchialis is represented by a single muscle (Fig.45). It arises from the ventral surface of the anterior portion of the vertebral column, passes directly forwards and is inserted on the last pharyngobranchial behind the origin of the 3rd Obliquus dorsalis superioris.

The Attractor arcus branchialis is not represented in this fish.

#### Mastecembalus

The Transversi dorsales : There is a single Transversus (Fig.46) separated into an anterior and a posterior part. Both the parts are broad in the middle and narrow towards the ends. The anterior part extends in between 2nd and 3rd branchial bars and is inserted on them at the junction of the 2nd and 3rd ceratobranchials. The posterior part which is narrow anteriorly and broader towards the posterior end is similarly disposed in between the 4th and the 5th branchial bars.

The Levatores arcuum branchialium consist of five muscles (Fig.46). Besides the 1st and the 2nd which are divided into an external and an internal fasciculus as usual, the 4th

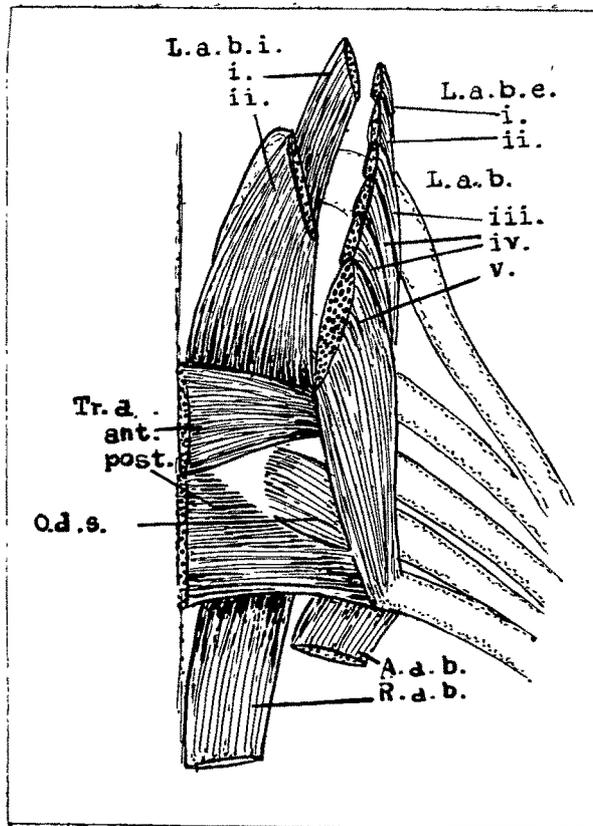


Fig.46. Mastecembalus.  
Dorsal series of branchial muscles of the right side.

muscle is also divided into 2 fasciculi, viz. an anterior and a posterior. The internal fasciculus of the 2nd and the posterior fasciculus of the 4th and the 5th muscle are comparatively developed better than others. All these muscles arise as usual from the cranium (the first two arising from the basioccipital and the rest from the exoccipital). They are inserted as usual, those of the internal fasciculi being on the pharyngeal pads.

The Obliquus dorsalis superioris : This is a single muscle (Fig.46) which arises from the pharyngeal pad in between

the posterior ends of the two parts of the Transversus dorsalis. It runs obliquely backwards to be inserted on the 4th epibranchial near its junction with the 4th ceratobranchial.

The Obliquus dorsalis inferioris is not represented in this fish.

The Retractoress arcuum branchialium are represented by a single muscle which arises from the ventral surface of the centrum of the 8th vertebra, passes forwards in close association with its fellow of the opposite side and becomes slightly broader a little behind the anterior extremity to be inserted on the last pharyngobranchial behind the origin of the Obliquus dorsalis superioris (Fig.46).

The Attractor arcus branchialis which is a single muscle has its usual origin and insertion (Fig.46).

### Discussion

The Transversi dorsales : They are present in Callichrous, Macrones, Notopterus and Mastecembalus and remain absent in Barbus, Ophichthys, Ophiocephalus, Osphronemus and Boleophthalmus. In Callichrous and Notopterus, it remains single whereas in Macrones and Mastecembalus, it consists of an anterior and a posterior part. This muscle is feebly developed in Macrones.

The Levatores arcuum branchialium : In Barbus, Notopterus and Mastecembalus, these muscles are associated with all the branchial bars, five muscles being present. In Ophichthys, Ophiocephalus, Osphronemus and Boleopthalmus, only four muscles are present, while in Callichrous and Macrones, there are only three of them. In Callichrous, Barbus, Notopterus, Osphronemus, Boleopthalmus and Mastecembalus, the first two muscles are divided into an external and an internal fasciculus. In Mastecembalus, the 4th muscle also is divided into an anterior and a posterior fasciculus. The origin as well as the insertion of these muscles show little variation.

The Obliquus dorsalis superioris is represented in all the fishes examined as a single muscle. In Mastecembalus, it remains undivided whereas in Callichrous, Macrones, Notopterus and Osphronemus, it is represented by two parts viz. an anterior and a posterior one. In Barbus, Ophichthys, and Ophiocephalus, it is represented by three parts viz. an anterior, a medial and a posterior, whereas in Boleopthalmus, it is divided into four parts.

The anterior part remains single in Barbus, Macrones, Notopterus, Ophichthys and Ophiocephalus. In Notopterus, it is split into two fasciculi while in Callichrous, Osphronemus and Boleopthalmus, each of them is split into three. The middle part of Barbus, Ophichthys and Ophiocephalus remains single. In Boleopthalmus, the 2nd and the 3rd parts are split

into 2 fasciculi each. The last one remains single in Callichrous, Barbus, Notopterus, Ophichthys, Ophiocephalus, Osphronemus and Boleopthalmus, while in Macrones, it is split into two fasciculi.

The Obliquus dorsalis inferioris which remains single, is present only in three fishes viz. Barbus, Macrones and Notopterus. In Macrones, it is undivided. In Notopterus, it consists of two parts while in Barbus, three parts are present.

The Retractoress arcuum branchialium group of muscles are represented by a single muscle in all the fishes except Notopterus. It remains undivided in Macrones, Osphronemus, Boleopthalmus and Mastecembalus. In Callichrous, Barbus, Ophichthys and Ophiocephalus, the Retractor arcus branchialis is divided into an anterior and a posterior part. Excepting Boleopthalmus and Mastecembalus, the origin of this muscle is from the cranium. In those, the muscle originates from the centrum of one of the anterior vertebrae. The insertion in the fishes investigated, is as usual with one exception viz. in Ophiocephalus. Here the posterior fasciculus is inserted on the median pharyngobranchial.

The Attractoress arcuum branchialium are absent in Macrones, Notopterus, Osphronemus and Boleopthalmus. In Ophichthys, there are three of them and in others only a single muscle is present. In Ophiocephalus and Mastecembalus, it remains undivided, whereas in Barbus and Callichrous,

it is divided into two fasciculi.

Ventral series of branchial muscles

The Transversi ventrales : These muscles are present on all the branchial bars, with which they are attached on the ventral surface. Each of these muscles passes inwards towards the median line from the lower parts of the branchial bar. Those of the 4th and the 5th branchial bars are usually in continuation with their fellows of the opposite side. In a few forms, the 4th muscle is divided further into an anterior and a posterior part. The 5th muscle is continuous posteriorly with the Sphinctor oesophagi.

They have a fleshy origin usually from the cerato-branchials towards their junction with the basibranchials and pass either directly inwards in a transverse manner or inwards and forwards obliquely. When they run obliquely, they are also termed as the Obliqui ventrales. In some forms, either one or more of the first three muscles are split each into a Transversus and an Obliquus part. The insertion which is usually fleshy is on the junction of the basibranchial with the hypobranchial or the hypobranchial only.

Due to the contraction of these muscles the branchial bars are brought close together, resulting in the narrowing of the gill slits.

The muscles of the 1st branchial bar are innervated by the post-trematic branch of the IXth (Glosso-pharyngeal) nerve, whereas the muscles of the remaining bars are innervated by the post-trematic branch of the Xth (i.e. Vagus) nerve.

The Subarcuales recti : These are a series of longitudinal muscles which remain ventral in position to the Transversi ventrales and connect the branchial bars from one bar to the anterior one in the series. The origin is usually from the ceratobranchials behind and ventral to that of the Transversus ventralis. The insertion is usually on the hypobranchial of the preceding branchial bar. In some cases the insertion is on a tendinous cord which runs obliquely forwards so as to connect the preceding or any of the more anterior bars. The last i.e. the 5th muscle usually develops into a subarcualis communis which extends forwards from the last branchial bar for a variable distance anteriorly and the insertion may be on the hypobranchial, basibranchial of any one of the anterior branchial bars, hypohyal or urohyal. Still in some others the last muscle splits into an arcus and a communis parts. The origin as well as the insertion of all these muscles is usually tendinous.

These muscles, by their contraction, bring about the separation of the branchial bars whereby the gill slits widen.

The innervation of these muscles is from the post-trematic branch of the Xth nerve.

The Coraco-branchialis : A single coraco-branchialis muscle is present in all the fishes examined and it is usually divided into an anterior and a posterior fasciculus. In only one fish (Ophichthys) examined it remained undivided. The origin of this muscle is fleshy from the ventral portion of the pectoral girdle. When the muscle is divided into two fasciculi, the external of these is more anteriorly situated than the internal one. The external fasciculus passes forwards, inwards and upwards and has a fleshy insertion on the 5th ceratobranchial. The internal fasciculus passes backwards, inwards and upwards and is inserted on the last ceratobranchial as well as the adjoining basibranchial. Thus the insertion of the internal fasciculus remains anterior in position to that of the external one.

The contraction of these muscles results in bringing together of the gill arches whereby the gill slits become narrow.

This muscle is innervated by the post-trematic branch of the Xth nerve.

The Coraco-hyoideus : This muscle is formed of the hypobranchial muscle. In all the fishes examined, it arises either only from the cleithrum of the pectoral girdle, or partly from the cleithrum and partly as a continuation of the ventral body muscle. It arises from a fleshy origin from where it passes forwards and inwards. Towards the anterior

end it is generally fused with its fellow to form a common attachment towards the insertion. The insertion which is usually tendinous is on the hypo-, basi-, uro-, or glossohyal.

The contraction of this muscle brings about the opening of the mouth, the widening of the opercular slits and the separation of the gill arches.

The innervation of this muscle is from the occipito-spinal nerve.

The following is a description of the various ventral series of muscles in the fishes investigated :-

#### Callichrous

The Transversi ventrales : All the five muscles (Fig.47) are present in this fish. The first three of these are situated obliquely. The 4th Transversus remains single and the 5th muscle has the usual disposition.

The Subarcuales recti : There are five of them (Fig.47) and the last one is represented by a communis muscle. All of them arise from their respective positions from the ceratobranchials and as they pass forwards, the outer fibres get themselves inserted on the preceeding branchial arch in the usual manner. The inner fibres are however become continuous with the subarcualis communis. The common insertion

of all these fibres as well as the insertion of the communis muscle is on the hypohyal.

The Coraco-branchialis : It is divided into two fasciculi as usual viz. an external and an internal (Fig.48).

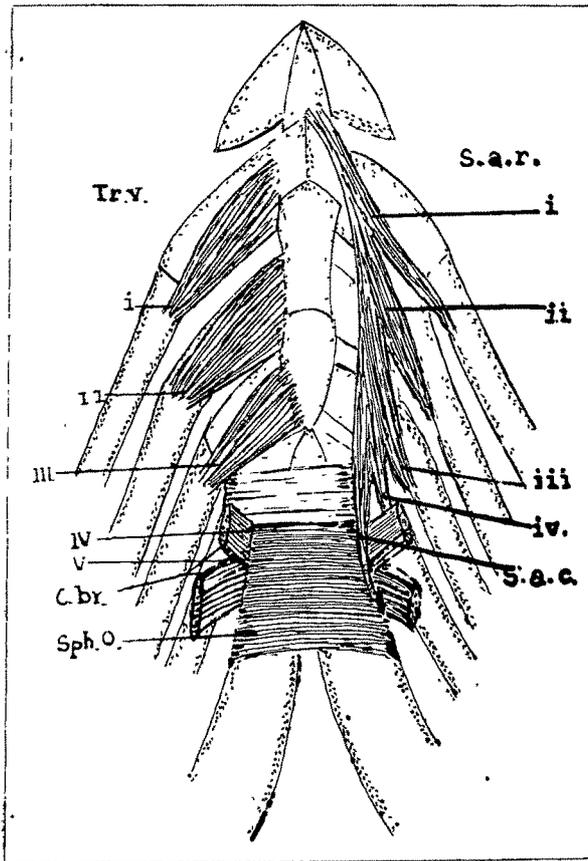


Fig. 47.

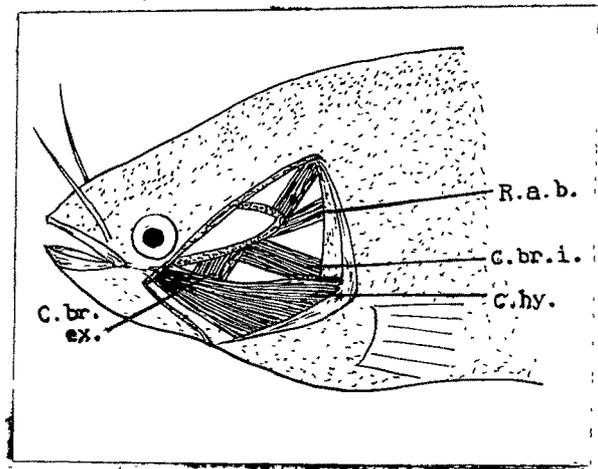


Fig. 48.

Figs.47-48. Callichrous. Ventral branchial muscles

Lettering for figures 47-64

B.BR. - Basibranchial; B.HY. - Basihyal; C.BR. - Cerato-branchial; C.br. - Coraco-branchialis; C.br.ex. - C.br.externus; C.br.i. - C.br.internus; C.hy. - Coraco-hyoideus; H.HY. - Hypohyal; R.a.b. - Retractor arcus branchialis; S.a.c. - Subarcualis communis; S.a.r. - Subarcualis rectus; Sph.o. - Sphinctor oesophagi; Tr.v. - Transversus ventralis.

The former arises from the anterior portion of the clavicle while the latter arises from the inner angle of the girdle internal and in between the origin of the Coraco-hyoideus.

The Coraco-hyoideus arises from cleithrum alone. Its insertion is on the hypohyal (Fig.48).

### Barbus

The Transversi ventrales : These muscles are developed on all the branchial bars (Fig.49). Each of the first three is further split into a Transversus ventralis and an Obliquus ventralis parts. The 4th and the 5th muscles are developed in the usual manner.

The Subarcuales recti : The muscles of the first four arches are present as recti muscles as usual (Fig.49). The 5th one however forms the Subarcualis communis and is inserted on the 3rd hypobranchial.

The Coraco-branchialis : The external fasciculus of this muscle arises from the anterior portion of the clavicle whereas internal one is from the anterior surface of the cleithrum internal to the origin of the Coraco-hyoideus (Fig.50).

The Coraco-hyoideus : The upper fibres of this muscle arise from the cleithrum of the pectoral girdle, whereas the lower fibres are continuous with the ventral body muscles. The insertion is on the urohyal (Fig.50).

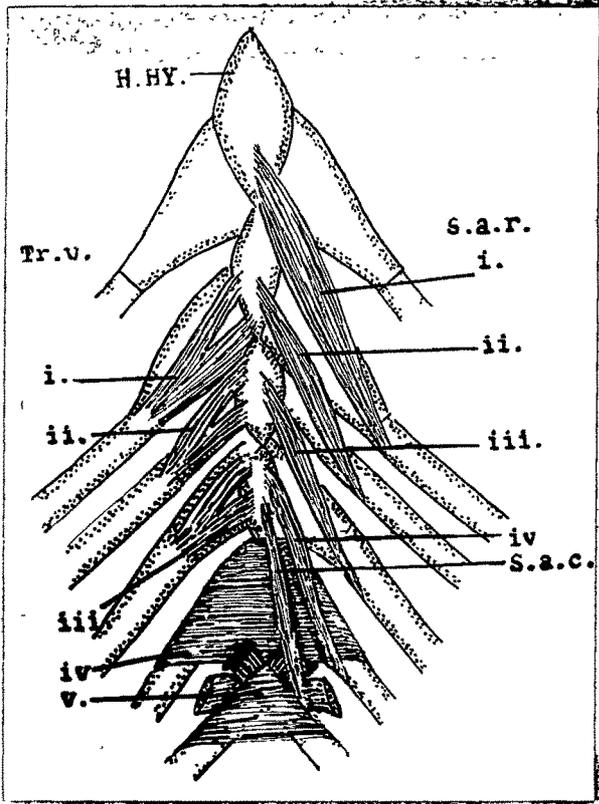


Fig. 49.

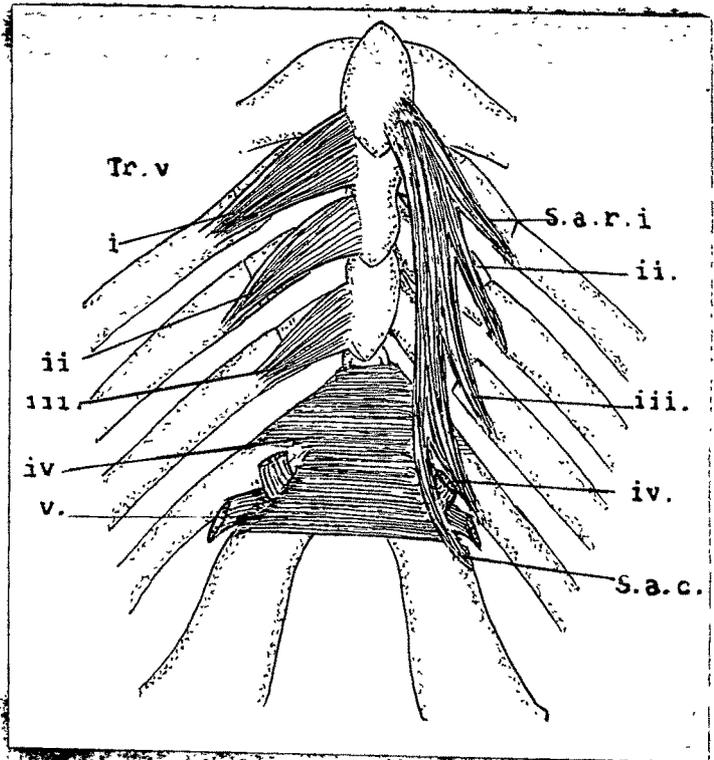


Fig. 51.

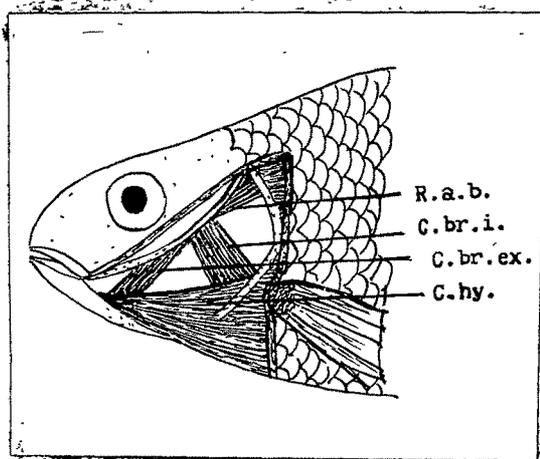


Fig. 50.

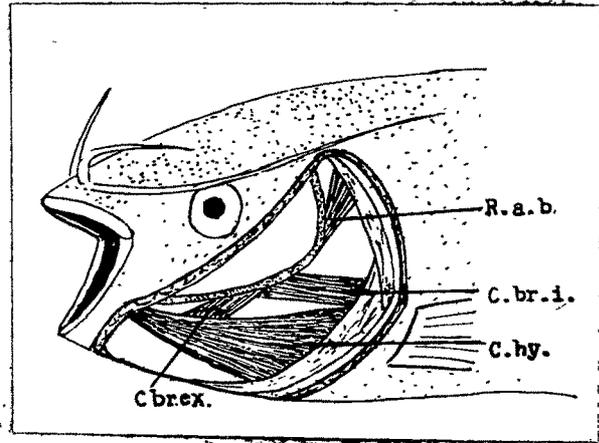


Fig. 52.

Figs.49-50. Barbus. )  
 Figs.51-52. Macrones. ) Ventral branchial muscles

### Macrones

The Transversi ventrales : All the five muscles are present and are disposed in the usual manner (Fig.51), the first three of them being situated obliquely.

The Subarcuales recti : The first four muscles are present as recti muscles and the 5th one forms the Subarcualis communis (Fig.51). As in Callichrous, the outer fibres of all the recti muscles are inserted on the respective bars and the inner fibres become continuous with those of the communis muscle. The common insertion of these fibres as well as that of the communis is on the hypohyal.

The Coraco-branchialis is divided into its two usual parts, the external one being slightly shorter than the internal (Fig.52). The origin of the external fasciculus is from the anterior portion of the clavicle, whereas that of the latter is from the cleithrum above the origin of the Coraco-hyoideus.

The Coraco-hyoideus : This muscle arises from the cleithrum only and is inserted on the hypohyal (Fig.52).

### Notopterus

The Transversi ventrales : All the five muscles are present and all are well developed (Fig.53). The 5th does not however, arise close behind the 4th one as in other fishes.

The Subarcuales recti : Only four muscles are present in this fish (Fig.53). The first two are disposed in the usual

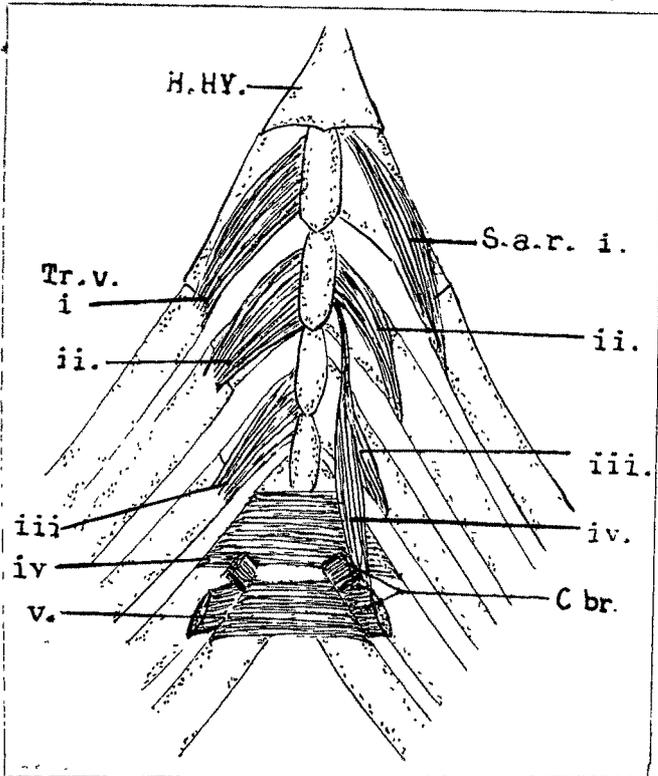


Fig. 53.

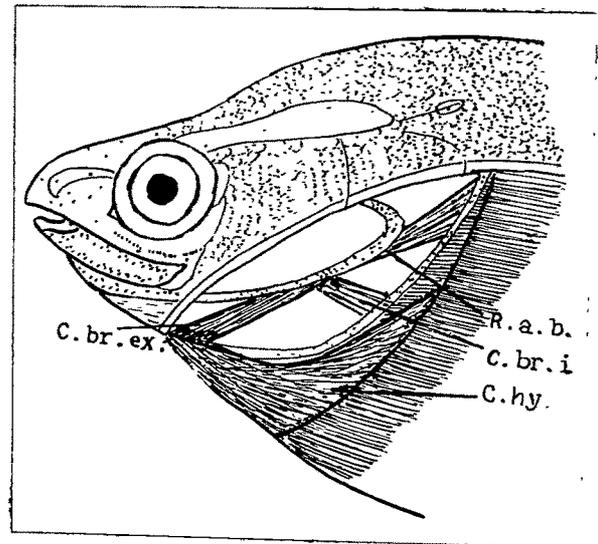


Fig. 54.

Figs.53-54. Notopterus. Ventral branchial muscles

manner. The origins of the 3rd and the 4th muscles are as usual from the ceratobranchials of the respective branchial bars. Their insertions are however on a common tendinous cord which arises from the junction of the 2nd hypobranchial with the 2nd basibranchial. As a result the 3rd muscle remains the longer of the two. The Subarcualis communis is absent in this fish.

The Coraco-branchialis : Both the parts of this muscle are ribbon shaped and the external fasciculus is the longer of the two (Fig.54). The origin of the external fasciculus is from the anterior portion of the clavicle whereas the origin of the internal is from the upper half of the cleithrum.

The Coraco-hyoideus : All the fibres of this muscle arise from a membranous partition situated behind the pectoral girdle and inserted on the basi- and glosso-hyal (Fig.54).

#### Ophichthys

The Transversi ventrales : All the five muscles are present in this fish and the first three of them disposed obliquely (Fig.55).

The Subarcuales recti : Only three muscles are present in this fish (Fig.55). The muscles corresponding to the third recti as well as the Subarcualis communis are absent. The first Subarcualis rectus is a spindle shaped muscle having the origin as well as the insertion as usual. The second Subarcualis rectus also arises from the ceratobranchial 2, as usual. Anteriorly however it runs as a long tendinous cord to be inserted on the hypohyal behind the insertion of the 1st. The 3rd, which corresponds with the Subarcualis rectus 4 of other fishes arises along the anterior border of the ceratobranchial 4, and is inserted on the hypobranchial 3.

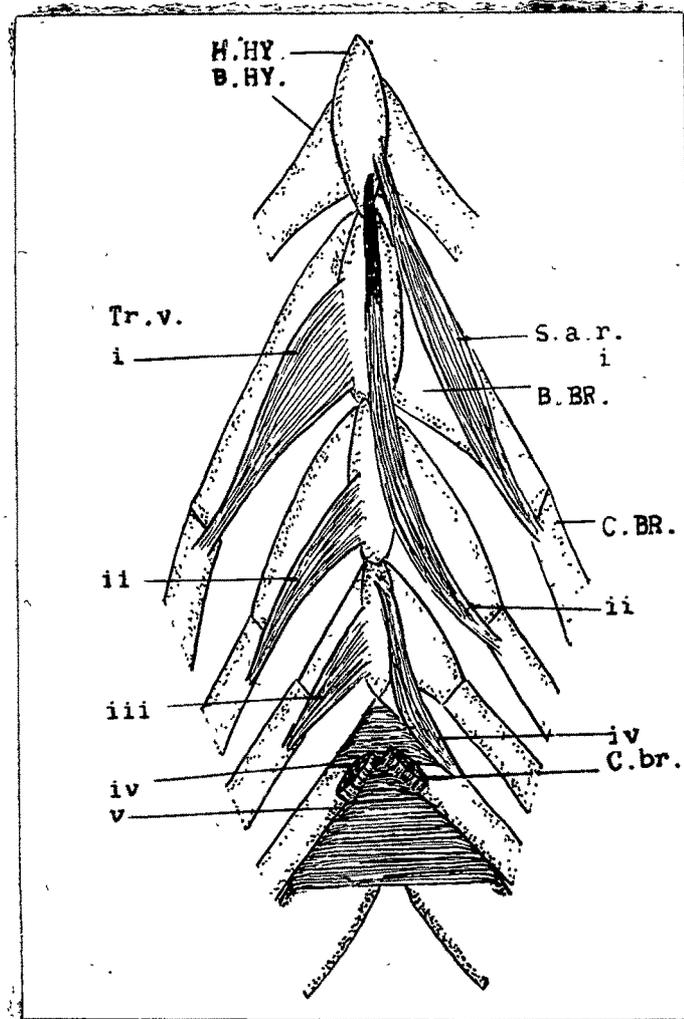


Fig. 55.

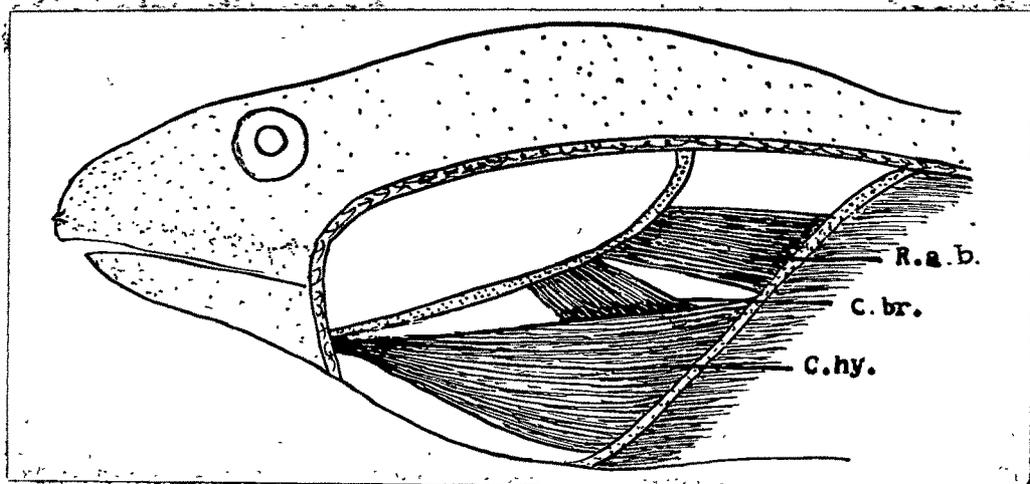


Fig. 56.

Figs. 55-56. *Ophichthys*. Ventral branchial muscles

The Coraco-branchialis : Unlike in other fishes it is not split into two fasciculi but remains single (Fig.56). The origin of this muscle is from the cleithrum internal to the origin of the Coraco-hyoideus. It passes forwards, upwards and inwards and is inserted on the ceratobranchials 4 and 5 towards their junction.

The Coraco-hyoideus : All the muscle fibres (Fig.56) arise from the pectoral girdle and are inserted on the hypohyal.

#### Ophiocephalus

The Transversi ventrales : All the five muscles are present in this fish (Fig.57). The first two are situated obliquely, whereas the disposition of the 3rd muscle is transverse. The 4th muscle is divided into an anterior and a posterior part. The anterior is more slender and is united with its fellow of the opposite side by means of a short horizontally disposed tendinous cord. The latter is a comparatively better developed one and its disposition is similar to that of its anterior counterpart. The 5th muscle arises a little behind the 4th one and is divided into a number of obliquely disposed muscle blocks.

The Subarcuales recti : Only one muscle is present and it corresponds with a combined subarcuales recti 3 & 4 of other fishes (Fig.57). It is narrow towards the origin

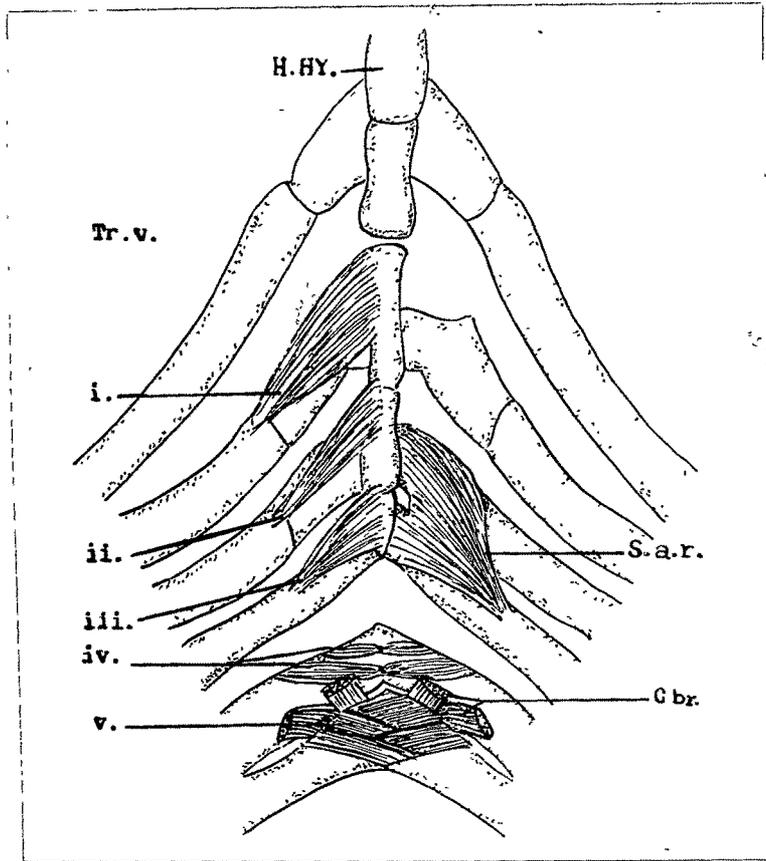


Fig. 57.

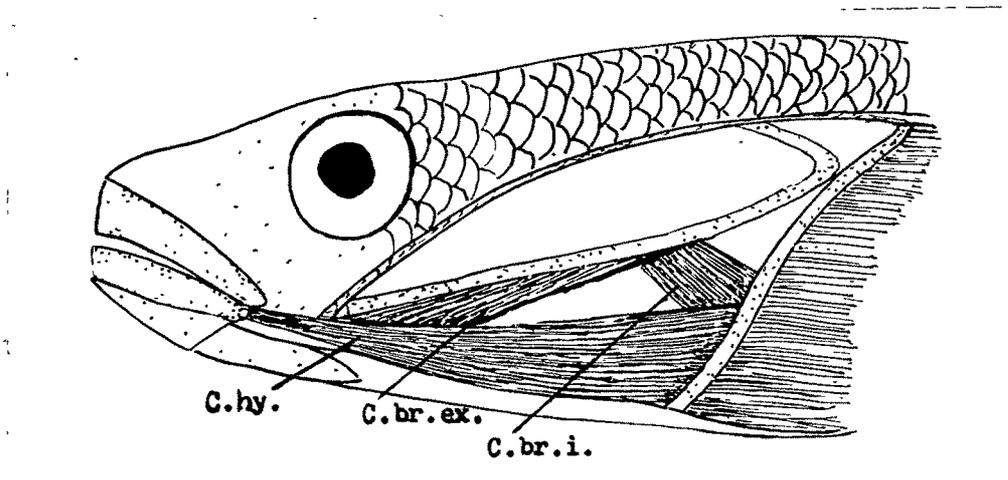


Fig. 58.

Figs.57-58. Ophiocephalus. Ventral branchial muscles

which is along the anterior border of the ceratobranchial 4 and is much broader towards the insertion which is situated on the basibranchials 2 and 3.

The Coraco-branchialis : Of the two fasciculi of this muscle, the external one is more slender and longer than the short and thick internal (Fig.58). The origin of the external fasciculus is from the anterior portion of the clavicle, whereas that of the internal is from the cleithrum of the girdle partly internal to and partly above the origin of the Coraco-hyoideus.

The Coraco-hyoideus : All the fibres arise from the cleithrum of the pectoral girdle and the insertion is on the basihyal (Fig.58).

#### Osphronemus

The Transversi ventrales : All the five muscles are present in this fish and they are disposed in the usual manner (Fig.59).

The Subarcuales recti are represented by two Subarcuales recti and a Subarcualis communis (Fig.59). The muscles corresponding to the 1st and the 2nd recti muscles of other fishes are not found here. In this fish the 1st and the 2nd recti muscles therefore correspond to the 3rd and the 4th muscles in others. The 1st rectus arises from the

hind border of the 3rd ceratobranchial and the 2nd from the hind border of the 4th ceratobranchial. The insertion

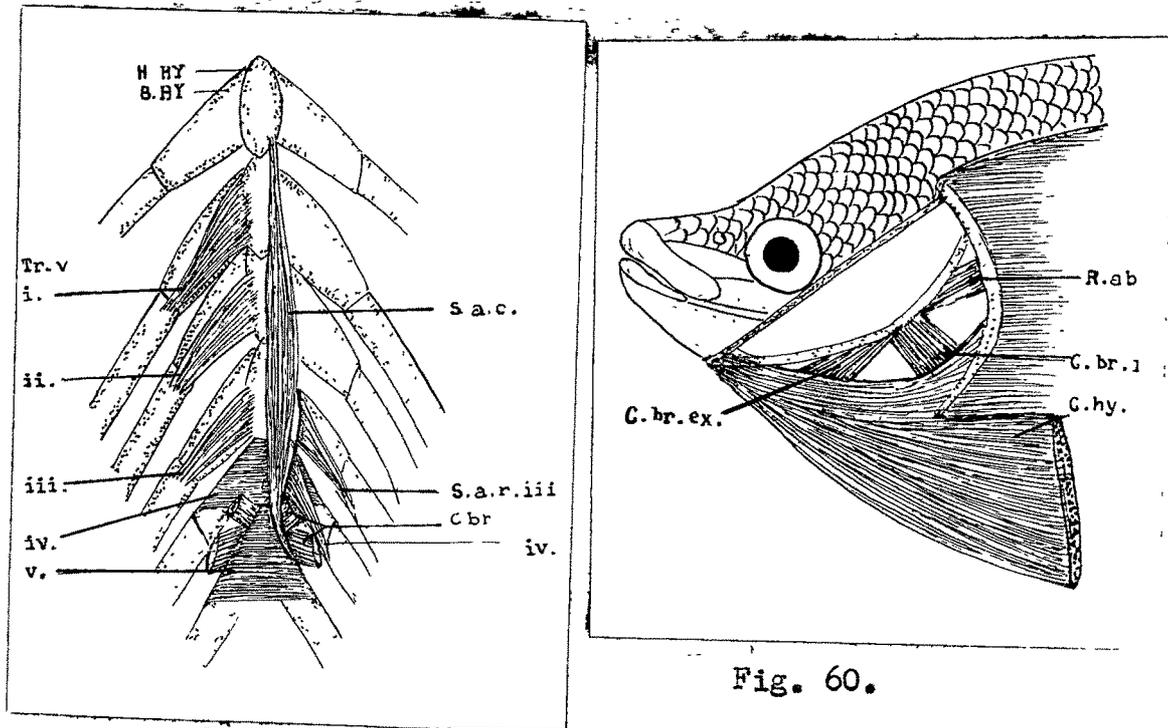


Fig. 59.

Fig. 60.

Figs.59-60. Osphronemus. Ventral branchial muscles

of both these is on a common tendinous cord, extending between the 2nd and the 4th hypobranchials. The Subarcualis communis arises from the 5th ceratobranchial. It is spindle shaped and its insertion is on the hypohyal (Fig.59).

The Coraco-branchialis is divided as usual into two fasciculi. The origin of the external fasciculus is from anterior portion of the clavicle whereas that of the internal is from the cleithrum internal to the origin of the Coraco-hyoideus (Fig.60).

The Coraco-hyoideus arises partly from the cleithrum and partly it is continuous with the ventral muscles of the body. The insertion is on the hypohyal (Fig.60).

Boleopthalmus

The Transversi ventrales : All the five muscles are represented in this fish (Fig.61). Each of the first three is further split into an Obliquus and a Transversus parts. The 4th Transversus is also divided further. The anterior of these is obliquely disposed like the anterior Transversus. The posterior part, like the 4th muscle of other fishes, is continuous with the fellow of its opposite side. The 5th muscle is disposed in the usual manner.

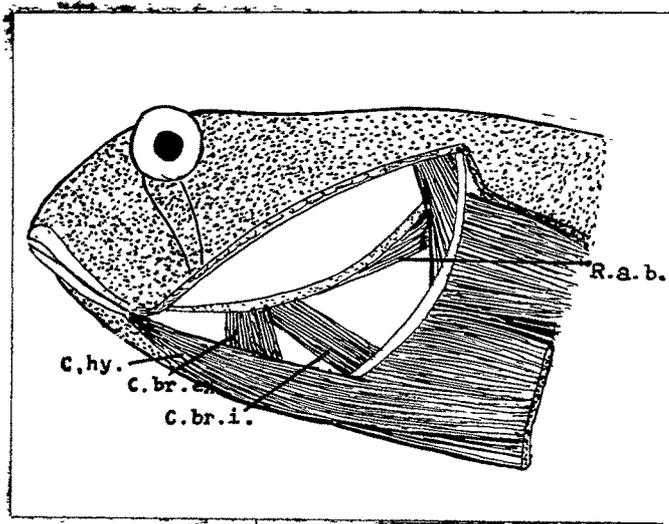
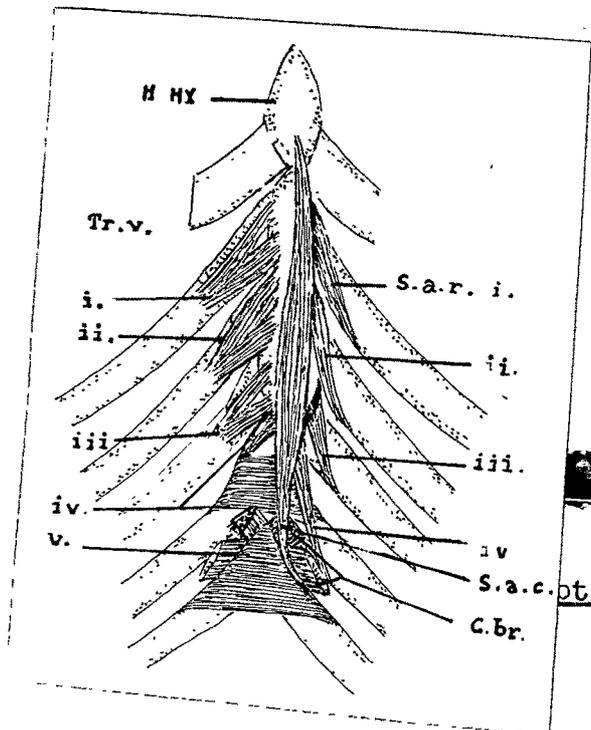


Fig. 62.

Boleopthalmus. Ventral branchial muscles

The Subarcuales recti : These muscles (Fig.61) are present on all the branchial bars. The origin as well as the insertion of the first two muscles is as usual. The origin of the 3rd and 4th muscles is also in the usual manner. The insertion of these two muscles is however on a common tendinous cord which connects the 2nd branchial bar with the 4th. The 5th muscle is present as a Subarcualis communis and its insertion is on the hypohyal.

The Coraco-branchialis : The muscle is divided into two fasciculi as usual (Fig.62). The origin of the external fasciculus is from the anterior portion of the clavicle whereas the origin of the internal is from the cleithrum above the disposition of the Coraco-hyoideus.

The Coraco-hyoideus : All the fibres of this muscle are continuous with the ventral muscles of the body (Fig.62).

#### Mastecembalus

The Transversi ventrales : All the five muscles are present (Fig.63). The first two are disposed obliquely and the 3rd is split into a Transversus and an Obliquus part. The disposition of the 4th and the 5th is as usual.

The Subarcuales recti : These muscles are present on all the branchial bars (Fig.63). Their origin is as usual. The insertion of the 1st muscle is on the junction of the

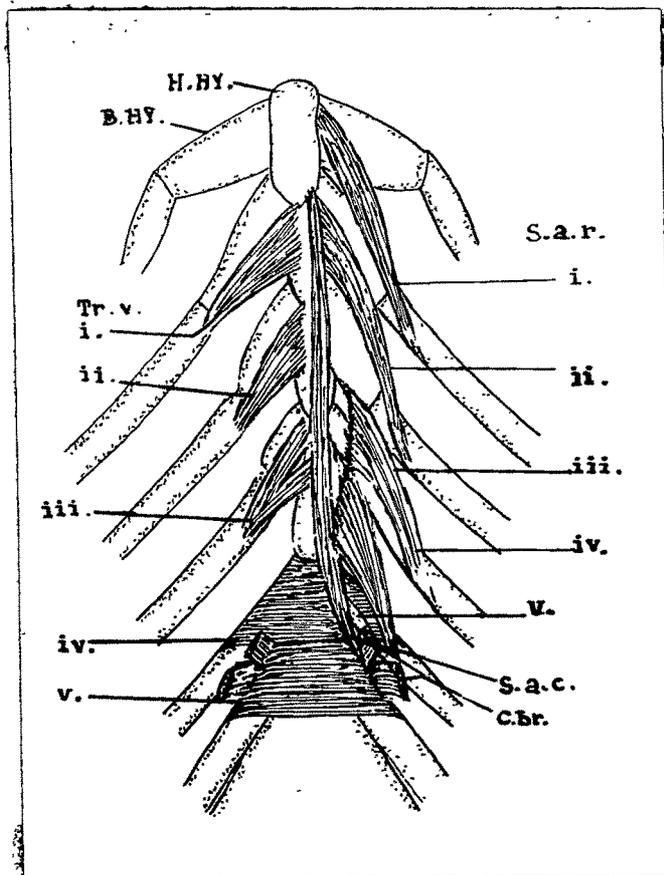


Fig. 63.

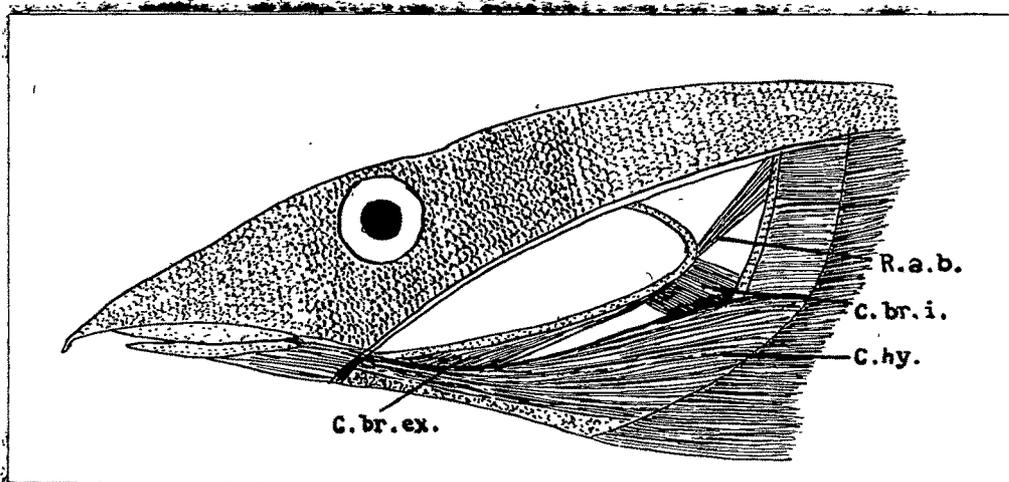


Fig. 64.

Figs.63-64. Mastecembalus. Ventral branchial muscles

hypohyal and ceratohyal while that of the 2nd is on the 1st branchial bar. The 3rd and the 4th are inserted on a common tendinous cord connecting the 2nd branchial bar with the 4th. The 5th muscle is split into a rectus and a communis, the former being inserted on the 4th bar whereas the latter, on the hypohyal.

The Coraco-branchialis : The external fasciculus which is longer and thinner arises as usual from the anterior portion of the clavicle and the internal which is thick and short arises from the cleithrum partly directly internal to, and partly internal and above the origin of the Coraco-hyoideus (Fig.64).

The Coraco-hyoideus : All the fibres of this muscle are in continuation with the ventral body muscles arising as a separate block (Fig.64). The insertion is on the hypohyal.

#### Discussion

The Transversi ventrales : All the branchial bars are provided with these muscles. The disposition of all these muscles is normal in Callichrous, Macrones, Osphronemus and Ophichthys. In Barbus, each of the first three is split into a Transversus and an Obliquus. In Boleopthalmus, the first two and in Mastecembalus, the 3rd, are split similarly. Except in Ophiocephalus and Boleopthalmus, in all other fishes examined the disposition of the 4th is normal. In

these, this muscle is further divided into an anterior and a posterior part. In the former the anterior part is united with its fellow of the opposite side into a common tendinous cord and in the latter it is present as an Obliquus muscle. In both these fishes the posterior part is continuous with the fellow of the opposite side. In Ophiocephalus, the disposition is similar to that of its anterior counterpart. The disposition of the 5th muscle is similar in all the fishes investigated, except in Ophiocephalus, where it is split into a number of blocks and in Notopterus, where it is situated a little behind the 4th.

The Subarcuales recti : They are present on all the branchial bars in Callichrous, Barbus, Macrones, Boleopthalmus and Mastecembalus. In Notopterus, these are developed on the first four branchial bars only. In Ophichthys, only three muscles corresponding to S.a.r. 1, 2 and 4 are present. In Ophiocephalus, it is represented by a single muscle corresponding to a joined S.a.r. 3 and 4 of other fishes. In Osphronemus, only three muscles are present and they correspond to S.a.r. 3, 4 and 5 of other fishes. The 5th muscle is represented by a Subarcualis communis in Callichrous, Barbus, Macrones, Osphronemus and Boleopthalmus. In Mastecembalus, it is divided into a Subarcualis rectus and a Subarcualis communis.

The insertion of the Subarcualis rectus of the 1st branchial bar is normal in all the fishes investigated. The

insertion of the 2nd Subarcualis rectus is also normal in Barbus, Notopterus, Boleopthalmus and Mastecembalus. In Ophichthys, its insertion is on the basihyal. The 3rd and the 4th muscles are inserted on a common tendinous cord in Notopterus, Osphronemus, Boleopthalmus and Mastecembalus. In Barbus, Ophichthys and Ophiocephalus, the insertions of these muscles if present, are on the preceding bars. The insertion of the Subarcualis rectus portion of the 5th muscle is on the 4th branchial bar. The insertion of the Subarcualis communis muscle is on the 3rd basibranchial in Barbus and on the basihyal in other fishes investigated. In Callichrous and Macrones, the insertions of the outer fibres of all the muscles are as usual. The inner fibres however have become continuous with those of the Subarcualis communis muscle to gain a common insertion on the basihyal.

The Coraco-branchialis : This muscle remains single in Ophichthys and in all other fishes investigated it is divided into external and internal fasciculi. But for this, the muscle shows very little variation.

The Coraco-hyoideus arises from the pectoral girdle only in Callichrous, Macrones, Ophichthys and Ophiocephalus. In Notopterus, Boleopthalmus and Mastecembalus, this muscle is wholly continuous with the ventral body muscles. In Barbus and Osphronemus, the upper fibres arise from the pectoral girdle whereas the lower ones are continuous with those of the body muscles.

THE MUSCLES OF INSPIRATION AND EXPIRATION AND THEIR ROLE  
IN AIR-BREATHING

In the teleostean fishes investigated, the process of inspiration starts with the opening of the mouth. This is achieved mainly due to the contraction of the Intermandibularis posterior, the Interhyoideus and the Coraco-hyoideus. The contraction of these muscles results in the lowering of the lower jaw, whereby the mouth opens suddenly thereby creating a negative pressure in the bucco-pharyngeal chamber as a result of which water/air rushes into it. In air-breathing forms such as Ophiocephalus in which the aerial respiratory organs are associated with the bucco-pharyngeal chambers, the air directly comes into contact with the respiratory organs resulting in the gaseous exchange. Meanwhile, the mouth is already kept closed by the contraction of the Mandibular levators and the relaxation of its depressors. The air, which has entered into the bucco-pharyngeal chamber may be retained there for some time and may not be allowed to pass into the branchial chamber immediately. The prevention of the air from entering into the branchial chamber is made possible due to the contraction of some of the constrictor muscles of the gill slits. The branchial muscles such as the Transversi dorsales, the Levatores arcuum branchialium, the Obliqui dorsales, the Attractores arcuum branchialium, the Transversi ventrales,

the Subarcuales recti and the Coraco-branchialis serve this purpose. By contraction, they bring the gill arches close together and the gill slits become narrow. Moreover, in Ophiocephalus, there are special outgrowths which arise from the branchial arches, in addition to the gill rakers, which are pressed firmly against the adjoining gill arches as well as a portion of the side wall of the bucco-pharyngeal chamber. These outgrowths also help in making the chamber air-tight and preventing the air from escaping into the branchial chamber.

The expiratory phase of respiration may or may not start immediately. More usually the air is retained in the chamber for some time. During expiration, the air may be ejected out either through the mouth or the opercular slits. Ophiocephalus is observed to eject the air either through the mouth, through the opercular slits, or by employing both the methods one after another. The ejection of the air through the mouth is made possible due to the contraction of the mandibular depressors, at a time when the constrictors of the gill slits are still in the state of contraction. However, as happens sometimes, the mouth is kept closed and the branchial constrictors relax. As a consequence, the gill arches separate and the gill slits become wide. The contraction of the Retractores arcuum branchialium also possibly helps in the separation of the gill arches. The widening of the gill slits while the mouth is still kept

closed, results in the air entering into the branchial chamber. The air escapes to the outside immediately due to the widening of the opercular slits. This is achieved mainly due to the contraction of the Levator operculi and to a certain extent, the contraction of the Dilatator operculi.

In fishes such as Haplochilus, Mastecembalus and others where the gills and/or the epithelial lining of the branchial chamber are/is utilised for absorbing atmospheric oxygen, as well as in the fishes such as Osphronemus, Clarias, Heteropneusteus and others where the accessory respiratory organs are associated with the branchial chamber, the process of respiration does not end with admitting of the air into the bucco-pharyngeal chamber. In these fishes, the air has to be admitted first into the branchial chamber before the gaseous exchange is effected. The bucco-pharyngeal chamber merely serves as a passage for the passing of air from the outside towards the branchial chamber. This process is essentially similar to the one which is employed during aquatic respiration for admitting oxygen into the gill chamber. The process of expiration however may not start immediately as is the case during aquatic respiration. The air may be retained in the branchial chamber for some time to facilitate gaseous exchange, before it is driven out to the exterior. This is made possible due to the contraction of the constrictor muscles of the opercular gill slits, viz. the Adductor operculi and the Hyohyoideus. The former brings the edge of the operculum

in close contact with the body while the latter also serves the same purpose by bringing the branchiostegal rays nearer to one another. Moreover, the normal position of the operculum is such, that the opercular slits are naturally closed. Thus the opercular slit is closed when the air is admitted into the branchial chamber and it opens for the escape of the air only when the dilators of the opercular slits contract.

From the above mentioned account it is seen that, whether a fish resorts to aquatic respiration or the aerial one, the muscles brought into action are the same and process involved is also more or less similar. The only main difference observed is that among the teleosteans such as the Ophiocephalus, the air which enters into the bucco-pharyngeal chamber does not necessarily enter into the branchial chamber immediately. Moreover, the expiratory passage may be the same as the inspiratory one. In those teleosteans in which aerial respiration is associated with the branchial chamber, like water, air is also made to enter immediately into this chamber. The water during aquatic respiration is however forced out of the branchial chamber immediately. It is not the case in aerial respiration. The expiratory phase may not start immediately. The air may be retained in the branchial chamber for sometime to facilitate the gaseous exchange to take place, before it is ejected out by widening of the opercular slits.

## CONCLUSION

1. Functionally the muscles associated with respiration can be divided into three main groups viz. (i) the mandibular group of muscles, which serve mainly as depressors and levators of the lower jaw, (ii) the opercular group of muscles which serve mainly as the constrictors and dilators of the operculum and (iii) the branchial group of muscles which serve mainly as the constrictors or the dilators of the branchial slits.

2. The depressor muscles of the mandibular group, which bring about the opening of the mouth by lowering the lower jaw are the Intermandibularis posterior and the Interhyoideus. In a number of forms the Intermandibularis posterior and a part or whole of the Interhyoideus together forms a single muscle known as the Protractor hyoidei. The Intermandibularis anterior which is phylogenetically associated with the Intermandibularis posterior is situated behind the symphysis of the rami of the lower jaw. It does not take part however in the lowering of the lower jaw.

3. The levator muscles of the mandibular group which bring about the closure of the mouth belong to a group of muscles known as the Adductor mandibulae. The Adductor mandibulae may remain single or more usually divided into a Maxillaris, a Mandibularis superficialis and a Mandibularis profundus. Each of these parts may remain single or divided further.

4. The Mandibularis group of muscles which are not actively associated either as depressors or the levators of the lower jaw are (i) the Levator arcus palatini and (ii) the Adductor hyomandibula. The latter muscle is represented by Adductor arcus palatini in most of the fishes except in the siluroids investigated where this muscle is represented by the Adductor arcus palatini as well as the Extensor(es) tentaculi.

5. The Hyohyoideus muscles of the Mandibular group serve mainly as constrictors of the operculum. Other muscles which serve as constrictors of the opercular slit are the Adductor operculi of the opercular group. The other two muscles of this group viz. the Dilatator operculi and the Levator operculi serve as dilators of the opercular slit,

6. The Coraco-hyoideus muscle which is grouped along with the branchial series, serves a number of purposes. It serves partly as a depressor of the lower jaw, partly as the dilator of the opercular slit and partly as the dilator of the branchial slits.

7. Besides the Coraco-hyoideus, other muscles which comprise the branchial group of muscles are the Obliqui dorsales superioris, the Obliqui dorsales inferioris, the Retractores arcuum branchialium, the Attractores arcuum branchialium, which constitute a dorsal series of muscles and the Transversi ventrales, the Subarcuales recti and the

Coraco-hyoideus, a ventral series. All the above mentioned muscles except the Retractoress arcuum branchialium and the Coraco-hyoideus bring about the closure of the branchial slits, by drawing the branchial bars closer to one another. The last mentioned muscles on the other hand bring about the separation of the branchial bars and thus serve as the dilators of the branchial slits.

8. As regards the disposition of all these muscles, it is observed that the following muscles viz. the Intermandibularis posterior, the Interhyoideus, the Hyohyoideus, the Adductor mandibulae, the Adductor hyomandibula, the Adductor Transversi dorsales, the Levatoress arcuum branchialium, the Obliqui dorsales superioris, the Obliqui dorsales inferioris, the Retractoress arcuum branchialium, the Transversi ventrales, and the Subarcuales recti show a good deal of variation in the different fishes.

The Intermandibularis anterior, the Levator arcus palatini, the Dilatator operculi, the Levator operculi, the Adductor operculi, the Coraco-branchialis and the Coraco-hyoideus muscles show only minor variations in different fishes.

9. No modifications in the disposition of these muscles as such have taken place due to the air-breathing habit. It should however be mentioned that in aquatic respiration the expiratory phase follows soon after the inspiratory phase

while in aerial respiration some time may elapse in between these two phases.

10. The inspiratory passage and the expiratory one are always different during aquatic respiration. While this is true with aerial respiration also in the majority of the cases, at least one fish viz. Ophiocephalus is found to employ at times the same passage for inspiration as well as expiration which seems to suggest a higher level in the evolution of the air-breathing habit.

The following tabulated statement gives a general account of the origin, insertion, disposition, innervation etc. of the different respiratory muscles in teleosts.

Summary statement in tabular form describing the respiratory muscles in the fishes studied

Name of the muscle	Origin	Insertion	Disposition	Action
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Intermandibularisanterior

Extends between the dentaries

Situating behind the angle of the symphysis of the dentaries

To keep the anterior part of the mandibles in place

posterior

Ventral bones of the hyoid bar

Dentary

Connects the hyoid bar with the lower jaw

Lowering of the lower jaw

InterhyoideusVentral bones of the hyoid bar external to the origin of the Intermandibularis posteriorDentary behind the insertion of the Intermandibularis posterior

- Do -

- Do -

Hyohyoideus superior

Branchiostegal rays

With anterior branchiostegal rays in the series

In between the branchiostegal rays

Lowers the lower jaw and helps in the closure of the opercular slits

inferior

Lowermost br. ray or in addition, the cerato- and/or epi-hyal

Basi-, hypo-, glosso-, or uro-hyal

Connects the operculum with the inner elements of the hyoid bar

- Do -

Name of the muscle	Origin	Insertion	Disposition	Action
<u>Mandibularis</u> ( <u>superficialis</u> and <u>profundus</u> )	Distal bones of the visceral arch and/or the lateral bones of the cranium	Mandible	Behind the orbit	Adduction of the lower jaw to close the mouth
<u>Levator arcus palatini</u>	Bones on the lateral and ventral parts of the cranium	Bones forming the Palato- pterygo-quadrata bar	Behind the orbit	No distinct action
<u>Adductor arcus palatini</u>	- Do -	- Do -	Internal to the <u>L.a.palatini</u> muscle	- Do -
<u>Dilatator operculi</u>	Immediately behind the <u>L.a.palatini</u>	Upper portion of the preopercle and/or outer surface of the antero-dorsal portion of the opercle	Extends between the outer surface of the operculum and the cranium	Widening of the opercular slits
<u>Levator operculi</u>	Behind and internal to the <u>D.operculi</u>	Inner surface of the antero-dorsal or entire portion of the opercle	Extends between the inner surface of the operculum and the cranium	- Do -

<u>Name of the muscle</u>	<u>Origin</u>	<u>Insertion</u>
<u>Levatores arcuum branchialium</u>	Otic bones of the cranium	Epi- or cerato- branchials
<u>Obliquus dorsalis superioris</u>	Pharyngobranchial	Epibranchial of the same or successive branchial bar
<u>Obliquus dorsalis inferioris</u>	Epibranchial	Epibranchial of the any of the posterior bars
<u>Retractor arcus branchialis</u>	Otic region of the cranium	Last cerato- branchial and/or pharyngobranchial
<u>Attractor arcus branchialis</u>	4th epibranchial	5th cerato- branchial
<u>Transversi ventrales</u> I - III	Ceratobranchial	Basi- and/or hypo-branchial of the same bar
IV - V	- do -	United and conti- nuous with the fellow of the opposite side

Name of the muscle	Origin	Insertion	Disposition
<u>Subarcuales recti</u>			
I	Ceratobranchial-I	Basi- or this and hypo-hyal	Connects the first branchial bar with the hyoid bar
II - V	Ceratobranchial	Basi- or this and hypo-branchial	Runs usually from one bar to the anterior one in the series
<u>Coraco-branchialis</u>			
<u>externus</u>	Anterior portion of the clavicle	5th Cerato-branchial	Connects the pectoral girdle with the ventral end of the last branchial bar
<u>internus</u>	Cleithrum	5th Cerato-branchial and adjoining basibranchial	- Do -
<u>Coraco-hyoideus</u>			
	Pectoral girdle and/or the ventral body muscles	Hyoid bar elements of the ventral side	Connects the pectoral girdle and/or ventral body muscles with the hyoid bar