

**Article X.—AN ADULT PUG-HEADED BROWN TROUT,
SALMO FARIO, WITH NOTES ON OTHER
PUG-HEADED SALMONIDS**

BY E. W. GUDGER

PLATE XXI; TEXT FIGURES 1 TO 19

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INTRODUCTION

In a recent number of *Natural History* (1928, No. 1), I published an article entitled, 'Guillaume Rondelet's Pug-headed Carp, the Earliest Record—A. D. 1554.' This short article was written to make known to students of fishes the earliest published record of this anomaly, and which, buried in his book, 'Libri de Piscibus' (Lyons, 1554, Pars Altera, p. 154), was lost to students of the teratology of fishes. The article excited some attention and led to the sending to me of a picture of a pug-headed trout published in the rotogravure section of a Buffalo (New York) newspaper. This in turn led to correspondence with its captor, Mr. Louis P. Miller of Cairo, New York, and to the loan of the mounted fish for study. I am greatly indebted to Mr. Miller for this loan and for the data relating to the capture of the fish. Mr. Jack Brawley of New York City has kindly furnished a photograph of the head of the fish made while it was yet fresh. The first part of this article (the latest describing a pug-headed fish) has been based on these data.

That this deformity is of fairly common occurrence is attested by the large number of citations to the subject in the section on 'Teratology' in the index volume of the 'Bibliography of Fishes,' and under the same heading in the classified card catalogue of fish literature since 1914 in my office in the American Museum. By far the largest number of these citations refers to members of the carp family, a thing to be expected since these fishes have been for centuries and even now are the ones most raised in ponds for food. Next most abundant are the references to and figures of bulldog-headedness in members of the great family of the salmon, the fishes most studied and sought for sport.

Of the scores of references to this deformity among fishes, only those referring to salmonids will be considered herein, and they will be taken up only after the specimen at hand has been considered, and will then be compared with it.



Fig. 1. The head of a 13.5 inch recently caught pug-headed brown trout (*Salmo fario*).
From a photograph.

A PUG-HEADED BROWN TROUT

This fish, a brown trout (*Salmo fario*), was taken with a wet fly on a 4.5 oz. fly rod by Mr. Louis P. Miller in Shinglekill Creek, about half a mile from the town of Cairo, New York, on May 25, 1928. Figure 1 is from a photograph made while the fish was fresh. In it the deformity of the head may clearly be made out. With its steeply descending forehead and its projecting lower jaw beset with teeth, it indeed looks like a bulldog.

This fish made several attempts to take the fly, would rush at it and follow it up with its lower jaw shovelling along on the surface of the water, before it was finally hooked in the upper left jaw. This behavior struck Mr. Miller as most unusual, but he had a better understanding of the matter when the fish was finally landed. Lord Home, as quoted by Yarrell (1841, p. 99), had difficulty in catching a similarly deformed trout. His account of how he hooked this fish, the only one known to me which gives any details, reads as follows:

Once, while fishing in the Tweed for Trout with a minnow, a Trout rose and missed. I threw the minnow over him at least twenty times; each time the fish rose eagerly, and made the most unfishlike (if I may use the expression) attempts to seize the minnow; at last a tail-hook took hold of him, and I got him out. It proved to be a Trout with the upper jaw formed exactly, or very nearly like that described [and figured on page 108 of Yarrell's Vol. II, and like Mr. Miller's specimen]. . . . This Trout was lank and thin, but weighed a pound and a half.

The behavior of this fish was markedly like that caught by Mr. Miller, this due of course to the inability to grasp the bait by reason of the lack of the upper jaw. Yarrell's figure, the first of a salmonid ever published so far as I know, is reproduced herein as Fig. 7. It will be described later.

Mr. Miller's fish has been mounted and lies before me as I write. It is 292 mm. (11.5 in.) long from the tip of the lower jaw to the tip of the caudal fin. The depth, measured just in front of the first dorsal fin, is 63 mm. (2.5 in.). The fish (as mounted) seems, otherwise than in the matter of the mouth, entirely normal and this is confirmed by Mr. Miller who writes that at the time of capture, the fish, notwithstanding its malformed upper jaw, was in fine condition. In fact, the only abnormal structures about it are to be found in the shape and form of this upper jaw, and to the fact that the left nasal apparatus seems to be absent. The right is present and I am inclined to think that the left was also but that it has become obscured in the process of mounting and painting. The upper jaw has been tremendously shortened and bent down vertically to the long axis of the fish. A fair measurement of the lower jaw is 17 mm. (0.7 inches), while that of the upper is 4 mm. (0.09 in.); i.e., the lower jaw projects beyond the upper by 13 mm. (0.5 in.). The lower jaw has five teeth on the left side and nine on the right, while the upper has three only on the left side and about twelve in the right.

In order to give a fair presentation of the appearance of the whole fish, the outline drawing (Fig. 2) has been made. This gives one an excellent idea of the fish as mounted and shows how abruptly the dorsal line of the body falls away to the gaping mouth. It is the only figure

known to me showing a whole pug-headed adult salmonid, all others show the head only. The head and jaw structures being fairly clearly shown in the mounted fish, a drawing of the head only in quartering view

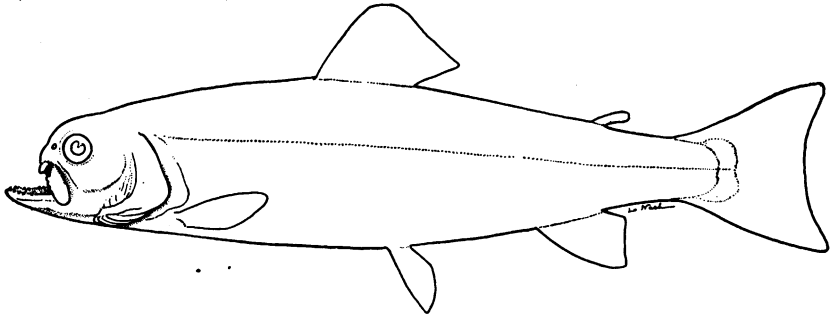


Fig. 2. A lateral view of the pug-headed brown trout, to show full form and proportions.

Drawn from the mounted specimen loaned by Louis P. Miller.

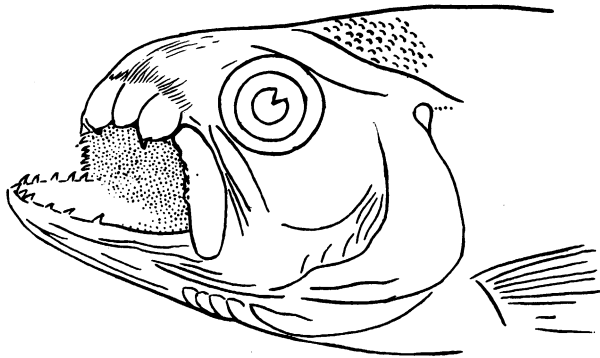


Fig. 3. Quartering view of the head of fish under consideration, to show details of the mouth. See also Figs. 1 and 2.

Drawn from Mr. Miller's mounted specimen.

(Fig. 3) has been made to show the details of these. In this figure the teeth can be made out better and the anomalous structure of the upper jaw is made clearer.

Extending almost vertically from the angle of the jaw, the maxillary shows on its front (lower) edge a number of rugosities which are presumably the bases of broken off teeth. It will be remembered that the fish after repeated attempts to take the fly was hooked in the upper left jaw. The right maxillary shows the teeth intact. In front of and slightly below the level of the eye, the point of junction of maxillary and pre-

maxillary can be made out. The latter has one very prominent tooth near the median line and a rudiment (probably the base of a broken off tooth) farther back (possibly on the front part of the vomer). On the left the same structures are duplicated. Between the two premaxillaries is found a median element of the skull, composed apparently of the ethmoid and nasal bones bent downward and flattened vertically and probably of the vomer underneath. The definite determination of these structures is very difficult in this mounted specimen. If examination of the fresh fish could have been had, one could more definitely say what these bones are. However, we plainly have here, a case of arrested development and of consequent distortion of the front part of the skull and of the upper jaw.

When I first saw this fish, I was struck by the fact that it was adult, apparently full-grown, and looking at the abnormal jaws I thought that it must be an unusually large specimen of a pug-headed fish. However, a brief study of the literature soon showed this conclusion to be erroneous so far as salmonids are concerned. Of the direct references which I have been able to consult, the majority deal with adult fish, while those which make incidental mention of the deformity generally give no idea of the size of the fish. References to this abnormality in newly hatched or very young salmonids are very few, as will be shown in the next section.

As stated above, Mr. Miller's fish when caught was in good condition, well-fed, and fat. In view of the difficulty it had in taking the artificial fly, and indeed a sunken one, this fatness is almost non-understandable if one is to suppose that this trout fed solely or even chiefly on natural flies. However, Mr. Miller offers as a possible explanation the fact that a short distance up the creek is the county almshouse, the scraps from the dining room of which are thrown into the stream. These are eaten by multitudes of shiners and other minnows, which in turn probably serve as food for the trout in the pool a short distance below.

OTHER PUG-HEADED SALMONIDS

As stated above, consideration will be given and comparison made only with salmonid pug-heads. Since most authors comment on the fact that few embryonic forms are on record, the few available accounts of these among salmonids will be set out first.

YOUNG FORMS

References to pug-heads among newly hatched or very young salmonids are but four, presumably because this condition would hardly

be perceived in such small specimens which, from inability to lay hold of the food fed young fish in hatcheries, probably die shortly after the absorption of the yolk-sac and before attaining sufficient size for them to be noticed.

The earliest account (reprinted in 1877) is from the pen of Frank Buckland, who noted this defect in young salmon just out of the egg-shell. Next comes Girdwoyn (1877) who figures (my No. 4) a pug-headed salmonid embryo still attached to the yolk. Not being able to read his brief description (the size is not even given), I have no data available for this specimen. However, it is a plain case of pug-headedness with an abruptly rounded forehead descending to a projecting lower jaw twice as long as the upper. The eye (on the right side at any rate) has also failed to develop. The genus and species are not indicated.

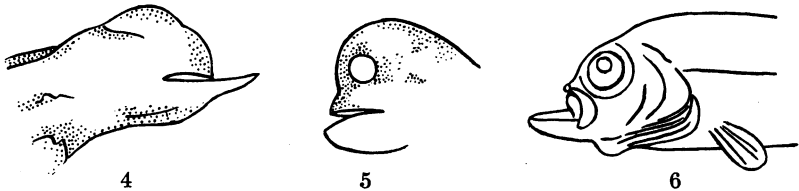


Fig. 4. Head of a salmonid embryo still attached to the yolk.

After Girdwoyn, 1877.

Fig. 5. Head of a trout embryo (twenty days old) still attached to the yolk.

After Quatrefages, 1888.

Fig. 6. Head of a twenty-two months old rainbow-trout (*Salmo irideus*). Contrast this head with those shown in Figs. 1 and 2.

After Yung. (1901).

Quatrefages (1888) figures and describes another pug-headed salmonid embryo (genus and species not given). It is one of a pair of twin trout-monsters lying on opposite sides of the yolk of an egg. It came to him in 1859, about twenty days after hatching, and lived twenty-six days longer. As is practically always the case, one of the twins (in this instance the pug-headed one) was the larger. It developed more rapidly and (except in the matter of the mouth and the eyes) more normally than its twin.

When the twins first came to Quatrefages, the head of the more advanced was decidedly of the pug-headed kind. The lower jaw was longer than the upper, but the mouth, however, had a bird-beak appearance (Fig. 5). At the time of death, twenty-six days later (forty-six after hatching), the fish's head had taken on that abnormal shape called "round-headed," the jaws being short and the lower but slightly longer

than the upper, while the head retained its rounded form in front. Here also the eye was undeveloped.

Yung (1901) states that he had a number of times observed pug-headedness in young lake trouts (*Salmo lacustris*). He does not give sizes, but since he calls them "jeunes truites" and not "embryons" they were presumably fingerlings. However, in 1900 he received from a fish hatchery a young pug-headed rainbow-trout (*Salmo irideus*). This he kept under observation in an aquarium until it died at the age of twenty-two months, having attained a length of 76 mm. (3 in.). The head of this little fish is shown in Fig. 6. The lower jaw is normal while in the upper the premaxillary is reduced to a small, rounded object, and the maxillary is very much shortened and stands in a nearly vertical position. The little fish had difficulty in feeding and although perfectly healthy was, nevertheless, noticeably smaller than others of the same hatching but having normal jaws. The author tried feeding this fish on daphnias but with poor success; it was unable to catch them. Nor did he have better success when he suspended before the fish bits of food caught on a thread. This, in part at least, was due to the fact that the little fish never lost its fear of him. The fishlet foraged for itself, using its lower jaw like a spatula to dig *Tubifex* and other worms from the soil at the bottom of the aquarium. At its death (from some undetermined cause), autopsy showed its stomach to be full of partly digested *Tubifex* worms. The forehead of this fish (if one may so designate it) is very unlike all the others portrayed herein. Yung also figures the right side of this head which shows other defects in addition to pug-headedness. The eye is entirely lacking and the whole side of the head is deformed. This state of things undoubtedly had part in giving the head, as seen from the left, the long sloping curve shown in Fig. 6. Note should also be made of the fact that the nares are found on the right side, but lacking on the left.

Reference to young forms of *Leucaspis delineatus* will be made in the section dealing with transmissibility of this defect. Here we are dealing only with salmonids.

ADULT PUG-HEADED SALMONIDS IN GREAT BRITAIN

Other and older pug-headed salmonids of which there are descriptions or figures, or both, will now be briefly considered, particularly from the standpoint of the shape of the upper jaw, and of size as indicative of age. In all cases where possible, outline figures of these will be given for comparison. Those from Great Britain will be considered first of all, since the oldest reference to such a salmonid comes from that country.

The earliest account known to me is from Thomas Tod Stoddart who, in 1835, wrote that: "On the Tay we once took an individual [trout] with a short round upper head, like that of a bulldog, and the lower lip projecting beyond it. We understand that a variety of this kind is to be found in Loch Dow in Inverness-shire." Stoddart unfortunately gives no figure and also does not indicate the species.

The next early account of a bulldog-headed trout is to be found on page 59 of volume I of Yarrell's 'British Fishes' (1836). He quotes the account from "T." next to be given, and concludes with these words: "Such a Trout from Lochdow was presented to the Museum of the Zoölogical Society by the Honorable Twisleton Fiennes; the vignette [my

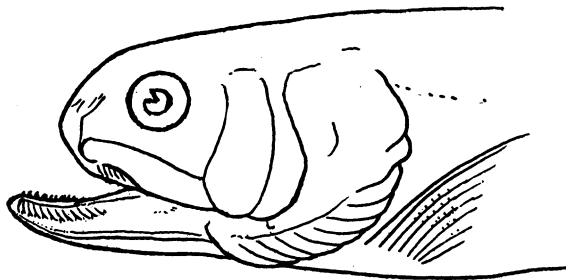


Fig. 7. A pug-headed brown trout from Lochdow, Scotland. This is the first published figure of a pug-headed salmonid.

After Yarrell, 1836.

Fig. 7] is a representation of the head of that specimen." The fish is a *Salmo fario*, and the account and figure are both reproduced in the second edition (1841) of Yarrell's work.

The figure shows a head somewhat like that of Mr. Miller's fish. The premaxillary seems to be absent, at any rate, no teeth are shown. The maxillary is shortened and apparently devoid of teeth; the ethmoid seems to be bent downward and backward; and finally the head is very much rounded. Yarrell seems to have considered that these deformed trout constituted a distinct variety.

The writer (who signs himself merely with the letter T.) on 'Angling' in the 'Encyclopædia Britannica' (7th Ed., 1842, footnote to p. 144) says that: "In 1829 we received some very singular Trouts from a small loch called Lochdow, near Pitmain, in Inverness-shire. Their heads were short and round, and their upper jaws truncated, like that of a bulldog. They do not occur in any of the neighboring lochs, and have not been observed beyond the weight of half a pound."

While it is possible that T's and Yarrell's accounts may have been based on the same specimens, it seems probable that T's fish, seen seven years before Yarrell wrote, were different specimens. How Yarrell in 1836 could have quoted T's account published in 1842 (the date is correct for I have examined the volume) is difficult to explain. Perhaps Yarrell had a proof sheet of T.'s article.

Couch, in the first edition of his work on 'British Fishes' (1865), mentions Yarrell's fish and figure and writes in such fashion as to leave the impression that he had seen various specimens of such a deformed trout. He concludes in these words: "In other particulars, this [deformed] fish does not differ from other Trouts; the most remarkable circumstance concerning it is, that it is not merely a casual deformity of an individual, but is common in lakes or pieces of water which lie at some considerable elevation in hills of great height. Such is the case in a small loch called Loch Dow, near Pitmain in Inverness-shire."

I had hoped to get something definite from Günther, the learned keeper of fishes in the British Museum, but in his 'Catalogue' (1866) he says of his two deformed specimens of *Salmo fario*: [1] "Upper part of the snout shortened. Old collection," and [2] "Upper part of the snout shortened. Loch Roy. Inverness-shire. Presented by H. C. Pennell, Esq." Whether or not the locality for the second specimen is identical with Loch Dow, it is significant that here is another pug-headed trout from Inverness-shire.

In 1872 there was published the first edition of B. T. Lowne's¹ work on teratology. In this, on page 40, is a statement for specimen No. 141 that it is "The head of a young Salmon [size not given] with a truncated face, the maxillæ are placed almost at right angles to their normal position, and lap over the mandibles on either side." This is a significant fact. What is meant, I take it, is that the lower ends of the maxillary bones extend downward across the lower jaw at the angle of the mouth. I had not understood this until there was recently sent me for study the head of a pug-headed sea-bass showing this identical displacement of the maxillaries. This has not been found in any other salmonid.

Buckland (1877) noted this deformity in quarter or half-grown salmon of which he had casts made for his museum. However, his third and largest fish (which must have been quite 36 inches long) weighed 29 lbs.—the record for size among pug-heads. In all of these specimens the upper jaw had been turned down and inward on itself and had be-

¹I have not been able to consult the 1893 edition of Lowne's work and do not know whether this contains a more extended description. It is very unfortunate that there is no figure of this unusual structure.

come hard, taking the place of the palate, very like the specimen under consideration. He unfortunately gives no figures.

In 1884, Day wrote of these pug-headed fishes: "A deformed race of trout is asserted to exist in a small loch in Inverness-shire near Pit-main; among them there appears to be an arrest of development in the upper jaw, giving their heads a slight resemblance to those of bulldogs, due to the projection of the lower jaw." That Day ever saw these fish is at least problematical.

Next for England, Malloch (1910) figures two pug-headed trouts, both of the round-head type very similar to Yarrell's, the upper jaw having almost entirely disappeared. No descriptions are given but the captions state that both were taken in the River Tay, Scotland. Presumably both were adult, it being noted that the larger weighed 1.5 lbs.

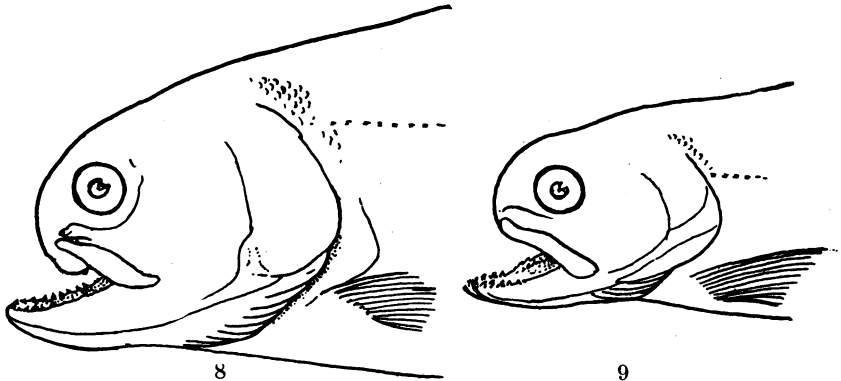


Fig. 8. A bulldog-headed sea-trout (weight 1.5 lbs.) having the upper jaw elements greatly reduced.

After Malloch, 1910.

Fig. 9. A pug-headed trout from the River Tay. The maxillary seems nearly normal, but there appears to be no trace of the premaxillary.

After Malloch, 1910.

The first (my Fig. 8) is a sea-trout. Here, in what seems to be the central head region, the anterior part of the snout is bent downward, backward, and inward very much as is shown in Mr. Miller's trout (my Figs. 1, 2, and 3). This is apparently the premaxillary, the maxillary being more normal in position and form. The second figure (No. 9 herein) is also of the round-headed type. The premaxillary is not visible, having suffered reduction and probably having been bent backward and inward, the maxillary remaining nearly normal. The lower jaws of both fish are well provided with teeth. The second fish is merely labeled "trout."

It is to be expected that Gemmill in his great general work on malformations in fishes (1912) would have described his own specimens while discussing this abnormality. But he merely states that pug-headed specimens of *Salmo fario* and *S. salar* have been sent to him (from Scotland presumably). He does not even indicate their sizes.

I have to thank Mr. R. L. Marston, editor of The Fishing Gazette, London, for sending me photographs of a pug-headed trout and of a salmon with similar deformity, with the references to their publication. The first of these photographs, reproduced herein as plate XXI, figure 1, shows the head in profile, and Fig. 2 is a "head-on" view of the fish. It is the first figure ever published showing a pug-headed fish looking into the camera. Comparison should be made of it with Fig. 3, a sketch of the head of Mr. Miller's fish. The figures in this plate were published in The Fishing Gazette, 1926, by Mr. J. A. C. Forsyth, and Mr. Marston has kindly allowed me the use of Mr. Forsyth's original photographs. Reference will be made to the radiographs later.

The trout portrayed in figure 1 of plate XXI is somewhat like those figured by Malloch (Figs. 8 and 9), perhaps more like the second of these. But in a number of ways it is the most unusual pug-head of any genus yet figured by any writer. The head proper is unusually high, level on top, and abruptly rounded. The eye has been carried very high and is especially near the front. It is not so high as the eye of Yung's juvenile specimen shown in Fig. 6, but it has less "forehead" in front of it than any fish studied. For this point compare the embryo shown in Fig. 5 and the adults in Figs. 13 and 14. The lower jaw seems normal, but the upper is represented by the maxillaries only, the premaxillaries are bent back into the mouth, only a remnant showing, as seen in figure 2 of plate XXI. These conditions are almost identical with those found in Miller's fish. Mr. Forsyth writes of his fish that: "The lower jaw projected half-an-inch beyond the upper. . . . Despite this deformity, the trout was in excellent condition. It was a 12 in. fish and weighed three-quarters of a pound. Caught on the dry fly, it was hooked in the palate, the barb of the hook protruding through the right nostril." He adds that the fish was reared in a hatchery and that he has never seen such a deformed wild trout. The deformation of the bones seen in figures 3 and 4 of the plate will be considered later.

The photograph of the second pug-head sent by Mr. Marston is of a ten-pound salmon found by Mr. A. E. Whittington in a fishmonger's stall in Liverpool. It is recorded in The Fishing Gazette of Oct. 13, 1928. The fish seems to have the same general type of head as Mr.

Miller's fish with the backwardly displaced maxillary standing at an angle of nearly 60 degrees. So far as I can see it is like the other pug-headed salmonids of what will later be called the first type; i.e., having the premaxillaries bent back into the mouth, and the maxillaries present but standing at a high angle. The photograph is too small and indistinct to show any details and will not be reproduced herein. However, it seems well to make note of it and to insert the reference in my bibliography.

Finally, in answer to inquiries by letter, certain data have come which I am privileged to quote. Major J. W. Hills, the well-known English angler and author of books on trout fishing, writes that in a long fishing experience he has caught only three or four pug-headed brown trout, but no sea-trout or salmon. He transmits a letter from Mr. Arthur Wood of Glassel, Aberdeenshire, who has caught a number of pug-headed trout but never such a deformed salmon. However, Mr. W. J. M. Menzies of the Scottish Fishery Board writes that in all his experience he has seen but two pug-headed salmon. From this expert testimony, in connection with that given above, we may judge how unusual this malformation is, even in Great Britain whence the majority of cases have been reported.

Pug-headed brown-trouts have also been recorded from Irish waters. Thus Thompson speaks of them in 1856, unfortunately without giving any figures:

[1] *Salmo fario* . . . with short upper jaw, just as figured by Yarrell . . . [Fig. 7 herein]. It is seven inches long. . . . The upper jaw has a singular appearance, being doubled in with all the teeth in it, as if it were perfect. This specimen was taken in a pond at Sally Park, near Dublin in 1838; the pond is supplied by a mountain stream.

[2] Deformed trout [presumably a pug-head since he is speaking of such], taken in a river flowing from Loch Ruthven, half an English mile from the lake, one of three hundred and twenty taken in three days, during the second week in September, 1839.

[3] Trout with malformed head, just as figured by Yarrell, brought to the Museum from a small stream near Doagh, County Antrim, where a second one of larger size was also taken, May, 1844.

Couch (1865) likewise notes deformity in trout from Lough na Minna, County Clare, which is 700 feet above sea-level. He concludes that this and other deformities are possibly in some unknown way due to the elevation. Neither he nor Thompson give any figures.

Houghton (1879), after speaking of English pug-headed trout like Yarrell's in such a way as to leave one in doubt whether he had actually seen such specimens, concludes by saying that: "I learn from Mr. Haynes, of Cork, that similarly deformed Trouts [*Salmo fario*] have

been killed by him in County Cork and County Clare: he has sent me an ink sketch, which exactly resembles Yarrell's woodcut, only the lower jaw is more elongated. Mr. Haynes has seen three specimens of these fish."

ADULT PUG-HEADED SALMONIDS IN FRANCE, GERMANY,
HOLLAND AND HUNGARY

Leaving the pug-headed trouts of Great Britain, let us next consider such malformed fish from the continent. First we will take up the account of Cornay (1847), who obtained his specimen of salmon-trout from the market at La Rochelle to which it had been brought from a small stream near by. It was 31 cm. (12.2 in.) long. Being fat and full-grown, it evidently had not suffered from lack of food because of its anomalous upper jaw. The lower jaw was slightly shorter than the normal, while the upper had been shortened and turned downward and backward on itself exactly as in the specimen under consideration. No figure is given.

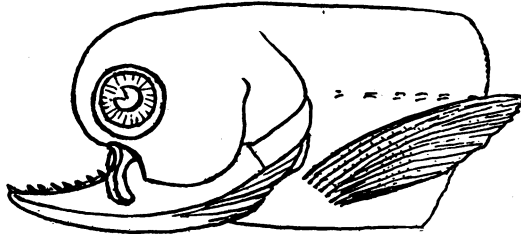


Fig. 10. Head of a "truite mopse," having all the upper jaw elements invisible save the much reduced maxillary which stands vertically. Note the markedly round head.
After Carlet, 1879.

Valenciennes (in Cuvier and Valenciennes, 1848, XXI, p. 335) found two adult pug-headed trouts in the collections of the great Paris museum. One was slightly over 8 in. in length. Valenciennes expresses wonder how this fish managed to obtain food since the intermaxillaries were bent backward and underneath so that they touched the tissues of the roof of the mouth. The lower jaw extended beyond the upper by its whole length; i.e., the front part of the head was abruptly rounded downward, as will be shown later in figures. Unfortunately, no illustrations of these two fish are given.

Carlet's trout (1879) came from the River Isère in southeastern France, at an elevation of over 2000 m. (5700 feet). His figure (my No. 10) shows a trout with a much projecting lower jaw, and with the head curving downward and backward in a perfectly smooth outline.

The premaxillary is entirely lacking, while the maxillary is reduced to a mere fragment standing vertically at the angle of the jaw. Yet, notwithstanding this anomaly, the fish was well grown (18 cm., 7.1 in. long) and in good condition. It was a female whose ovary was filled with eggs which on microscopic examination proved to be perfectly normal. From a study of its mouth structure, Carlet concluded that it could not have caught insects but must have nourished itself on small fish or on worms and other animals found in or on the bottom of the river. Carlet's figure is reproduced herein as number 10, being the first to show a perfectly round head curving smoothly into an open buccal cavity.

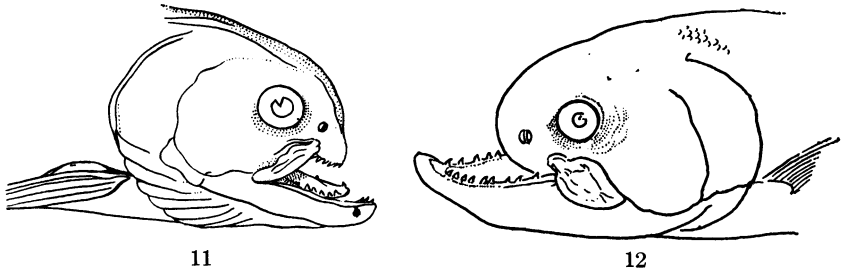


Fig. 11. Head of a deformed 9.9 inch salmon-trout (*Salmo trutta*). Note the similarity of the upper jaw to that shown in Figs. 1 and 3.

After Lidth de Jeude, 1885.

Fig. 12. A pug-headed, six-pound male salmon (*Salmo salar*). The rounded head shows no trace of premaxillaries which are bent in and on to the roof of the mouth. Compare with Figs. 10 and 15.

After Lidth de Jeude, 1885.

In 1885, Lidth de Jeude figured and described the heads of a *Salmo trutta* (salmon-trout) and of a salmon (*Salmo salar*) obtained in the rivers of Holland. The first (my Fig. 11) was an unripe female, 25 cm. (9.9 in.) long, in good condition. Its upper jaw is almost identical with that of Mr. Miller's fish. The premaxillary on the left side is abruptly bent downward and bears four teeth. The maxillary (the right one is better developed) is much reduced and inclines forward at an angle of about 45 degrees. No description is given of the anomalous structure figured in the left lower part of the mouth. It looks like the left half of the lower jaw but is presumably the tongue with teeth on its edges. Of this fish the author says:

The prenasal portion of the head is but slightly developed and therefore the normal under-jaw projects in front of the snout. The præmaxillaria are small, and asymmetrically developed, the right one being the largest and bearing 4 teeth, the left one smaller with only 3 teeth. These præmaxillaria are not directed forwards, but

curved, and each growing towards its fellow; therefore the head gets a short and broad appearance. The two bones do not meet at the midline but are connected by a cartilaginous strip. This strip is 4 mm. broad, and shows at the underside a rounded emargination, giving to the snout some resemblance with a hare-lip. The supramaxillaria are a little shorter than in the normal state, slightly curved and bearing small teeth, which are directed inwards.

The second fish was a ripe adult male, weighing 2.7 kg. (6 lbs.), and was in fine condition. In it (Fig. 12) the lower jaw is apparently normal and filled with teeth. The upper jaw seems wholly lacking, save for the remnant of the maxillary at the angle of the mouth, and there is found the same rounded head as that figured by Carlet (my Fig. 10) and less clearly by Yarrell (my Fig. 7); the upper jaw has seemingly failed to develop. But Lidth de Jeude specifically states that the pre-maxillaries "fully developed but directed backwards are consequently lying under the palate," the teeth being directed upward and forward.

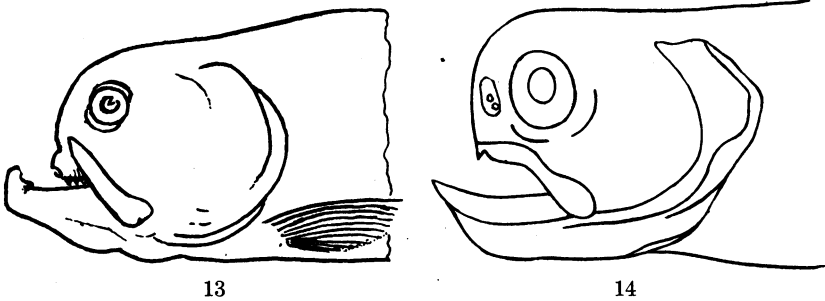


Fig. 13. An adult male salmon having a pug-head very similar to that shown in Figs. 1 and 8.

After Hofer, 1904.

Fig. 14. A pug-headed brook-trout with remarkably shortened lower jaw and very steep forehead.

After Törnier, 1908.

A year later (1886) Krauss described a "Mopskopf" trout from Nagold in Würtemberg. This was an adult, 20 cm. (7.9 in.) long, and very similar to but intermediate in the structure of the upper jaw between Lidth de Jeude's two specimens. The lower jaw projected beyond the upper by 1 cm. (0.4 in.). Unfortunately, he gives no drawing.

Bruno Hofer, the distinguished fish pathologist, in his 'Handbuch der Fischkrankheiten' (Munich, 1904, pp. 308-310, Fig. 198) portrays (without indication of its source) the head of a rainbow-trout afflicted with "Mopskopf," but unfortunately gives no size nor description. His fish, however, is apparently an adult (see my Fig. 13) with the characteristic hooked lower jaw of the sexually mature male salmon.

Tornier (1908) figures rather diagrammatically the head of a "Bachforellenmopskopf" (presumably from German waters) and his figure is reproduced herein as No. 14. This fish is interesting in that the lower jaw, while notably longer than the upper, is considerably shorter proportionally than that of any other adult figured in this paper. The forehead is high and vaulted and falls away almost vertically close to the eye. The maxillary is nearly normal in length and position and is separated from the premaxillary by a slight notch as in Mr. Miller's fish. The premaxillary has one tooth only, as has Miller's fish. Unfortunately, Tornier does not indicate the size of this fish.

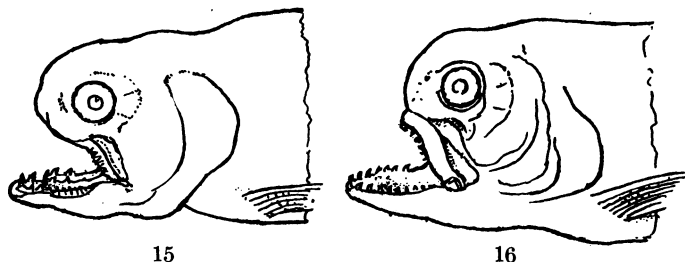


Fig. 15. A pug-headed brown trout of the round-headed type with maxillary much reduced.

After Hankó, 1922.

Fig. 16. A pug-headed *Salmo fario* having the upper jaw much reduced but still more usable than that of most pug-heads.

After Hankó, 1922.

Last of all, Hankó, in 1922, published an article on fishes with malformed heads found in the collections of the Hungarian National Museum. Among these he figures the heads of two brown trout (*Salmo fario*). One (Fig. 15) has the head rounded almost as in Carlet's fish (my Fig. 10) and Lidth de Jeude's second fish (my Fig. 12). In the drawing the maxillary is reduced to a remnant at the corner of the mouth. Apparently, this bears some teeth. In the second fish (Fig. 16) the toothed maxillary extends apparently well toward the median line of the head. Each lower jaw is well provided with teeth. The sizes of these fishes are not given.

ADULT PUG-HEADED SALMONIDS IN AMERICA

In all the work done in the American Museum on the 'Bibliography of Fishes' and on the continuation card catalogue thereof, not a single reference to this condition in salmonids in America has been found. In this state of affairs I have sought information from ichthyologists who

have given particular study to the Salmonidæ, and from sportsmen of wide experience in taking these fishes.

Dr. David Starr Jordan, dean of American ichthyologists, writes that he has never seen this malformation in any salmon or trout. Mr. B. A. Bean has had the extensive collections of the U. S. National Museum searched without finding a single specimen. Dr. W. C. Kendall of the U. S. Bureau of Fisheries, perhaps the foremost student of American Salmonidæ, says that he does not distinctly remember a pug-headed trout, but thinks that one such specimen was sent in to the Bureau, from Vermont, many years ago. Mr. Henry O'Malley, U. S. Commissioner of Fisheries, has had the collections of the Bureau looked through without finding the above or any other specimen.

Among sportsmen, Mr. F. Gray Griswold writes that in fifty years of fishing for salmon he has never taken a pug-head in America, but has seen them in England. My brother, David Gudger, has fished for brook-trout in the streams of western North Carolina all his life without ever taking a pug-head. The only American sportsman who has, so far as I know, is Mr. Charles Zibeon Southard of Groton, Mass. Mr. Southard has fortunately kept careful records and has courteously communicated the data on pug-heads now to be presented.

His first pug-headed trout was taken with bait in a brook near Groton in 1898. During the next few years he took two or three others in this brook. In 1905, in the outlet of Big Kennebago Lake, Maine, he took with the fly a nine-inch specimen. In 1907, in the Debsconeag region of Maine, he caught a ten-inch pug-headed trout which was in such fine condition that he cooked and ate it for lunch. From 1910 to 1927 Mr. Southard took several pug-head trout in the Kennebago Lakes and in the Rangeley Lake region and in the various waters between Kennebago Lake and Rangeley town. In all, this experienced angler thinks that in sixty years of fishing he has taken more than 50,000 trout (most of which have been thrown back) and in all that number not more than twenty-five have been pug-heads. "All these [pug-headed] fish were healthy, plump, fat, but were seldom more than 10 inches in length." It seems to him a significant fact that all his pug-heads have been taken in much-fished waters, never in wild or wilderness streams. From this, and from the added fact that he has taken many fish with torn and malformed lower jaws, he has come to the conclusion that all these malformations of the snout, whether in upper or lower jaws, result from injuries consequent on the tearing out of the hook. While this conclusion, as will be seen later, is not in agreement with that arrived at by scientific

men, there is reason to believe that malformations comparable with pug-headedness may so arise. Mr. Southard has not noted any peculiar behavior on the part of his pug-heads in their attempts to take bait or fly.

To sum the matter up for American salmonids: this phenomenon is apparently very rare in our waters compared with those of Great Britain. Possibly this is due in part to the fact that such catches have not been published.

This then concludes the review of the literature of pug-headedness in salmonids. It is not improbable that a careful search through the general literature of the teratology of the Salmonidæ would bring to light various more or less incidental accounts of pug-headedness in such fishes. But since such work would be based on mere possible finds, it has not been undertaken.

It is a fact that the accounts given of pug-headedness in Salmonidæ refer mainly to *Salmo fario*, the European brown trout. There are herein referred to about 26 more or less definite accounts of specimens of pug-headed salmonids. Of these 13, or 50 per cent, are named as the brown trout, and I think it likely that a number of cases referred to as "common trout" should be credited as *S. fario*, thus still further increasing the percentage. However, one must not conclude that this deformity is more common in it than other members of the family, but that, since it is necessarily the most widely diffused salmonid, and hence the one most commonly caught, it is merely the form in which the deformity has been most often noticed.

PUG-HEADED SALMONIDS OF TWO KINDS

In all these salmonids afflicted with what the Germans call Mops-*gesicht*, it is notable that the lower jaw is always markedly longer than the upper—i.e., the lower is normal, the abnormality being found in the upper jaw and neighboring head parts. Even in Girdwoyn's eyeless embryo (my Fig. 4) this is true. However, Quatrefages found that in his embryo (my Fig. 5) the lower jaw, which was at first notably longer than the upper, suffered a retardation in development as time went on and at the time of the death of the fish was hardly longer than the upper jaw.

Attention must, however, also be called to the lower jaw of Tornier's specimen (my Fig. 14), which is markedly shorter than any others figured

save those of the embryos. Presumably, this fish was adult, but unfortunately Tornier does not give its size. Short as this lower jaw is in comparison with all the others, it is markedly longer than the upper jaw of any adult fish studied herein.

However, in the course of this investigation, there has come to light a fact to which attention has not been called before; namely, that there are two distinct forms of pug-headedness in salmonid fishes, so far as concerns the shape of the front of the head.

In group I the head descends steeply and nearly at right angles to the lower jaw, there are the rudiments of an upper jaw present, particularly the maxillary which reaches well medianward to about its normal point of junction with the premaxillary, and there are teeth on both. It is as if the upper jaw had been forcibly flattened downward and backward, almost at a right angle. This is seen in Mr. Miller's fish (my Figs. 1, 2, and 3), in Lidth de Jeude's first fish (my Fig. 11), in Hofer's figure (my Fig. 13), very clearly in Tornier's fish (my Fig. 14), and hardly less plainly in Hankó's second drawing (my Fig. 16).

In the second group, the premaxillaries are bent clear backward, inward, and upward, to form the roof of the mouth and hence are invisible from the exterior. Thus, the front of the head rounds in almost circular fashion back to the angle of the mouth where the much reduced maxillary is found standing at an angle more or less approaching the vertical. This is seen in Carlet's fish (my Fig. 10), in Lidth de Jeude's second figure (my Fig. 12), in Malloch's second illustration (my Fig. 9), and lastly in Hankó's first figure (my Fig. 15).

Some of the specimens figured herein can hardly be classified in either of these groups but constitute intermediate forms connecting group I with group II. Such are Yarrell's fish (my Fig. 7) and Malloch's second specimen (my Fig. 9), where we find the maxillary long and placed fairly normally, while a remnant of the premaxillary can be seen but with no teeth on it.

PUG-HEADEDNESS IN SALMONIDS AND CARPS CONTRASTED

Head abnormality in fishes, known as "Bulldog Head," "Lion Head," "Löwenkopf," "Mopskopf," "Pug-Head," "Tête du Chien," in the English, French, and German languages, is rare but by no means uncommon. It has been reported in at least twenty-five different species of fishes and in almost as many genera. Unfortunately, no general study of this deformity, no comparison of the different types of structure in the heads of various fishes, has as yet been made. Furthermore, it is

not my intention to do so here since time and material are lacking. However, since there is at hand a figure of a pug-headed carp, which is very typical of a certain clearly marked form of this abnormality found not only in carps but in other kinds of fishes, a brief comparison of the forms of bulldog-head in salmonids and carps may not be amiss.

Figure 17 is made from a photograph of Rondelet's illustration of a pug-headed carp published in 1554 (see Gudger, 1928). Pug-headedness

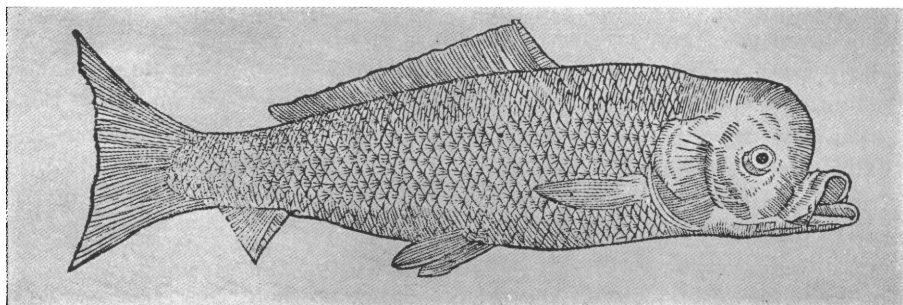


Fig. 17. Rondelet's pug-headed carp. Note the short somewhat upturned snout with open mouth, characteristic of such deformed carps.

After Rondelet, 1554.

has been reported in a considerable number of genera and species of the Cyprinidæ, and I have examined all the available figures. None of these have the elongated lower jaw found in all the salmonids; they all have this short and generally slightly upturned. All the figures show the round head found in the salmonids, but while this falls away abruptly, giving a rounded bulging forehead, it does not fall into an open buccal cavity. The upper jaw seems always to be present, even though it is very much reduced, and is always shorter than the lower jaw. Thus, the snout is always very much shortened, slightly turned up, and the mouth is generally more or less open, as is portrayed in Fig. 17. In fact, such a malformed carp's head much more resembles a bulldog's head than that characteristic of the salmonids.

Undoubtedly, these differences are due to the fact that the salmonids have long jaws and the carps short ones. Presumably, this difference will hold in a general way for other fishes having jaws of these two types. At any rate, the figures of pug-headed eels and pikes show a long lower jaw such as is found in the salmonids, while the short-jawed carps and cods in their pug-headed forms have short "pursed-up" mouths as seen

in Fig. 17. It would seem that in these various forms of bulldog-headedness there is opportunity for an interesting bit of research.

THE OSTEOLOGY OF PUG-HEADED SALMONIDS

It is, of course, impossible to skeletonize the present fish, and no other is at hand for the purpose, so brief quotation from the work of others must be made to give some definite idea of the changes in the bones involved. It is, however, clear from inspection of the figures that the changes due to this deformity are confined almost wholly to that part of the head in front of the eyes. Seemingly frontal pressure has been exerted to compress, bend downward, inward, and backward the bones comprising the upper front part of the snout and at the same time to cause a great uprising and bulging in the eye region.

Tornier has figured semi-diagrammatically (Fig. 18) a normal trout skull, and as Fig. 19 the skull of the pug-head shown in Fig. 14. Comparison of these figures shows that, save for a change in shape of the eye socket and a vaulting of the skull in the eye region, there is practically no change in the middle and none whatever in the hinder part of the skull.

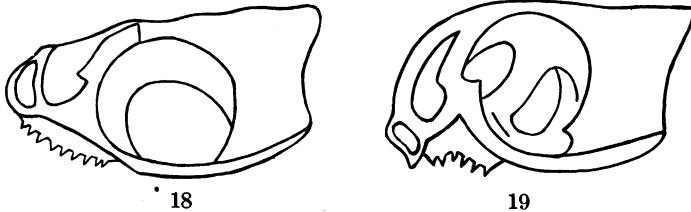


Fig. 18. The skull (semi-diagrammatic) of a normal salmon.
After Tornier, 1908.

Fig. 19. The skull (semi-diagrammatic) of a pug-headed salmon.
After Tornier, 1908.

In front of the eyes the skeletal elements are present but are reduced in size and much changed in form and position, being curved downward and generally inward. In the basal region of the skull the parasphenoid has been shortened in its anterior part; the vomer, if not shortened, has been displaced backward and has been bent in the form of an inverted Δ with the apex upward as is shown in Fig. 19. The ethmoids and nasals have been bent downward, carrying with them the anterior part of the frontal, the whole being much reduced and standing more or less vertically. The premaxillaries are much reduced and hence bear fewer teeth, as has been noted. In all forms they are displaced backward to some

degree, and in the extreme roundheaded forms like Carlet's fish (my Fig. 10) they are bent backward and upward out of sight to form the palatal part of the mouth, the teeth being directed upward against the roof of the mouth. The maxillaries are in most cases shortened and displaced backward. Generally they stand directed upward at a sharp angle and frequently are almost vertical in position. It is also clear from an inspection of the various figures that the anterior limb of the suspensorium is shorter than that in the normal jaw.

Since the above was written, Mr. Forsyth's radiographs have come to hand, as noted previously. These figures 3 and 4, of plate XXI, are the first ever published. In figure 3 it can be seen how tremendously the head has been shortened before the eyes, that part anterior to them being almost entirely lacking. The vaulting of the skull in the eye region has been so great as to make the dorsal surface of it nearly as level as the basis cranii. In short, the top and bottom surfaces of the skull are marked off by lines almost parallel, as can be seen in figure 3. The anterior end of the parasphenoid, that part in front of the eyes, has failed to develop. The frontal, the ethmoids and nasals may be made out to be abruptly bent downward. The vomer and the palatines have been displaced backward. The dark patch in the front of the mouth is apparently composed of the inturned premaxillaries with their teeth superimposed on the front part of vomer and palatines. The maxillary and the opercular bones are very poorly shown.

The structures of the lower jaw, the hyoid region, and the shoulder girdle parts are confused, probably because the radiograph does not show these in a strictly vertical plane. The wide and far-backwardly reaching cleft between the roof of the mouth and the lower jaw apparently results from the focus having been in the cavity of the mouth itself. However, careful inspection with a glass will show some of the elements of the hyoid, the basi and ceratohyals which are seen underneath the jaw bones.

In figure 4 of plate XXI, the skull of this pug-head is seen from above, and its extreme shortening is again noticeable. The toothed lower jaw is fairly clear as is the anterior part of the hyoid region (the basihyal). The outlines of the maxillæ may be made out and inside these the inwardly and backwardly displaced tooth-bearing palatines are faintly visible with their teeth pointing upward and inward toward the base of the skull. The junction of skull and spinal column is plainly visible, as are the opercular bones and the gill-arches. The dark body in front of the head is the frontal bent downward and presumably showing in two

thicknesses and having under it the inpushed premaxillæ and the anterior part of the vomer.

This is about all that can be said here as to the changes in the bony parts of the anterior region of the skull of pug-headed salmonids. The changes indicated are fairly apparent from a study of the figures of the various heads reproduced herein, and from a consideration of Tornier's semi-diagrammatic figures (my Figs. 18 and 19). They are made much clearer by study of Mr. Forsyth's radiographs, which I am fortunate in being able to reproduce. There are many interesting changes in the skull involved in this deformity, especially since it has been shown herein that there are at least two types of pug-headedness in salmonids. To work out thoroughly the changes involved, especially in those forms with extreme round heads, would require a considerable series of specimens for dissection.

THE BRAIN IN PUG-HEADED SALMONIDS

The reader has probably conjectured before this as to the effect on the brain of this bending and deformation of the anterior part of the skull in pug-heads. However, since this deformation is practically confined to the preorbital part of the skull, about all that will be affected are the olfactory nerves and the nasal organs. In the mounted specimen before me I can make out the nares on the right side but am unable to find these openings on the left side, nor are they visible in the photograph (Fig. 1) showing the left side of the head. This is probably due to poor focussing of the camera and to rather poor mounting of the fish.

It would of course be of very great interest to dissect a full-grown pug-headed fish, not merely to study the bones as noted above, but also to get at the displacements and changes in the brain structures. This has been done by one man, Yung (1901), but on a small specimen only 36 mm. long. This had the left eye normal but no left nasal organ. The right eye was lacking but the nares were present; i.e., the conditions were exactly reversed. The behavior of the fish was equally one-sided since it swam continually in circles around an imaginary axis on its left side. This led Yung, on the death of his little fish, to dissect out the brain, and later to imbed it and cut sections. He figures the brain seen from above. In this the forebrain seems to be reduced in size, the entire right side of this part from the cerebellum forward is, in keeping with the external conditions of the right side of the head, very much reduced and defective, and finally the right olfactory nerve is lacking. However, since these internal lesions accompany external abnormalities, one must conclude that they are defects due to failures in development probably

quite independent of pug-headedness. This judgment is of course based in part on the fact that none of the other pug-headed salmonids described show any defects other than in the anterior part of the skull only.

In short, all that can be said, concerning the effect of "Mopskopf" on the brain, is a Scotch verdict of nothing proven. It is to be hoped that some one with abundant material at hand will, by dissection, be enabled to set forth the facts.

THE CAUSE OF PUG-HEADEDNESS

Considering all the pug-headed salmonids figured above, it looks as if strong frontal pressure had been exerted on the snout to flatten and depress it, as may be seen in Fig. 3, or to push the premaxillaries back into the buccal cavity where they form the functional roof of the mouth, while the maxillaries are diminished in size and driven backward to stand nearly vertically at the angle of the mouth, as may be seen in Fig. 10.

The cause of this abnormality is not certainly known, but it is generally believed to be due to some defect in the germ, aided perhaps, during the development of the embryo, by environmental factors such as pressure. Emphasis may be laid here on the fact that it has been reported in newly hatched embryos (Buckland, 1877, Girdwoyn, 1877, Quatrefages, 1888); in fingerlings by Yung, 1901, and by Knauthe, 1893*a*, 1893*b*. Tornier (1908) carried on experimental investigations on this and other cephalic variations which lead him to conclude that pug-headedness results from disturbances in the development of the germ into the embryo, due to upswellings of the yolk-substance underneath the embryo, resulting from an undue intake of water. He thought that pressure is thereby exerted on the developing head parts caught between the yolk and the egg-shell and that this results in this particular malformation.

A careful translation of Tornier's paper and consideration of his conclusions leave me unconvinced, as they have a number of others who have critically followed his recorded work, and I understand that Tornier himself now thinks that these alleged causes are not sufficient to account for the results.

However, certain conjectures may be set forth as a possible partial explanation. Salmonid embryos in early stages have very short snouts and are much blunter headed than adults. Then, if development of the entire snout is arrested at this stage, there will result that abnormality in fishes called round-headedness. But in the cases under consideration the lower jaw has developed normally while the upper remains in an essentially embryonic stage. As in the somewhat analogous case of the

bulldog noted by C. R. Stockard¹ in his Harvey Society lecture on 'The Significance of Modifications in Body Structure,' the pug-like face may be due to the failure of the base of the skull to elongate. This failure in development of the anterior part of the parasphenoid in these salmonids has apparently tied down the ethmoid, the nasals, and the anterior end of the frontal, so that they permanently remain in an essentially embryonic position.

As to the cause leading to this arrest, nothing certain is known. Possibly experimental work in the early stages of development might clear the matter up, but none of the experimental embryologists seem to have caused or even found such abnormal forms in the course of their work. Hence, all that can be said here is that pug-headedness arises early in development from causes not now understood but believed to be due possibly to disturbances in the endocrine system.

IS PUG-HEADEDNESS IN FISH TRANSMISSIBLE?

Here again, no sure answer can be given. However, if this deformity is due to some defect or derangement in the protoplasm and nucleus of the egg, or in the developing germ, it would seem that pug-headed parents would transmit this abnormality to their offspring. In this connection the accounts previously quoted of the occurrence of an alleged race of such deformed fishes in Lochdow, Inverness-shire, Scotland, is very interesting and if definitely proven would be very significant. The only sure way to test the matter is by breeding experiments. Such have been carried out and reported upon briefly by Knauthe (1893a, 1893b). These will now be summarized.

In 1891, Knauthe prepared three small ponds completely covered over to prevent access of ducks and other birds. In each of two of the ponds he placed two pairs of normal *Leucaspilus delineatus* whose parents, however, were pug-headed. About a year later he emptied the ponds in order to get every single specimen and reported as follows: In No. 1 there were 250 fry, of which 30 or 12 per cent were pug-headed like their grandparents and 220 normal like their parents; in the second pond there were 180 young, and of these 50 or 27.78 per cent reverted to the grandparental type, while 130 were normal. In the third pool Knauthe placed two pairs (4 fish) of normal *Leucaspilus delineatus* whose parents were normal but whose grandparents had had pug-heads; they produced 210 offspring, 20 or 9.5 per cent of which had reverted to the great-grandparental form, while 190 were normal. Thus, in these three

¹1923, Harvey Society Lectures, Ser. 16. p. 41.

experiments, out of 640 young, 540 were normal, and 100 or 18.5 per cent were pug-headed.

In 1892, Knauthe prepared another pond, divided into halves by a high brick wall coated with cement. Into one half he placed the carefully selected normal yearlings (number not stated) obtained from the breeding experiments described in the preceding paragraph, the progeny of normal parents and grandparents; i.e., the third generation of normal forms. Of this lot four females and six or eight males were observed to be engaged in breeding; these produced 160 normal offspring and 6 pug-heads (3.57 per cent) like their great-great-grandparents. In the other half of the pool he placed as a control brood the same number of young bleak of the same age; these produced 250 fry with not a single pug-head among them. In the meantime, two pairs of *Leucaspis*, grandparents of the brood of fish in division No. 1 of the pond just described, had brought forth a new batch of progeny, only 8 per cent of which were pug-headed.

Later, Pellegrin (1908) found that what he calls dolphin-headed perches had been caught for a number of years in the Seine at a place called Port-Villez. Some of these deformed fishes had been placed in a pond belonging to a neighboring fish cultural establishment, and had there multiplied greatly. At the time of his report, Pellegrin estimated that there were between 300 and 400 of these fishes in this pond, in which also were many perfectly normal specimens. It was noticeable that these dolphin-headed perches differed in the degree of cranial defect and that all were slower in development than normal fish.

These experiments are very interesting and very suggestive, and seem to indicate that this teratological condition is inheritable and transmissible. However, they need to be repeated and largely extended under conditions of strict control; i.e., in glass aquaria where the fish can be kept under constant observation.

HOW DO PUG-HEADED SALMONIDS FEED?

Having completed the anatomical part of this study, there is yet left the physiological one, the answer to the insistent question: "How do these pug-headed salmonids feed?" This is difficult to answer but it is a fact that they do feed and flourish. The great majority of specimens described in this paper were adult, well-nourished, even fat. They varied in size from 76 mm. (3 inches) and a weight of a few grams (Yung) to 29 pounds and probably 36 inches (Buckland, 1877), the majority, however, being over 9 inches long.

A number of these have been taken with the hook but only two fisherman (Miller and Home) have described the behavior of the fishes. Both fishes had difficulty in laying hold of the bait, a wet fly in one case and a minnow in the other. Yung is the only man who has tried to feed a pug-headed trout, using the water-flea, *Daphnia*. His little fish, however, was unable to catch these even in swarms. It fed almost entirely on *Tubifex* worms, digging these out of the mud at the bottom of the aquarium with its lower jaw. After death its stomach was found filled with them.

These are the known facts, but certain conjectures may properly be set forth. The salmonids normally feed on insects on or above the surface of the water, on worms, insect larvæ, and on small fish in the water. For taking these, their rather long mouths and their jaws (the lower slightly longer) beset with teeth admirably fit them. In short, their jaws are for prehension not mastication, and, lacking an upper jaw, prehension in pug-heads must be very difficult. It would seem that these fish must catch, compress, and hold their food between the lower jaw and the roof of the buccal cavity. The hooked teeth of the lower jaw undoubtedly help, as do those on the tongue. How close the lower jaw may be brought to the upper surface cannot be said. Probably the movable tongue (shown in Fig. 11) helps considerably just here. The maxillaries would help also, especially in those fish in which they are not greatly reduced.

Finally, it seems certain that a pug-headed salmonid cannot catch insects in the air. If on the surface of the water, they would be pushed away by the projecting lower jaw. To feed at the surface the fish would have to swim obliquely up stream so that floating objects might drift back against the rounded head and be directed into the open buccal cavity. It might also catch, in this way, worms or other food floating below the surface. It might likewise catch objects projecting from the bottom or from stones. Furthermore, one can see that it might, by plunging downward, lay hold of small fishes and then might, by holding such against a stone, manage to work the fish around so that it could be swallowed. It would be exceedingly interesting to have such a fish in an aquarium and there study its feeding habits.

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PLATE XXI

PLATE XXI

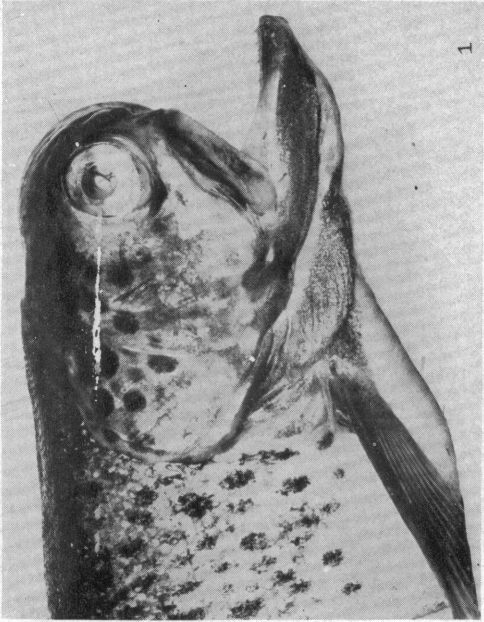
Fig. 1. Lateral view of the head of a "Mopskopf" brown trout having a very round head nearly level on top, and a very forwardly placed eye.

Fig. 2. Head-on view of the same fish showing the conformation of the mouth and buccal cavity.

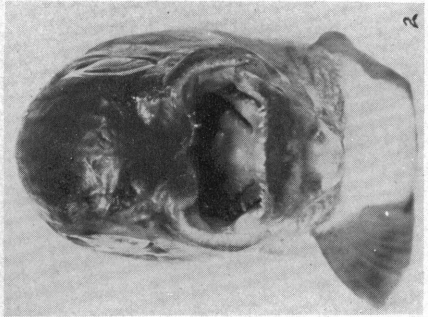
Fig. 3. Radiograph in lateral view of the same trout head. The roof and the base of the skull lie between lines almost parallel. Note how the frontals, nasals and ethmoids are bent down on to the inpushed premaxillary.

Fig. 4. Radiograph from above of the same head, showing the abrupt ending in front.

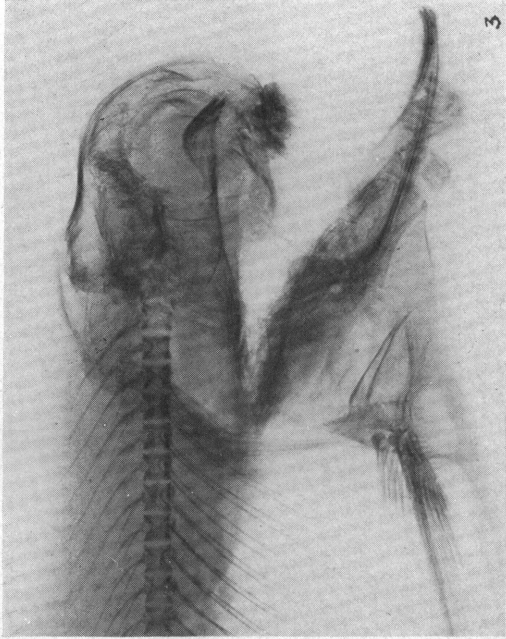
All figures after Forsyth, 1926.



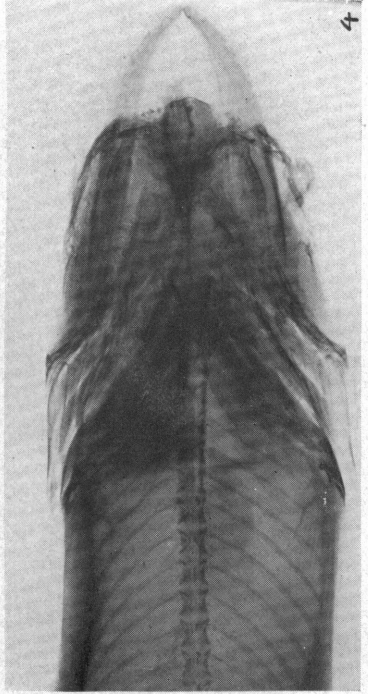
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