On the So-called Accessory Respiratory Organ "Gill-helix" Found in Some Clupeiform Fishes, with Special Reference to Its Function and Its Genealogy

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Introduction

As far as I am aware, Cahl Joseph HYRTL (1855)[1] is the first author that described gill-helixes in *Chanos salmoneus* and *Heterotis ehrembergi*, the clupeiform fishes, as the accessory organ of the respiration. Afterwards, T. W. BRIDGE (1910)[2] also stated the same opinion as the previous author did on the function of the organ. But as the results of my investigation as to the gill-helixes in *Chanos chanos* (FORSKÅL) and *Konosirus punctatus* (T. & S.), I reached the conclusion that the gill-helixes found in these fishes are rather more reasonable to be recognized as the accessory alimental organ than as the accessory breating organ. And in addition to this, in *Sardinella zunasi* (BLEEKER), an allied species of *Konosirus*, I found a pair of pouch-shaped appendages on the dorsal side of the pharynx, which induced me to recognize it as an unfinished gill-helix.

The details on the facts will be stated on the following pages.

General descriptions of the gill-helix and pharyngeal pouch

Gill-helix of *Chanos chanos* (FORSKÅL).——The gill-helix is a pair of elongate tubular sac which bents strongly just like a fish-hook, and lies ventral to the vertebral column and dorsal to the pharynx. It originates from the dorso-lateral wall of the hind region of the pharynx, before the commencement of the oesophagus, and runs, from origin, forward for some distance and then takes a sudden turn backward to reaches until near its origin, tapering distally; and thus, it acquires two rami, an outer or broad ramus, and an inner or narrow one, which are so closely set with each other as to be misconceived as an oval mass.

At origin (base), it is perforated by a large orifice by means of which its lumen communicates to the pharyngeal cavity; but at end (apex), it is blind. It intercarates the most part of the external side of its outer ramus between the cartilaginous plates which represent the respective epibranchials of the 4th and 5th gill-arches, and thus those plates are necessarily destined to participate in the formation of the wall of it. The dorsal or epibranchial part of the 4th gill-slit, which is found between the epibranchials of the 4th and 5th gill-arches of *Clupea pallasii* and others is completely disappeared. The structure of the wall is different according to the parts of the rami; the walls of inner or narrow

1. HYRTL, C. J. ——
The original report was not accessible, so only the description of the organ given by T. W. BRIDGE has been consulted.
2. BRIDGE, T. W. —— Fishes. Cambridge Natural History, vol. vii, 1910.

ramus and of the anterior or distal thirds of the outer or broad ramus are thick and coated by the highly developed muscles, and their interior surfaces are entirely lined by the mucous layer with many pointed papillae and pads varying in form and size, while the wall of the remaining part, i. e. the posterior or proximal two thirds of the outer or broad ramus, is thin, mostly consisted of the cartilage and fascia. The interior of the cartilaginous part is provided with many fine cartilaginous narrow lamellae arranged in two rows, dorsal and ventral, which are considered to be the rudiments of the gill-rackers of the 4th and of the 5th gill-arches respectively.

The length is about 46mm., diameter 9mm., capacity of its lumen 0.6 cc. (when moderately inflated in the individual measuring 35 cm. in length and 365 gr. in weight.

Gill-helix of *Konosirus punctatus* (T. & S.).——In this species, the gill-helix is the same as that of *Chanos* in the essential points, differing only from the latter in possessing a short slit at the ventro-external side of the posterior or basal region of the outer ramus, and which is opened to the branchial chamber, and is recognized to correspond to the dorsal or epibranchial part of the 4th gill-slit.

It is about 0.11 cc. in capacity of its lumen, 26 mm. in length and 6 mm. in width in the specimen weighted 123 gr. and measuring 18.9 mm. long.

Pharyngeal pouch of *Sardinella zunasi* (BLEEKER).—The pharyngeal pouch (the author newly named) is a pair of saccular process highly projecting from the dorso-lateral side of the pharynx. It lies, one on each side of the longitudinal axis of the pharynx, in the space between the cranium and the pharynx, directly behind the 3rd gill-arch and before the commencement of the oesophagus. It is, when viewed behind, roughly scyphiform in its outline; accordingly it gives for description four margins, an outer, an inner, an upper or dorsal and a basal or ventral. Of the margins, the outer is rather straight and nearly vertical to the longitudinal axis of the pharynx, being bordered with the epibranchials of the 4th and 5th gill-arches, and the dorsal or epibranchial part of the 4th gill-slit is distinctly found between those bones; the inner is moderately concave and inclined inwards; the upper or dorsal is largest in length, distinctly arched and slightly inclined outward; the ventral or basal is smallest in length and attached to the pharyngeal wall into which it is merged. It is moderately compressed antero-posteriorly, so as to present two sides, an anterior and a posterior; the anterior side is rather flat and mostly covered with the plate-like epibranchial of the 4th gill-arch, while the posterior is distinctly convex and coated with the thick muscular layer. It has a large lumen which opens ventrally to the pharyngeal cavity and dorso-laterally to the branchial chamber. The interior surface of the lumen is similar to that of the pharynx in structure.

The reasons why I hesitate to recognize the gill-helix as the accessory respiratory organ

1. No habit of air-breathing is found.——As far as I hitherto observed on the respiratory habits of *Chanos chanos* and *Konosirus punctantus*, there is no habit of air-breathing in these fishes; accordingly it is certain that the gill-helix is not the air-breathing organ, differing from the accessory respiratory organs for air, such as the suprabranchial chamber

of *Ophicephalus argus*, the air-sac of *Macropodus opercularis* and the intestine of *Misgurnus anguillicaudatus*.

2. The lumen of the gill-helix contains various substances.——As the results of examination on the individuals of *Chanos* (35 individuals) and *Konosirus* (500 individuals) it was found that, almost in all the cases, the gill-helix contains a certain quantity of food or non-food substances, such as malacostracan crustacea, diatoms, fragments of aquatic floral plants, algae, grains of sand, etc.; it is, moreover, always filled with some mucous fluid.

From these we can assume that the circulation of water in the lumen of the gill-helix is carried on very slowly. And if it is the case, we can scarecely expect the water-breathing effect forced by the gill-helix.

3. The gill-helix is structurally unsuitable for the water-breathing. ——Although the gill-helix is not a main, but is a supplemental respiratory organ; the capacity and the superficial area of its lumen are too poor as the organ for the water-respiration. For example, in a specimen of *Chanos chanos*, 332 gr. in weight, the capacity of the lumen is only 0.6 cc.; and furthermore, it bents strongly at the middle of its length and its wall is not so inflatable. Consequently it can not be considered so effective as serves the purpose of the supplementary respiration for water.

4. *Chanos and Konosirus* are not long-lived in the air.—— In general, the fishes having the accessory respiratory organ are long-lived in the air, while *Chanos* and *Konosirus* are very short-lived when they are out of water. So, it is clear that the gill-helix is not the air-breathing organ, differing from the air-chamber or suprabranchial chamber of *Ophicephalus*, the air-sac of *Macropodus* etc.

5. The gill does not show any sign of degeneration.——Generally, the fishes possessing the air-breathing organ as the accessory respiratory organ in the interior of the body, such as *Ophicephalus, Anabas, Macropodus, Misgurnus,* etc. present the tendency of degeneration of the gill. And in these fishes the gill-filaments are fewer in number and smaller in size than those of the respective allied species, such as *Mugill cephalus, Cypselurus agoo, Cyprinus carpio,* etc., all of which having no accessory respiratory organ. But *Chanos* and *Konosirus*, provided with the gill-helix which has been recognized to be the accessory breathing organ, do not only show any sign of degeneration of the gill, but it is rather more well developed than those in their affined species, such as *Clupea pallasii, Ilisha elongata,* etc., which are wanting in the accessory breathing organ.

Examining now the above facts, we can easily undertstand why the gills in *Ophicephalus, Macropodus* and *Misgurnus*, which are provided with the accessory breathing organ, are poor in development.

But it is very difficult to solve the question why the gills in *Chanos* and *Konosirus*, all of which possess the gill-helix recognized as the accessory respiratory organ, are well developed, unless we are allowed to conject that the gill-helix is quite or nearly powerless for respiration, or that *Chanos* and *Konosirus* require especially the large amount of oxygen compared with *Clupea, Ilisha,* or that the gills in *Chanos* and *Konosirus* are ineffecient for the oxygen-acquisition in comparison with those in *Clupea, Ilisha,* etc..

Table showing the number and size of the gill-filaments in the species having either of the gill-helix or the other accessory respiratory organ for air, and of those in the species having neither of those organs.

Presence and absence of accessory respiratory organs and their names.	*Names of fishes*	Body length (cm)	Body weight (gr)	Number of gill-filament		Largest gill-filament Length × width (mm)
				Right	Left	
Present (Suprabranchial or air-chmber)	*Ophicephalus argus*	31	357	608	644	7×2.0
	〃	30	288	719	—	7×2.0
	〃	25.5	221	683	688	5.5×1.5
	〃	--	—	803	811	8×2.0
Present (Labyrinth folds)	*Anabas scandens*	4.1	2.7	258	261	1.5×0.9
		—	—	274	262	—
Present (Air-sac)	*Macropodus opercularis*	4.3	3.5	280	277	1.0×0.8
Absent	*Mugil cephalus*	31.1	45.9	1305	1282	18×1.0
	〃	40.0	107.0	1401	—	—
	〃	39.0	94.8	1419	—	25×3.0
	〃	38.2	91.0	1501	1420	23×3.0
	〃	38.0	90.0	1462	1452	22×3.5
	〃	27.5	34.0	1244	1274	—
Absent	*Cypselurus agoo*	21.7	14.7	852	854	9×2.5
	〃	25.3	19.5	968	932	10×1.0
Present (Intestine)	*Misgurnus anguillicaudatus*	14.1	32.5	285	287	2.5×1.0
	〃	13.2	24.0	278	282	3.0×1.0
	〃	14.3	22.5	270	260	3.0×1.0
	〃	12.1	19.5	282	282	—
	〃	11.6	12.0	272	270	2.5×0.6
	〃	28.6	55.5			
Absent	*Parasilurus asotus*	24.9	159.0	889	878	8.0×2.5
	〃	24.0	145.0	871	864	8.0×2.5
	〃	23.5	120.0	847	839	8.5×2.5
	〃	23.0	108.0	899	876	8.5×2.3
	〃	14.4	29.0	736	738	5.0×1.1
	〃	11.8	17.0	734	730	4.8×1.0
	Cyprinus carpio	20.8	242.0	961	915	12.0×3.0
	〃	21.0	292.2	941	984	12.0×3.0
	Carassius auratus	11.3	53.5	—	789	5.7×2.0
	〃	12.0	62.5	864	886	6.5×1.2
Present (Gill-helix)	*Chanos chanos*	31.0	425.5	1472	1466	10.0×1.0
	〃	26.0	332.5	1284	1274	—
		24.0	—	1368	1376	10.0×1.0
	Konosirus punctatus	18.9	123.0	948	996	11.0×2.0
	〃	19.2	115.0	869	959	11.0×2.0
	〃	19.1	112.5	1024	997	10.0×2.0
	〃	18.2	106.0	935	926	9.0×1.5
	〃	17.9	94.0	961	993	
Absent	*Clupea pallasii*	28.0	314.0	872	860	11.0×2.0
	〃	22.5	103.5	768	767	9.0×1.2
	〃	19.9	84.0	733	733	7.0×1.0
	〃	20.4	78.5	766	764	6.5×1.1
	〃	19.5	63.0	735	735	7.0×1.0
	Amblygastr melanostictum	17.8	61.0	930	923	11.0×1.1
	〃	17.5	52.0	944	950	11.0×1.0
	Ilisha elongata	45.5	1220.0	640	639	16.5×2.5
	Coilia nasus	12.5	15.0	603	600	4.0×0.5
	Plerethrissus gissu	39.5	486.0	600	607	6.0×9.0
	Sardinella zunasi	10.4	19.0	508	558	5.0×0.5
	〃	9.6	16.5	523	516	5.0×0.5
	〃	9.0	13.5	424	542	3.7×0.5
	〃	8.8	12.0	480	557	3.7×0.5
	〃	8.2	10.0	449	535	3.0×0.5

Consideration as to the genealogy of the gill-helix

Comparing the structures of the pharynxes in *Clupea*, *Sardinella*, *Konosirus* and *Chanos* we can recognize that the gill-helix and also pharyngeal pouch are nothing more than the sacs which are formed by collaborating with the partial swelling of the dorsal wall of the pharynx and the epibranchials of the 4th and 5th gill-arches in *Clupea*. The genealogical relation of them may be considered to be as follows: —

Firstly, in *Clupea*, wanting in the gill-helix, the epibranchials of the 4th and 5th gill-arches lay horizontally or the dorsal wall of the pharynx, being arranged one after the other, between which sandwiching the 4th gill-slit as in that of the ordinary fishes. But they are fused with each other at tip where the 5th being set dorsal to the 4th; this arrangement is obviously the first step of formation of the gill-helix. Consequently it may be said that the bud of the gill-helix is found in this species.

Secondarily, if the epibranchials of the 4th and 5th gill-arches of *Clupea* lift vertically themselves together with a part of the dorsal wall of the pharynx to which they are firmly attached; and the dorsal or epibranchial part of the 4th gill-slit, i. e. the aperture between the epibranchials of the 4th and 5th gill-arches, be remains perfectly as it is, then the simple saccular protuberance, which makes us remember the pharygeal pouch found in *Sardinella*, will be obtained.

Thirdly, in the pharygeal pouch of *Sardinella*, if the slit developed along the upper or dorsal margin of it i. e. the dorsal or epibranchial part of the 4th gill-slit be slightly reduced, and if the inner or proxmal part of the wall of the posterior side of it be extraordinarily inflated and projected backward, then the fish-hook like tube, i. e. the gill-helix, as seen in *Konosirus*, will be naturally produced there.

Finally, in the gill-helix of *Konosirus*, if the reduction of the slit at the postero-lateral side of the basal region of the gill-helix, i. e. the epibranchial or dorsal part of the 4th gill-slit, be more pronounced to complets it, then the gill-helix as seen in *Chanos* will be perfectly formed.

Conclusion

From the above mentioned facts and assumption we can conclude that the gill-helix is neither the accessory organ for air nor for water, and may probably be a diverticulum of the alimental canal, functioning as a temporary reservior of food; and the pharyngeal pouch of *Sardinella*, the gill-helix of *Konosirus*, and also that of *Chanos* are the homologous organs, the former being the intermediate form which stands between the *Clupea* and *Konosirus*-types, the middle presenting the transitional form from the *Sardinella*-type to the *Chanos*.

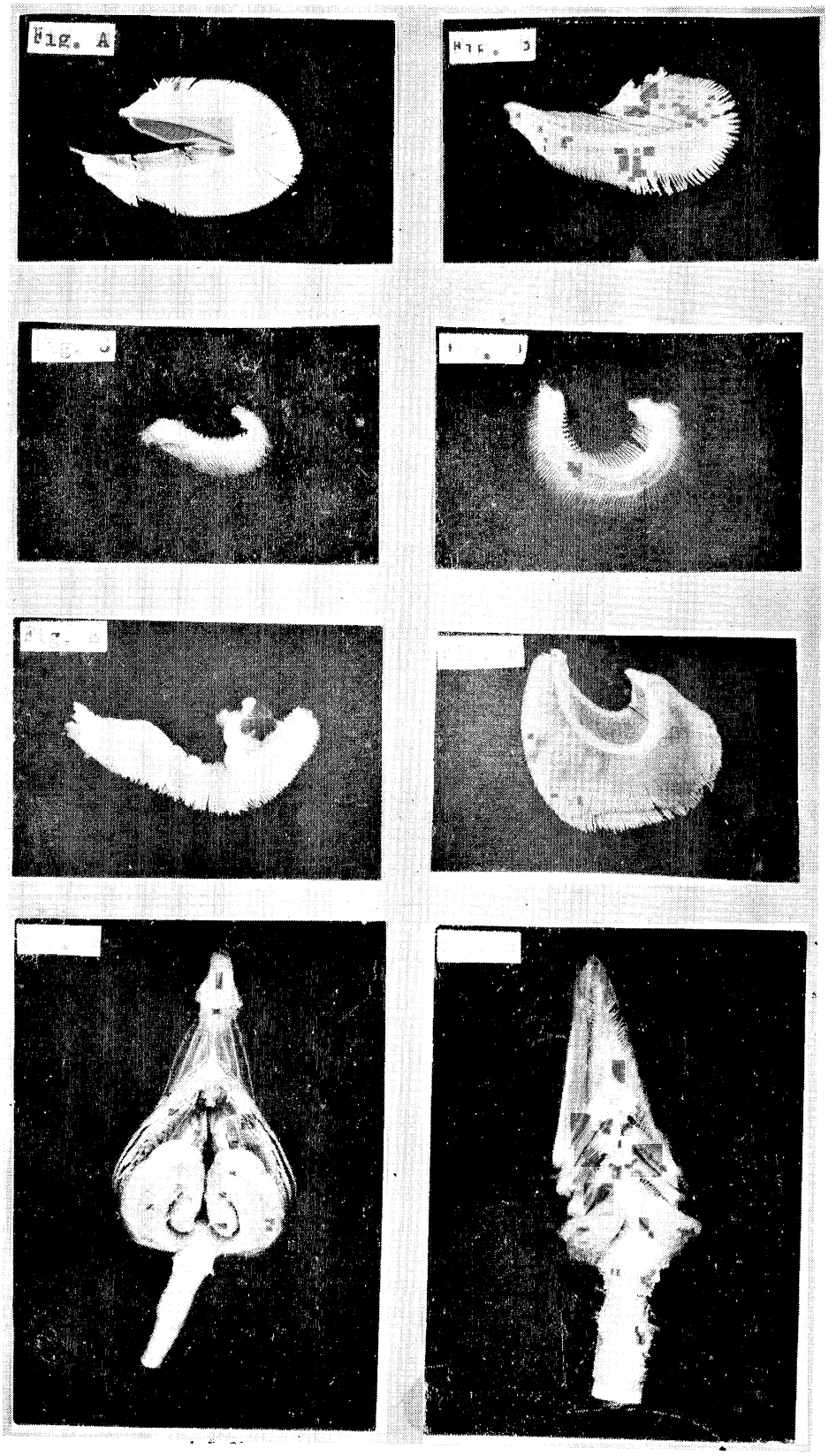
Fig. A

Explanation of plate

Figs. A–F. Side view of the first or outermost gill-lamella. × 1

Fig. A. Gill-lamella of *Chanos chanos* (FORSKÅL) measuring 31cm. in length, 425.5 gr. in weight.

Fig. B. Gill-lamella of *Clupea pallasii* C. & V. measuring 28cm. in length, 311.0 gr. in weight.

Fig. C. Gill-lamella of *Misgurnus anguillicaudatus* (CANTOR) measuring 28.6 cm. in length, 55.5 gr. in weight.

Fig. D. Gill-lamella of *Carassius auratus* (L.) measuring 11.3cm. in length, 53. 5gr. in weight.

Fig. E. Gill-lamella of *Ophicephalus argus* CANTOR measuring 31cm. in length, 35.7 gr. in weight.

Fig. F. Gill-lamella of *Mugil cephalus* L. measuring 31.1 cm. in length, 45.9 gr. in weight.

Figs. G–H. Dorsal view of gill-helix and pharyngeal pouch.

Fig. G. Gill-helix of *Chanos chanos* (FORSKÅL). × 1

Fig. H. Pharyngeal pouch of *Sardinella zunasi* (BLEKER). ×2