On the Caudal and Anal Fins of Gold-fishes.

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With Plates XVIII—XX.

As is well known, the fins of fishes have been put under two categories, the paired and the unpaired. The former includes the pectoral and ventral fins, and the latter, the dorsal, caudal and anal fins. On this point, however, there is a remarkable deviation in our gold-fish. Here we find not only the pectoral and ventral fins, but also the anal and caudal fins distinctly paired in many individuals. In such cases, the fish presents a series of four paired appendages, a circumstance that has no parallel in all known natural species of Vertebrates.

That our gold-fish is an abnormal form which has been cultivated is an acknowledged fact, and many of its characters are no doubt mere products of artificial selection and devoid of all morphological significance, but the paired state of the caudal and anal fins is, in my view, of great interest when considered in connection with the problem on the nature of the paired and unpaired fins.

In the present article are embodied the results of my researches into this curious condition in the caudal and anal fins of the gold-fish.

The investigation was begun in the autumn of 1885 and continued until the summer of the following year under the supervision of Prof. Mitsukuri and Prof. Ijima. To these gentlemen, I owe my sincere thanks for their constant encouragement and valuable suggestions.

I regret to say that I have not been able to obtain access to some works more or less connected with the present subject. Under this disadvantage I do not feel qualified to enter into an extensive discussion of the question bearing on the morphology of the paired and unpaired fins. I therefore confine myself in the present paper principally to the description of the structure of the caudal and anal fins of the gold-fish and to few suggestions.

Before proceeding further, it would perhaps be well to make a few remarks on the various breeds of gold-fish. We generally distinguish three distinct breeds, viz., the "*Japanese*," the "*Corean*" and the "*Loo-chooan*." These are the commonest breeds to be met with in Japan.

The Japanese breed or the "*Wakin*" has a slender body, closely resembling that of the common Carassius or carp.

The Corean breed, otherwise called the "*Maruko*" or the "*Ranchiu*," is characterized by an exceedingly short body, being in some cases almost globular in shape (Figs. 4—5, Pl. XVIII). The dorsal fin is generally entirely absent. The head is usually disfigured by rough-looking protuberances of the skin which often attain a considerable size.

The Loo-chooan breed or the "*Riukin*" (Figs. 1—3, Pl. XVIII) has a short body with a rounded abdomen. Of all the breeds, this has the most beautiful tail, which is very large and often longer than the rest of the body.

In foreign works it is frequently asserted that these animals were first reared in Japan as well as in China. That the latter country first produced them, is quite probable; but there is sufficient reason to show that Japan was not their original home. History bears direct testimony as to the date of their first introduction into Japan, the exact locality where they were introduced, etc.

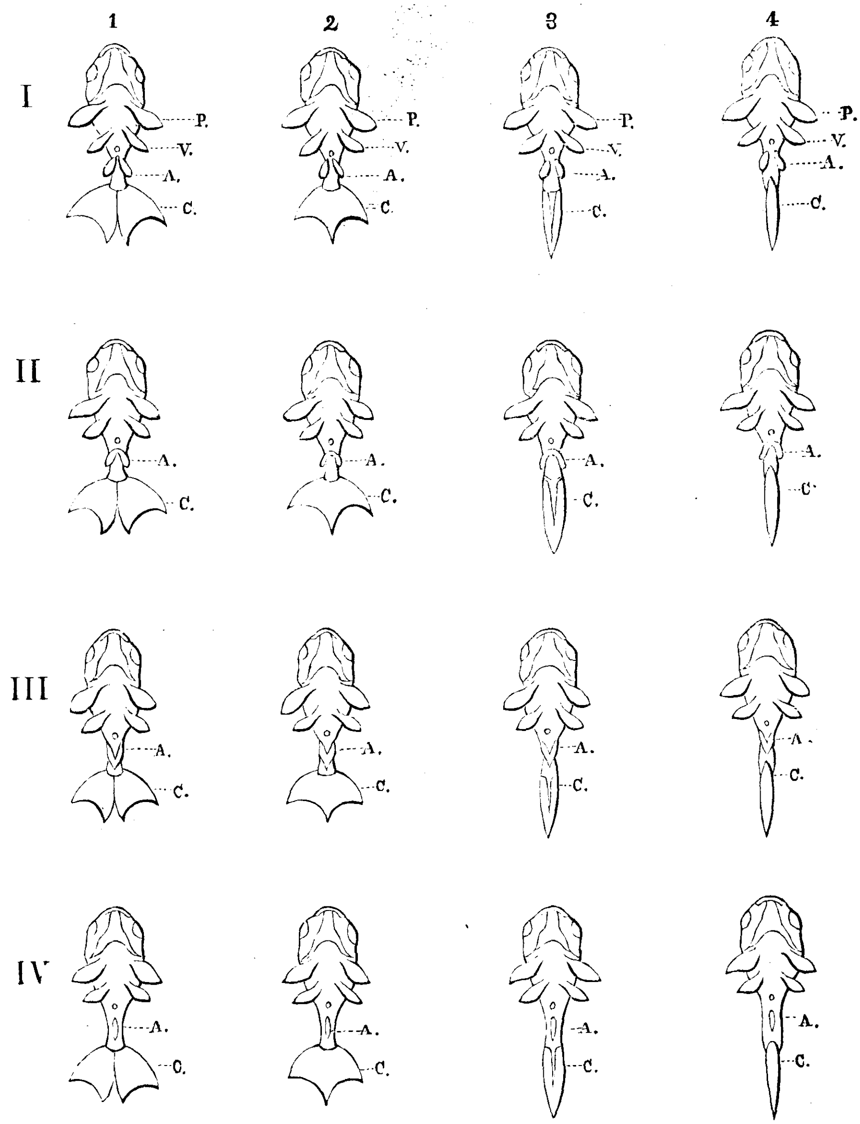
It is known that they were introduced in all probability first from China, at the beginning of the sixteenth century, and subsequently at frequent intervals from China, Loo-choo and Corea.

It is to be gathered from such imperfect descriptions as exist, that the first introduced breed was what we call at present the "Japanese breed." The name has, it is to be assumed, nothing to do with the *nativity* of the breed. Perhaps it was the priority in the date of introduction which caused it to be so designated, in order to distinguish it from the breeds brought in later from Loo-choo or Corea.

Gold-fish breeders of the present day can freely produce the "*Riukin*" or "*Maruko*" from the "*Wakin*." Hence there can be no doubt that the last named breed represents the primitive form, a fact that is also sufficiently apparent from the configuration of the body. There certainly exist various intermediate forms between the above mentioned breeds.

In all gold-fishes, irrespective of what breed they belong to, the tail-fin is above all other parts subject to the greatest variation. It is to be found in one of the following three states: 1. it has three-lobes, one median and two lateral (Fig. 5, Pl. XVIII & Fig. 7, Pl. XIX); 2. it consists of two separate halves (paired) giving rise to a four-lobed tail (Fig 1); and 3. it is vertical and normal. In the first two cases, the lobes are more or less horizontally spread.

Next to the caudal fin, the anal fin undergoes a remarkable variation. It is either median and normal or distinctly paired. In the former case, especially when the caudal fin is also normal, the


1
2
3
4
I
II
III
IV
P.
V.
A.
C.

gold-fish closely resembles a common Carassius. There are all stages of caudal and anal fins intermediate between the normal and the paired states; thus, the tail-fin with its lower portion alone in a double state (Figs. 20—22, Pl. XIX), or the anal-fin, with either its anterior or posterior portion double and the remaining parts single, is of quite a common occurrence. These different conditions of the two fins combine in various ways in different individuals, thus giving rise to manifold varieties of form, the typical ones of which are shown in the accompanying wood-cut.

In series I those forms are shown in which anal fins occur plainly in pairs. The caudal fin however occurs in four different conditions. In No. 1 it is distinctly paired, giving rise to the "*four-lobed tail*" or the "*Yotsuo-wo*" In No. 2 the two halves of the tail are connected at the dorsal edge, giving rise to the "*tri-lobed tail*" or the "*Mitsu-wo.*" No. 3 represents a case in which the caudal fin is double only at its ventral edge and No. 4, a case with a perfectly normal tail-fin.

In series II forms are represented in which the anal fin is single and median in front but double posteriorly. The caudal fin behaves in four different ways as in the preceding series.

In series III the anal fin is in a reversed condition from that represented in series II; namely its anterior portion is double while the posterior portion is single and median. The caudal fin shows the same variation as before.

In series IV the anal fin is always single and median, the caudal behaving as before.

We shall now proceed to make a closer examination of the caudal fin.

The Caudal Fin. The simplest transitional state from single to double, is seen where the tail, normal in all other respects, has the ventral edge slightly furrowed by a median groove. Fig. 8, Pl. XIX, shows a tail of this kind. The greater part of it is vertical and median, but its lower portion (*C'*) occurs double. When viewed from the ventral side, a shallow groove extends from the point of attachment down to the extremity of the tail, as represented in Fig. 9 (*B*).

In some cases, this groove extends further upward, almost as far as the middle line of the height of the tail. In other instances, the groove is still deeper and extends above for more than half the height of the tail. The furrow may reach the dorsal edge of the tail and thus divide it into two halves which then expand right and left. These halves may or may not be connected at the median line, at the dorsal edge. In the former case, the tail is represented by a more or less horizontally expanded single piece. In the latter it is distinctly paired. I shall soon return to these various forms of tails when considering their skeletal elements.

The remark may not be out of place here that it is only the ventral lobe of the caudal fin (*V. L.*, Fig. 7) that is liable to become split into lateral halves. The dorsal lobe, i. e. that part lying dorsal to the notochord (*D. L.*, Fig. 7), has as yet never been met with in a paired condition.

It will be necessary first of all to get acquainted with the bony structures of a normal tail fin. A close study has shown that the vertical and median forms of the caudal fin of gold-fishes have the bones arranged identically as in other Cyprinoides, such as a carp or common Carassius.

I shall give here a brief description of the caudal skeleton of a carp (Fig. 6), the large size of which affords a greater facility for study than that of a gold-fish.

The few hindermost vertebræ, as is well known, differ somewhat in form. Thus, the centrum of the antepenultimate vertebra

(Fig. 6, *a.p.v.c.*) is beset with two neural spines, *a.p.n.* and *a′.p′.n′.* The posterior of these processes is prolonged backward and takes a small share in carrying the fin rays of the dorsal lobe of the tail. The hæmal spine (*a.p.h.*) of the same vertebra is thicker and longer than those of preceding ones, and carries at its thickened termination a few of the fin-rays constituting the ventral lobe of the tail. The penultimate centrum (*p.v.c.*) is beset with one neural and one hæmal spine. Both of them are respectively stronger and larger than the corresponding spines of the preceding vertebra. Each carries a few of the caudal fin rays. From the last recognizable centrum (*l.v.c.*) many processes start out. The uppermost and most anterior of these is a short lancet-shaped piece (*l.*), which occupies a position similar to that of more anteriorly situated neural spines.

The next succeeding process—the urostyle (*u.*)—consists of a pair of long, styliform plates, running obliquely upward. The two pieces are arranged in the fashion of a razor-sheath and enclose between them the hinder end of the notochord, while the spinal chord runs along their dorsal edge. The urostyle is, in fact, the continuation of the vertebral column, representing a certain uumber of coalesced vertebral bodies. At its distal end is found a pair of free slender bones (*h.*), one on each side.

The third process, structurally connected with the last recognisable centrum, is a flat, dilated bone (*e.*) which running backward forms an acute angle with the urostyle. Just below the root of the third process (*e.*) and facing obliquely backward and downward, there is in the last vertebral centrum a depression, to which the fused extremities of two flat bones (*f.* and *g.*) are connected by cartilage. The centrum (*l.v.c.*) may in fact be considered as possessing one neural (*l.*) and three caudal appendages (*e, f, g.*).

In the angular space formed by the urostyle (*u.*) and the uppermost hæmal process (*e.*) there is a series of four bones (*a*, *b*, *c*, *d*), whose anterior extremities are wedged into the space between the two pieces of the urostyle. A narrow space on the line of prolongation of the vertebral axis divides the whole series of hypural bones—as the bones under the urostyle have been called—into two groups. The posterior edges of these hypural bones are all truncated in much the same way, and present an almost even line at which the caudal fin-rays are attached. The seven flat hypural bones and the two hæmal spines from the penultimate and ante-penultimate centra support the rays of the ventral lobe of the caudal fin.

Between the urostyle and the neural spine from the penultimate centrum there is found a freely suspended piece of bone—the "*falscher Dorn*" (*f.d.*). The urostyle, the "*falscher Dorn*" and the two neural spines from the penultimate and the ante-penultimate centra, constitute bony supports for the rays of the dorsal lobe of the caudal fin.

It is thus apparent that the greater portion of the tail is to be designated as the ventral lobe while the dorsal portion occupies only a comparatively insignificant part of the whole. The original diphycercal state, in which the ventral and dorsal lobes were equally distributed on both sides of the vertebral axis, is now disturbed by the upturning of the latter near its caudal termination. The great development of the inferior appendages and the backward condition of the superior consequent on this, resulted in the expanded, fan-shaped arrangement of the caudal skeleton.

With this brief description of the bony elements in the vertical form of the tail, we proceed to the examination of those of gold-fishes in various stages of modification. We will first take up a gold-fish with the tail divided in three distinct lobes as shown in Fig. 7. In comparing the caudal skeleton of such a form with that of a vertical form (Fig. 6) we observe a general agreement in the arrangement of the various pieces, except in one important respect, namely, that in the former case there is a double series of bones supporting the rays of the ventral caudal lobe (in Fig. 7 *a*, *b*, *c*, *d*, *e*, *f*, *g*, *p.h*, *a.p.h.* forming one series and *a'.p'.h'*, *p'.h'*, *g'*, *f'*, *e'*, &c., forming the other) corresponding to the two lateral halves, into which the tail fin is divided. In the case of Fig. 6 in which all caudal rays are arranged in one vertical plane, the bones supporting them form one series in one plane (*a*, *b*, *c*, *d*, *e*, *f*, *g*, *p.h.*, *a. p.h.*).

Here I will mention that the bones supporting the caudal fin-rays in a gold-fish, are each tipped by a cartilaginous cap at their distal ends (Fig. 7). At the lower portion of the ventral caudal lobe and close to the cartilaginous cap just mentioned there is on each side a small piece of cartilage (*K.* Fig. 7) freely intercepted between the roots of fin-rays. In our figure the left piece alone is represented.

The comparison of some individual bones in a single and a double state of the caudal fin will bring out the points of difference into a clearer light.

Fig. 10 represents a penultimate vertebra from a common Carassius in which the tail is normal. Fig. 10 *a* is the corresponding bone taken from a gold-fish with a double tail. The neural appendage and the centrum are similar in both. In the gold-fish the hæmal arches, after uniting in the median line, again separate and diverge in different directions (*h.s.*, & *h'.s'.*). In the common Carassius however, the hæmal arch sends out but one process,—the hæmal spine (*h.s*, Fig. 10).

Fig. 11 and 11*a* represent the last vertebral centrum with their appendages. The former is taken from the vertical and normal tail of Carassius and the latter from the gold-fish with paired tail. It will be observed that the hindmost process (*e*) is single in the former and double in the latter (*e*, *e′*).

Figs. 12 and 13 are two corresponding bones, the fourth hypural bone, from a single and a double form of the tail respectively. The former is single whereas the latter consists of two diverging limbs. Its apical portion lies wedged in between the two pieces of urostyle.

In the tail fin with its ventral edge furrowed by a shallow groove, (Figs. 8 & 9), the hæmal spines from the penultimate and antipenultimate centra proceed from their origin in a distinctly paired state in order to support the paired portion of the tail. In other cases in which the groove is deeper, those skeletal supports corresponding in position to the groove occur in pairs.

Figs. 19—23 represent diagramatic cross-sections of the several forms of the tail-fin.

Fig. 19 shows the arrangement of bones in a vertical and normal tail. On comparing this figure with others it will readily be seen that the difference in the depth of the ventral groove affects the bony structures in corresponding degrees.

The paired state of hypural bones in gold-fishes is of no small interest in connection with the view that the hypural elements are homologous with the more anteriorly situated subvertebral appendages, and that the styliform urostyle is a coalesced representative of a certain number of vertebral bodies. On comparing the subvertebral appendages in various regions of the body, we observe that, in the trunk, the appendages start in pairs (transversal processes) and end in pairs; that, in the caudal region, they start likewise in pairs (hæmal arch) which however soon coalesce and terminate in a median process (hæmal spines); and that in the caudal extremity, the appendages start from the beginning in a coalesced state as median spines. The above is the usual arrangement that is to be met with in Teleostei. In the gold-fish however, appendages in the caudal extremity may start in pairs and end as such, somewhat like hæmal appendages in the trunk region.

It now remains to consider the system of caudal fin-rays, which in fact plays a very significant part in causing the anomalous phenomena of the tail of gold-fishes. Each fin-ray consists of a pair of similar parts running along-side and closely applied to each other for the greater part of their length. At the proximal extremity the two diverge a little and firmly clasp the terminal portion of the caudal skeleton. They are smooth and simple at the base, but become distally segmented into a number of small joints and moreover longitudinally split into a number of finer rays. Crescentic marks surrounding the caudal skeletons in Figs. 19—23 show the distribution of fin rays in various forms of the tail.

It will now be easy to conceive in what light the three or four lobed tails are to be regarded in relation to an erect and normal form. Thus, when a normal tail with an emarginate outline (Fig. 14, Pl. XIX), is split into two halves in a vertical plane, each half retaining its emarginate form, the "four- lobed tail" comes into existence (Fig. 15). When the splitting is not complete and the two halves remain united at their dorsal edge, the form known as the tri-lobed tail is the result (Fig. 16).

The Anal Fin. The anal fin of gold-fishes in its vertical form consists of nine fin-rays, supported by seven inter-hæmal bones. These numbers however vary to a certain extent with the individual. The first three of the fin-rays are solid spines, of which the third is the longest and the strongest of all. The following six fin rays branch into finer rays. The inter-hæmal bones bring the anal fin into connection with the hæmal spines.

Each fin-ray consists for the greater part of its length of two similar pieces placed side by side and closely applied to each other. At the thicker end, with which they come in contact with the inter-hæmals, the two pieces diverge and present the shape of Y. In the bay formed by the parted extremities a small bony nodule is intercepted (Fig. 17).

In the double form of the anal fin (Fig. 18), bony structures similar to those of the single form are present in pairs. The observer is at once struck with the close resemblance existing between the paired inter-hæmal and the pelvic girdle. The anal fin also very closely agrees in appearance with the ventral fin and one might think that such a fish has a third pair of extremities (Fig. 3, Pl. XVIII). The double anal fin often makes a flapping motion and seems to be capable of serving the same function as the ventral fin, although on a much more limited scale. When the anal fin is partially paired, the corresponding interhæmal bones alone occur in double state, while the rest is unpaired and median.

Primordial Fin-folds of the Gold-fish Embryo.

The examination of gold-fish embryos shows that the double anal and caudal fins are already laid out in the primordial fin-folds. In a gold-fish in which these fins are unpaired, the primordial fin-fold is likewise unpaired as shown in Fig. 27 Pl. XX. Where they occur in pairs however the primordial folds are laid out as two longitudinal thickenings along the ventral side of the post-anal section of the body. Fig. 26 represents an embryo taken from an egg three days after it was laid. The ectodermal cells aggregate in two similar ridges (*f,' f'*) along the ventral side in the posterior position of the body, forming the foundation of primordial fin-folds. A similar aggregation of ectodermal cells forming a dorsal median thickening constitutes the beginning of the dorsal fin-fold. This fold extends backward and around the caudal termination and passes over to the double primordial ridge (*f*,' *f*') on the ventral side.

With the growth of the embryo, the ridges or folds grow in height. The dorsal fold extends anteriorly as far as the level of the eyes. The two ventral ridges behind the anus diverge from each other at a later period as shown in Figs. 28 and 29.

Still later, at two regions, one behind the anus and the other at the hind end of the body, the folds greatly develope and become markedly broad, specially at the latter region as represented in Fig. 33.

The portion lying between these two local thickenings remains undeveloped and becomes finally atrophied.

The thickenings (*a.'f'.*) just behind the anus are the rudiments of anal fins and the hind ones (*c.'f'.*), those of caudal fins.

Fig. 29 represents an embryo of this stage as seen from the ventral side. This state of the ventral fold gives rise to the paired anal and caudal fins. In other cases, the paired portion is restricted to the region just behind the anus, the remaining portion being unpaired (Fig. 31). Such a state would give rise to a form in which the anal fin alone is paired. In others again, it is in the caudal extremity alone that the fold is double (Fig. 30). From such an instance there arises the form with the caudal fin alone paired, while the anal remains normal.

The varying extent to which the ventral portion of the primordial fin-fold is cleft is the cause of all those intermediate fins between the paired and the unpaired state. Fig. 32 represents a case in which only a shallow groove runs along the ventral margin of the fin-fold. Such an embryo, for instance, would give rise to fins which are only partially double.

Thus, there is in the embryo as in the adult, a complete series of gradations between the paired and the unpaired form of fins. The anomalous condition observed in the anal and caudal fins of gold-fishes is apparent from the very begining of their existence.

Preanal Folds. The structure known as the preanal fold is usually well-marked in gold-fish embryos. It often occurs in a paired state extending from the anus up to the level of the spots where the ventral fins appear later (Fig. 33, *p.' a.' f.'*) The two often unite at their anterior ends into a median fold (Fig. 29, *m.*)

The latter extends further anteriorly beyond the level of the ventral fins. The preanal folds originate as ridges of ectodermal cells like the caudal or anal fins.

The existence of double preanal folds in the embryo is another interesting feature of gold-fishes. Thus there exists a pair of continuous longitudinal folds running along the ventral side of the body from the level of ventral fins down to the very end of the body, save the single local interruption on account of the existence of the anus (Figs. 24, 25, 26, 28).

To show how such an embryo gold-fish differs from the embryo of a normal teleost in this respect, I refer to Figs. 24 and 25. I have connected the roots of the fins and preanal folds with dotted lines. Fig. 25 shows the ventral aspect of a young gold-fish, half an inch in length, in which the ventral fins have just begun to bud out and the double preanal folds are in process of atrophying. The above-mentioned dotted lines are furthest apart from each other at the pectoral region and slightly converge toward the ventral fin; behind the latter, they suddenly approach each other, almost meeting in front of the anus, behind which the two again gradually diverge.

At the commencement of the caudal fin the divergence becomes suddenly marked and finally they meet with each other. In a normal teleost the case is quite different (Fig. 24). Here the two lines suddenly converge behind the ventral fins and unite with each other, in which state it continues down to the end of the body. The preanal folds are embryonic structures; they vanish as the embryo advances in development.

General Observations.—From what has been said about the skeletal element of the paired anal and caudal fins, it is sufficiently evident that they are accompanied by somewhat profound structural deviations from their normal type. It seemed to me exceedingly doubtful if such deviations were purely accidental productions of artificial selection, designed after the breeder's fancy and devoid of any significance whatever from the standpoint of comparative morphology. The examination of embryos has clearly proved that the paired state of those fins is anticipated from a very early embryonal period, being laid out as two longitudinal folds. The idea that the law of abbreviated heredity had here been active in shifting the artificially acquired paired condition of the anal and caudal fins into the embryonal period, seems to be untenable. On the other hand, the most plausible explanation lies in assuming that under certain circumstances certain fishes have the anal and caudal fins laid in a double state and that breeders have taken advantage of this fact in producing their double-tailed forms.

The development of double folds as "*Anlage*" for the anals and the caudals, I regard as a case of reversion to the primitive state. It stands in favor of the view entertained by St. Mivart, Thacher, Dohrn, Balfour and Mayer with regard to the origin of vertebrate limbs. These authors claim, in contradistinction to the well-known gill-arch theory of Gegenbaur, that the paired fins of fishes were derived from originally continuous lateral folds and further that the anal as well as the ventral portion of the caudal fin arose through coalescence of the same folds.

The occurrence of double preanal folds in gold-fishes coincident with the double post-anal folds, harmonizes with my view. The median preanal and post-anal folds usually met with in a normal Teleost are then both to be looked upon as the coalesced state of the two folds.

The dorsal fin has also been interpreted by some authors to have arisen through coalescence of two dorsal folds (Parapodia). As the probable cause of this coalescence, is assigned the closing of the medullary plate. In this connection it ought to be mentioned that in gold-fishes the dorsal fin and that portion of the caudal lying dorsal to the vertebral axis are never met with in a double state,—showing that the median unpaired condition of the dorsal fold is more strongly rooted than in the ventral fold.

Provided that the pectoral and the ventral fins are really specializations of the same lateral folds as the post-anal fins, all these are to be regarded as homologous. The interhæmals might then be looked upon as representatives of the pelvic or shoulder girdles. The homology of the anal fin with the more anteriorly situated limbs is most apparently borne out in the case where it is paired as was described on page 258. The paired caudal fin, accompanying the most complicated portion of the axial skeleton, has undergone such modifications that the recognition of all parts homologous with those of the more anteriorly situated appendages has become a difficult task. The analogy of position however disposes me to assume that the free cartilaginous nodule (Fig. 7. K.), intercepted between the diverged extremities of caudal fin-rays, represents either some degenerated Interhæmals or some bony nodules similar to those found in the anal fin (Figs 17 & 18, *n*, *n'*,), or perhaps the aggregate of both.

To recapitulate;

(1) In the paired anal and caudal fins of gold-fishes, the internal bony structures are also paired.

(2) The view that the hypural bones of Teleostei are homologous with the more anterior pairs of subvertebral appendages receives a certain confirmation by the actual occurrence of paired hypural bones in the gold-fish.

(3) If the pectoral and ventral fins are to be looked upon as specializations of originally continuous lateral folds in the pre-anal section of the body, the anal and caudal fins are to be regarded as specializations of the same folds in the post-anal section of the body.

(4) The four pairs of appendages may therefore be considered as homologous structures.

(5) A certain degree of similarity is still recognizable in the structure and arrangement of parts in these four pairs of appendages in the adult.

(6) In many gold-fish embryos, a pair of pre-anal and post-anal folds are developed, which may represent the once continuous lateral folds.

List of Works Consulted.

1. BALFOUR.—"A Monograph on the Development of Elasmobranch Fishes." 1878.
2. BALFOUR.—"Comparative Embryology." Vol. II.
3. BALFOUR.—"Paired Fins of Elasmobranchs," Proc. Zool. Soc. London, 1881.
4. BALFOUR & PARKER.—"On the structure and Development of Lepidosteus." Philosophical Transactions, 1882. Part II.
5. DOHRN. A.—"Der Ursprung d. Wirbelthiere und d. Princip. d. Functionswechsel" 1875.
6. DOHRN. A.—"Studien zur Urgeschichte des Wirbelthierkörpers." Mitt. aus der Zool. Stat. zu Neapel, Bd. 5. Die Paarigen und Umpaarigen Flossen der Selachier." 1885.
7. GEGENBAUR.—"Comparative Anatomy." English Translation, 1878.
8. GEGENBAUR.—"Ueber die Entwicklung der Wirbelsäule des Lepidosteus mit vergleichend-anatomischen Bemerkungen." Jen. Zeitschr. Tom. 3. 1867.
9. GOETTE.—"Beitrage zur vergleichenden Morphologie des Skeletsystem der Wirbelthiere." Archive für Mikr. Anat. Bd. 15. 16 1878—1879.
10. HUXLEY.—"Observations on the development of some parts of the skeleton of fishes." Quart. Journ. Micros. Sci. Vol. VII, 1859.
11. LOTZ, T.—"Ueber den Bau der Schwanzwirbelsäule der Salmoniden, Cyprinoiden, Percoiden und Cataphracten." Zeit. f. Wiss. Zool. Bd. 14, 1864.
12. MAYER P.—"Die unpaaren Flossen der Selachier." Mitt. der. Zool. Stat. zu Neapel. Bd. 6. 1885.
13. THACHER.—"Median and Paired Fins." Trans. of the Connecticut Acad. Vol. III, 1877.
14. RYDER, J. A.—"An Outline of a Theory of the Development of the Unpaired fins of Fishes," American Naturalist, Jan. 1885, Vol. XIX.

EXPLANATION OF FIGURES.

PLATE XVIII.

Fig. 1. Dorsal view of a gold-fish belonging to the breed "Riukin." Natural size. P., pectoral fin; V., ventral fin; C., caudal fin; D., dorsal fin.

Fig. 2. Lateral view of the same gold-fish. Half natural size. A., anal fin.

Fig. 3. Part of the ventral view of the same gold-fish, showing the paired anal fin A. An., anus.

Fig. 4. Dorsal view of a gold-fish belonging to the breed "Maruko," otherwise called the "Corean breed." Half natural size. Dorsal fin absent; head and face with protuberances. Tail three-lobed. S., a sickle-shaped appendage on the dorsal edge of the tail.

Fig. 5. Part of the same viewed from the ventral side and showing the paired anal fin.

PLATE XIX.

Fig. 6. Caudal skeleton of Cyprinus carpio L. Natural size. *a, b, c, d, e, f, g,* hypural bones. *h.*, a slender bone freely attached to the urostyle; left piece of the pair.

f.d., "falscher Dorn"

l., lancet-shaped process.

l.v.c., the last recognizable centrum.

p.h., haemal spine of the penultimate centrum.

a p.h., the same of the anti-penultimate centrum.

p.v.c., penultimate vertebral centrum.

p.n., neural spine from the penultimate centrum.

a.p n. the anterior of the two neural spines proceeding from the antipenultimate centrum.

a.p.n., the posterior neural spine of the same.

a.p.v.c., anti-penultimate vertebral centrum.

u., urostyle.

i.h., inter-haemal spines.

A., anal fin.

Fig. 7. Caudal skeleton of a gold-fish with tri-lobed tail, much enlarged posterolateral view. The left lower lobe of the tail-fin is omitted. Most of the letters are same as in Fig. 6.

e'., f'., g'., p'.h'., a'.p'.h'., show the right halves of hypural bones, corresponding to *e., f., g., p.h., a.p.h.*, of the left. K., the free cartilaginous nodule. The cartilaginous terminal caps of hypural bones are colored blue. D.L., the dorsal lobe and *V. L.*, the ventral lobe of the caudal fin (the latter consisting of two halves).

FIG. 8. Tail fin of a gold-fish, with a shallow groove along its ventral margin. Letters as in figs. 1 and 2. *C'*, the paired portion of the tail-fin.

FIG. 9. Ventral view of the same. *B*, the ventral groove.

FIG. 10. Penultimate vertebra of Cyprinus carpio.

n.a., neural arch ; *v.c.*, vertebral centrum ; *h.a.*, haemal arch.

h.s., haemal spine.

FIG. 10*a*. The same of a gold-fish with tri-lobed caudal fin. *h. s.* occurs in a pair. Enlarged.

FIG. 11. The last vecognizable vertebral centrum of Cyprinus carpio. Lateral view. *l.v.c.* centrum ; *l.*, lancet-shaped spine ; *u.*, urostyle ; *e.*, 5th hypural bone.

FIG. 11*a*. The same of a gold-fish with trilobed caudal-fin. Enlarged. *e'* and *e'* correspond to *e* of fig. 11.

FIG. 12. The 4th. hypural bone of Cyprinus carpio, corresponding to *d.* of Fig. 6. Vertical (*a*) and lateral (*b*) views.

FIG. 13. The same of a gold-fish. Enlarged. Vertical (*a*) and lateral (*b*) views.

FIG. 14. Normal tail-fin of Cyprinidae, with two lobes *a* and *b*.

FIG. 15. Four-lobed (*a*, *a'*, *b*, and *b'*) tail-fin of a gold-fish.

FIG. 16. Three-lobed tail-fin of a gold-fish.

FIG. 17. Transverse section through the region of normal anal-fin diagramatically represented. *i.s.*, interhaemal spine ; *n.* bony nodule ; *f.r.*, fin ray.

FIG. 18. Transverse section through the same region of a gold-fish with distinctly paired anal-fins. Diagramatic. *i'. s'.*, interhaemal bones ; *n'.* bony nodules ; *f.'v'.* fin rays.

FIG. 19–23. Diagramatic figures (transverse sections) showing the topographical arrangement of the caudal skeleton in different forms of the tail. *s.c.*, spinal chord. *u.*, *u'*, The two halves of the urostyle, intercepting the notochord.

PLATE XX.

Fig. 24. A young gold-fish, 13 mm. long. An, anus. The preanal fold (*p. a. f.*), the anal fin (*A*) and the caudal fin (*C*) are in unpaired condition. Lines drawn through the roots of various appendages on both sides of the body converge behind the ventral fins and unite altogether at the beginning of the preanal fold.

Fig. 25. A young gold-fish of the same size as the preceeding. The preanal fold (*p'*, *a'*, *f'*), the anal fin (*A'*) and the candal fin (*C'*) are all in paired state. Lines connecting the roots of various appendages on both sides of the body run separate throughout the entire body-length.

Fig. 26. An embryo gold-fish, 3 mm. in length and taken out of an egg

three days after it was laid. *p.a.f.*, rudiments of the preanal fold. *f,' f'* paired postanal folds. *d.f*, dorsal fold.

Fig. 27. A gold-fish embryo with vertical fin-folds. 5.5 mm. in lengeth. *d. f.*, dorsal fold. *c. f.*, caudal fold. *a.f.*, anal fold. *p.a.f.*, preanal fold. *p.f.*, pectoral fin. An, anus.

Fig. 28. A gold-fish embryo, 6.5 mm. in length. The preanal fold (*p.' a.' f.'*), the anal fold (*a.' f'.*) are double. The latter is continuous with the double caudal fold (*c.' f.'*). The dorsal fold (*d. f.*) alone is median and unpaired.

Fig. 29. A gold-fish embryo, 8 mm. in length. Ventral view. m., median portion of the preanal fold. *p.' a.' f'*, double preanal folds. *a.' f'*. double anal folds. *c.' f'*, double caudal folds. *p. f.*, pectoral fin. An., anus.

Fig. 30. Postanal section of an embryo, in which the ventral fold is double only at the region of the caudal fin (*c.' f.'*).

Fig. 31. The same, in which the ventral fold is double only at the region of the anal fin (*a.' f.'*).

Fig. 32. The same, in which the ventral fold is double only at its free edge.

Fig. 33. Posterior half of a young gold-fish, 7.5 mm. in length. This specimen belongs to the breed "Maruko" and does not possess the dorsal fin fold. *p.' a.' f'*, double preanal folds. *a.' f.'*, double anal folds (anal fin). *c,' f'*, double caudal folds (caudal fin).

Fig. 3.

Fig. 1.

Fig. 5.

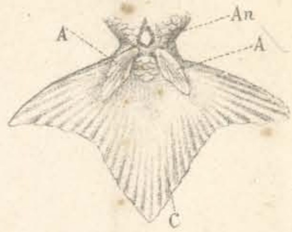


Fig. 4.

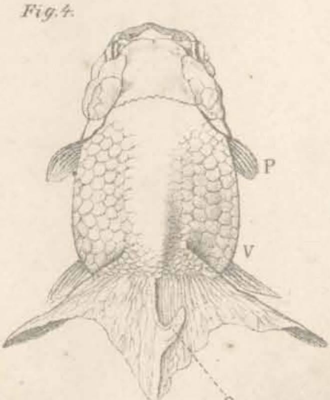
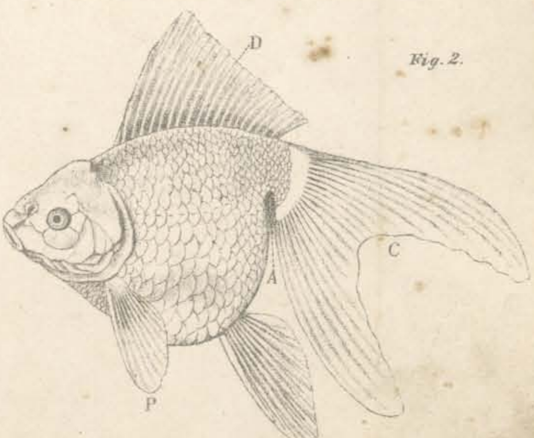


Fig. 2.



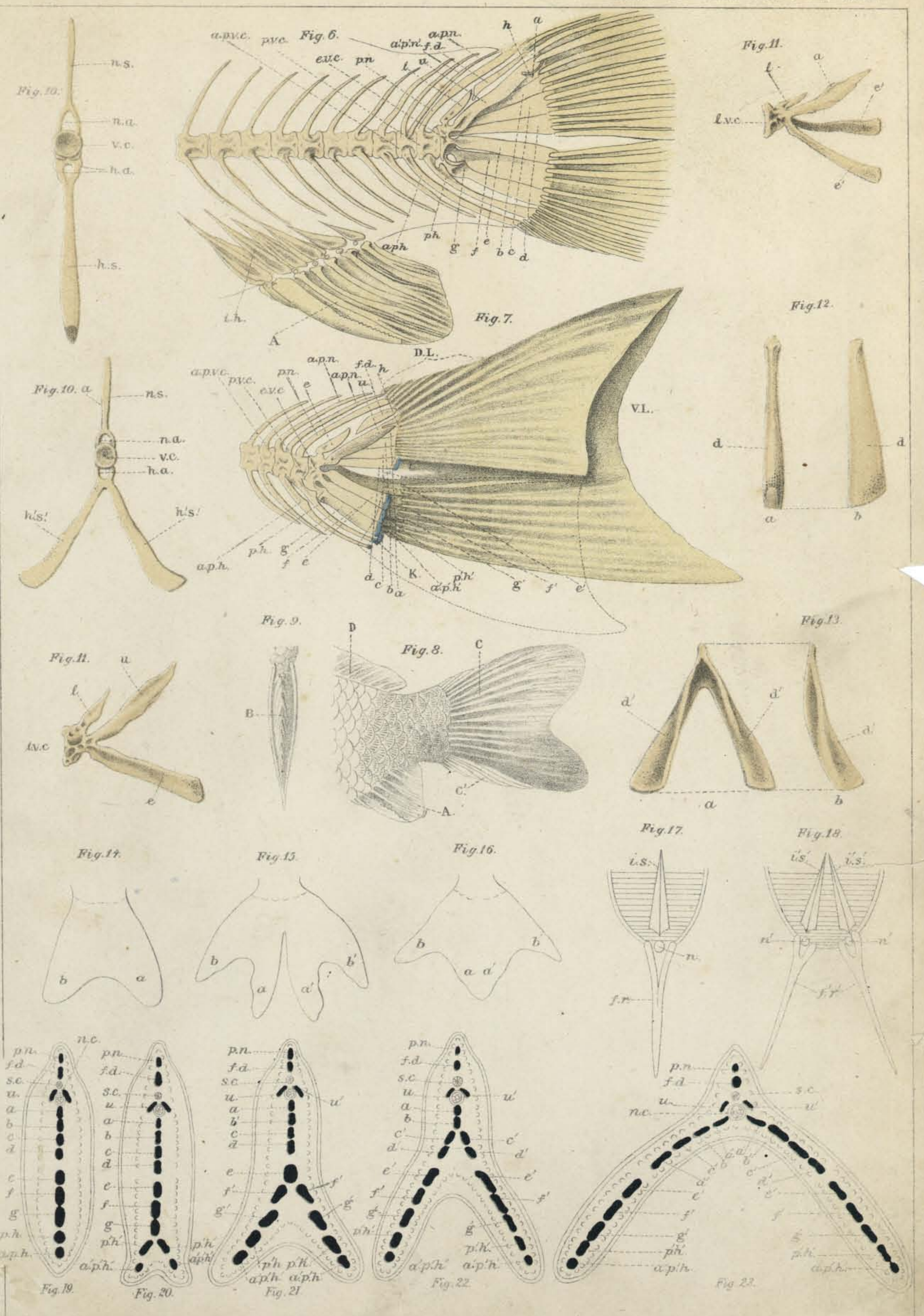


Fig. 6.
Fig. 7.
Fig. 8.
Fig. 9.
Fig. 10.
Fig. 10. a
Fig. 11.
Fig. 11.
Fig. 12.
Fig. 13.
Fig. 14.
Fig. 15.
Fig. 16.
Fig. 17.
Fig. 18.
Fig. 19.
Fig. 20.
Fig. 21
Fig. 22.
Fig. 23.

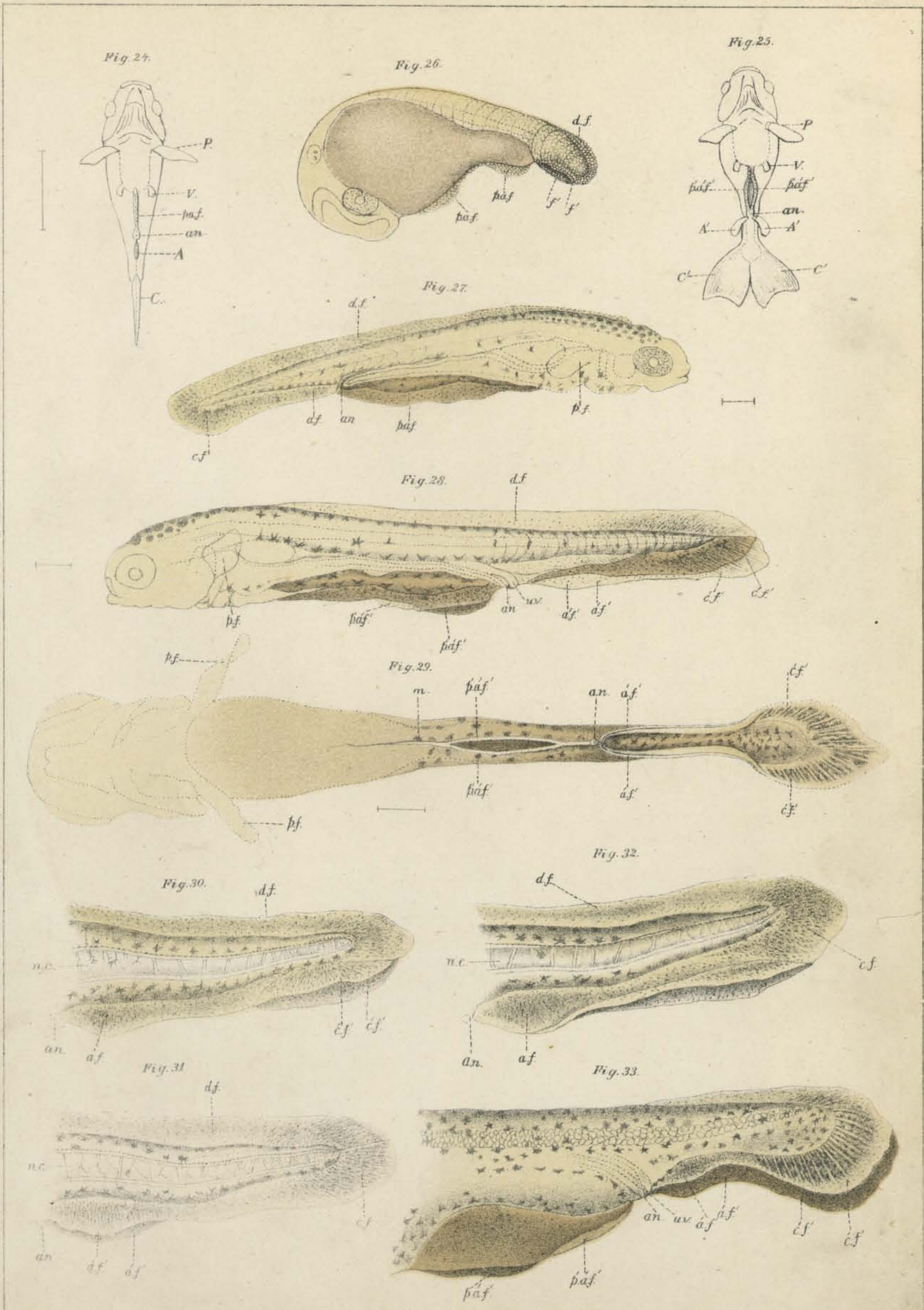


Fig. 24.
P.
V.
paf.
an
A
C.
Fig. 26.
d.f.
paf
paf.
f'
f'
Fig. 25.
P
V.
paf'
paf'
an.
A'
A'
C'
C'
Fig. 27.
d.f.
df
an
paf
pf.
cf'
Fig. 28.
d.f
pf.
paf'
paf'
an
uv.
af'
af'
cf'
cf'
pf.
Fig. 29.
m.
paf'
an.
af'
cf'
paf
af'
cf
pf.
Fig. 30.
d.f.
n.c.
an
af
cf
cf'
Fig. 32.
d.f.
n.c.
c.f.
an.
af.
Fig. 31
df.
n.c.
cf
an
af
af
Fig. 33.
an
uv.
af
af'
cf'
cf
paf
paf'