XXIV. *On the Structure and Development of the Skull in the Batrachia.*—Part II.

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Introductory Remarks.

The first paper offered by me to the Royal Society on the structure of the skull in this group was on that of the Common Frog; this has been followed by a similar piece of work treating of the Salmon's skull, and this latter by another on that of the Pig.

But these are merely an earnest of what I have in hand, and hope in due time to offer to the Society—my one steadfast desire being to master the problem of the skull, and to have the results of my labours published in the 'Philosophical Transactions.'

My former memoir on the Batrachian skull was wrought out under very great difficulties; I was not guideless absolutely, and yet much of my way had to be felt out in the dark. After exactly four years had elapsed from the reading of that paper, Professor Huxley, my main helper before, took up the Amphibian skull once more (his earlier researches were partly given in his 'Croonian Lecture' delivered in November 1858); and this new work* resulted in the discovery of sundry errors and deficiencies in my account of the development of the Frog's skull. These criticisms given to me *orally* soon commended themselves to my own mind, now gaining greater light; and the great difficulty of the subject, a difficulty acknowledged freely by my friend and guide, has acted in producing the intensest desire in me for a fuller knowledge of these most instructive, if perplexing, types.

It was unfortunate for me that I took up by far the more difficult problem, namely, that of the skull of the 'Anura,' whereas that of the 'Urodela,' the Salamander and its companions, is a much simpler structure, undergoing much less metamorphosis.

Therefore the masterly account given by Professor Huxley of the skull of *Menobranchus*, a very low and simple type, has shed a most welcome light upon the skull of these air-breathing 'Ichthyopsida.'

We have now carefully worked, more or less in each other's view, at the structure and development of several types of skulls of the Anura and Urodela; and at last the truth of the matter seems to be revealing itself.

In the present paper I shall show, as I proceed, all those deficiencies and actual errors which now, after these years, and after fresh and much holpen labour, appear in the older memoir.

* See the article on Amphibia in the new edition of the 'Encyclopædia Britannica,' and his paper on *Menobranchus* in the 'Proceedings of the Zoological Society,' March 17, 1874, pp. 186–204, plates 29–32.

This is, in itself, a most agreeable part of my work; and I hasten to sift away all that appears now to be untrue, however well winnowed it once appeared.

The advantages above mentioned are not all, nor even the greatest of those I have of late derived from the researches of my valued fellow-labourer; most suggestive and promising are the views which have lately been laid before the Society (Proc. Roy. Soc. Dec. 17, 1874, vol. xxiii. p. 127) on the *Amphioxus* and its structural relations to the Lamprey, its larvæ, and its kindred. This short paper is, if I am not greatly mistaken, of almost equal value with the 'Croonian Lecture'; if the author's deductions stand the test of further research, they will light up the darkest recesses of Vertebrate morphology.

I shall suppose the reader to be familiar with that communication, and it will be open to us now to consider the ordinary Vertebrata, or *Holocrania*, to be highly specialized and metamorphosed descendants of long-lost 'Entomocrania.'

In the latter the long, many-jointed skull may be compared to that part of a plant in which all the 'internodes' are developed; whilst the skull of ordinary Vertebrata may be likened to a *flower*, where the internodes are not developed, and where the foliar organs, being brought nigh to each other, coalesce in various ways and undergo remarkable modifications of form and of relative size.

At present I bring forwards corrected figures of the skull of the adult common Frog (*Rana temporaria*), and new results obtained by a study of the development of the skull of the common Toad (*Bufo vulgaris*), correcting, by these observations on equivalent stages, those which are imperfect or untrue in the first memoir.

In that paper the *figures* are seldom inaccurate, but both these and the descriptions will be brought now into comparison with these newer results.

After this has been done, I shall show the structure of the skull in various stages of the 'Aglossal' Toads—namely, *Dactylethra*, the Cape Toad with nailed paws, and *Pipa*, the remarkable Surinam Toad.

These will take up all the space available in a single paper; afterwards, my researches on the Bull-frog (*Rana pipiens*) and the Paradoxical Frog (*Pseudis paradoxa*) will, with others, be offered to the Society, and, also, as time and opportunity serve, figures and descriptions of the less-modified tailed types of Amphibia.

Such terms as are new in the present paper are adopted from the two memoirs of Professor HUXLEY just referred to; the gradual introduction of accurate morphological terms is not only desirable but absolutely necessary, yet these cannot be given before the true nature of the parts is understood.

In the Class of Fishes the specialization of the parts of the skull and face is greatest in the Teleostei, and least in the Marsipobranchii; the Elasmobranchii come nearest to the latter, the Ganoids nearest to the former; all these types of skull must be brought into light; of my own work only that on the Teleostean skull has as yet appeared.

One thing which misled me in working out the Frog's skull was the expectation of finding its development much more in harmony with that of the Teleostean type than it turns out to be.

As in the adult Urodelous Amphibian, so in the larval Anuran, certain parts are abortively developed or even quite suppressed.

In the metamorphosed young of the Common Frog and Toad these parts appear, but not until after the lapse of some time; this *anachronism* is much less in *Pipa* and *Pseudis* *.

The advantage of working independently, and yet with constant intercommunication both by word and letter, with no little controversy and mutual criticism, seems to me to be very great; this has been of late more than ever the plan adopted by Professor HUXLEY and myself.

Many unresolved doubts still await further labour; and in some points of nomenclature I hold to what I gave in my former paper. In the account here to be given of the skull of *Dactylethra* and *Pipa* I shall give more time and care to even the adult skull than the author of the article "Amphibia" (just referred to); and, besides this, I have succeeded in obtaining early stages: thus I possess a sure key to the difficulties of the adult skull †.

On the Skull of the adult Common Frog (Rana temporaria).—*Nasal region.*

Before my former paper was in print, I had seen and figured the free trabecular cornua projecting from the nasal capsule of the adult Bull-frog (*Rana pipiens*); but I had missed them in the common kind, and supposed that they were peculiar to the larger type. But, in his article "Amphibia," Professor HUXLEY figured and described them in *Rana esculenta* (p. 755, fig. 9, *r.p.*) as "rhinal processes." These are not shown in my figures of the chondrocranium of the adult *R. temporaria* ("Frog's Skull," Phil. Trans. 1871, plate ix. figs. 6 & 7). I doubted their existence in that type; but early in 1874 Prof. HUXLEY sent me a pen-and-ink sketch of them in this species, and I soon after found them myself (Plate 54. figs. 1, 2, *c.tr.*). The same letter gave the position of *one* of the two permanent upper labials (*u.l.'*); the other (*u.l.''*) was soon found by me, and then it was seen that much of the nasal outworks are formed, in the adult skull, of the greater segment of the originally simple upper labial ("Frog's Skull," plate v. figs. 3 & 4, *u.l.*). These, in the specimen figured in the present paper, were quite distinct from the true alinasal and aliseptal folds of cartilage; they may, however, become coalesced in the adult, as they certainly do in the Toad (Plate 54. figs. 3–5) ‡.

* At present I can only compare the skulls of the *Anura* and *Urodela*, not having worked out the *Peromela* (Cæcilians); for an account of this type of skull the reader is referred to Prof. HUXLEY's description of the skull of the adult *Epicrium glutinosum* (Enc. Brit. art. Amphibia, p. 761).

† I have to thank Professor HUXLEY for the loan of adult skulls of *Pipa* and *Dactylethra*; Dr. DOBSON, F.L.S., of Netley, for another adult *Dactylethra*; my friend, Mr. T. J. MOORE, of Liverpool, for *nine* larvæ of various stages of *Dactylethra* (besides most valuable specimens of other kinds); Professor W. H. FLOWER, F.R.S., for permission to examine specimens of ripe young of *Pipa* contained in the Museum of the Royal College of Surgeons; and Dr. GÜNTHER, F.R.S., for tadpoles of that type.

‡ The relation of the upper labials to the vestibule of the nasal labyrinth is of great interest; I have carefully worked out these parts in Sharks, Skates, Teleostei, Anura, Serpents, many kinds of Birds (Trans. Linn. Soc. ser. 2, vol. i. plates 1–5 and 20–27; and Trans. Zool. Soc. 1875, vol. ix. plates 54–62), and in the Mammal (the "Pig's Skull," Phil. Trans. 1874, plates xxxi.–xxxvi.).

The meaning of these facts will come out with great distinctness when I come to describe their development in the "Aglossal" Toads; and in all the Batrachia we have most instructive foreshadowings of the complex nasal labyrinth of the bird, and of the endless galleries of the ethmoidal and septal structures of carnivorous and herbivorous mammals.

At once it may be well to state that in those higher forms the distal ends of the trabeculæ, "hypotrabecular" or "recurrent cartilages," do not straighten out as in these Batrachia; but the hooked or retral condition seen in the Bird and Pig also occurs in many of the Batrachia. The median or keystone part (prenasal or basitrabecular cartilage) is but little developed in the Frog (Plate 54. figs. 1 & 2, *pn.*); it is more distinct in *Pipa* (Plate 62. figs. 5 & 6, *pn.*).

The actual end of the trabecular cornu remains as a shrunken pedate process with its "toe" turned to that of its fellow of the opposite side; this is the "rhinal process" of HUXLEY, whose figure (*op. cit.* fig. 9, p. 755) seems to show it as a distinct cartilage: it is, however, continuous with the outspread subnasal plate (*al.n.*) formed by expansion of the larval trabecular bar.

In the same figure the foliar outgrowths of the trabeculæ are called "prænasal processes" (*pn.l.*); they correspond to the distal part of the trabeculæ, and are very simple in birds and mammals ("Pig's Skull," plate xxxvi. fig. 1, *c.tr.*). Moreover, as the comparison of these parts in many types teaches me, the outer cervicorn part answers to the floor of the down-turned alinasal growths of the hot-blooded Vertebrata.

There is no appearance in the Frog of three distinct territories in the roof of the internasal plate such as we see in higher types, namely aliethmoidal, aliseptal, and alinasal laminæ, the plates whose outgrowths are the turbinals of those various regions. The trabecular floor (fig. 2) is the widest in front; the ethmoidal roof is widest behind (fig. 1). In the very front of the nasal sac the cartilage becomes laminated, a sort of attempt at the formation of turbinals ("Frog's Skull," plate x. fig. 3). Professor HUXLEY stated his doubts to me as to the existence of these laminæ; but *new sections* show the truth of my old drawings*.

The 2nd upper labial (*u.l.''*) is a solid club, with an out-turned and pointed handle; the 1st (*u.l.'*) is a pisiform cartilage, serving as a cushion on which the premaxillary rests. The annular ethmoid ("Frog's Skull," plate viii. fig. 7, *eth.*) is rightly represented in my 9th stage as beginning above as a transverse ectosteal bar; but the chondrocranium afterwards calcifies, and then becomes completely ossified; the fore-and-aft extension of this "os en ceinture" varies greatly in different types of Amphibia, as this paper will show; in *Lissotriton punctatus* the little skull becomes a very strong osteocranium.

Professor HUXLEY calls the fore part of the cartilaginous palatine bar the "antorbital process;" there is a pre-, post-, and superpalatine region here, the latter being the conjugational bar between the trabecula and the pterygo-palatine arcade, one of the

* In the same plate the sections show the distinctness of the "2nd upper labial," which acts the part of an ala nasi (see figs. 3 & 6, *v.e.n.*). I did not at that time see the meaning of my own sections and drawings.

three swinging-points by which the first postoral is yoked on to the preoral bar in the Batrachia *.

On the Structure and Development of the Skull in the Common Toad (Bufo vulgaris).—*Last stage, adult.*

The figures illustrating the skull of the adult Toad show a chondrosteous structure, the chondrocranium with its soft tracts and its partially calcified and wholly ossified territories; the investing bones are faintly indicated by outlines.

For these latter bones are of much less morphological importance than the parts they cover in, being deep or shallow strata of connective fibrous tissue converted into regular bony tracts; the essential primary skull is early formed in hyaline cartilage, and tracing the development and modification of its elements is the difficult part of work of this kind.

This structure is now entirely continuous, with the exception of the antero-superior labials (Plate 54. figs. 3, 5, 6, *u.l.'*), and has been made up of the parachordal region, the whole of the foremost pair of bars (trabeculæ), the upper part of the first postoral (palato-quadrate), the impacted ear-sac, and the postero-superior labials. The main part, or cranial cavity, is an irregular trough or barge, which is flat above (fig. 3) and convex below (fig. 4). The lower surface is filled in by cartilage, with certain passages infero-laterally; whilst the upper surface is covered in in front, behind the middle, and near the end. Under the deck-like ethmoidal roof the cranial cavity is bored by the olfactory crura; behind, the great cavity is wide open for the large medulla spinalis.

In front, the entire bony girdle is the ethmoid, trespassing upon the orbito- and presphenoidal regions, which do not differentiate any proper bony tracts. The posterior sphenoid also gains the "larger wings" merely as an ongrowth of the large prootics (*pro.*). For here we see that the Batrachian skull takes an intermediate position between the Elasmobranchs, which have only a somewhat calcified chondrocranium, and the Teleostei, whose osteocranium is made up of many special bony territories. Here are no calcareous tesseræ, as in the Shark; but there is some disposition to the gathering together of the calcified tracts into larger plots, that, if finished within and without, would answer to the ordinary osteocranial bones. The girdle-bone (*eth.*) answers to so much of the mammalian ethmoid as would exist if bony matter were to surround the olfactory recesses (in that class multiperforate), run a little backwards into the fore edge of the anterior sphenoid, and harden a moderate tract of the perpendicular ethmoid. Here, in the Batrachian, we have these parts devoid of all those coiled outgrowths

* These two bars may be conjugated at *five* different points in the Vertebrata, namely, 1st, by the palato-trabecular or "antorbital;" 2ndly, by the orbital process, as in the Toad and Lamprey; 3rd, by the pedicle of the mandible; 4th, by the junction of the basipterygoids (external pterygoids) with the pterygoid bone; and 5th, by a sliding joint of the pterygo-palatine arcade (in its mesopterygoid region) on the trabecular beam, as in Birds.

called turbinals; and yet, simple as these structures are, they are not easy to understand or to describe. In front of the girdle-shaped ethmoid three large cartilaginous growths project. The median growth is a vertical plate, the unossified continuation of the perpendicular bone; this is the septum nasi (*s.n.*). On each side of this middle wall the sinuous enfoldings of the olfactory or Schneiderian membrane lie. The openings into this labyrinth, or outer nostrils (fig. 3, *e.n.*), lie at a good distance from the septum, at its fore end. The openings by which this labyrinth communicates with the cavity of the mouth, the inner nostrils (fig. 4, *i.n.*), are also a good distance apart, opposite the hinder part of the septum, at least behind its middle. Now, unlike the eye-balls, which are permanently separate, and the ear-balls, which were so at first, but lose their independence, the nasal sense organ has no independent growth of cartilage; the main part is borrowed from the trabeculæ cranii, and the rest from the upper labials.

For in the ethmoidal region the coalesced trabeculæ (see the early stages in Plate 55, soon to be described) not only grow together to form an 'internasal plate,' but behind this part, from their edges, a cartilaginous growth proceeds, which fills in all the interspace up to the hinder or parachordal region of the skull floor. Then, besides this, they grow up into a wall on this side and on that; and not only grow into side walls, but also develop cartilage, which divides the cranial from the nasal chambers, building in the foregrowing olfactory nerves (*crura*). Below, the nasal labyrinth is well floored; above, very imperfectly (figs. 3 & 4).

In the larvæ, as we shall see (Plate 55, *tr.*), the trabeculæ flatten out, and straighten out, instead of keeping the down-bent form acquired during the existence of the "mesocephalic flexure." The flattening out of these bands is similar to what we see in the Shark. The internal nostrils (fig. 4, *i.n.*) set bounds to these right-and-left laminæ towards the hinder third; they then become very large and leafy, each leafy plate sending out two lateral claws, one pointed and looking backwards, and the other obtuse and stretching forwards and outwards. Then, all of a sudden, the trabeculæ cease to grow, and their terminal part, or "cornua," project forwards and look inwards from the middle of the rounded fore edge of the nasal floor. These "cornua trabeculæ" are Professor HUXLEY's *prorhinal* cartilages. These *distal ends* of this basal part are much smaller in the Toad than in the Bull-frog and our native kind (figs. 1 & 2, *c.tr.*).

From the broad, double, concave floor arises the partition wall, or septum nasi (*s.n.*), and from this wall a roofing-plate, right and left (fig. 3, *al.s.*). This roofing-cartilage is scarcely a third as broad as the floor, whereas in the Frog (figs. 1 & 2) it is the larger of the two. It is wider behind where it runs into the aliethmoid; and also in front it spreads, thickens, and shelves over into an oblique front wall, which has two round windows close to the front of the floor for the exit of the nasal nerves (fig. 5, *al.n.*, *n.n.*, *c.tr.*). On each side of these openings the outer nostril (*e.n*) is guarded by a thick, oval leaf of cartilage, the "1st labial" (figs. 3, 5, 6, *u.l.'*), a segment from the large single piece seen on each side in the Tadpole (see "Frog's Skull," plate v. *u.l.*). This cartilage is crested above at its outer part, whilst the inner, rounded end is enclosed in a fold of the premaxillary, the trihedral part lying between the arms of the curious horseshoe-shaped "septo-maxillary" (fig. 6, *u.l.'*, *px.*, *s.mx.*).

Possibly in old Frogs, certainly in full-grown common Toads, the second labial (*u.l.''*) coalesces with the chondrocranium.

The deficient roof arising from the septum nasi is here largely supplemented by the second upper labial (*u.l.''*). This is, on the whole, lanceolate, but it is twisted in a sigmoid manner, and is irregularly dentate, and even fenestrate, on its outer margin. The ends are narrow; the fore end has coalesced with the stunted alinasal cartilage (*al.n.*), and the hinder end with the *antorbital*, or palato-trabecular bar, near its junction with the ethmo-palatine (*p.tr.*, *e.pa.*) An irregularly crescentic membranous space separates the inner edge of the second labial from the aliseptal fold. This valve to the outer nostril corresponds to the "appendix alæ nasi" of the mammal ("Pig's Skull," plate xxxvi. fig. 1, *ap.an.*); and the small inturned cornua trabeculæ answer to the "recurrent cartilages" of the Bird and the Pig (same fig., *rc.c.*).

I spoke of lateral cartilaginous outgrowths from the chondrocranium in front of the girdle-bone. These, which look also somewhat forwards, are the "conjugational processes" that run out to unite the trabeculæ with the palatal bar. They are in the Toad (not in the Frog) instructively segmented off from the orbital process of the palatine or ethmo-palatine (figs. 3–5, *p.tr.*, *e.pa.*)*.

In front of the girdle-bone, where the olfactory crura pass out, the true olfactory region is the recess on each side, backed by the narrow antorbital, on which no "middle turbinal" is formed; roofed by the "aliethmoid" and aliseptal (from which there grows no "upper turbinal" behind and above, nor "lower turbinal" in front and then below); and is floored by the outspread, concave, subnasal trabecular leaf. Laterally in the skull there is no true bone from the girdle in front to the great openings for the 2nd and 5th nerves behind. Infero-laterally, the prootic bone (*pro.*) creeps along the alisphenoidal region, half embracing the great optic passage (2). Further back each prootic seeks its fellow, but stops short a little within the edge of the parasphenoid; enough, however, is found to enclose the trigeminal nerve (5), the *foramen ovale* and *foramen rotundum* being all one passage, and enclosed by the "petrous bone" (*prootic*). A line drawn through the cranial trough a little in front of the hinder edge of the girdle-bone, and another through the middle of the optic passage, would be true landmarks of the anterior sphenoid, which we see is soft, or partially calcified (superficial endostosis), or has a

* This segmentation throws light upon the connexion of the palatine with the *ethmo-trabecular* structures in the Vertebrata generally. In the lower Urodela, *e.g.* *Proteus* and *Menobranchus*, the ethmo-palatine bar is all that is chondrified of the pterygo-palatine arcade (HUXLEY, on *Menobranchus*, Proc. Zool. Soc. March 17, 1874, p. 190, pls. xxix., xxx., *A.o*). In these the trabecula grows out towards this palatine rudiment, but not so much as in the Toad. In the Frog (figs. 1 & 2, *e.pa.*, *p.tr.*) the two bars run into each other. In the Salmon there is a joint ("Salmon's Skull," Phil. Trans. 1873, plate vi., *e.pa.*), and as a rule the orbital or ascending part of the palatine is distinct from the trabecular outgrowth; the ethmo-palatine, in many Birds, is developed into the very variable "os uncinatum." (See Trans. Zool. Soc. 1875, pls. liv.–lxii., for several instances of this bone in the Passerines.)

borrowed bony margin (in front). All that part of the prootic which encloses, and lies in front of, the trigeminal nerve is a bony trespass on the posterior sphenoidal region, whose bounds are from the optic passage forwards to the hinder surface of the trigeminal.

As in the Ichthyopsida generally, the posterior sphenoid seeks to become (in the chondrocranium) a perfect girdle—a "sclerotome." Here, as in the anterior sphenoid, the trabeculæ have each a mural upgrowth; but in this part the wall-plate thickens, and a ceiling is thrown over, which, however, is narrow near the side and then wide at the middle, where it is fused with the *occipito-otic* ceiling. Such a conformation leaves *skylights* in the ceiling of an oval form; these are the posterior *fontanelles*, a little behind the square, main fontanelle (*l.fo.*,*fo.*); and both these are filled up with a parchment of strong fibrous tissue, and roofed with a large shingle of fibrous bone—the fronto-parietal (*f.p.*).

But the wall and its wall-plate in the posterior sphenoidal region is a solid concrete of endosteal bone, thinly enamelled by ectostosis. The ceiling, above, is mostly unossified up to the edge of the foramen magnum; but, below, the prootic bones, laterally, have only a narrow tract of cartilage separating them from the exoccipitals, which bones, without a basioccipital threshold or a superoccipital keystone, are all that appertain to the occipital girdle-bone. Above, the prootics are most, and the exocciptals least; below, the contrary takes place (figs. 3 & 4, *pro.*, *e.o.*). Thus, below, a cross of cartilage is seen dividing the bones before from the bones behind; and this soft part is more than floored by the cross-shaped parasphenoid (*pa.s.*). The ear-sacs, which in the larva (Plate 55, *au.*) were little cartilaginous egg-like bodies, are now, through the development of the great tubular arches above and the sacs below, distended into a new shape from within. And to this modification by the swelling and rising within of the ear-labyrinth is superadded the coalescence of the auditory mass itself on its inner edges with the skull, and the fusion with it on the outside of the facial bars.

Nothing but a careful analysis of these outstretching wings, and a knowledge of the history of their growth, could give any adequate idea of their meaning. Their structure will be described now, and their development next (see Plate 55).

Above (fig. 3, *pro.*), we saw that the prootic had hardened the wall-plate in the posterior sphenoidal region; behind that part it forms a roof to most of the anterior semicircular canal (*a.s.c.*). The bony growth then fails on the inner side, and at the junction of that canal with the posterior (*p.s.c.*) there is only cartilage *unusually calcified*, an initial "epiotic" bony centre (*ep.*). This rounded, arched elevation has its convex edge limited by the exoccipital (*e.o.*), and its concave or outer edge by the prootic. The prootic then dips, where it lies over the interspaces of the semicircular canals, but is convex again where it enroofs the horizontal canal (*h.s.c.*); it then forms a sudden, sinuous margin, leaving unossified a large ear-shaped mass of cartilage at the outer edge of the occipito-otic wings: this free, soft part is the "tegmen tympani."

This latter part is thick at its edge, runs forwards, then passes inwards, and slopes downwards and forwards into the scooped anterior face of the auditory mass (fig. 3). In front the tegmen is continuous with the "otic process" of the mandibular pier (*ot.p.*).

The foramen magnum is largely open on the upperside (fig. 3, *f.m.*); thus, being oblique, it seems to be a heart-shaped space, for its outline is narrow and rounded above, bulging at the sides, and emarginate below. This emargination, where the notochord has been aborted, is the end of the parachordal plate, at its middle. On each side of this there are the right and left occipital condyles (*oc.c.*), having a core of bone and a bark of cartilage.

The exoccipitals are pinched in outside the condyles, and they elegantly expand to receive and to enclose the large posterior canals. This is above (fig. 3, *e.o.*, *p.s.c.*); but below (fig. 4), the bone, true to its Batrachian nature, occupies all its own and also the "opisthotic" territory (see also fig. 7).

The hypoglossal nerves do not pierce, but pass out *behind* the occipital; but the exoccipital bone enrings the nerves that pass out of the chink between the occipital arch and the ear-sac. These are the glossopharyngeal and vagus (9, 10); they are separated by a bar of bone, which divides this foramen into two*.

The *opisthotic region* of the exoccipital (figs. 4 & 7, *e.o.*) is seen below the vestibule, in front of the double foramen (9, 10), and outwards to the hinder edge of the stapes (fig. 7, *st.*). Here it is seen growing downwards as a hook, whose concave face is forwards. This roughly represents the bar which, in the higher types, separates the *fenestra ovalis* from the *fenestra rotunda*, and which, in the Crocodile, forms a ring round the neck of the cochlea (Huxley, Elem. Comp. Anat. p. 223, fig. 89, A, *Op.O*, *c*, *Chl.*). In fig. 7, where most of the tegmen tympani (*t.ty.*) has been cut away, the extent and relations of those two great bones, the prootic and the exoccipital, are well seen, as also how near they come to each other.

As my views upon the meaning and nature of the parts of the facial bars attached to this auditory mass have undergone much change, owing to Professor Huxley's criticism, his own work, and my renewed research, the description that follows will be found to differ in several particulars from that given in my paper on the Frog (see also, Huxley, "On *Menobranchus*," Proc. Zool. Soc. March 17, 1874, and his article on the "Amphibia," Encyc. Brit. new edit.).

The dorsal ends of the mandibular and hyoid arches have been the most difficult parts to work out, owing partly to developmental *anachronism*, and partly to their relation to the auditory mass, and the metamorphosis dependent upon, and ruled by, that relation.

The manner in which the mandibular pier is attached to the auditory mass is best seen from below (fig. 4); its apex originally passed into the trabecula, on its outside

* I must now change the *number* of the nerves, and pass from the "old style" to the new. Henceforth the portio mollis is to be marked as 8, and not 7 *a*, and the glossopharyngeal and vagus 9 and 10, and not 8 *a* and 8 *b*.

near its end (Plate 55); but afterwards it also contracts an adhesion with the fore face of the auditory mass.

It can be traced nearly up to the outer edge of the prootic (fig. 4, *pro.*, *pd.*); and this coalesced "pedicle," before passing into the mass of the quadrate (*q.*), gives off, from its posterior edge, a rounded condyle (*c.pd.*); this is much smaller than in the Frog (see "Frog's Skull," plate ix. figs. 2 & 7, *i.h.m.*)*. This coalesced bar and the condyle upon it are formed out of the primary apex or dorsal end of the mandibular visceral arch (Plate 55); but the "pier" also attached itself to the otic mass, *above*, by the "otic process" (fig. 4, *ot.p.*).

This process also coalesces with the auditory mass, namely, to the front of the tegmen tympani (figs. 3 & 4, *t.ty.*, *ot.p.*); it is an upgrowth from the *elbow* of the pedicle (Plate 55) as the *condyle* is a downgrowth.

From the point where these parts unite with the ear-mass there is a large fore-and-aft growth of cartilage; that behind, which curves also downwards, is the quadrate (*q.*); that which runs forwards is the pterygoid. The hinge of the quadrate nearly reaches backwards as far as the occiput, to give size to the gape, a state of things acquired during growth.

The pterygoid (*pg.*) runs forwards, wide at first and narrow afterwards, from the pedicle, and its lower part is continuous with the inside of the posterior margin of the quadrate. Midway to the antorbital region the flat tape-like pterygoid stops; then there is a tract of fibrous tissue, and these fibres fasten the pterygoid to the narrow postpalatine band (*pt.pa.*). As in Passerine birds, the palatine sends out an angular transpalatine process (*t.pa.*); it then runs forwards, retaining its larger breadth, curving a little inwards, and sending up the "orbital process" or ethmopalatine (*e.pa.*); it then ends in a free prepalatine spike (*pr.pa.*), whose flat upper end is attached by fibrous tissue to the palato-trabecular outgrowth. All this *prequadrate* growth is a development of the conjugational bar that ties together the anterior third of the 1st and 2nd bars in the skull of the embryo (Plate 55). In the Frog there is not any segmentation, either between the palato-trabecular bar (figs. 1, 2, *e.pa.*) or between the pterygoid and palatine ("Frog's Skull," plate ix.). The free mandible of the Toad is quite like that of the Frog; the "inferior labials" are not lost; they ossify as mento-Meckelian bones which unite with the small dentary, and the ends of these are mutually united by an elastic ligament. The articular region and much of the rod is enclosed in an *ununited* ectosteal "articulare"†. The next arch presents, perhaps, the most difficult problem in morphology; I have in

* I mistook this for part of the "hyomandibular;" it is there called the "infra-hyomandibular" (*i.h.m.*). In the adult Frog the pedicle cannot be traced further up than this condyle; it, apparently, becomes fibrous above. I find that the bony plate which covers the inner face of this pedicle is much more distinct in the Bull-frog; it is the "metapterygoid," and in the latter species there is a small "mesopterygoid" as well. In the Toad the pterygoid proper covers the diminished condyle.

† Professor HUXLEY (art. "Amphibia," p. 753, fig. 6, *an.*) calls this bone the "angulare;" but it is united to the hardened rod itself in the "Aglossa," as in the Sauropsida.

the adult only figured the upper part; that which corresponds *to the whole* of the hyoid of the Urodela (HUXLEY, "On *Menobranchus*," plates xxix., xxx., *hy.*) has its apex only figured.

In the Batrachia there is an *antero-superior* rod intimately connected with the "stapes" (*st.*); but in most Batrachia (not in *Pipa*) it is *late* in its development. The antero-superior palatine and the fore-turned part of the mandibular arch are also late; and both in Teleostei and Ganoidei amongst the Fishes, and in all the air-breathing Vertebrata, this region, the "pterygo-palatine arcade," is behindhand in growth, and suffers an extraordinary amount of metamorphosis. The mandibular is, as it were, a double arch.

So also is the hyoid an arch, which becomes subdivided into, or develops separately, *in an untimely manner*, two distinct and very dissimilar facial arches.

Its morphology is very varied in different groups; in the Shark the segment called hyomandibular forms a hinge with the distal part or stylo-cerato-hyal; they are related like a rib and sternal rib, or like the quadrate and the free mandible.

But that change in the disposition of parts which suggested to Professor HUXLEY the term *hyomandibular* is seen in the Skate, in the early embryo of which the hyoid arch is seen to chondrify into, (1) an antero-superior segment, broad above and having a round point below, which lesser end is tilted upwards and forwards, and is strongly articulated to the pier of the mandible; and (2) the proper, gill-bearing hyoid arch, which is separately attached to the skull.

In the Salmon it is otherwise (see "Salmon's Skull," plates i. & ii.); for in that type the hyoid chondrifies as one bar on each side, which splits almost from top to bottom (a little obliquely), and then the anterior segment becomes changed in form, tilted, and articulated with the inner face of the quadrate, to form the characteristic hyomandibular *swing*. The hinder piece, and a short segment from below, becomes the proper functional hyoid arch, and is swung by a secondary ("interhyal") bone from the antero-superior piece, just within its middle part. It is perfectly plain that the hinder piece in the Osseous Fish, and the short distal segment, the "hypo-hyal," correspond to the long and short pieces of the hyoid arch of *Menobranchus* (*op. cit.* plates xxix. & xxx., *Hy*, *Hh*, and *ch.*), and also to the undivided, *low-hung* hyoid of the larval Batrachian (Plate 55, and *infra*). The gradual *ascent* of that bar and its change of form was traced in my paper on the Frog; in that type it ultimately *articulates* with the antero-inferior ridge of the auditory mass, below and in front of the fenestra ovalis and stapes. In the common Toad (Plate 54. figs. 4 & 7, *st.h*) it is thoroughly fused with the periotic cartilage at the same point. In the figure just referred to the tegmen tympani is cut away to expose the facial attachments, and above the massive stapes (*st.*) there is seen a partly ossified bar having, on the whole, the same relation to the cerato-hyal that the upper tilted segment has in the Skate.

In that type this part is not ossified, but in Osseous Fishes it acquires two ectosteal sheaths, and becomes two bones, united by synchondrosis ("Salmon's Skull," plates v. & vi.

h.m., *sy.*). The specialization in the Toad is in one respect different from what we see in the Fish; for the distal end of the bar in the former passes *outside* the quadrate, and in the latter on the *inside*. But both *inside* and *outside* are secondary relations altogether, as may be seen in the position of these parts in embryo Teleostei and in the Sturgeon, where the lower segment of the antero-superior piece is simply placed *behind* the quadrate (see 'Monthly Microscopic Journal,' June 1, 1873, plate xx. fig. 1, *sy.*, *q.*). In the Frog and Bull-frog the antero-superior bar is in two segments, as in the Sturgeon; in the Toads (*Bufo* and the "Aglossa") the bar is ossified as a larger proximal and a smaller distal bony rod, without segmentation of the intervening cartilage. Also, in the young of all, and in most Teleostean fishes, the head of the hyomandibular is unossified, and the foot or distal part of the "symplectic" or terminal piece. Moreover, Professor HUXLEY, who has shown me the great difficulties here to be encountered in the interpretation of the parts, knows full well that the portio dura nerve passes *over* the columella of the Toad and the hyomandibular of the Fish alike. One more remark: if the parts here taken to be the hyomandibular and symplectic, although modified to form the curious auditory "columella," are not developed at the *same time* as the hyoid bar, neither are they contemporaneous with the stapes, into which category Professor HUXLEY seems inclined to place them. Further evidence will turn up in the embryo of the common Toad, and also in the development of the "Aglossa" (*infra*); to my own mind the stapes is a *new thing* in the Amphibia, not existing in the Fishes; and when an antero-superior bar is developed, as in the Batrachia, its upper segment is the hyomandibular, and its lower the symplectic, whatever names these parts may receive on account of their auditory modifications*. In this, as in other Toads, the columella is a very elegant structure (Plate 54. figs. 7 & 8); its parts take their names from their stapedial (auditory) relations. As in the Frog, the fenestra ovalis is a window lying in a deep recess of the side wall of the ear mass; that recess is mainly filled by the irregularly oval, lenticular stapes, whose flat face is applied to the fenestra, whilst the convex face looks outwards.

The proximal part of the columella is shaped like a planting-"dibble," but the conical end is all soft, and the ensheathing bony shaft narrows and twists itself as it runs forward (fig. 8, *it.st.*). The rounded face of the subconical part fits against a shallow notch on the antero-superior edge of the stapes, and its inner face lies in the *recess*. Considered as a *segment* this answers to the short "interstapedial" of the Frog (*op. cit.* plate viii. fig. 9, *it.st.*).

But that which forms the main bar in the Frog, the "medio-stapedial," is here one fourth only the length of the proximal piece, and is a very small cylindrical bone. The two bones fit close together, and the end piece leaves much cartilage unossified—a soft-ended "symplectic." The soft part bends at right angles upon the little "medio-sta-

* It cannot be an unmeaning fact that, whilst the Frogs subdivide their columella into two segments of cartilage, as in the Sturgeon, the Toads should have theirs marked off into two parts by two separate bony rods, as in the Osseous Fishes.

pedial" (*m.st.*), and suddenly dilates into a large plate, like the blade of a spade; this is the "extrastapedial" (*e.st.*). This plate, which has some calcified patches, sends upwards and backwards from its inner face a band of cartilage which coalesces with the tegmen tympani; this is the "suprastapedial" (*s.st.*). In the Grey Frog this part does not coalesce above; in the Bull-frog it does. The relation of the extrastapedial flap to the membrana tympani is shown in the side view (fig. 7, *e.st.*, *m.t.*); it is imbedded amongst a rather loose gauze of fibres, which arise from the shelving outer surface of the thick-edged crescentic, cartilaginous "annulus" (*a.t.*). This part was developed, originally, from a little trifoliate cartilage which, in the larva, bridged over the space between the *elbow* of the mandibular pedicle and the tegmen tympani; it detaches itself and becomes crescentic*.

The portio dura passes *over* the "medio- and inter-stapedial" bar, but when its fibres come across the "annulus," they pass *beneath* it; in the larvæ of *Dactylethra* (*infra* Plates 56 & 57) the early conditions of the *annulus* and *tegmen* are so remarkable, that even Professor HUXLEY himself was doubtful (before he ascertained for me the course of the portio dura nerve) as to whether these were not the rudiments of the huge columella of that species.

There remain to be described the investing bones; these are faintly shown in the figures for the purpose of a better display of the fundamental cranium: they are very similar to those of the Frog ("Frog's Skull," plate ix.). Above, the principal bone is the fronto-parietal (*f.p.*); each double bone keeps distinct, by a suture, from that on the other side. The nasals (*n.*) are large convex plates, subtriangular above, and sending down a process to join the face, where the maxillary, palatine, and pterygoid meet.

Below, the great dagger-shaped parasphenoid (*pa.s.*) has the basitemporal *haft* with a point at the end of each process, and not abruptly truncated as in the Frog; these processes are nearly as large as the blade. Each vomer (fig. 4, *v.*) is a 4-sided bone, concave below, toothed in front, and emarginate externally. The palatine (fig. 4, *pa.*) is a thin *knife* of bone, passing from the outer part of the cartilaginous bar to the edge of the parasphenoid, almost transversely, but a little deflected towards its inner end; this and the following properly belong, not to the *parosteal*, but to the *ectosteal* series. The pterygoid (fig. 7, *pg.*) is a curious obliquely triradiate bone, convex below, where it wholly invests the cartilage, and concave above, where it leaves it somewhat exposed at the end. Its arcuate front spur reaches the transverse palatine bone, its inner spur runs up beneath the pedicle and aborts the metapterygoid, and its external spur runs backwards, forming a strong splint to the inner face of the quadrate. A bony sickle (*q.j.*), representing in one piece the ectosteal plate of the quadrate and the quadrato-jugal of the *Sauropsida*, is strongly attached by its broad end to the quadrate outer face, is overlapped by the handle of the squamosal (*sq.*), and has its convex ridge attached, in front, to the jugal process of the maxillary (*mx.*). The great hammer-

* See "Frog's Skull," plates v.–vii., where it is lettered, both in its attached and its free stage, as *s.h.m.*; for I was deceived by it, and took it for the rudiment of the "columella auris."

shaped temporal (squamosal, fig. 7, *sq.*) in its upper part rides over the auditory mass, and sends forwards and outwards a postorbital process; its handle is largely enclothed with the tympanic curtains; but the lower end is apparent, overlapping both the quadrate cartilage and its bony style.

I have already described the lower bones of the gape; there now remain the upper. The whole bony arch is thrown round the upper face, and reaches nearly to the quadrate by the jugal process of the maxillary. This bone gradually broadens to its fore part, is abruptly truncated in front, and sends upwards a process to articulate obliquely with the anterior edge of the descending crus of the nasal. The arcuato-oblong premaxillaries (*px.*) form a double keystone to the great arch; they fit by straight surfaces to each other and to the maxillaries. The nasal process of the premaxillary (fig. 6, *n.px.*) is large and convex; the palatine process is a short spur bounding the inner end of the emarginate posterior margin, below, as in the frog (*op. cit.* plate ix.). There remain two bones to be described: these are the "cornets" of DUGÈS, my septo-maxillaries (fig. 6, *s.mx.*, and "Frog's Skull," plate ix.). Professor HUXLEY (art. "Amphibia," p. 754) did not observe them in *Rana esculenta.*

In the Toad (fig. 6, *s.mx.*) they are unusually large and well developed; in shape they are *hippocrepiform*, and, indeed, their likeness in outline is great to the shoe of a horse turned up for the frost, but the sides are largely connected by bony matter. The antero-superior labial (*ul.l'.*) has its round inner end encased by the premaxillary, but the trihedral blade rests on the upper face of the septo-maxillary*.

Structure of the Skull in Bufo vulgaris.—*First Stage. Embryos one third of an inch (4 lines) long.*

At this stage the external branchiæ are becoming short, and the internal are just developing. It corresponds to the *third stage* as given in my paper on the Frog's Skull (plate iv. figs. 7–12).

Before describing this stage in the Toad I shall show the weak points in the former paper.

In the earlier stages (1 and 2) I find no error as yet; but the facial parts are coloured lilac, as though they were cartilage, when they are still only very solid indifferent tissue.

In the figures showing the auditory sac the open membranous space is shown as though it were supero-lateral, whereas it is superior in position.

In the third stage this is figured and described as filled in (plate iv. fig. 7, *au.*), whereas it is open for some time afterwards. In the same figure is to be found that mistake which became the parent of several more. The hyoid arch is figured as two cartilages

* The term "cornet," or *turbinal*, is wholly inapplicable to this bone; it answers to one of the "preorbital series" of a Ganoid or Teleostean (Siluroid) fish, and reappears, in a specialized form in relation to the nostrils, not only in the Batrachia, but also in Snakes and Lizards, where it has its fullest development, and in Birds, whose palato-nasal structures are metamorphosed to the utmost.

(*hy.* and *h.m.*); the upper (*h.m.*) is merely the outer edge of the mandibular pier (figured in its lower part as *qu.*); the part answering to the hyomandibular of a fish does not chondrify until several weeks (4 to 6) after the metamorphosis of the larva is apparently complete, that is, until early summer.

As I have already stated, the part in the succeeding figures lettered as *i.h.m.* is only part of the *pedicle* of the mandible, and not an infrahyomandibular; whilst *s.h.m* is not the upper part of that bar, but the rudiment of the "annulus tympanicus." The remaining things to be noticed are deficiencies: thus the fore part of the chondrocranium of a newly metamorphosed frog (plate vii. fig. 11) does not show the subdividing labial on each side. Also, there is this deficiency in the figures of the adult chondrosteous cranium: the second upper labial is somewhat displaced (figured *al.n.*), as though it were the alinasal fold; the first labial is not drawn, and also the prorhinals, or cornua trabeculæ, were missed. The lower figure, but for the absence of the little pedate cornua (see Plate 54. figs. 1 & 2, *c.tr.* of the present paper) is quite correct; and I have there truly lettered the bony plate formed on the condyle of the pedicle as *m.pg.* It is the metapterygoid, but does not cover any *coalesced part* of the hyoid arch. In plate x. the second labial is correctly shown as distinct, but incorrectly lettered *al.n.* (figs. 3 & 6).

In the diagrammatic figures (11–20) the third (fig. 13) is incorrect (as in plate iv. fig. 7). The others are correctly drawn, but the colouring is wrong from 13 to 19. There should be no hyoid colour (lilac) on the back of the great mandibular pier, as we now know that no part of the hyoid arch has coalesced with it.

The development of Frog and Toad is so precisely alike, that the observations now to be given relate to both equally. Professor HUXLEY worked mainly at the young of the Frog, and my new results have been obtained from the Toad.

The reader must compare my results in this early stage of the Toad's skull with those of Professor HUXLEY on the Urodelous Axolotl and Newt (*op. cit.* "On *Menobranchus*," plate xxxi. figs. 1 & 2).

In this stage I have merely figured the trabecula and anterior arches (Plate 55. figs. 1 & 2). The branchials (indicated in fig. 2 by outlines) are simple arcuate rods, beginning to coalesce at their ends.

But all the seven pairs of arched rods were at first quite distinct (see "Frog's Skull," plates iii. & iv.); they lay very close together, were very massive relatively, were composed of a rather solid mass of young cells, the outer of which could be seen as differentiated from the inner by a clear line, the first indication of the separation of the perichondrium from the cartilage within. These formed a very regular series, but the first pair of bars were most tilted upwards and were the largest.

By the time, however, when the external gills are beginning to disappear, the larva is one third of an inch in length; these arches, then, are formed of clear (hyaline) cartilage, sharply defined from the fibrous tissue cells that enclothe it as its perichondrium. Moreover, the change of *substance* is correlated with a change also of *form*. Each bar has assumed a series of curious bendings (Plate 55. figs. 1 & 2); the second, or mandibular, has developed a free bud at its distal end, and has united itself, by its proximal end, and also beyond its middle, to the first bar. The first of these two pairs of *conjugations* show the first condition of the union of the pedicle of the mandible (*pd.*) with the elbowed part of the trabecula (*tr.*) near its apex, and the second the rudimentary pterygo-palatine arcade (*p.pg.*). The bud of cartilage at the free end of the second bar is the free mandible (articulo-Meckelian rod), and all the rest is its suspensorium. The upper part of the hyoid arch has not become chondrified; the lower part, or cerato-hyal (fig. 2, *c.hy.*), has become very much flattened out, and, pressing its antero-superior angle against the superior margin of the arch in front of it, has begun to form a remarkable *temporary* articulation, with a joint cavity. Besides the visceral arches, the ear-sacs are now enclosed in a cartilaginous capsule (*au.*), which is unfinished at the upper part.

Save the branchial arches and the parts just mentioned, there is no other cartilage in the cranio-facial basketwork at this stage, for the "parachordal" region (*nc.*) is still membranous.

The first pair of bars, or trabeculæ, extend from their *posterior end*, which overlaps the fore end of the notochord, to the frontal wall of the face, their anterior ends running up to the cartilages that form the thickness of the upper lip (*u.l.*, here shown in outline). On the whole, the figure made by the trabeculæ is lyriform, but the bars are bowed and bent in the manner of gnarled branches. The apical or hinder part is bent suddenly inwards, at little more than a right angle, and this part is terete, with a round and somewhat knobbed end. Then the bar thickens, and, being bent on itself at nearly a right angle, it runs convergingly inwards. This is done twice, the second time in a crescentic manner, suddenly; and thus the right and left bars are brought fairly into contact, their free ends flattening somewhat and then becoming clubbed (like the apices), these swollen, distal ends looking outwards, away from each other. Thus, with the round end of the notochord stopping the gap behind, we have a *pituitary space* of huge relative extent; it is heart-shaped, with an anterior acuminated apex and somewhat concave sides.

There are the rudiments of two "myotomes" (mt^1, mt^2) on the sides of the huge notochordal extremity, which is somewhat pinched at its waist; but there is no parachordal cartilage. The soft tissue which lies on the muscular segments rapidly chondrifies after this time; so rapidly that in a few days there is no distinction of trabecular and parachordal cartilage (fig. 3, *tr.*, *iv.*). Thus the trabeculæ show their independence by their *priority*; they are perfect for several days before the investing mass (parachordal region) is chondrified.

In this model and platform of a skull the *ear-balls* are as independent as the *eye-balls*. At present all the cartilage that exists is *below*. The cranium, save at the base, is a "membrano-cranium," and the nasal qouches are soft membrane.

The posterior or outbent elbow has the pedicle of the mandible conjugated to it; the anterior inbent elbow touches that of its fellow of the other side, and these two cartilaginous knuckles form the foundation of the nasal superstructure; by touching, they begin to build the "internasal plate." The clubbed ends will be the lower part of the nasal labyrinth; they send out the free "prorhinals." The gentle outbend of the trabeculæ, where the fore part of the next bar conjugates, will lie as the foundation-stone to the lateral ethmoid; it is the antorbital region. These bent rods have the cranial bag resting upon them; the pituitary body dips in front of the end of the notochord ("Frog's Skull," plate iv. fig. 8); and the "third vesicle" lies on the notochord and the gelatinous tissue which invests it.

The first postoral arch ("first visceral arch" of embryologists) is bowed and bent much after the fashion of the trabecula. Its apical part is bent suddenly inwards; and then the bar, in growing forwards, also turns inwards, subparallel to the other; but curving somewhat outwards, as the trabecula does somewhat inwards, there is a space left of an oval form—the "subocular space," or "fenestra" (*so.f.*). Before this second bar gives off the pterygo-palatine rudiment (*p.pg.*), on the other, or outer, side it is cupped for the head of the hyoid *half-arch*. The rest of the main bar then curves inwards towards the outbent trabecular horns (*c.tr.*), and ends in a rounded condyle, which fits in the hollow proximal end of the Meckelian bud (*mk.*), an ovoidal nodule of cartilage, cupped above and rounded below. This free mandibular rudiment looks towards its fellow, and not from it, as in the case of the *continuous* distal region of the trabeculæ. The nasal passage lies over this little nodule, and opens into the palate in front of the pterygo-palatine rudiment (see figs. 2 & 3).

The next arch, whose lower half only is developed, corresponds now to the lower piece in the hyoid of a Shark, and to the *whole* of what appears in a tailed Amphibian (HUXLEY, "On *Menobranchus*," plate xxix. *Hy*, plate xxx. *Ch*). Its low position corresponds with that of its homologue in the adult Osseous Fish ("Salmon's Skull," plate vi. *ep.h.*, *c.h.*). In that type it has descended gradually, after its segmentation, from the primary bar; here, in the Toad's larva, the hyoid arch chondrifies only in that low part; and for the remainder, above, we must look three months afterwards, some weeks subsequent to the escape of the creature from the water. The articulation of this bar, which is properly the *postero-inferior* segment, failing the *front* and *upper* part, or hyomandibular, articulates directly with the posterior face of the mandibular pier. I am now perfectly satisfied that this connexion of the hyoid with the mandibular arch is the only one that takes place during larval life.

The form of the cerato-hyal at this stage (Plate 55. fig. 2, *c.hy.*) is oblong; it is curved externally and flattish within. Of the upper angles the anterior is rounded (as a condyle), and the posterior produced and leafy; so are both the lower angles. Between the right and left bars there is a nodule of cartilage (*b.br.*), which becomes the larger basibranchial behind, and the lesser basihyal in front.

Besides the branchial arches there are two pairs of labials (upper and lower, *u.l.* & *l.l.*). Thus, altogether, at this stage there are as *chondrocranial* elements already cartilaginous, seven pairs of bars, two pairs of labials, and one pair (we do not count the *eye-balls*) of "paraneural" elements.

Most of the cranium, therefore, is "membrano-cranium;" but the foundations of this small "lodge" are fairly marked out, and are rapidly solidifying by chondrification.

It is open to me to remark how that this type, even at its early stage, only gives evidence of possessing *two* "somatomes"* in its head. However complex what we call the *skull* becomes, it is largely built up upon the foundation of the trabeculæ cranii, these being the chief elements. The hinder third of the skull is parachordal.

A figure like this (fig. 1) would have made a proper series in Professor HUXLEY'S valuable plate ("On *Menobranchus*," plate xxxi. figs. 1 & 2, *Siredon* and *Triton*). In all the three we see, fairly, in the interauditory or occipital region, two myotomes. Those Urodelous types differ from the larval Toad and Frog in the early appearance of the bony plates; they come very much later in the Batrachia.

Skull of Bufo vulgaris.—*Second Stage. Tadpoles* 5 *lines long.*

During the time in which one of these larvæ is one fifth longer, the head has grown twice the size, and the development of the parts has gone on very rapidly. The external gills are no longer apparent, and the form and appearance is that of a perfect *bull-head.* The chondrocranium at this stage (fig. 4, a *half-figure*, seen from below) is much more perfect than in the last, for the gelatinous stroma that lay over the myotomes on each side of the notochord has become hyaline cartilage. I cannot view these parachordal tracts (*iv.*) as the growth backwards of the apices of the trabeculæ, but as quickly transformed cells, the fore margin of whose territory is lost in the trabecular tract (*tr.*) as soon as the solidification takes place. The notochord (*nc.*) has retreated, and has its fore margin bounded by a solid belt of cartilage, from which on either side the parachordal bands run, binding on the sides of the notochord, and ending behind in the occipital condyles. In the Salmon-fry of the second week after hatching (my 5th stage, *op. cit.* plate iv. p. 127) the trabeculæ and "investing mass" are quite distinct, the former *crossing fingers* with the latter in a most evident manner. Here, where the chondrification is not synchronous, there need, surely, be no difficulty in the interpretation of the parts: they are distinct in the Newts.

The trabeculæ, which pass forwards as broad, flattish bands, have coalesced in front, forming an internasal plate (see also fig. 3), and now their large flat cornua (*c.tr.*) are falcate, with a slightly notched convex margin.

The pituitary space enclosed by them, under the middle brain, is now more regularly oval; and the subocular fenestra formed by the trabecula and mandibular pier is now widest at its hinder part. A *prenarial ligament* (*p.n.l*) connects a tooth-like process

* The Urodela in an early stage show a subdivision of the notochord into two rudimentary "centra;" this is best seen in the larva of *Seironota perspicillata.* Most of them, thus, have a rudiment, in this way, of a basioccipital, which represents two or more centra.

on the outer edge of the trabecula with the inner face of the quadrate (*q.*) near the hinge. This ligament is cartilaginous in the next type (*Dactylethra*), and is an important structure in *Rana pipiens* and *Pseudis paradoxa*. Between this ligament and the broad, flat, pterygo-palatine band we see the valvular "inner nostril" (*i.n.*). In the former stage the trabecular elbow was the greater of the two; now it is the mandibular, which projects most (fig. 4, *pd.*), the fastened band running in a loop-like manner a little distance in front of the ear-sac (*au.*), arching round its front convexity. The second bar thus, in an outwardly arched manner, curves inwards to the other, or pterygo-palatine binder; its last *fifth* is free; this is the quadrate cartilage; it ends in a rounded condyle, on which the sinuous face of the free mandible (*mk.*) is hinged. At the middle of its side and a little below there is a notch and a subconcave facet, in which the hyoid (*c.hy.*) rolls; between them there is a joint cavity. Above this part is the "orbitar process;" this will be described in the next stage (fig. 3, *or.p.*). The small, free mandible (*mk.*) is somewhat arcuate, clubbed at its distal end; has a sinuous notch for the quadrate, and a large, solid angular process.

The hyoid cornu (*c.hy.*) is an obliquely oblong, massive plate of cartilage, somewhat twisted and strongly ridged below for muscular attachment. The antero-superior angle has been formed into an oval, gently convex condyle; the hinder corner is produced upwards into a large snag. Below, it is pedate, the sharp and somewhat upturned *toe* looking forwards. The hinder margin of the plate is gently concave, and the fore edge is sinuous.

The form of the still distinct ear-capsule is now that of a badly-shaped egg, with the broad end foremost; above, the cartilage is imperfect; below, it is becoming membranous at one point, although well chondrified on the whole.

This imperfect space is near the front and outer margin, a little behind the elbow of the mandibular pedicle; in it the cartilage-cells are being sundered, and the vacant place, the beginning of the "fenestra ovalis," is filled in with gelatinous tissue *. From this scooped space, backwards, the capsule is bevelled towards the edge; that projecting edge is the "tegmen tympani." Both the 5th and 7th nerves make their escape over the interspace between the pedicle and the auditory capsule.

Skull of Bufo vulgaris.—*Third Stage. Tadpoles* $5\frac{1}{2}$ *lines long.*

With but little increase in the entire length of the larva in this stage, the size and development of the head is remarkable. Most of the description of the last is applicable to this stage; but I here display the pattern of the Tadpole Toad's skull, as seen from above, with the hyoid cornua, the free mandibles, and the labials not drawn (Plate 55. fig. 3). One thing of great importance strikes the eye at once; this is the

* When the Tadpole is twice the size of this stage, viz. five sixths of an inch, then the gelatinous plug will be an oval plate of cartilage—the "stapes." My early observations on its formation were faulty; Professor Huxley pointed that out to me. We agree now as to the manner in which this plate is formed.

projection of the parachordal cartilage (*iv.*) in front of the auditory capsule. Now, in the Salmon ("Salmon's Skull," plate ii. fig. 5, *iv.*, *tr.*) the free ends of the parachordal bands, or "investing mass," look a little inward; but in the Fowl (HUXLEY, Elem. Comp. Anat. p. 138, fig. 57, F; "Fowl's Skull," plate lxxxi. fig. 2, *lg.*) the terminal part of each of these plates looks outwards and is abruptly truncated.

A line drawn, on each side, obliquely from the front of these processes to near the apex of the notochord (fig. 3, *nc.*) would be the true land-mark separating the trabeculæ from these hinder bands. The pyriform pituitary space (*pt.s.*) is now seen to have a low, but sharp wall enclosing it, on this side and on that. This wall is a crest growing upwards from the trabecula, and is the simple rudiment of the anterior and posterior sphenoidal wings and ethmoid, in one. Where these crests begin to die out, in front, there we see a cartilaginous bud on each side of the beginning of the internasal commissure. This is the first upgrowth of the prefrontal mass or lateral ethmoid. Afterwards (see "Frog's Skull," plate v. fig. 3) these buds will coalesce with each other and with the lateral crests, so as to form the round fore end and straight sides of the growing cranial trough.

Opposite these buds, above where the concave facet for the hyoid is formed, the mandibular pier is bent inwards, and from this concave margin there has arisen a large triangular, sessile leaf of cartilage (*or.p.*), which is *decurrent*, for it runs backwards along the mandibular stalk, cresting its outer edge. This sessile, broad-based leaf is apiculate, and the apex of it has coalesced with the trabecula, just outside the ethmoidal *bud*. This is the "orbitar process," which arches over the temporal muscle.

In the Common Frog ("Frog's Skull," plates v. & vi.), the Bull-frog, the Paradoxical Frog, and the Aglossal Toads (*infra*) this perfect arching over does not take place*.

At present the internasal plate (*i.n.p*) is only half as long as the free cornua (*c.tr.*); in front, where the curved bars lie back to back, it has their thickness, but behind it is bevelled; and this thin-edged plate is the commencement of a most extensive commissure, which will in time, when the larva is perfect, fill in the whole of the pituitary space, as in Sharks and Rays. One measure of the extent of metamorphosis undergone by these Batrachians can now be given. By my study of the huge Tadpoles of *Rana pipiens* and *Pseudis paradoxa*†, I learn that the projection from the outer side of the cornu trabeculæ, which gives attachment to the inner end of the "prenarial ligament" (*p.n.l.*), is the rudiment of the "alinasal floor," which projects outwards in a *cervicorn* manner (Plate 54. figs. 3 & 4) in the adult.

* Professor HUXLEY informed me (summer of 1874), after showing me this perfect arch in Tadpoles of the Toad I had supplied him with, that he had found, from the distribution of the facial nerves, that the so-called "palato-pterygoid" of the Lamprey (see HUXLEY, Elem. Comp. Anat. p. 193, fig. 76, *e.*) really corresponds with the *external* orbital arch, and not with the true palato-pterygoid. This *petromyzine* structure, and the segmentation of the true palato-pterygoid arcade, make the skull of the Common Toad an object of great interest; further research amongst the "Bufonidæ" is also suggested.

† To be given in my next communication.

From this point to the posterior edge of the pterygo-palatine bar is the nasal region, and, with the help of the upper labials, this tract grows up into all that labyrinth. The trabecular cornua in front of that process grow, indeed, as long as the larva is a larva, and afterwards give off the "prorhinals" (Plate 54. figs. 3, 4, *c.tr.*).

The prenarial ligament in the Tadpole binds together the rudimentary *alinasal floor* and the inner face of the quadrate (*q.*); the corresponding point of the quadrate in the adult is exactly opposite the anterior margin of the exoccipital bone, which corresponds with a line drawn across through the middle of the cranial notochord *.

The auditory sacs (Plate 55. fig. 3, *au.*) are now obliquely pyriform; the cartilaginous coat, stretched almost to bursting by the rapid growth of the labyrinth, has yielded to the form of that which it bears within. An elegant, large, oval fenestra still exists on the top of the capsule, towards its inner side. This is the counterpart of the membranous space which lingers for some time in the roof of the capsule in the embryo of the Salmon ("Salmon's Skull," plates i., ii., iii., *au.*); this is the remains of the "aqueduct" or primary involution of the ear-sac (see "Pig's Skull," p. 299, plates xxviii. & xxix.). The huge semicircular canals shine through the hyaline cartilage and their fenestral membrane (fig. 3).

Skull of Bufo vulgaris.—*Fourth Stage. Tadpoles* 8 *lines long.*

In Tadpoles twice the length of the first stage here given, viz. two thirds of an inch long, I obtain a view of the substance, now considerably differentiated, which becomes the *stapes*. Professor HUXLEY had suggested that my first view ("Frog's Skull," p. 157) was incorrect, and that it was not *segmented out* from the already cartilaginous capsule, but formed later, by chondrification of the tissue lying in the fossa or primitive "fenestra ovalis" (see fig. 4, *f.s.o.*). I had long before found a *cleft* in the floor of the capsule in ripe embryos of *Salamandra maculosa*, and it seemed to me that this cleft went on to *cut out*, as it were, a large "bung." This process does take place in the "Urodela" (*Siredon*, *Salamandra*), but not in the "Anura." The pitting of the sac, below, in Toad Tadpoles 5 lines long (fig. 4, *au.*), is the commencement of a peculiar involution and subsequent rupture of the cartilaginous wall (fig. 5, *au.*, *st.*). By the huge, growing anterior and horizontal semicircular canals, and the development of the "tegmen tympani," the little pit is brought more beneath the capsule; it has also grown backwards, as a cleft, absolutely as well as relatively. The involution of the periotic wall appears as though it had been made by pushing in with a finger, obliquely, and the size of the opening is much less than it appears from the surface. It is an obliquely pyriform space, looking inwards, and extending its narrow end backwards; as is the

* For the further development of the nasal labyrinth in the Batrachian, I must refer the reader to my former paper on the Frog, remarking that the part in the newly metamorphosed Frog (plate vii. fig. 11) does not show either the "labials" or the prorhinals. In the "Aglossa" I shall presently show very simple conditions of the labyrinth; but the most perfect elucidation will be given when I come to the Paradoxical and Bull-frogs.

shape of the fenestra, so is that of the *plug* which fills it (*st.*). The tissue of the walls of the capsule have long been hyaline cartilage (see figs. 1, 2, 3, *au.*); the plug (figs. 5 & 5^a, *st.*) is still composed of granular *indifferent tissue*, very consistent, but not cartilaginous; it *will be* cartilage when the Tadpole is the tenth of an inch longer, or in two or three days; for in Tadpoles one third longer than this stage (1 inch long) it is very solid cartilage. In seeking to settle the dispute as to the nature of this plug, it may be remarked that it lies at the bottom of the periotic fossa, and that its outer surface is scarcely flush with the periotic wall around it, and that its inner face is in immediate contact with the membranous labyrinth. Now the upper segment of the "columella," which is chondrified two months or more afterwards, does fit into the depressed part or fossa (see "Frog's Skull," plate vii. fig. 16, and plate viii. fig. 9); the interstapedial segment (*it.st.*) lies in the fore part of the *stapedial fossa* (*st.f.*), but the stapes itself covers the fenestra ovalis. When it is removed, the otoconial masses (*ot.*) shine through the fenestra (*fs.o.*).

I shall next describe the tardy-growing antero-superior segment, which attaches itself to the periotic plug or stapes, and whilst homologous in its nature with the fish's "hyomandibular," becomes, by specializing change, in *time* and in *form*, the auditory columella of a high Amphibian *.

Skull of Bufo vulgaris.—*Fifth Stage. Young Toads* 5 *lines long.*

These observations have been made to show the relation of the first and second post-oral arches to each other and to the auditory sac. My results correspond exactly with what Professor HUXLEY obtained *first*, in observing *Rana temporaria*. Seen from within (Plate 55. figs. 6, 7), with the basis cranii somewhat tilted up, the ear-capsule is found to be quite confluent with the parachordal cartilage (*iv.*); and now the tegmen tympani (*t.ty.*) is very large, and under its shadow we see the large, oval, plano-convex stapes, fitting into the recess which is open at its fundus behind, as the fenestra ovalis. The vestibular floor is gently convex, and is of less extent than the upper surface of the capsule, where the semicircular canals are imbedded; it retires most laterally, on account of the tegmen, but in front also, where the pedicle of the mandible runs (*pd.*), and also behind, where the 9th and 10th nerves (9, 10) pass out. The pedicle is much narrower, and clings close to the fore face of the capsule, as it passes into the trabecula (*tr.*), beneath the 5th nerve (5). But if the upper part of the pedicle is thin and narrow, its lower part is thick and broad; and it is the great distinctness of this tract of cartilage, and the special facet or condyle upon it (*c.pd.*), which beguiled me in my early

* Whilst carefully expressing my indebtedness to Professor HUXLEY for taking up this subject, and seizing by instinct, as it were, upon the erroneous parts of my description, I yet hold, most tenaciously, to my old view as to the homologies of the parts; namely, that the "stapes" is a *periotic*, and the whole, complex "columella" a *hyoidean* element. The fact that the stapes is formed out of the already chondrified periotic wall in the "Urodela," as is most plainly seen in young Axolotls $2\frac{1}{4}$ inches long, settles the stapedian homology; that the columella of the Batrachia is the homologue of the hyomandibular of *Proteus*, I have not the shadow of a doubt.

studies of the metamorphosing Tadpole (see "Frog's Skull," plate vii. figs. 1–5, and plate viii. figs. 1–4, *i.hm.*—"infra-hyomandibular," the erroneous name I gave to it). Even the fact that this tract was ossified by a bony plate (in the Common Frog and Bull-frog), which I correctly designated as the "metapterygoid," did not undeceive me.

In the third stage (fig. 3) the elbow of the mandibular pier is quite free from any otic attachment; but in larval forms of several kinds of Batrachia I have found *two* distinct binders, attaching these two unrelated parts together. In Tadpoles of the Frog an inch or more in length, and with hind legs apparent, there is a band which runs from the elbow, and then becomes pedate, attaching itself to the edge of the *tegmen* in front ("Frog's Skull," plates v. vi. vii., *s.hm.*). This part becomes detached as a small trefoil of cartilage; it lies *outside* the "portio dura," and becomes the "annulus tympanus." The next attachment is by a much larger band, the "otic process" of the mandibular pier ("Frog's Skull," plate viii. figs. 3, 4, *m.pg.*); in a further stage (fig. 8) it lies above *m.pg.* and *i.hm.*

In the Toad in this and the next stage it is seen outside the pedicle (fig. 8, *ot.p.*); it has coalesced with the anterior edge of the tegmen, and is invested with the squamosal: in the figure, being on the outside, much of the breadth is hidden.

The rest of the pier is now at right angles with the axis of the skull, and forms a large angle with the metapterygoid step on the pedicle: this is the quadrate region: its lower surface is obliquely scooped for the sinuous articular part of the free bar (fig. 6, *mk.*). The pterygoid bar (*pg.*) passes off at right angles with the quadrate, by a broad base in front of the meeting of the quadrate and metapterygoid regions; a bony ectosteal plate is forming on it, which runs forwards, and will spread upwards and downwards. Here we miss that other ectosteal plate which the Frog possesses, namely, the metapterygoid ("Frog's Skull," plate viii. figs. 4 & 8; it is lettered *m.pg.*, although attached to *i.hm.*).

The hyoid bar (*c.hy.*) was seen in the larva (figs. 2, 4) neatly articulated to the mandibular pier below the outer edge, and a little behind (=above) the outer or pterygoid end of the pterygo-palatine bar. Now that the quadrate condyle is opposite the optic foramen, instead of being opposite the nasal passage, the hyoid has had to go backwards with it. By such a change of position it has come very near to the fore margin of the auditory capsule, within easy reach of its external and lower edge, its ultimate destination (see Plate 54. figs. 4 & 7). This plate has become a narrow bar; it has become sundered from its neat joint, and its little rounded inturned condyle is now rather loosely attached by ligament; yet it retains, very nearly, its old attachment as to the *region* of the mandibular pier, which was, from the first, a little behind, or *above*, the root of the pterygoid.

The large, oval, externally convex stapes (*st.*) is nearer the posterior margin of the capsule than the anterior; its front end is a considerable way behind the condyle of the "pedicle;" it is attached to the outer face of the periotic capsule, under a large crescentic eave of cartilage—the *tegmen*. Only the hinder part of this plug has its inner face in contact with the membranous labyrinth, and that part is covered, outside, with muscular fibres (*m.*). All the fore part of the primary dint (fig. 4, *au.*) is floored with cartilage in front of the fenestra ovalis, and that part of the stapes which fits into this *closed fossa* is invested, on its outside, with a tissue that I failed to make out in my earlier researches. This tissue is a soft mass of fusiform cells, and is in shape like a half-opened fan, the sharp handle of which is twisted a little, and finds its way behind, and a little *outside* the pedicle of the condyle (figs. 6, 7, *c.pd.*, *co.*). This soft tissue fills in the inverted fossa beneath the fore part of the tegmen; it fines away to a point in front, but is copious where it lies in front of, and begins to invest, the stapes.

I do not suppose that the whole of this tract chondrifies; there is more of it than is wanted to form such a "columella," as we shall see in the next stage (fig. 8, *co.*). My view is that a filiform "core" of cartilage-cells is developed within this mass of tissue, and that the last is formed into fibrous connective tissue, the outer part of which is loose, and that further inwards more dense, forming the perichondrium of the slender rod.

Skull of Bufo vulgaris.—*Sixth Stage. First Summer Toads, 8 lines long.*

The figure here given is carefully drawn from my own preparation; but I had previously supplied Professor HUXLEY with numbers of young common Frogs of the same stage, and my first view of the first stage of a chondrified columella was from his preparations made from the Frogs. The drawings in his possession (made by him) differ in no way from these newer figures made by me; *newer*, however, by merely a few weeks.

The quadrate, with its obliquely scooped condyle, turns further backwards than in the last stage, the pterygoid ectostosis is spreading further up and down, and the hyoid is nearly touched by the leafy tegmen tympani (Plate 55. fig. 8, *q.*, *pg.*, *c.hy.*, *t.ty.*).

The arcuate "annulus" (*a.t.*) is seen, partly, through the chink between the hyoid and quadrate.

The stapes has now acquired its permanent shape (Plate 55. fig. 8, *st.*, and Plate 54. figs. 7 & 8, *st.*). Its otherwise regularly oval form is spoiled by a slightly concave emargination outside its fore end; against this emargination there lies the bulbous end of a small styloid cartilage. This rod is gently arcuate, and its convex margin is on the inside; it lies in an extension of the primary *inverted fossa* (see Second Stage, fig. 4, *au.*), which we saw began very near the mandibular "elbow," and then grew backwards. This style is the "columella" (*co.*); it fills the chink in front of the excavation of the stapes, a good distance from the fenestra ovalis, and growing forwards, turns outwards also, pricking its way by its delicate filiform end, between the tegmen and the condyle of the pedicle (*t.ty.*, *c.pd.*). It is evident, if we compare this rod with the perfect columella, that the extrastapedial plate and the suprastapedial rod (Plate 54. figs. 7, 8, *e.st.*, *s.st.*) have in this stage no existence; they are aftergrowths from the filiform end.

In our native Frog, by the first autumn the columella has become quite perfect ("Frog's Skull," plate viii. figs. 7, 8, 8^a, p. 172); not, however, in the manner of the Toad.

The points of importance in which the Toad's skull differs from the Frog's are the following:—

a. The "orbitar process" in the Tadpole forms a perfect arch over the temporal muscle.

b. The second upper labial coalesces in the adult with the internasal plate in front, and with the antorbital bar behind.

c. The palatine cartilage is segmented off both from the ethmoidal (palato-trabecular) and also from the pterygoid.

d. The upper part of the mandibular pier can be traced in the adult above the "condyle of the pedicle;" the stylo-hyal coalesces both with it and with the ear-sac.

e. There is no separate metapterygoid bone.

f. The columella does not subdivide its cartilaginous core; the subdivision here takes place far forwards, and not near the stapes, and is segmented, merely, as in Osseous Fishes, by separate bony shafts.

g. The extrastapedial is a large semioval leaf, and the suprastapedial *coalesces* with the "tegmen."

h. The hyoid bar coalesces with the periotic capsule.

i. The cartilaginous "annulus tympanus" forms only two thirds of a circle.

j. The common aliethmoidal, aliseptal, and alinasal roof is only one fourth the size.

k. The prorhinals or cornua trabecula are much smaller.

On the Skull of the Clawed Cape Toad (Dactylethra capensis, CUVIER).—*First Stage.*

For the skulls of the adult of this *aglossal* Toad I am indebted to Professor HUXLEY and Dr. DOBSON, of Netley; for the larval forms, in their various states, to Mr. T. J. MOORE, of Liverpool.

The young of this type was supposed by the late Dr. J. E. GRAY, F.R.S., to be a distinct species, and it was called by him *Silurana tropicalis* (Ann. & Mag. Nat. Hist. ser. 3, vol. xiv. p. 316, and Proc. Zool. Soc. Nov. 8, 1864, pp. 458–464). I have the satisfaction to find that Dr. GÜNTHER considers all these stages to be merely the changing forms of the ordinary Cape Toad. As to whether there is any real specific difference between *Dactylethra capensis*, CUV., *D. lævis*, GÜNTHER, and *D. Mülleri*, PETERS, does not affect this piece of research. The young specimens were brought by R. B. N. WALKER, Esq., from Lagos, and those dissected by me were taken from the same bottle as those described by Dr. GRAY (Proc. Zool. Soc. Nov. 8, 1864, p. 463, figs. 1, 2).

These marvellous siluriform larvæ appear to me to be equal in zoological and morphological value to any type whatever; to me their only rivals are the larvæ and young of *Pipa*, the other aglossal Toad.

The youngest of the larvæ brought home by Mr. WALKER are figured in full (Plate 56. figs. 1–3); these are much younger than the larvæ figured by Dr. GRAY (Proc. Zool. Soc. fig. 1). The outer form of the early stages of all the Vertebrata is of great importance to the morphologist, and also gives the zoologist a lively idea of the relation of the young of one kind to the adult of another.

In this type, also, I have had the advantage of fellow-working with Professor HUXLEY, who had made out much of the adult skull, carefully observing the nervous trunks, and who also examined the skull and cranial nerves of one or two small larvæ.

Help from such a quarter was of the utmost importance to me, and we both felt that we had to deal with a most difficult and enigmatical type.

The figures of early larvæ given in my former paper ("Frog's Skull," pl. iii.) do not show *the whole* of the creature; yet, as far as they go, they show how different our typical Batrachian larva is from that of the Cape Toad.

Equally important, both to Zoology and to Morphology, are the most patent differences: these are as follows, namely:—

a. The mouth is not inferior in position, suctorial, and small, but is very wide, like that of the "Siluroids" and *Lophius*; has an *underhung* lower jaw, an immensely long tentacle from each upper lip, and possesses no trace of the primordial *horny jaws* of the ordinary kind.

b. In conformity with these characters the head is extremely flat or depressed, instead of being high and thick.

c. There are no "claspers" beneath the chin ("Frog's Skull," pl. iii. figs. 10 & 11, *cp.*).

d. The branchial orifice is not confined to the *left* side, but exists also on the right (HUXLEY).

e. The tail, like the skull, is remarkably *chimœroid*; it terminates in a long, thin, pointed lash, and the whole caudal region is narrow and elongated as compared with that of our ordinary Batrachian larvæ.

f. The fore limbs are not hidden beneath the opercular fold.

To the anatomical reader I scarcely need explain the importance of these characters, especially that of the absence of the horny jaws; as it is at once seen that here this aglossal form agrees with most of the "Urodela," and that it helps to lessen the *reentering angle* between the diverging lines of those two amphibian groups, the Batrachia and the Urodela.

At present, in this the youngest larvæ, whose whole length is an inch and a quarter (three fifths of which is *caudal*), the fore and hind limbs are nearly equal in size (figs. 1 & 3); afterwards they show a different rate of growth; this is explained when we look at the disproportionate size of the hind limbs in the adult (GRAY, *op. cit.* p. 461).

In seeking to decipher a chondrocranium like that of this stage of the Dactylethra's Tadpole, the earliest condition of such a skull, that is, as soon as this cartilage appears, must be held in mind. Now we have seen that such a simple framework can be made out, and that it differs but little in the Batrachia and Urodela (Plate 55. figs. 1, 2; and HUXLEY, "On *Menobranchus*," plate xxxi. figs. 1, 2). The points in which the two types differ are the early appearance of the bony plates in the Urodela; the absence in them, at this time at least, of a pterygo-palatine conjugation; the non-coalescence, at this early stage, of the pedicle of the mandible with the elbow of the trabeculæ; and the membranous condition of the fore part of the trabeculæ, namely, the internasal region and cornua. The hyoid is also longer, slenderer, and more loosely attached to the bar in front of it (HUXLEY, *op. cit.* fig. 2, *Hy*).

Now it may be safely taken for granted that the earliest chondrocranium of *Dactylethra* would exhibit all the essential Batrachian characters; and the condition here to be described in the earliest stage in my possession agrees with this assumption.

I shall therefore take the diagrammatic model or platform of the earliest chondrocranium of the Common Toad as the pattern of the foundation of this advanced chondrocranium of *Dactylethra* (see Plate 55. fig. 1).

For immediate comparison of a like stage to this, the reader is referred to the *third* stage of the Common Toad's Skull (Plate 55. fig. 3); the counterpart of this in the Common Frog is seen in Professor HUXLEY's last quoted paper (plate xxxi. fig. 3); the figures given in my former paper ("Frog's Skull," plate v.) correspond very exactly to the *second stage* of *Dactylethra* (Plate 57. figs. 1, 2). We shall need all these figures, and many more, for comparison; and when this most remarkable, flat chondrocranium is interpreted, it will serve as a key to unlock the mysteries of other remarkable chondrocrania, both of those which now exist, such as we see in *Chimæra* and the "Dipnoi," and of those that *did exist*, such as *Coccosteus* and *Pterichthys**.

Surely, in these latter, under the dermal scutes that are preserved there was a chondrocranium—the true endoskeletal skull—whose shape and whose morphological development must have answered, more or less closely, to that now under review, a *temporary* form and structure in this almost extinct kind of Toad.

The cranial structures in this Tadpole were much more flattened out than a side view of the creature itself (fig. 3) would indicate; for the outer skin is very loose, and the subcutaneous stroma is copious and extremely gelatinous. Unlike what we find in larvæ of the Common Frog and Toad, these Tadpoles are very delicately transparent, although richly supplied with brown pigment.

In this stage the occipital arch (Plate 56. fig. 4, *e.o.*) is imperfect above in the hind skull, and in front the internasal plate (*i.n.l.*) is flat, or rather subconcave, for the ethmoidal wall (see "Frog's Skull," plate v. *eth.*) has not yet been built. At present, then, we have a common cranio-nasal valley, whose bottom is formed behind of the parachordal cartilage and notochord (*iv.*, *nc.*), and in front, for twice the extent, of the trabeculæ, to whose extended edge in the frontal wall a long *labial* has been attached.

Laterally, the union of the parachordal bands with the auditory capsules (*iv.*, *au.*) has taken place very early; and with the antero-internal angle of each of these the trabeculæ are united, as well as with both the parachordals. The sides of the cranial valley are soon embanked into a narrow space by convergence of the trabecular elevations. There, at the narrowest, the brain ends, and the olfactory crura (1, indicated by a dotted line) are as long as the brain. Outside the wide *precerebral* valley we see the mandibular arch (*pd.*, *q.*), to which is attached the hyoid (*c.hy.*), and outside the mandibular pedicle

* Note in HUGH MILLER's 'Old Red Sandstone,' plates i., ii., iii. & xi. pp. 72, 76, 78, & 279; and HUXLEY, 'Memoirs of the Geological Survey,' 10th Decade, 1861, p. 30, fig. xix.

(*pd.*) a large sinuous flap of cartilage growing from the front and side of the auditory capsule, and ending in a free "foot" (*t.*, *ty.*, *a.t.*).

All these parts have now to be described in detail. They are:—1, parachordal; 2, trabecular; 3, mandibular; 4, hyoid; 5, auditory; and 6, labial.

The branchial arches will be described in the next stage.

1. The parachordal bands enclose a large, long cone of notochord, with a rounded end, which is opposite the middle of the anterior semicircular canal (*a.s.c.*). It has retreated considerably. Tracing the grooved tracts of newer cartilage, we see where these bands have united with the large auditory capsules (*au.*), but not where they have passed into the *older* trabecular tracts (figs. 4, 5, *iv.*, *au.*, *tr.*). Below, the parachordals form a flap-shaped investment of the sides of the notochord; and they expand to reach the auditory capsules, where the 9th and 10th nerves pass out (9, 10).

Owing to the bulging of those capsules, these bands are pinched in the middle, and then they expand in front, where they are lost in the continuous mandibular and trabecular plates. Above, the parachordals are growing upwards, but they do not yet form a ring (fig. 4, *e.o.*). In front of the notochord and its investment, looking especially at the lower view (fig. 5), we see the cartilaginous floor growing forwards and outwards as *five* diverse leaves. The middle "leaf" is formed of *two* that have coalesced by their inner edges; these are—

2. The "trabeculæ," the first parts to chondrify. These confluent leafy bands extend from the notochord (*nc.*) to the great, transverse, "upper labial" (*u.l.*), fore and aft, and to athwart the "subocular fenestræ" (*s.o.f.*) and pterygo-palatine plates (*p.pg.*) on either side. They are more thoroughly seen above (fig. 4) than below (fig. 5). This is on account of the somewhat lower position of the mandibular pedicle (*pd.*). Most of the median part is *commissural*, having been formed, later than the primary bars, beneath the huge pituitary space (see Plate 55. fig. 1). The actual *relative* width of the primary bars can still be seen where the "cornua" curve round in front of the nasal sac (*e.n.*, *i.n.*), and behind the upper labial (*u.l.*). Hence we may infer that the large, gently concavo-convex plate (seen best below, on its *convex* face), up to the nasal sacs, is most of it the newer cartilage of the pituitary floor. On the sides, looking at the under surface (fig. 5), the trabecular boundaries of the old pituitary space have become leafy and hollow, elegantly, with an arcuate margin, widening up to their union with the pterygo-palatine bars (*p.pg.*). There they have become thick, and then, opposite their internasal region, they give off a pair of arms, like the arms of a sign-post. These arms (*p.pg.*) end in the quadrate condyle (figs. 4 & 5, *q.*), which scarcely projects beyond the pterygo-palatine (compare Plates 55 & 56).

From above we see that where the trabecular thickenings end there the banks of the median valley are not erect, but overhanging; so that, in front, the cranial sac is somewhat enroofed with cartilage; but all in front of that cavity, up to the nasal sacs (*i.n.*), is the ethmoidal region, which is almost as long as the cerebral. The ethmoidal part of the valley is now filled with a watery tissue; but in the next stage (Plate 57. fig. 1) it will be filled in with cartilage—two tubes, like drain-pipes, allowing the exit of the olfactory crura (1). Massive as the trabeculæ seem, as seen from above (fig. 4), from below (fig. 5), the interorbital margins (the eye, *e*, is seen to be indicated by a dotted outline) are merely thin, arched leaves of cartilage.

Besides the straight "arms" (*p.pg.*) which pass from the trabeculæ to the quadrate condyles, another pair of curved arms, in front of these, unite the trabeculæ with the distal part of the mandibular piers. These are the middle pair of transverse arms, or wings, growing from the front of this remarkable chondrocranium. In our native Batrachia the trabecular cornua (in the *tongued* types generally) are gently bowed outwards (Plate 55. fig. 4, *c.tr.*); but in the "Aglossa," as in the Sauropsida and Mammalia, they turn backwards, or, rather, they retain the retral condition they acquired during the "mesocephalic flexure."

Here, breaking free from the closely cleaving labial band (*u.l.*), on each side, the "cornu trabeculæ" (*c.tr.*) is seen to run outwards and then backwards, shutting in the nasal passage (*i.n.*), and losing its free end in the pterygo-palatine plate behind (*p.pg.*), and in the quadrate in front (*q.*). In this case the end of the cornu and the tooth-like process at its side which gave attachment to the "prenarial ligament" in the Toad (Plate 55. fig. 4, *p.n.l.*) have grown into one flat plate, and their cartilaginous substance has converted the ligament into a *lamina* (figs. 4 & 5, *p.n.l.*). Inside the condyle of the quadrate (*q.*) a toothed process is seen; this is for the insertion of the quadrate end of the ligament now chondrified. In *Pseudis paradoxa* the cartilaginous process from the quadrate runs across to the trabecula, but does not coalesce with it; in *Rana pipiens* the tooth is short, and from it the ligament passes to the even outer edge of the trabecula; in *Bufo vulgaris* (Plate 55. fig. 4, *tr.*, *p.n.l.*) the *tooth* is on the trabecula, and not on the quadrate.

3. The mandibular arch.

The origin of the next arch is best seen from below (fig. 5, *pd.*); and although the dorsal end of the mandibular arch is not equal to the trabecula, it is of great width. It runs winding itself in between the basis cranii and ear-capsule. On the whole, it lies, from end to end, on a lower plane than the inner arch; but even the quadrate, with its condyle on the antero-superior face, looks, in a bird's-eye view, to be nearly as high as the upper labial and cornu trabeculæ.

We miss here that elbow of the pedicle seen in the sigmoid mandibular pier of the ordinary Tadpole (Plate 55. fig. 4); for the bar runs forwards and outwards, almost straight, to the orbitar process (fig. 4, *or.p.*); between that and the pedicle it has lessened in width. It attains its greatest width where the elegant orbitar process grows out. This process, like a sessile leaf, is not sensibly *decurrent* along the outer edge of the bar, yet its base is broad. Quite normally, the edge of the base of that process is concave, for beneath it (fig. 5, *hy.c.*) is the hyoidean facet, a crescentic scooping away of the substance of the bar. The bar is also scooped into another elegant hollow on its upper face at the end of the fixed part (*q.*). This convexo-concave facet is for the articular end of the free mandible (fig. 6, *mk.*; it is here drawn separately with the hyoid to lessen the complexity of the main figure). Giving off two spurs to coalesce with the trabecula, the "prenarial" and the pterygo-palatine, the quadrate is of great breadth at this part.

Behind the pterygo-palatine bar, and between the trabecula and pedicle, we have a falcate membranous space, the "subocular fenestra" (*so.f.*); it is rounded in front, and its sharp end runs inwards behind. The eyeball (*e*) rests somewhat outside this space, on the mandibular pier.

The free mandible (fig. 6, *mk.*) is extremely small as compared with the hyoid (*c.hy.*); in the adult the mandible is much the larger of the two. At this stage the mandible is very long as compared with that of a common Tadpole (Plate 55. fig. 4, *mk.*), their mouths being so different. It is a slender, terete, sigmoid rod; the distal end is pointed and the articular end dilated. The articular and angular parts are curious; the former is not a notch nor the latter a spur, but the dilated end is excavated above, and surrounded by a ridge below. The points of the mandibular rods do not meet, but they are connected together by the interposition of a pair of short, terete, inferior labials (*l.l.*), which differ from those of the Frog's tadpole ("Frog's Skull," plate v. *l.l.*), for they do not *dip* into a steep "mentum," but lie almost on the same plane as the Meckelian rods. Their position may be understood by reference to the full figures (1–3), where it is seen that the lower jaw and lip point forward a little beyond the upper lip.

4. The hyoid arch.—Here there is nothing at present but the homologue of the infero-posterior piece of an Osseous Fish's embryo, the cerato-hyal (*c.hy.*), with no distinction of stylo-hyal above or of hypo-hyal below, and no inter-hyal placed between it and the mandibular pier. This huge, broad, solid bar (fig. 6, *c.hy.*) is typically Batrachian, with its rounded condyle on the antero-superior angle, its produced postero-superior angle, and its broad, pedate base. The sigmoid hinder margin is scooped on the inner side, and the outer side is ridgy.

The narrow helve of a thick-bladed trowel of cartilage separates and unites the hyoid cornua. The solid blade is lozenge-shaped; it is the 1st basibranchial (*b.br.*). The helve is the continuous basihyal (*b.h.*). In the Common Frog (*op. cit.* plate v. fig. 5) the basihyal is a small, distinct nucleus: the difference is, a little more differentiation in the common type.

5. The auditory capsules.—These "paraneurals" are so remarkably modified by cartilaginous outgrowths that they present no easy problem to one coming to them fresh from the common kinds. As in the fourth stage of the Toad (Plate 55. fig. 5), the fenestra ovalis is opening, but is only filled with indifferent tissue (Plate 56. fig. 5, *fs.o.*). Behind and mesiad of that fossa the sacculus is marked out as a lesser oval within the large oval of the capsule. Above (fig. 4), the semicircular canals (see, also, next stage, *a.s.c.*, *h.s.c.*, *p.s.c.*) are seen to be large, and shine through the translucent cartilage. The tegmen tympani (*t.ty.*) projects as a uniform lobe behind the capsule, then narrows to the middle, and then widens again. Now, however, it grows from the whole fore margin of the capsule, wedging

in and filling up all the space between it and the flat mandibular pedicle (*t.ty.*, *pd.*). Taking this antero-lateral start, it runs forwards, equal to the capsule in breadth and in length—a huge wavy ribbon of cartilage. In front it is not distinct, as cartilage, from a foot-shaped flap, which, added to it, almost doubles its length; for the *toe-end* nearly reaches the hyoid condyle (fig. 5), and overlaps the orbitar process (fig. 4). Just outside the front of the capsule the cartilage is punched, as it were, into a neat, round, nearly perfect hole, in which is imbedded a gland (? the "thyroid," *tr.g.*). This preauditory growth is the homologue of what I took to be the upper part of the hyomandibular ("Frog's Skull," plates v., vi., vii., *s.h.m.*). It behaves somewhat differently, however, for the anterior part does not coalesce with the mandibular pier, which, here, has no elbow; and the *foot part* answers to most of the little bar in the Common Frog. The broad proximal part is a huge awning to the *tegmen*, and the pedate part is the early condition of the *annulus*. The two parts show, *at present*, no sign of past or promise of future separation: they will separate, as we shall see (see Plate 58). Comparing these parts with what we see in the adult (Plate 59), with its huge columella with two bony shafts, ending in a huge heart-shaped leaf of cartilage, the extrastapedial, it seemed to me (and until the nerves were worked out by him, Professor HUXLEY sympathized with me in the matter) that here, if anywhere, we had the *supero-anterior* segment of the hyoid, the true hyomandibular, with its *symplectic* distal part.

The course of the "portio dura" beneath this awning directly contradicted this view, and a careful comparison of the various stages showed me how the pedate flap changed slowly into the cartilaginous tympanic ring. It became evident that, as in our native Batrachia, the "columella" is very tardy in development. I could not find it at all chondrified in the largest young (4th stage, Plate 58. figs. 2 & 3), although these were outwardly metamorphosed, save for the presence of a considerable tail (see Dr. GRAY'S illustration, Proc. Zool. Soc., Nov. 8, 1864, p. 463, fig. 2).

6. The labial cartilages.—In these, as in the other parts, the connecting-tracts have chondrified, and fused together parts morphologically diverse. Moreover, the right and left moieties have lost all distinction (Plate 56. figs. 4, 5, *u.l.*). This double labial (right and left in one) is equal in breadth and more than equal in transverse extent to the two cornua trabeculæ. Its fore edge is greatly concave; its hind edge is obliquely grafted on to the shelving fore edge of the internasal part of the trabeculæ; but a fissure appears on each side, and then the two bands diverge from each other (*u.l.*, *c.tr.*). Outside these is a sudden notch, but not an end to the labial; for this ribbon runs, as a gradually attenuating thread of true cartilage, to the very extremity of a long labial tentacle, so long at this stage that it reaches to the end of the abdominal cavity (figs. 1–3). This answers evidently to the persistent "maxillary tentacle" of the Siluroid fishes, e. g. *Clarias capensis*, *Arius rita*, &c.

I see no traces of any other tentacles than these. The Siluroids have two or three pair of them, or even more, the lower lip also possessing them. In *Dactylethra* the lower labials (fig. 6, *l.l.*) are smaller than in the common, and much smaller than in the Bull-frog.

The pointed end of MECKEL'S cartilage is tied to the upper surface of the corresponding labial; this shows no tendency to become cirrose*.

On the Skull of Dactylethra.—*Second Stage. Tadpole* $1\frac{2}{3}$ *inch long.*

The skull of the next Tadpole is more than one third bigger, and the length is greater in proportion to the breadth; thus the large preauditory flap does not nearly reach the hyoid condyle. This relative, as well as real, elongation of the chondrocranium makes it less anomalous, and more easily comparable with that of the common kind.

Below (Plate 57. fig. 2), the cephalic part of the notochord (*nc.*) is less, and reaches a shorter distance between the auditory capsules. It is more completely embraced by the investing parachordals (*iv.*); where they clasp it behind there is on each side a gland, the "thymus" (*tm.g.*), close behind the double passage for the ninth and tenth nerves (9, 10). Above (fig. 1), the parachordals have united so as to form a superoccipital region (*s.o.*), which has a concave margin in front exactly over the end of the notochord. Where the parachordals are lost in the trabeculæ (fig. 2, *tr.*), there the gently convex cartilage is translucent enough to show the brain through it. Above (fig. 1), the brain is seen to be roofed over behind the optic lobes (C^2), this hides the medulla oblongata.

The sides of the "great fontanelle" are somewhat overhung behind by the auditory capsules, and in front by the ascending plate of the trabecula. The hemispheres ($C\,1^b$) show in front of them the olfactory lobes ($C\,1^a$), and from these the crura are seen, through the transparent cartilage, burrowing their way to the olfactory sacs (*ol.*). The median ethmoidal space is much denser, from the cranial cavity onwards; and a solid "mesethmoid" (*eth.*) is seen near the nasal organs (*ol.*) growing transversely to each hypertrophied trabecula, and forwards between the nasal sacs; this is the true perpendicular ethmoid, and when it has grown well forward, the fore part will be the septum nasi. Looking below (fig. 2) we see that the chondrified pituitary floor at the middle has become much narrower, and that from beneath the mid brain, halfway to the frontal wall, there is beneath a delicate style of bone, with a truncated hinder end; this *first bone* is the parasphenoid (*pa.s.*). Altogether the trabecular plates are narrower, although still convex above and concave below; the notch running from the subocular fenestra (*so.f.*) to the pedicle (*pd.*) is much more distinct. The trabecular plate is suddenly narrowed close to the nasal sacs below (fig. 2); here crescentic "subnasal alæ" (*sn.l.*), which converge towards the narrowest part of the internasal plate, bulge with the overlying nasal sacs (*ol.*). In front of these sacs the suddenly

* With regard to the probability of the existence of Teleostean fishes, related to the existing Siluroids, during the Devonian epoch (HUXLEY, Mem. Geol. Surv. Decade 10, p. 29) it may be suggested that the Siluroids now existing may be the specialized Teleostean representatives of truly *Ganoid* fishes, having a similar form, and existing in that early time. If so, we have three isomorphic groups of flat-headed Ichthyopsida, namely, such forms as the ancient *Pterichthys*, the modern *Clarias*, and the larval stage of this almost extinct kind of Toad (*Dactylethra*).

outturned cornua trabeculæ (continuous with the labial, *c.tr.*, *u.l.*) partly enclose the sacs by a tooth-like process; behind, on the front of the "palato-trabecular lamina" (antorbital), there is a similar tooth. Outside these teeth-like flaps is the internal nostril (*i.n.*); it is bounded within by these projections, and the nasal sac in front by the curving "cornu;" behind by the pterygo-palatine (*p.pg.*); and externally by the apex of the cornu, where it has coalesced with the quadrate, by the intermedium of the chondrified *prenarial* ligament. Below (fig. 2), it is easy to see that the upper labial (*u.l.*) is largely hidden by the underlying trabecular cornua; above, the reverse is the case, the labial tape being stitched on to the upper surface of the shelving frontal region of the trabeculæ. The conjugational plate (*p.pg.*) lies on a lower level than much of the trabecular band, above (fig. 1); it is, indeed, hollow above, in front of the fenestra (*so.f.*).

Also on a lower plane lie the ventral ends of the first arch, the mandibular, whose broad pedicle (*pd.*) runs into the trabecula behind its concave lower face (fig. 2). The notch between the first and second bar is rounded, and then, both having their contiguous edges convex, they come into contact for some distance, widening to form the fenestra (*so.f.*). All the landmarks round the pedicle are faintly visible, the intense chondrification having united this bar to the trabecula, the auditory capsule, and to the huge "tegmen" (*t.ty.*). Where the mandibular pier escapes, on the one hand from the tegmen and on the other from the trabecula, it runs as a broadish, straight band up to the hyoidean and "orbitar" expansions; the latter of these (*or.p.*) is less curved over the temporal muscle. From the quadrate condyle (*q.*), inwards, the common conjugational plate (*p.n.l.*, *p.pg.*) is of great breadth.

The free mandibles (*ar.*, *mk.*) are fast thickening, they are more arched, and the inferior labials (*l.l.*) are shown in their obliquity, dipping slightly into the gently convex *chin*.

The free hyoid arch (Plate 57. fig. 2, *c.hy.*, and Plate 58. fig. 1, *c.hy.*, *b.hy.*) is a solid, oblongo-arcuate bar, with ridges and sulci externally, for muscular attachment. The basihyal does not segment itself from the basibranchial (*b.hy.*, *b.br.*); they form one piece.

The branchial arches (Plate 58. fig. 1, *br.* 1–4) are a very remarkable structure; they are quite confluent with each other, opening freely within and without by three clefts. The first arch is a large bag of cartilage with thin, sinuous walls, through which are seen the radiating rows of *lophobranchiate* branchiæ. The second and third arches appear outside, as far as the clefts go, as moderately wide bars, but the fourth arch is a pouch, much less, however, than the first, and having its external face concave. Through the clefts can be seen the interdigitating hillocks of tissue from which the dendritic gills grow (see "Frog's Skull," p. 156).

On the edge of the upper lip a row of about twenty small teeth is seen, but the parostoses that are to form their foundation are not yet developed.

The auditory capsule is still unossified, the two sacs are more parallel than in the former stage, and the floor of the sacculus coming nearer to the outer edge, the now well-formed fenestra ovalis (*f.so.*) is almost vertical, on the outer wall, under the tegmen tympani. An oval, externally convex cartilaginous stapes (*st.*) is now formed. The tegmen is developed into a distinct "ear" behind, and helps to enclose the thymus gland (*tm.g.*); it is then narrow to the middle, and then suddenly spreads into the broad *awning*. Now may be noticed a better differentiation of these parts. The broad part of the tegmen in front, opposite the fore margin of the ear-capsule, is not punched out just at the edge, as in the last stage, but is snipped out twice as deep, so that the cut lip of the tegmen projects largely beyond the (? *thyroid*) gland.

Moreover there is now a good round notch on the fore margin of the flap of the tegmen, then a triangular tooth of cartilage, and outside, the long foot-shaped process, whose "heel" is now pointed. The broad, notched, outer part of the great flap of the tegmen is convex above and concave below, and so is the foot; between the two a more definite fossa has appeared, the commencement of a process which will pull asunder the outer piece, that it may become the Batrachian "annulus tympanicus," a part not *homologous* with the tympanic bone.

Skull of Dactylethra.—*Third Stage. Tadpoles at their largest size*.*

The changes remarked in the last stage are still more noticeable in this; moreover there are several new structures. The fore face, in the first stage, was much the wider part. Now the greatest breadth is across the auditory region, if we include the *tegmina*. This is a steady growing towards that elbowing outwards of the auditory capsules which characterizes the skull of the adult Batrachian; and as the mandibular pier is attached to these masses, this their out-thrusting is a correlate of the immense gape ultimately possessed by all the members of this group, glossal or aglossal.

The much diminished notochord (Plate 57. figs. 3, 4, *nc.*) is now almost invested by the parachordals (*iv.*); it escapes behind between well-formed occipital condyles (*oc.c.*), and is most exposed above (fig. 3). In front it is hidden, below, by the haft of the dagger-shaped parasphenoid (fig. 4, *pa.s.*), which has now a "guard," giving its middle part a diamond shape. The foramen magnum (*f.m.*) is now neatly formed, and its sides in front of the rim are ossified, both by internal and external bony growth; these bones are the exoccipitals (*e.o.*); they leave, as they always will leave, an unossified upper and basal tract (*s.o.*, *e.o.*). Below, these bones are encircling the ninth and tenth nerves (9, 10); they then form a sickle, the concave edge of which is external, and the blade of which nearly reaches the mandibular pedicle (*pd.*). Now, if we refer to the ossified tracts in the chondrosteous skull of the Common Toad (Plate 54. fig. 4, *pro.*, *e.o.*), we shall see that the exoccipital only reaches, below, to the middle of the periotic capsule, and that its fore part is ossified by the prootic.

As in the larva of *Pseudis*, I note here, in *Dactylethra*, this generalized character, namely, that there is no fair landmark between these bones. From the auditory to the nasal sacs the floor of the skull is one wide sheet of cartilage (as in Sharks and Rays); it is gently convex in the middle, and concave submarginally (fig. 4, *tr.*). The sides are sinuous, and the greatest breadth is opposite to where the parasphenoid ends.

* See Dr. GRAY's figure (1), Proc. Zool. Soc. Nov. 8, 1864, p. 463.

The subocular fenestra (*so.f.*) is narrower in front and wider behind; for now the pedicle (*pd.*) bends a little outwards, and its dorsal end can be better seen below, wedging itself in between the trabecula and the auditory capsule, and yet continuous with both. By their bending outwards we do get a very obtuse "elbow" to the mandibular pier, but this is masked by huge foregrowth of the tegmen (*t.ty.*).

The "orbitar process" (*or.p.*) is wasting, the articular pulley of the quadrate (*q.*) is now definitely seen in both the upper and lower view (figs. 3 & 4). Also, with greater clearness can we now see how the great labial adheres to the upper face of the internasal plate and cornua trabeculæ (*u.l.*, *i.n.l.*, *c.tr.*).

Small granular masses are forming around the nasal sacs, and are bearing new upper labials; there are two pairs above, and two pairs below (figs. 4 & 5, $u.l.^{a}$, $u.l.^{b}$, $u.l.^{c}$, $u.l.^{d}$). These cartilaginous nuclei will be described in the adult; the remarkable thing about them is that these *persistent* nostril-valves are not formed by the breaking up of the primary, upper labials (*u.l.*), and therefore they do not correspond with the two pair of persistent labials in the Common Frog and Toad (Plate 54).

The growth of the trabeculæ all about the nasal sacs is neater and fuller; the septum nasi (fig. 3) is now chondrified above, whilst its trabecular floor (fig. 4, *s.n.l.*) is narrower and longer. Besides this better setting of the nasal sacs, the cartilage along the huge ethmoidal region above (fig. 3, *eth.*), although translucent and showing the olfactory crura (1), yet is now solid. It is the extended counterpart of the little bowed wall of the Common Frog's Tadpole at the same stage ("Frog's Skull," plate v. fig. 3, *eth.* 1). The great fontanelle is exactly roofed over by a large pair of frontals (*f.*), which are gently convex, and together form an exact ellipse; stuck on to these, behind, are a very small pair of parietals (*p.*), sharp in front and broad behind; they overlap the frontals largely, and are just free behind. These, with the parasphenoid, are all the outer bony tracts I could find in this stage.

The large flap of the "tegmen" almost closes upon the thyroid gland (*tr.g.*), and the long outer lobe, broadening at each end, is becoming more evidently marked off from the tegmen, and more crescentic in form, ready to become the "annulus."

The tentacles (*tc.*) are one third shorter; altogether, this stage leads in gently towards the further metamorphosis of the large-legged Tadpole (Plate 58. figs. 2, 3).

Skull of Dactylethra.—*Fourth Stage. Young, with large legs and diminishing tail*.*

The meaning of the lesser modifications in the last stage will be plain now that these parts are still more metamorphosed.

The breadth of the hinder half of the skull is twice that of the front half, and the auditory capsules and their curtains have added to them the projecting condyles of the quadrate, which in the first stage came up to the fore margin (Plate 56. figs. 4, 5, and Plate 58. figs. 2, 3, *q.*).

The foramen magnum (Plate 58. figs. 2, 3, *f.m.*) is now perfectly formed; the noto-

* See Dr. Gray's fig. 2, *op. cit.*

chord (*nc.*) is much reduced, but can be clearly seen *on* the upper surface of the skull floor, and *through* the cartilaginous basioccipital region below. Between the occipital condyles (*oc.c.*), which look backwards and a little inwards, there is a deeper crescentic margination below, and a shallower above. Three fourths of the parachordal region, behind, and almost all the trabecular in front, is underspliced by a huge dagger of bone, the parasphenoid (*pa.s.*), which is rapidly acquiring its adult characters.

But as at first (Plate 57. fig. 2, *pa.s.*), the hinder margin is still concave. The "guard" is a large lozenge of bone, with the hinder angle produced considerably and the front part greatly; this part, narrowing gently, runs up to the septum nasi, and there ends in a blunt point, which point is guarded by a transverse semicircular bone, the vomer (*v*).

The exoccipital bone (*e.o.*), which in the last had crept up to the parasphenoidal handle, has now crept over its edges, and has not only ossified the sides of the investing mass, keeping accurately to the boundaries of that part in front, but after hardening the submesial fossa it runs beneath the vestibule, so as to leave it only a selvage of cartilage. Behind, the bone runs to the margin of the capsule, enclosing the 9th and 10th nerves (fig. 3. 9, 10) in a double foramen; in front it just touches the point where the apices of the trabecula and mandible coalesce (fig. 3, *tr.*, *pd.*).

Above (fig. 2) the exoccipitals keep apart so as to leave a soft, square supraoccipital region (*s.o.*); behind it runs to the edge of the foramen magnum (*f.m.*); externally it reaches to the posterior canal, and runs forward over the edge of that and the anterior canal, at once fringing the canals outside, and the "fontanelle" towards the middle. This upper part ends, curving outwards, in front of the ampulla of the anterior canal. All this bony matter began in the occipital arch behind, and has grown into the substance of much cartilage above and below (Plate 57. figs. 3, 4, and Plate 58. figs. 2, 3, *e.o.*, *pro.*); it is a "prootico-exoccipital"—a double bony element.

The breadth of the great trabecular floor is not yet lessened, and it runs full in width up to the fore margin of the ethmo-palatine bridge (*e.pa.*), the front edge of which is semicircular, as the hind margin of the internal nostrils (*i.n.*). The projection inside this notch shows the breadth of the trabecula; there, however, it suddenly narrows in to form the subnasal laminæ, the moderately alate base of the septum nasi (figs. 2 & 3, *s.n.*). The septum above (fig. 2) has no larger aliseptals than the Common Toad (Plate 54. fig. 3, *al.s.*), but the subnasal plates are very small as compared with the common kind (Plate 54. fig. 4, and Plate 58. fig. 3). This deficient nasal floor is a curious arrest of the cartilage, which is so profuse immediately behind this part. The hurried retreat of the quadrate condyle (*q.*) has curiously affected the nasal labyrinth; the large flappy cornua trabeculæ (*c.tr.*) are now small crescentic wings, tilted in front of the nasal cavity. Where these are set on the septum (fig. 3, *s.n.*) is trilobate; the median lobe is the arrested rudiment (*pn.*) of the long "prenasal" of the Elasmobranch fish and the bird, and the paired lobes (*al.n.*) are the bud-like rudiments of the floor of the alæ nasi of the higher Vertebrata. The cornua trabeculæ (*c.tr.*) are curiously overlapped by the most highly developed form of nasal valve with which I am acquainted.

We saw that as we came up, step by step, the large labial ribbon became more distinct from the cornua trabeculæ. Now, in this stage, it has become two, and each moiety is also tilted up in front of the nasal cavity, like the trabecular cornu. Whilst the long tentacle has been diminishing this change has taken place, and it has become expanded into a pouch or "sling," which lies more over the upper than the lower surface. The point of this corded sling is the anterior valvular plate of the external nostril (*e.n.*), which in the Frog and Toad (Plate 54) was merely two thirds of each lateral labial piece. Besides these two there are three or four pair besides, as we saw in the third stage (Plate 57. fig. 4), but the third pair (*ul.*[c]) escaped my observation in this stage; they are well seen in the adult (Plate 59)*. Above (fig. 2), there is one pair over the edges of the septum nasi and another pair attached to the valvular fold behind the outer nostril (*nl.*[a], *nl.*[b], *e.n.*). Below, the outer pair (*ul.*[d]) lie in the folds that envalve the inner nostril (*i.n.*); these are large and somewhat trilobate: in the adult we shall see their homological meaning. Different as all this is from what takes place in the ordinary kinds, it is consonant with the generally unusual conditions of this type. The upper ethmoidal region (fig. 2, *eth.*) is still an unwonted structure. All the broad part of cartilage which extends from the frontal roof of the fontanelle (*f.*) to the nasal septum, merely corresponds, morphologically, with the cribriform plate and its cartilaginous setting in a young Mammal ("Pig's Skull," plate xxxiv. fig. 6, and plate xxxv. fig. 4, *cr.l.*, *al.e.*); and the pair of tubular passages, here, correspond to the many pairs of passages in the higher type.

The perpendicular ethmoid passes insensibly into the septum nasi now; the space between the olfactory crura (1) is much greater than the thickness of that partition wall. There comes out in this stage a process on the antorbital (palato-trabecular region), which is not definite in the earlier stages. In the Frog ("Frog's Skull," see plate v. fig. 3, and plate vi. fig. 3, *inside or.p.*) it helps the "orbitar process" to enclose the temporal muscle, but in the Toad (Plate 55. fig. 3) we saw that the two processes were united into a perfect bridge.

Since the last stage the condyle of the quadrate (*q.*) has retreated backwards a distance equal to one third the length of the entire skull; from being opposite the middle of the septum nasi, it is now opposite the fore margin of the frontal bone. Still being, like the trabeculæ, of great width, the intervening subocular fenestra (*so.f.*) is still a mere chink. Below (fig. 3, *pd.*), the pedicle is seen at its narrowest, where it is fused with the trabecula; from that point it spreads into a huge leaf of cartilage, which spreads outwards as far as the crescentic "annulus" (*a.t.*). But here we see that the once continuous cartilage in front of the auditory capsule has become divided into *three* distinct morphological structures.

The mandibular pier and the foliaceous tegmen (*t.ty.*) are quite sundered, and from the latter the annulus is detaching itself. The "elbow" of the mandibular pier, so striking a character in all the ordinary Batrachia, now, for the first time, is evident; it is no great distance behind the condyle, and runs by an almost transverse, sinuous edge

* The third pair (*u.l.*[c]) are probably not distinct, but are the "prorhinal" growths of the trabeculæ.

into the pedicle, *beneath* the annulus. Above (fig. 2, *a.t.*, *pd.*, *q.*), that large cartilaginous crescent has pushed, as it were, the solid substance of the mandibular pier before it, as though it had been so much dough. The one has taken a visible impression of the other.

Beneath the elbow the condyle for the hyoid (fig. 3) has become faint, for that bar (fig. 4, *c.hy.*) is loosening its attachment there. Over that, part of the orbitar process (*or.p.*) has been reduced to a sigmoid style, overlapping the angle of the pier.

The pterygo-palatine is no longer an extensive isthmus merely, which keeps the quadrate very close to the ethmoid; but added to that conjugational part is a retreating band, wide at first, but still steadily widening backwards, until it passes externally into the quadrate angle, and internally into the pedicle (*pd.*, *q.*). This newly developed tract is the pterygoid; for in the last stage the whole of the pterygo-palatine was merely an "ethmo-palatine," like a *secondary* conjugational band. A little crest of cartilage marks the point where the postpalatine passes into the pterygoid, and in front a prepalatine knob has appeared, which, below (fig. 3), has a thickened, condyloid appearance.

As a correlate of this retreat of the quadrate angle and trochlear facet, the mandible has grown largely (Plate 58. fig. 4, *ar.*, *mk.*), for the mouth is no longer *Siluroid*, but has become *Batrachian*. The whole arch is an elegant half-hoop; the articular end is very thick; and a uniform condyle projects from its upper surface, answering to the neat scooping on the angle of the quadrate. At the end of each Meckelian rod is the "inferior labial" (*l.l.*); and this, with its fellow, is more than ever in a line with the mandible itself. These labials help to form the "mentum;" they do not degenerate into fibrous tissue, or coalesce with the ventral end of the mandible, but become the "mento-Meckelian" element, in most Batrachia. But the adult shows no signs of them (fig. 6), nor has it any "mento-Meckelian" bone. In front of the mandible there is a small dentary, and below and within it a large *ectosteal* articulare (*d.*, *ar.*).

Notwithstanding that the stapes has been solid cartilage for the three last stages, there is, to me, no appearance of a chondrified columella, although I have sought for it with great care (Plate 57. figs. 2 & 4, and Plate 58. figs. 2, 3, *st.*).

And although the legs are large and strong, yet certain parts are but little metamorphosed at present. Thus the hyoid cornua (fig. 4. *c.hy.*) are now at their largest growth, although loosening themselves from their mandibular swinging point. What changes await these bars may be seen by comparing them in this fourth stage with those of the adult (fig. 5, *c.hy.*). They never reach higher towards the auditory sac than their counterparts in the "Urodela;" this is another peculiarity of this aglossal type. The basi-hyobranchial bar (*b.hy.*, *b.br.*) still retains its perfectly larval condition.

The auditory capsules, with their outgrowths, are mainly cartilaginous above (fig. 2), nearly the whole of the exquisite canals of the labyrinth being visible through the clear walls; they have ruled the outer form of the capsule. But that outer form is still further modified by the "awning," which is stretched out from their antero-external margin; this has changed greatly since the last stage (Plate 57. figs. 3, 4, *t.ty.*, *a.t.*). Nearly separated from the outer crescent, the true "tegmen," as seen from above (fig. 2, *t.ty.*), looks as if the valve of a leguminous fruit had grown obliquely from the capsule; and, indeed, this is its shape, for it is convex above and hollow below (figs. 2, 3).

The crescent itself (*a.t.*) seemed to me at one time to be the early condition of the "extrastapedial" of the adult (Plate 59, *e.st.*). Supposing the "tegmen" to be its stalk, and ready to ossify into the "medio-stapedial" and "interstapedial" shaft-bones, this heart-shaped leaf of cartilage, blade and petiole, seemed all ready to become the columella of the adult, and the homologue of the fish's hyomandibular and symplectic *.

The *thyroid gland* (fig. 3, *tr.g.*) lies now beneath the stalk and leaf of cartilage; I have indicated its position by dotted lines. The stapes (*st.*) has been teased away from the fenestra ovalis (*fs.o.*) to show its shape, it is irregularly oval and convexo-concave, and its outer convex surface is seen to be covered with muscular fibres.

The fossa (fig. 3), now fairly on the side of the auditory capsule, is only *open* behind; even the stapes itself is much larger than the fenestra, which is covered by its hinder half.

The new bones now apparent are the vomer, nasals, premaxillaries, maxillaries, dentaries, and articulars; the two latter have been described already. The vomer (fig. 3, *v.*) is semicircular, with the hinder, abrupt edge sinuous; it invests the apex of the huge parasphenoid (*pa.s.*). The maxillaries and premaxillaries (*mx.*, *px.*) form a crescentic row of bones outside the front of the face, and on their under surface we see the teeth. The maxillaries run scarcely twice the extent of the premaxillaries; the latter have already a nasal and a palatine process (figs. 2 & 3, *px.*).

The nasals (fig. 2, *n.*) are large, accurate crescents; they are margined with a flap of membrane on their concave or anterior margin, and this is further margined by a labial ($u.l.^b$); this complex nostril-cover is behind the external passage (*e.n.*). Altogether, this Toad has its breathing-passages protected by a most complex valvular apparatus.

The frontals (fig. 2, *f.*) have increased in size, and, save at the hinder margin, are well ankylosed together; the parietals (*p.*) are parasitic plates, overlapping the frontals.

By comparison of this half-metamorphosed young specimen with the adult, seeking side-lights from more familiar Batrachians, we shall be able now to appreciate the remainder of the metamorphic modifications, by which the skull of the Siluroid, and almost Chimæroid larva of *Dactylethra* passes into that of the adult. In its last stage we shall find as many notable things as in the larval; for this type is very contrary, not only to the common tongue-bearing types, but also to the other aglossal form, namely, *Pipa*.

* The merciless rigour of my fellow-labourer Professor HUXLEY's criticism has been of the utmost value to me in this and in many other cases; and I am truly grateful for the effect upon me, of the wholesome incisiveness of his inborn, logical severity.

Skull of Dactylethra.—*Fifth Stage. The adult Toad* *.

The occipital condyles of *Dactylethra* are quite normal: they are principally seen on the upper surface (Plate 59. figs. 1, 2, 4, *oc.c.*), and they look only a little outwards, much of the cartilage lying towards the articular mid line. The foramen magnum (fig. 4, *f.m.*) is very large and steeply placed; it is squarish, the upper and lower margins being somewhat convex, and the lateral margin concave. A narrow tract of cartilage, above and below, separates the two great side bones, the exoccipitals (*e.o.*): these synchondroses are the super- and basioccipital regions (*s.o.*, *b.o.*). The chondrosteous cranium is overlapped almost to the end by the fronto-parietal slab (*f.p.*), and the basal region is only free at the very end from that long bony bulk, the parasphenoid (*pa.s.*).

A lobular process from each exoccipital mass arches over, on each side, the hind skull; these lobes are united into one roof by the superoccipital synchondrosis. Below (fig. 2), the exoccipital bony mass is flat on each side of the handle of the long parasphenoidal sword, behind. Then on each side where the handle narrows to the "guard," the sides of the skull-floor are largely scooped, which scooping is part of the huge *Eustachian vaults*; for here the first postoral cleft forms a large chamber on each side, the door of these chambers being common †.

Above, when the fronto-parietals have been removed (fig. 1), we see one large fontanelle (*fo.*) reaching from the occipital ring to the front of the cranial cavity. There are no subsidiary fontanelles as in the common kind (Plate 54. fig. 3). Nearly the whole of the side of this open roof is solid bone; and this side wall, in the wider fore part, thickens and shelves over the cranial cavity, in some degree. Below (fig. 2) the bony substance has crept nearly up to the nasal domes; and at the sides (fig. 3) to a short distance behind the "palato-trabecular junction." Nothing but cautious observation of many types and many stages will show what is the meaning of this abnormal girdle-bone, which is so unlike that of the Common Frog and Toad (Plate 54. figs. 3, 4; and "Frog's Skull," plate ix.).

Regionally, it corresponds with the whole sphenoidal territory of a Mammal ("Pig's Skull," plate xxxv. figs. 4, 5), and its fore edge does but reach the hinder margin of the ethmoidal territory. To what a narrow, transverse headland of cartilage this once huge territory is reduced, may be seen by comparing this with the early stages; here (figs. 1, 2, 5, *eth.*) its breadth is not greater than that of the fore part of the fontanelle. The kind of ossification here seen is that which is common in Batrachia when the chondrocranium becomes solid bone; the cartilage-cells first calcify, superficially, then true ostosis takes place in and among them, and, finally, the process reaches to the perichondrium; but there is no separate, preformed *ectosteal* lamina.

* I have worked at the two skulls of the adult; one kindly lent me by Professor Huxley, after partial dissection by him; and the other by Dr. Dobson, of Netley. For Professor Huxley's views as to the skull of *Dactylethra*, see his recent Article on the "Amphibia" in the Encyc. Brit. p. 755.

† "The Eustachian tubes [are] united into one pharyngeal orifice" (Gray, "On *Dactylethra*," Proc. Zool. Soc., Nov. 8, 1864, p. 464).

There was, we saw, however, such a lamina, the first starting-point in the formation of the Frog's girdle-bone; and it existed when ossification of the actual cartilage had barely set in (see "Frog's Skull," plate viii. fig. 7, *eth.* p. 173, stage 9th). In that observation I was right as to the bone, but did not fully see that the ossification of the underlying cartilage right and left took place *independently* of, but in consonance with, this ectosteal "superethmoidal" plate. The fact is that the girdle-bone in the frog is formed in the same way as its "suprascapula," the outer and inner bony growths being, at first, quite independent of each other ("Shoulder-girdle and Sternum," plate v. var. figs., *s.sc.*, p. 79). In the common Toad and Frog this upper plate soon coalesces with the circle of bone which is formed around the ethmoidal region, changing the solid cartilage into dense bone (see "Frog's Skull," plate ix. var. figs., *eth.*).

In *Dactylethra* this does not take place; here (Plate 59. figs. 1 & 3, *s.eth.*) a large elegant "supraethmoidal" plate lies unattached on the surface of the unossified ethmoidal cincture, which in the frog is marked out by being bony, whilst in this type it is mapped out very exactly, behind, by the arrest of bony deposit, and in front by the presence of the nasal membranes. The overlying "supraethmoid" is a common bone among Ganoid and Teleostean Fishes ("Salmon's Skull," plate vii. fig. 1, *eth.*); it crops up again in Lizards and Struthious Birds. Its form, here, is triradiate—its fore ray being an oblong bar overlying the septum nasi, and the hinder part consisting of a pair of pointed wings.

When this bone has been removed (Plate 59. fig. 5) the ethmoidal region of the skull shows a transverse, serrated margin. The outer of these serrations are the short, prepalatine spikes (*pr.pa.*); the median projection is the perpendicular ethmoid overlying the grooved top of the septum nasi (*s.n.*); the intermediate serræ grow forwards from the broad junction of the antorbital projection of the ethmoid with the ethmo-palatine bar (*e.pa.*).

Below (fig. 6) the bone of the common sphenoidal trough reaches into the substance of the ethmoid, behind; but its fore part is soft; and an elegant crescentic thickened rim curves round behind the nasal pouches,—very *Selachian* pouches they are.

This rim reaches as far as the condyloid boss on the under face of the palatine, and the two thickenings together form a sigmoid structure. The postnasal rims pass into the narrow hinder part of the feebly alate base of the septum nasi (*s.n.*), which ends in front in three buds of cartilage; these are the rudiments of the azygous prenasal and the alæ nasi (*pn.*, *al.n.*). Above (fig. 5) the aliseptal laminæ are not more developed than the subnasal, below. They have clubbed ends, distinct from the alinasal rudiments.

The cornua trabeculæ (fig. 6, *c.tr.*) are extremely unlike those of the frog and toad (Plate 54); they are continuous with the great labial pouches in front (*u.l.*), and with the septum nasi in the middle. These cornua are not seen above (fig. 5), being covered by the labial pouch; but below they are seen, as in the last stage, to be tilted plates, with their convex face in front; they grow outwards and turn backwards, and help to give complexity to the infoldings of the Schneiderian membrane. The variously roofed nasal domes are like enough to those of a Skate or Shark below, and their valvular cartilages are homologous; but their roof is imperfect and, as becomes an air-breather, *perforate* (figs. 1, 3, 5, *e.n.*). Besides the investing bones to be described anon, there are three pairs of *labial* valvular cartilages above. The most notable pair look like leathern bottles, the neck of each looking inwards and forwards; but they are mere "slings" that have lost their "tentacular" cord (Plate 57. figs. 2 & 3, *u.l.*). Below (fig. 6) we see this, their lower edge being inturned only slightly. The inner end of these conchoidal cartilages is covered with a small spatulate separate piece (fig. 5, *ul.*[a]), and as this is attached at right angles to the large labial a space is formed; this is the fore margin of the external nostril (*e.n.*). Its hind margin is formed of membrane, a large space existing where the aliseptals are so deficient; across the middle of this space, another labial, oblong, and twice the size of the last, runs inwards and forwards to the septum (fig. 5, *u.l.*[b]). Below (fig. 6, *u.l.*[c]) another pair of spatulate cartilages ("? prorhinals") are seen, near the septum, and having their "handles" looking backwards. Helping to close the open nasal space below (fig. 6, *u.l.*[d]) the last pair of "upper labials" is seen. Each cartilage lies inside the arcuate rim, nearly touching the prepalatine by its outer end; it is a thick, short, arcuate, twisted bar of cartilage; this bar has its exact counterpart in the Shark.

Passing to the mandible and its outgrowths, we find characters very unlike those seen in the ordinary Batrachia. The pier of the mandible could be well traced in the last stage, with its flat pedicle and the elbowed rudiment of the otic process (Plate 58. fig. 3). The upper part of the pier is largely cartilaginous even now, but it is much hidden by a number of bony plates; whilst the quadrate region is converted into a true (*ichthyic*) quadrate bone (Plate 59. figs. 3, 4, 8, 9, *q.*). The metapterygoid region may be seen as a tract of cartilage in the front face of the pier of the mandible, where the long processes of the pterygoid and squamosal, and the shorter plate of the quadrato-jugal, have been cut away (Plate 59. fig. 9, *ot.p.*, *pd.*, *pro.*, *sq.*, *q.j.*, *q.*, *pg.*).

There is no metapterygoid bone covering the pedicle, but merely, as in *Bufo vulgaris*, a process of the pterygoid bone (*pg.*). Looking at the skull from behind (Plate 59. fig. 4), we see that there is a large synchondrosial tract connecting the prootico-exoccipital mass above and the quadrate below (*pro.*, *e.o.*, *q.*); this is the common territory of the tegmen tympani and "otic process" of the mandibular pier. This tract is also seen in the upper view (fig. 1), but there we only see the cartilaginous selvage which belongs to the "tegmen;" the squamosal (*sq.*) covers the otic process. The backward extension of the quadrate angle and condyle is not equal to what is seen in the Frog and Toad (Plate 54. figs. 3 & 4); and we have here what is not seen in the common types, namely, a well-ossified *quadrate region*, as in the Osseous Fish ("Salmon's Skull," plate vi. figs. 1, 2, *q.*), and to a less degree in the "Urodela" (HUXLEY, "On *Menobranchus*," *op. cit.* plate xxx. fig. 1, *Qu.*). Here it is an obliquely oblong bone, oddly bent backwards from its metapterygoid cartilage above, and then having its base turned forwards again

(Plate 59. figs. 3 & 8, *q.*), quite unlike what we see in the common kinds. Again I must refer to the separated pier (fig. 9), seen as attached still to the prootic (*pro.*), but having all the projecting parts of the bones cut away, so as to clear the view. As in the side views (figs. 3 & 8, *q.*), the elegant quadrate *trochlea* has its fore part tilted up, and, lying round and above this articular region, we see a *squarish* quadrate bone (*q.*), with the external process of the pterygoid bone (*pg.*) clamping its inner face (see also fig. 2, *q.*, *pg.*). But above the square quadrate there is another bony plate (less square in form) grafted upon the cartilage also: this is the quadrato-jugal (*q.j.*, seen also in lateral view, fig. 8, *q.j.*). Over this is a third bone, only half as deep, and less strongly attached to the cartilage; this is the squamosal (*sq.*; see also fig. 8, *sq.*, where it is seen from the side).

The last bone, the squamosal, invests the otic process (*ot.p.*), whilst the pedicle (*pd.*) is the triangular tract of cartilage running from the outer to the inner side, where it is surmounted by the prootic (*pro.*) and supported by the pterygoid (*pg.*)*.

The general relations of the squamosal and quadrato-jugal will be considered with those of the other investing bones.

The ectosteal pterygoid (a huge bone) has eaten up all that cartilage which we saw in the last stage running from its broad root on the mandibular pier to the palatine region (Plate 58. figs. 2 & 3, *pg.*, *q.*). This bone, below (fig. 2), is gently convex throughout; its broad root is three-spurred: the inner and foremost of these spurs is a sharp, twisted style, which clamps the fore face of the prootic, external to the foramen ovale (*pro.*, 5, *pg.*). The outer spur is like unto it, but grows outwards and backwards in an exactly opposite direction, clamping the inner face of the quadrate, as we have just seen (fig. 9). The inner spur is an elegant, large, auriform lobe; it forms the outer solid floor of the tympano-Eustachian dome. Externally it lies under the ligamentous stylohyal (*st.h.*), hiding its attachment; internally, it gives off a strong fascia, which is attached to half of the transverse ridge that runs across the parasphenoid, in front of the "guard." Thus we see that the pterygoid binds beneath the skull from the mid line to the quadrate, and the huge Eustachian passages meet behind the pterygoid fascia, to open as one in the roof of the pharynx.

The stem of the pterygoid is first broad and then narrow. At first it elbows out towards the cheek, just catching the long squamosal spur; it then runs forwards and a little inwards, and is spliced on to the inner face of the postpalatine cartilage (*pt.pa.*). The pterygoid is distinct from the palatine—not, however, as in the Toad (Plate 54.

* The Batrachia are constantly breaking down in the matter of *parostosis* and *ectostosis*, which are true enough as distinctions in the higher groups. In the outer views of the quadrato-jugal I have left the bone (*q.j.*) uncoloured; but the part grafted upon the ascending otic process of the quadrate (fig. 9) is coloured, because here it acts the part of an "ectosteal" plate. I now have the satisfaction to agree with Professor Huxley (art. "Amphibia," fig. 9, *Qu.J.*, p. 755) as to the proper homology of the styloid bone which is attached by its broad, hinder end to the quadrate in the Frog and Toad (Plate 54. fig. 7, *q.j.*). Its *ectosteal relation* to the quadrate cartilage in the common kinds was a stumbling-block to me, and in my former paper it is called the quadrate ("Frog's Skull," plate ix. *q.* & *qu.*). It is one of the common instances in this group of *one bone* taking the functional place of *two*.

figs. 3 & 4), by proper segmentation of the cartilage, but because the pterygoid cartilage is used up by the bone; whereas the palatine is quite unossified, it has no ectosteal bar, and merely shows some *calcification* where it is set on to the ethmoid (*e.pa.*). At present this is the only Batrachian in which I miss the ectosteal palatine bar.

The free mandible has an oblique, sinuously convex condyle, accurately surrounded by the articular bony plate (Plate 58. fig. 6, and Plate 59. fig. 3, *ar.*); this is the angular (*An.*) of HUXLEY. This bone has transformed most of the cartilage, but in front it breaks out again, and shows no distal ossicle ("mento-Meckelian"), but, reaching to near its end, and running along the outside as a spinous splint, we have the dentary (*d.*); it is two thirds the length of the mandible. On the inner side (Plate 58. fig. 6, *ar.*) the articular ends in a spike, at a small distance from the fibrous symphysis.

In the hyoid arch the *antero-superior* element has appeared, which we saw not in the last stage (Plate 58. fig. 3), only a cerato-hyal being there present; but the stapes already, for several stages, had been perfect.

If we creep along cautiously, without taking thought either for *function* or for what shall be seen in higher types, it will not be hard to find that here, late in life, has appeared the lacking upper segment of the "2nd postoral arch." Holding in mind what is familiar in the various groups of fishes, this new part may be considered as the homologue of the hyomandibular and symplectic of the Osseous Fish ("Salmon's Skull," var. loc., *h.m.*, *sy.*), the proximal bone being the hyomandibular, and the distal, with its free cartilaginous extremity, the symplectic*.

But I gladly use Professor HUXLEY's *tympanic nomenclature* for this upper bar, this *hyostapedial* chain.

The "columella" of *Dactylethra* (Plate 59. figs. 1, 2, 3, 4, 7) is bufonine (see Plate 54. figs. 7 & 8), and does not agree with that of the Frogs ("Frog's Skull," plate viii. figs. 8 & 9). In the Toads there is no separation into two distinct segments of the primary cartilaginous bar (Plate 54. fig. 8, *co.*); but the more rounded proximal part, the *stalk*, is ossified as two separate shaft-bones, the proximal end of the proximal piece articulating with the stapes (fig. 7, *st.*).

The curve which has to be formed by the columella (figs. 1, 2, 3, 4), as it stands out from the stapes, which is set in the postero-superior face of the outspread ear-capsules, is evidently at the bottom of this peculiar segmentation.

The upper piece, or "interstapedial" (*it.st.*), is bent on itself; the second piece, or "mediostapedial" (*m.st.*), is bent on it; and this bar also is bent on itself, but gently, in an arcuate manner.

This curvature is still contained in the *leaf* (see from the inside, fig. 7, *e.st.*), which is applied over the outer face of the squamosal, quadrato-jugal, and quadrate, reaching further forwards than the fore margin of the foramen ovale (figs. 3, 5). The entire

* If it be asked why the end of the symplectic passes *over* the quadrate, whereas it was *under* in the Osseous Fish, I answer that they are both *secondary* morphological positions; primarily they are *serially homologous*, and should (*and did*) simply lie in the same plane.

curvature of the columella is equal to a quadrant; it is, however, oblique, for the large outer face of the leafy extrastapedial is well seen in the upper view, and only partially on the lower (figs. 1 & 2, *e.st.*). Seen from within (fig. 7) the leaf seems to be *cordate*; but its lobes overlap the stalk (see fig. 1), and closely approach each other, except at the base.

The extrastapedial of *Bufo vulgaris* (Plate 54. figs. 7, 8, *e.st.*) is small and inelegant compared to this, whose exemplar is the leaf of a water-lily. But the *setting* of this plate is equal to its *form*; around it is the attenuated *annulus tympanicus* (compare Plate 58. figs. 2 & 3, *a.ty.*, with Plate 59. figs. 1, 2, 3, 4, 7, *a.ty.*), whose upper deficiency, much less than in *Bufo*, is supplemented by two *true* tympanic bones, not *single*, as in the Mammal, but *divided*, as in the Bird (Plate 59. figs. 3, 7, 8, ty^a., ty^b.). The upper tympanic bone (fig. 3, ty^a.) lies on the junction of the medio- and interstapedial bars *.

The infero-posterior segment, or element of the second postoral arch, has dwindled to a mere tape (Plate 58. fig. 5, and Plate 59. figs. 2, 3, 4, *c.hy.*), whereas it was massive in the extreme (Plate 58. fig. 4, *c.hy.*). It does not reach the typical Batrachian place of suspension, namely, behind and below the otic process of the mandible, but is suspended thereto by a ligament, almost a quarter the length of the bar. This ascent of the cerato-hyal is about equal to that of a Urodele.

The cerato-hyal is but little wider in the middle; it is gently hooked round below, meeting its fellow at the basal bar. All these are nearly of the same breadth and strength; all are fused together, and the median part is still continuous with the basi-branchial (*b.br.*). The anterior part of the barred branchial pouch (Plate 58. fig. 1) is converted into a persistent functionless branchial (Plate 58. fig. 5, *br.* 1, 2) of great length and breadth. The apiculate anterior part of the two bars is bound together by the confluent broad basibranchial (*b.br.*); then there is an oval fenestra, and behind this a small hypobranchial band passes inwards, on this side and on that, and from the confluence of these there grows a wider band, which speedily becomes trifid. These three processes grow directly backwards: the middle is short and unossified, an oval lobe; whilst the paired processes are the huge, long, little-diverging "thyro-hyals," the *representatives* of the cornua majora of the Mammal—not formed, as in that group, out of the first branchial arch, but rather being a modified condition of the hypobranchial region of the third and fourth. The larynx (*lx.*) lies between these bars, which have each an osseous shaft, as in the Frog ("Frog's Skull," plate x. figs. 1 & 2, pp. 171, 172)†.

Together, the external and internal auditory structures form a large, double labyrinth, with the narrow cranial tube between the right and left regions.

* In the *inverted figure* (7) the whole columella is shown dislocated, to display its inner face, and drawn from under the upper tympanic.

† Professor Huxley contends with me as to the truth of this, remarking that the thyro-hyal structures are *median* in the Urodeles. They *are so* in them, and yet only submedian in the *Anura*; the changing of the distal part of a rod into a basal piece is a very simple and common process.

Below (fig. 2), but little is to be seen, for the floor of the vestibule forms the vaulted roof of the tympano-Eustachian cavities, and these are largely floored by the leafy pterygoid bones. Between the front and middle lobes of that bone the foramen ovale is seen (5)—a huge space when seen sideways (fig. 3). The thick, notched margin of this passage is formed, behind, by the prootic (*pro.*), and in front by the sphenoidal wall (*al.s.*), in which is seen the optic foramen (2), which shows where the orbito-sphenoidal region (*o.s.*) begins. The hinder part of the epiotic region (*ep.*) is seen roofing the double passage for the ninth and tenth nerves; from this part to the hind edge of the pterygoid the region is opisthotic.

Above (fig. 1), the elegance of the periotic masses appears; they form the massive piers of the occipital bridge, the keystone of whose arch is an oblong brick of solid cartilage (*s.o.*). But these periotic "piers" are of twice the extent of the arch, and they spread into rounded lobes far beyond the curving of the upper part, where the semicircular canals are imbedded. The carved work on the top varies; for whilst the anterior and horizontal canals (*a.s.c.*, *h.s.c.*) are simply rounded elevations, the posterior canal (*p.s.c.*) has a sharp (epiotic) crest growing from it, which looks backwards, and grows forwards and inwards.

In front of the anterior canal the prootic sends forwards and inwards a rounded lobe; this is separated by one rounded notch from the superoccipital and by another from another lobe. The inner lobe is separated by synchondrosis from the bony alisphenoidal wall (fig. 3, *al.s.*, *pro.*). The outer lobe is the front part of the tract that lies outside the horizontal canal, the "pterotic" region, which is concave close to the canal, then convex, and then, the bone ceasing, we have the "tegmen" running into the "otic process." This description of the upper view will be better understood if the eye is made familiar with the *side* and *end* views at the same time (figs. 3 & 4).

That part of the periotic mass which is directly connected with the *middle ear* is shown in a separate figure (fig. 7), more enlarged; it is inverted, and the columella carrying the stapes is drawn as dislocated and turned over. The squamosal and quadratojugal (*sq.*, *q.j.*; see also those parts not inverted in fig. 8) have the tympanic apparatus affixed to their outer surface, and the great extrastapedial leaf is imbedded in the fibrous "membrana tympani." Air finds its way between that leafy growth and the bones within, and can pass round the columella, through the opening (formed by the "annulus," the tympanics, squamosal, quadrato-jugal, quadrate, and a ligament, see fig. 8) into the vaulted tympano-Eustachian cavity. The fenestra ovalis marks the periotic regions, for that which surrounds it in front is the region of the prootic, that which is behind the opisthotic (fig. 7). The actual opening (fenestra ovalis) is a small funnel, lying at the inner and *hinder* extremity of an oval trough; the little, semiovoidal, cartilaginous stapes fits accurately into this funnel. The inbent proximal part of the interstapedial (*it.st.*) fits, by its gently convex condyle, into the gently concave outer face of the stapes (*st.*); apparently there is a joint-cavity here. Three fourths of the trough, which has a thick cartilaginous rim, is filled up by the inner inbent part of the interstapedial.

The trough and the fenestra were forming in the *first* stage (Plate 56. fig. 5, *fs.o.*); the stapes was developed in the *second* (Plate 57. fig. 2, *st.*); but in the *fourth* stage (Plate 58. fig. 3) there was no cartilaginous "columella," the differentiation of which is very late; and this element, although correlated with, is evidently not a part of the stapes.

Certain *deep laminæ* of fibrous tissue which had undergone ossification have been described as part of the largely ossified chondrocranium. Of these the pterygoid and articulare have largely used up the cartilage to which they were applied and related; but one of these plates, contrary to the wont of the Batrachia, has failed to do so, namely, the "superethmoidal" (figs. 1 & 3, *s.eth.*). I class it, however, with the endoskeletal bones in this group. Its counterpart in Bony Fishes may or may not attack the cartilage. Another bone, the quadrato-jugal, is a mere splint in the *Sauropsida*, but is a grafting-bone in the Batrachia. I think it better to keep it amongst the "investing bones," which are ossifications of *shallow laminæ* of fibrous tissue.

The first of these outer bones to appear was the parasphenoid (*pa.s.*), and it is now the most remarkable. This bone (fig. 2) reaches nearly to the foramen magnum behind, and almost to the premaxillaries in front. It is the perfect miniature of a straight sword with a blunt tip.

Protecting the under face of the blade of this bone, near its tip, is a small, transverse, bony shield, the vomer (*v.*); azygous only in this kind of Batrachian as far as I know (see "Frog's Skull," plate ix. fig. 2, *v*); here it has a rounded front and hind margin, and a rounded lobe on each side. In the notch between the front and side there is a strong ligamentous band which attaches it to each premaxillary.

The nasals (figs. 1, 3, *n.*) are small crescentic bars, lying on the hinder face of the large labial pouch (*u.l.*), and attached by their broader inner end to the second small labial ($u.l.^b$).

Together, the premaxillaries and maxillaries (*px.*, *mx.*) form an elegant arch, the two former being the keystones; these have a sinuous palatal process (fig. 2) below, and a trifoliate nasal process (fig. 1) above. The maxillaries (*mx.*) are thickish, gently curved bars, rounded above and scooped below; the whole series is dentigerous, and the maxillary teeth run back four fifths of its length. The jugal, non-dentigerous ends of the maxillaries end at an imaginary transverse line drawn through the middle of the skull.

Behind the interlocked junction of the maxillaries and premaxillaries, there is a seed-like ossicle; it lies on the neck of the great labial pouch; this is the "septo-maxillary" (*s.mx.*).

Over the great fontanelle (fig. 1, *fo.*) there now lies a huge slab of bone, which has shelving sides and ends, and a ridged top, like a "ridge-tile;" it reaches from the middle of the superethmoidal bone (*s.eth.*) to near the verge of the foramen magnum: this is the fronto-parietal; it is nearly all due to the frontal "centre." This roof-bone is very much unlike the counterpart in the Frog and Toad (see "Frog's Skull," plate ix. fig. 1, *f.p.*), where each "fronto-parietal" keeps distinct from its fellow, and their edges dip towards each other.

On the hind part of the cheek, also, the bones are not like those of ordinary Batrachia; the squamosal (figs. 7, 8, *sq.*) is not like a hammer, but a knife whose blade is upturned, and whose handle is excavated near its end. Here the "handle" part is absent, as in the *Chelonia*. So also is the quadrato-jugal (figs. 7 & 8, *q.j.*), like that of a Tortoise; it lies directly beneath the squamosal, is grafted on to the lower part of the "otic process," and clamps the outer face of the quadrate in front. The long blade of the squamosal nearly reaches the palatine cartilage (*pt.pa.*) over the elbow of the pterygoid; this process is certainly Batrachian, and is wanting in the Tortoise's squamosal. The two seed-like tympanic ossicles are new to me: the upper (figs. 7 & 8, $ty.^1$) is attached to the squamosal handle at right angles, and helps a ligament (*t.l.*) to finish the foramen for the columella. The second tympanic ($ty.^2$) is a bent ossicle; it lies, as a clamp, on the upper part of the junction of the quadrato-jugal and quadrate.

The "dentary" (fig. 3, *d.*) is the last of these investing bones; it has already been described.

I forbear to make any further remarks on the strange features of this *Aglossal* type, until the other, namely *Pipa*, has been described; these two, the Cape and the Surinam Toads, differ almost as much from each other, *in details*, as they do from the ordinary Batrachia.

On the Skull of the Surinam Toad (Pipa monstrosa).—*First stage, Embryos from the dorsal pouches 9 lines in entire length**.

This type has broken away from almost all the customs and observances of the Batrachia, being, indeed, a prolepsis of the "Abranchiate" Vertebrata. The lateral and dorsal views of the embryo show how unlike to a *Tadpole* it is (Plate 60. figs. 1 & 2); in its development it does not observe the times of the other Batrachia, but hurries, so to speak, through its stages, like a creature of high degree.

Altogether, this embryo is much more like that of the Salmon ("Salmon's Skull," plate i.) than an ordinary Tadpole. As in the larval *Dactylethra*, there are no horny jaws, and at this stage, as in the Urodela, there are no labials. In my youngest *Dactylethræ*, very much larger and more developed, generally, than this, the limbs were minute bud-like masses of cells; here they are relatively large, and the hind limbs show distinct toes. The intestinal coil was perfect in those free swimmers; here the yelk is scarcely used; it is a mass $\frac{1}{4}$ of an inch in diameter, and the tail of the flat, tape-like embryo almost meets the chin. In the larval *Dactylethra* the gill-operculum is open

* For these youngest *Pipæ* I am indebted to Dr. GÜNTHER, F.R.S.; for the ripe young from the maternal dorsal pouches to Prof. W. H. FLOWER, F.R.S.; and for the adult skull, already *partially* worked out by him, and described in the article "Amphibia," p. 756, I am indebted to Professor HUXLEY, Sec. R.S.

on both sides, not on the left only, as in common Tadpoles; here, with limbs such as usually are seen when the tail is lessening, the operculum (Plate 60. fig. 1, *op.*) is a small free flap, growing back from the angle of the gaping mouth. This operculum is like that seen in the "first stage" of the Salmon ("Salmon's Skull," plate i. figs. 3 & 9, *op.*). The gills are well developed in *Dactylethra*; but I had no stage in that type to show the external free branchiæ, as in the Frog ("Frog's Skull," plate iii. fig. 10). In *Pipa*, as in *Salmo*, there are no signs of such filaments (this embryo is immature enough to show them if they existed), and there are no branchiæ under the operculum, although the arches (Plate 60. fig. 4) are all present, and the vascular arches are here also. The normal *free branchiæ* exist in the unborn young of *Salamandra maculosa*, and are just aborted at birth; here, neither kinds have been found. As in the first stage of the Salmon, with which these embryos are in *structure* and in *stage* so closely comparable, the skull is largely membranous; it is only floored with cartilage; the brain is quite visible through the delicate gelatinous roof; and the eyeballs lie loosely, as it were, in their sockets, as though they had been planted in them, and were not a part of the primary structure (Plate 60. figs. 1, 2, and "Salmon's Skull," plate i.). The ear-sacs, with the hind brain, take up half the head, so large are they, much larger than in the Salmon's embryo, or in their counterpart in the Toad and Tadpole (Plate 55. fig. 3, *au.*). Moreover, in many respects, Tadpoles of the Common Frog and Toad only half the length of these embryos of *Pipa* are more advanced, and are free active individuals at one third their length. But in *Pipa* the whole metamorphosis is perfect before they awake; for they lie wrapped up like unborn Lizards, not in a proper primary uterus or oviduct, but in a *secondary* dorsal marsupium.

Notwithstanding the slight advance in the parts relating to *organic* life, the *animal* organs are fast advancing; the skull (Plate 60. fig. 3), in this recently differentiated band of blastoderm, is well nigh as far advanced as that of the youngest *Dactylethra* (Plate 56. figs. 4, 5).

These two "chondrocrania" come much nearer to each other than to those of the common kinds, and they mutually illustrate each other; yet, for all that, they are very diverse from each other. Here, as in *Dactylethra*, only the *floor* is, in this stage, solidified into cartilage, and in this type the basal view gives most of the morphology. In both the pituitary floor is chondrified earlier than in the Frog, and in *Pipa* it must have rapidly filled in. In few embryos have I seen such a long cephalic notochord (fig. 3, *nc.*): it is *half* the length of the chondrocranium, in the Tadpole of *Dactylethra* it is one third,—that is, in the latter the trabecular region is twice as long as the parachordal, and in the embryo of *Pipa* they are equal. This is partly a peculiarity of the type; but it shows that these embryos whose chondrocranium can be compared with that of the active Tadpoles of *Dactylethra* are very young, and that they develop with great rapidity. The "first stage" of the Pig's skull shows a similar state of things ("Pig's Skull," plate xxviii. fig. 8). The long parachordal tracts (Plate 60. fig. 3, *iv.*) are much more distinct from the auditory capsules than in the corresponding skull of *Dactylethra*;

these tracts do not reach to the notochordal apex, which is embraced by the apices of the trabeculæ. All trace of the composite nature of the cartilage there, is, however, obliterated, and from the "atlas" to the front wall of the face all is one continuous sheet of cartilage. The large primary, pituitary space (Plate 55. fig. 1) is, indeed, filled in here; but at the middle a faint line of imperfect chondrification can be seen, and thus the distance from this line to the small crescentic "subocular fenestra" (*s.o.f.*) gives the breadth of the trabecular band (*tr.*). This breadth is doubled in the internasal (*i.n.l.*) region, for here the converging trabeculæ have coalesced, back to back.

The trabeculæ, as in *Dactylethra*, do not end in the front wall of the face; their coalesced internasal portion ends there in a transverse, slightly emarginate plate; but externally the two bars are free again, and those distal, or "hypo-trabecular" continuations of the trabeculæ are the "recurrent cornua" (*c.tr.*). These cornua are much more suddenly bent backwards than even in *Dactylethra*; in the higher types, with much more *compressed* faces, these horns lie near each other, and often more or less coalesce ("Pig's Skull," plate xxxvi. fig. 1, *c.tr.*, *rc.c.*). Here the cornua end in a rounded spatula, which lies upon and almost coalesces with the "prenarial lamina" (*p.n.l.*), which is, here, a projection from the pterygopalatine band (*p.pg.*), and becomes the prepalatine spur. *Pipa*, in these things, is in essential agreement with *Dactylethra*; but the head is much more flattened out in the latter than in *Pipa*. The well-marked lateral part of the trabecular floor next to the subocular space (*s.o.f.*) is similar in both types; in both it forms a flap with a convex outer edge. The recurrent trabecular cornua not only lie on the conjugational part of the next arch, but they also close in upon the bars of which they form the distal ends. Thus is formed, outside the "internasal plate," by this looping of each bar, the space by which the outer nostril opens into the fore palate (*i.n.*). In *Dactylethra* (Plates 56 & 57) the outer nasal space is formed in the same manner; but the next bar (*p.n.l.*, *p.pg.*) assists to finish the loop, and the space itself is transverse, whereas in *Pipa* it is almost longitudinal. In the latter the transverse part of the trabecular internasal plate, in front, is of much less extent, and the inner cells of the upper lip are not yet chondrified, so that here we miss not only the tentacles, but also the long, transverse, upper labial, from which they spring.

Coming to the first facial arch, the mandibular, we find all its proximal part in close relation with the great trabecular sheet of cartilage. Moreover, here the morphological stage is one much further advanced than in the youngest larvæ of *Dactylethra*, and more in accordance with the fourth stage (Plate 58. figs. 2 & 3); this is further evidence of rapidity of development; at any rate it shows quick morphological change in these parts, the condition of the embryo, as an individual, being so immature.

The whole pier (the free part of the mandible has been removed, see fig. 4) is a multilobular plate, whose inner lobes are confluent with the trabecular margin (Plate 60. fig. 3, *pd.*, *tr.*). The hinder of these (*pd.*) is a wide flat plate of cartilage which runs in obliquely between the auditory capsule and the posterior end of the trabecula; with this it has completely coalesced, with the other partially, on its outside.

The convex margin of the subocular fenestra (*s.o.f.*) is the concave margin of the mandibular pier, which, in front of this, passes again into the trabecula, and then grows a little forwards into an auriform lobe: the conjugational part is the ethmo-palatine (see figs. 5 & 6, *e.pa.*); the free lobe, in front, is the prepalatine spur (*pr.pa.*),—in the early stage of a Batrachian embryo this is the "prenarial ligament" or "lamina," as the case may be. On this foremost bifid lobe the dilated end of the trabecular "cornu" rests (*c.tr.*). Outside the rudimentary palatine cartilage there is a large semicircular notch, and the lobe bounding this outside is a rounded condyle, the condyle of the quadrate (*q*), on which the *scooped* upper face of the free mandible hinges (fig. 4, *ar.*, *mk.*). On the upper face of the quadrate angle (Plate 61. fig. 1, *or.p.*), the outer muscles of the cheek run to be attached to its outer side, and the temporal muscle runs under and within it; it does not attempt to make a bridge across to the ethmoidal region of the trabecula, for it is scarcely as much developed as in *Dactylethra* (Plate 56. fig. 4, *or.p.*). The sinuous facet for the hyoid arch (fig. 3, *hy.c.*) is close behind the condyle of the quadrate, but it lies further outwards (compare figs. 3 & 4, the latter of which shows the arches that have been removed, *ar.*, *mk.*, and *c.hy.*).

But, unlike other types, the outer part of the quadrate sends a process, outwards and backwards, the lower face of which process is faceted for the *evanescent* hyoid bar; the process and the facet are as evanescent as the bar, which soon wholly disappears. Between the lobe for the hyoid and the last and longest of these lobes there is another semicircular notch, and from thence a long finger of cartilage grows backwards and slightly outwards. This long lobe rests its end beneath the tegmen tympani (*t.ty.*), at its foremost third; it is a little longer than the flat inner process, and its rounded end is free; this is the otic process (*ot.p.*). This spur is quite similar to what may be seen in the adult *Proteus* and the young (half-grown) Axolotl; it is far more developed than its counterpart in the fourth stage of *Dactylethra* (Plate 58. figs. 2, 3, *ot.p.*). The eyeball rests upon the broad central part of the mandibular pier, a little to the outside (Plate 60. fig. 3, and Plate 61. fig. 1, *e.*). Altogether, this fixed part of the mandible is very much advanced for so young an embryo.

The free part of the arch (fig. 4, *ar.*, *mk.*) is an elegant bow, moderately bent, and whose lateral "horns" bend gently backwards to where they are fused. This fusion of the free mandibles is rare in the lower types; it is perfect in some Mammals ("Pig's Skull," plate xxxi. fig. 7*a*, *mk.s.*); at present there are no "inferior labials," and I question their existence separate from the fused ends of MECKEL's cartilages. The upper surface of the articular region (*ar.*) is cleanly scooped out to roll on the rounded condyle of the quadrate. There is no bony investment to the mandible, as there is none to the chondrocranium generally.

The early visceral cartilages seen in the under face (fig. 4) have much in common: they are all united together by fusion at the mid line; but the last four pairs of bars also catch each other's edges, and unite, both above and below, to some extent. The second postoral arch (*c.hy.*) is large, more than twice as large as the rest; it is longer and less massive than in the Batrachia generally, being intermediate between that of an ordinary Tadpole (or even that of *Dactylethra*) and the hyoid of an adult *Salamandra maculosa*. It is also peculiar in uniting with its fellow, and showing no separate basal piece (compare Plate 56. fig. 6 with Plate 60. fig. 4, *c.hy.*).

The remaining four arches are the "branchials" (*br.* 1–4): these, where they touch above and below, are coalesced; they have no basal piece chondrified, although between them they have not only the rudimentary larynx (*lx.*), but also a large triangular patch of dense granular tissue, which chondrifies afterwards. These bars are flat, thin, somewhat pointed above, and below meet in one common isthmus uniting the right and left bars. These bars are supplied with the usual branchial arteries; but I can discover neither secondary branches to these, nor branchial filaments to which such branches should be distributed.

Notwithstanding the feeble condition of these bars, this is their highest state of development (compare Plate 58. fig. 1 with Plate 60. fig. 4, *br.* 1–5); they, indeed, remain in a fused and altered state; but the hyoid is at its height now, and will have vanished in the ripe young (Plate 60. fig. 7).

There is no such superfluity of cartilage growing from the auditory capsules as in *Dactylethra*; but the tegmen is a very distinct eave to the huge ovoidal capsules; they are fully chondrified, even above, and so quite come up in this respect to the first stage of *Dactylethra* (Plate 56. fig. 4). Beneath, the fenestra ovalis and its enclosing fossa is more advanced than in that larva. It nearly corresponds with that of the Common Toad's Tadpole when it is two thirds of an inch long, a little shorter than these embryos of *Pipa* (Plate 55. fig. 5), but which has been for two or three weeks an active self-determined larva.

In this stage the future fenestra ovalis (fig. 3, *fs.o.*) is a somewhat triangular depression, with the longest angle, like a lacerated wound, running backwards and a little inwards; in this, its faintest part, the perforation will take place. The obtuse, middle angle of this fossa looks inwards, and the foremost, which is rounded, forwards and outwards. Above the crescentic open space between the front of the capsule and the mandibular pier the 2nd and 3rd branches of the trigeminal nerves pass towards their destination; below that space the *thyroid gland* (?) (*tr.g.*) lies; behind the capsule the 9th and 10th nerves are seen emerging.

No further light upon the morphology of this peculiar chondrocranium was obtained by upper views, and only a partial figure of that aspect is here given (Plate 61. fig. 1), to show the size and relations of the "orbitar process." At present the side walls of the skull are not chondrified, and the conjoined trabeculæ form merely a flat internasal plate*.

* Notwithstanding the anxious care required to work out such chondrocrania as this and that of the younger *Dactylethra*, I consider that their elucidation has amply repaid me; they light up each other, satisfying the self-suspecting observer, when he sees the most strange modifications reappear a little altered. Conforming in all essentials to typical, larval, skulls of Batrachia, their most striking aberrations will be found to have meanings that relate to types beyond their own group, meanings also that will not all meet the eye until more is seen and known.

On the Skull of Pipa monstrosa.—*Second Stage. Ripe young,* $6\frac{1}{2}$ *to* $7\frac{1}{2}$ *lines in length.*

In this stage all the figures except one (Plate 60. fig. 7, *the mandible and branchials*) are from young that were showing their faces at the mouths of the dorsal pouches; these were $7\frac{1}{2}$ lines, or nearly two thirds of an inch, in length. The others were still rolled up and were slightly above half an inch, in length. Yet these *unawakened* larvæ were perfectly metamorphosed, and I could see no difference whatever, even in the degree of their ossification, which was intense, and far beyond what I expected to find in such small young of so large a species. Now in the earliest stage I have (Plate 60. figs. 1, 2) the entire length was 9 lines, nearly *half* the length being due to the tail; therefore it is seen that when metamorphosis is perfect the body is only one fourth of an inch longer than it was at the time that the yelk-mass was but little lessened in substance (not at all in *size*), and that the series of somatomes perfect themselves into the body, vertebræ, muscles, &c., by filling in, as it were, the original map, and scarcely modifying the size of the territories. Also it may be remarked that the head of the early embryo (Plate 60. figs. 1, 2) is *two lines*, or one sixth of an inch, in length, the condition of whose skull has just been described (Plate 60. fig. 3); whilst the head of the *unrolled* young is three lines long. Thus it is seen that the lengths are (without the tail) as follows:—Early embryo: head $\frac{1}{6}$ inch, body $\frac{1}{4}$ inch; total $\frac{5}{12}$ inch. Ripe young: head $\frac{1}{4}$ inch, body $\frac{1}{3}$ inch; total $\frac{7}{12}$ inch (taking the average of the two sizes of the young *Pipæ*).

The figures of the chondrocranium (Plate 60. figs. 3, 5, 6), the degree to which they have been magnified being considered, show how much the metamorphic action has modified the condition, and how little the size; a like case to that with which all are familiar, namely, during the "vernation" of trees (*e. g.* of *Æsculus*), when the new internode gains its length in three or four weeks, and takes the rest of the season to stiffen itself by deposit*.

The unexpected *finish* of these ripe, or nearly ripe, young *Pipæ* makes it necessary to modify, a little, my mode of illustration. The figures of the chondrocranium at this stage (Plate 60. figs. 5, 6) are made by drawing the still existent cartilage, and leaving out in those figures the *ectosteal* deposits (see, in contrast, Plate 61. figs. 2, 3).

And here is another anomaly, namely, that whilst the cartilage has been *used up* in the auditory capsules, leaving large spaces, above and below, only invested by bone, the same thing, contrary to wont and experience, has taken place where the great parasphenoid lies (Plate 60. fig. 6, and Plate 61. fig. 3; compare with these the adult Toad's skull, Plate 54. fig. 4). Here the development of an underlying "parostosis" has been coupled with the absorption of the *newer cartilage* of the primary pituitary space (see Plate 55. fig. 1, *pt.s.*), which lies upon that splint-bone. Here, again, in a Batrachian we see the want of any proper boundary line between a *parostosis* and an *ectostosis*, the difference between which is so clear in "Teleostean" Fishes, and the "Sauropsida," generally.

Such a chondrocranium as we see here (Plate 60. figs. 5, 6) is a fair and clear diagram

* There is a familiar instance nearer home, namely, in the *almost completed length* of the foal's "metatarsus" and "metacarpus" at the time of birth.

of the Batrachian type of skull, if we make allowance for the absorbed floor-plate. Yet at once we see a modification, for the occipital condyles (*oc.c.*) are more *outside* than behind. The absorption of the cartilage in front of the notochord takes place wittingly, as it were; it has marked out, again, the parachordal region (*iv.*) by absorption of the apices of the trabecula (see Plate 55. fig. 1, *tr.*) along with the newer cells of the pituitary floor. The notochord (*nc.*) is but little diminished; even now it lies mainly *over* the parachordal floor behind, and is free over the parasphenoid in front. On each side a fissure marks the almost absorbed auditory cartilage from the parachordal plate, and in front of that chink the auditory, parachordal, trabecular, and mandibular cartilages are all confluent, and form a gnawed tract on either side. Just where the optic nerves (2) pass out, there the trabecula is reduced to its primary size. But from thence each bar rapidly widens, running inwards to meet its fellow, and to form the ethmoidal floor: on this floor lie the olfactory lobes and the anterior *fourth* of the hemispheres (C 1). This zone is narrow above (fig. 5), and is there to be seen as the elegant arcuate front and junction of the steep side walls, which thin out extremely before they pass into the crest which runs from the auditory capsule (fig. 5). The ethmoidal belt, in front, grows into a median crest or keel and a pair of side wings: the keel is the septum nasi with its "cornua" (*s.n.*, *c.tr.*), the side wings belong to both the trabeculæ and the palatines (*e.pa.*).

This keel, and these "horns," are explained by the early stage (fig. 3), and they serve as a key to open the mysteries of the adult skull at this part (Plate 62). In front of the palatine conjugations the trabecular internasal plate has been reduced to less than one fourth of its former width (figs. 3, 5, 6). This narrowing produces a large crescentic notch on each side, which is, externally, the hind margin of the inner nostril. The subnasal lamina, or primary trabecular commissure, dilates twice, beyond the middle and in front, but is nowhere wider than the same winged part in a Passerine bird. In front the septum is broad, for the internasal plate there grows up into a wall, the rudiment of the alinasal laminæ; from this wall, above, the cornua trabeculæ pass backwards: the stem and the arms of this structure look like a miniature of the "governor" of a steam-engine.

When this fore part is cut through at the front of the septum nasi and in the roots of the "cornua," then it is seen that the septum is a thick and high wall, and that the rudimentary alæ nasi (fig. 8, *s.n.*, *al.n.*) are also thick, and have rounded inferior edges. Above, from the very narrow aliethmoidal bands (*al.e.*) to the front, the aliseptal plates (*al.s.*) are scarcely at all produced right and left (Plate 61. fig. 5).

The backgrowing "horns" of the trabeculæ (Plate 60. figs. 5, 6, and Plate 61. figs. 4, 5, *c.tr.*) form a small angle with the septum, and have a knobbed free end; they grow from the upper part of the internasal plates, and therefore lie nearly as high as the roof of the septum. The foliaceous prepalatine (*pr.pa.*) runs forwards outside, and parallel with the trabecular horn, but free of it, instead of being nearly flush with it and more or less coalesced, as in the embryo (fig. 3, *p.n.l.*).

The nasal capsules are thus seen to be but little indebted to trabecular outgrowths for their protection; these latter are somewhat supplemented by the upper labials (*u.l.*) to be described soon.

The changes that have taken place in the mandibular arch are easily traceable; the pedicle (figs. 5, 6, *pd.*) is long, the broad central part of the pier is now lost in the outer lobes, which now lie outside the foremost part of the auditory capsule. The two inner arms of this plate (compare figs. 3 & 6) are much altered by elongation and attenuation; and whereas the hinder (*pd.*) ran backwards to join the trabeculæ, it now runs forwards; also the front bar, which ran forwards, now runs backwards as well as inwards (figs. 5 & 6, *e.pa.*).

The former of these is now a narrow band which is dilated into a broad plate, where it joins the trabecula (*pd.*, *tr.*); the latter has grown now into three distinct regions, namely, the ethmo-palatine (*e.pa.*), the prepalatine (*pr.pa.*), and the common postpalatine and pterygoid bar (*pt.pa.*, *pg.*). This bar is now sigmoid in shape, and of great length; it sets on to the fore face of the quadrate close within the condyle, and is elbowed out just before it joins that part: two longer elbows, but less bent outwards, are seen, the first where the palatine runs into the pterygoid region, and the next at the root of the leafy prepalatine. This latter part (once the "prenarial lamina," *p.n.l.*) is a further development of the secondary antero-internal lobe; the secondary growth on the antero-external lobe, the process for the condyle for the hyoid (*hy.c.*), is now obliterated; this is a correlate of the absorption of the cerato-hyal (fig. 7).

The two external lobes are now seen to have become the outturned, scooped quadrate trochlea (*q.*); and the inturned otic process (*ot.p.*) a triangular wedge with a rounded apex, over which the columella (*it.st.*, *m.st.*) passes. Here the articular portion of the quadrate cartilage is a deep trochlear groove, the cartilage being most curved away below; it was a rounded condyle (fig. 3, *q.*). On the other hand, the articular surface of the free mandible (fig. 7, *ar.*) is a sinuously rounded head, and it was (fig. 3, *ar.*) a scooped hollow on the upper face of the end of the cartilage. The dilated end of the cartilage is covered with a bony sheath (fig. 7, *ar.*) which attenuates gradually forwards, clinging to the inner face of the rod, and ending near the symphysis in a point; this is the ectosteal "articulare," which ossifies the proximal part of the mandible. On the outer side is a bone (*d.*), the dentary; its broad part is in front of the symphysis, where it is tied to its fellow, and it ends where the upper third of the bar begins. Much of MECKEL'S rod is unossified within these two bones; there is no "os Meckelii" or mento-Meckelian element.

The cerato-hyal has disappeared; I have indicated its empty place by a dotted line (fig. 7). In the upper and anterior region of the second postoral arch there is a considerable osseo-cartilaginous bar (Plate 60. figs. 5, 6, and Plate 61. figs. 2, 3, 6); this is the columella: it is attached behind to the stapes (*st.*), now fully developed. All these things are new since the early stage in which all that was formed was a fossa containing gelatinous stroma. I strongly suspect that the development of these embryos is very rapid, for the lesser of the young in this stage are but little larger than the recently changed

Common Frogs and Toads; and the larger young are less than the Toad when its columella is first a cartilaginous rod (Plate 55. figs. 6–8).

But in these young *Pipæ*, with the body so little longer than that of the early embryo (figs. 1, 2), the columella is as perfect as it is in our common kind at the end of the first autumn. Supposing, as I do, that the stapes was solidified first, yet there was little time lost in either; thus this type begins to break down that want of synchronism in the development of the upper and lower rods developed as parts of the "2nd postoral."

Another matter of importance in this type is this, namely, that the *stapedial* fossa is nearly obliterated in front, and that the almost contemporaneous stapes and columella are related to each other in a manner which is, to say the least, very Mammalian. Let the short crus of the Mammalian *incus* be merely the upper "ear" of a heart-shaped cartilaginous "body"; let the "os orbiculare" ossify two fifths of a stout and somewhat outbent "long crus," the rest having its own centre, and stopping at the "body"; lastly the fenestrate part of the stapes is to be arrested,—and then this supposed modification of the Mammalian *ossicula* would exactly correspond to what really exists in *Pipa*.

But in this type the stapes is a neatly oval plug (Plate 61. fig. 6, *st.*), the flat face of which is outside, and the convex face placed inward, fitting into a funnel-shaped fenestra ovalis (*fs.o.*), the open mouth of which is the developed form of the long hollow (as though a piece had been torn away from the outer coat) which is seen in the first stage (Plate 60. fig. 3, *fs.o.*). Already the fenestra ovalis has been brought to the supero-external edge of the capsule, an elegant wedge of *opisthotic* cartilage finishing the outer margin above (Plate 61. fig. 6). In front of the fenestra the tegmen tympani (never large, see fig. 3) is receiving its squamosal investment (*sq.*), and that in a truly remarkable manner. Behind, it is a film tiling the auditory eave; it then creeps upwards to the cartilaginous selvage of the common bony plate, in which is seen the sweep of the horizontal canal (*hs.c.*). The descending growth of the squamosal in the outer face of the quadrate (*q.*) is hidden by the columella; but there is here an elegant anterior process (the long front part of the *hammer-head* in the common form of the Batrachian squamosal, Plate 54. fig. 7, *sq,*); this is growing into a cochleate process, and in this "spoon" the extrastapedial (*es.t.*) and "annulus" (*a.t.*) lies. The *side* of the auditory capsule being thus tilted up, the columella lies *on* the stapes, mandibular pier, and squamosal, and *outside* the diminished "tegmen"; it is well seen from above, although it is placed obliquely.

The primary cartilaginous rod is pinched in at two places, marking off the three regions, namely, the interstapedial (*it.st.*), the mediostapedial (*m.st.*), and the extra-stapedial (*e.st.*); in this, as in the other *Aglossal* Toad, there is no ascending supra-stapedial ("short crus"). The well-developed bony shaft covering the interstapedial region (*long* in the Toads, and not cut off as a distinct separate cartilage as in the Frogs) is two fifths the length of the mediostapedial (*m.st.*); its fibres radiate over the unossified bulbous end of the bar which articulates with the stapes: in the adult (Plate 62. fig. 9) this is still better seen. In front of the longer mediostapedial shaft-bone the cartilage escaping from the sheath is at first thick, and it bends downwards and inwards before it spreads into the extrastapedial (*e.st.*), which is like a water-lily leaf, as in *Dactylethra*.

In the interim between this and my first stage I have missed the formation of the U-shaped "annulus" (*a.t.*) on which the lips of the extrastapedial rest, but I have traced its formation in several kinds.

The rest of the auditory capsule may be described here.

The extreme degree of ossification of the whole "occipito-otic" region satisfies me that here, as in *Dactylethra* and *Pseudis*, it would at any time have been impossible to find any gap between the exoccipital and the prootic. These parts are now like a hard double fruit, with as hard a connective between them; this intermediate part is all strong, save at the mid line below (Plate 61. fig. 3, *b.o.*, *e.o.*). On the lower surface of the hard ear-ball there is also a break in the bony covering, like a line of dehiscence running in from the middle of the outer edge. This chink in the hard floor is, however, due to the manner in which the bony growth has radiated; it marks out the prootic region in front from the opisthotic behind; but it does not, even in the adult (Plate 62. fig. 9), run round behind the fenestra ovalis to form the well-known *opisthotic hook*, as in the Common Toad (Plate 54. fig. 7, *op.*). This common bony floor grows, shell-like, to the front edge of the capsule, but leaves an external lip of cartilage, and fails to floor it in towards the inner edge also. Where it curves and narrows inwards, running round and between the ninth and tenth nerves (9, 10), it floors three fourths of its own side towards the basioccipital synchondrosis, with the overlying notochord (*n.c.*). The bone runs to the lower edge of the foramen magnum (*f.m.*), leaving the middle and the condyle (*oc.c.*) soft. That condyle shows most above (fig. 2), and its face looks upwards and outwards; its shape is oval, and it is unusually flat.

Embracing these facets, the bone then wholly enarches the foramen magnum and the superoccipital region (*s.o.*); but beneath the bone the cartilage is perfect (Plate 60. fig. 5, *s.o.*). The whole oval top, which is larger than the floor, is roofed with continuous bone, which has set up absorption in the cartilage beneath (Plate 60. fig. 5), but not to the same extent as in the lower face. Through the strong but thin ectosteal plate and cartilage the semicircular canals (they are represented by dotted lines) can be seen in a well-prepared skull, examined as a transparent object *.

The cartilage reappears in the alisphenoidal region in front, and in the tegmen outside (figs. 2 & 6). The chondrocranium has other ectosteal plates that properly belong to the endoskeleton. One of these can be detected binding together the frontals (fig. 2, *f.*), which has, however, but little independence as a bone; this is the superethmoidal plate (figs. 2 & 4, *s.eth.*), a large and permanently distinct bone in *Dactylethra* (Plate 59. fig. 1), but here already a mere spike and under-thickening to the middle of the fore edge of the common frontal plate (*f.*). The pterygoid bone (Plate 61. fig. 3, *pg.*)

* After careful dissection, these skulls are treated with an ammoniacal solution of carmine, and then placed in glycerine.

invests the lower face of the cartilage both in the pterygoid and metapterygoid regions. This triacanthous plate binds on to the inner face of the quadrate (*q.*), and the under face of the pedicle (*pd.*), and of the lateral pterygoid bar of cartilage.

Then, except where it is invested by the maxillary (*mx.*), which runs to the inner side, almost meeting the pterygoid, the three regions of the palatine cartilage seem free from ectostosis. With great care, however, there may be found a style attached to the hinder face of the ethmo-palatine below; it runs outwards and forwards, and sets a pedate base against the antero-external angle of the parasphenoid (*pa.s.*): this is the ectosteal palatine (figs. 3 & 7, *pa.*); it exists in the Batrachia generally, but not in *Dactylethra* (Plate 59. fig. 2)*.

The above, with the pair of bones in each columella, and the "articulare" in each mandible, are all the *deep-layer* ossifications I can find in this stage; they are bones that can be easily identified with their homologues in Osseous Fishes, Sauropsida, and Mammalia.

The "investing bones" are of great interest in this stage and in this type; the largest and earliest of these is the parasphenoid (fig. 3, *pa.s.*). This huge bony shield is not like what we see in the Batrachia generally, but resembles that of an adult "Perennibranch," or a young "Caducibranch" Urodele. Its hinder half is the narrower; it gradually loses breadth behind, and then its rounded hinder margin sends backwards a sharp spike. In front it is also spiked, and then, for a short distance, is only one third its full breadth, but, by a sudden step on each side, attains it rapidly. Its narrowing takes place suddenly again, where the broad foot of the "pedicle" joins the trabecula. Beneath its front spike *there is no vomer*. A somewhat larger space is covered by the roof-bones above (fig. 2). This large bony part is very similar to that below; it is, however, convex along two lines and somewhat depressed along the middle, whereas the parasphenoid is convex generally. The upper tract is spiked in front, but from a borrowed source, the superethmoidal. It is *winged* in front; but the upper belong to it, whilst below they are borrowed. Behind, the roof is crenate and not spiked. This part is also formed, not from one, but from four centres, namely, the frontals, which are twice the length and breadth of the others, the parietals (*f.p.*). The anterior frontal wing (prefrontal process) binds the ethmo-palatine above, just as the palatine style binds it below. As the bony roof is larger than the floor, so the space to be covered (Plate 60. fig. 5) is also larger. As in *Dactylethra*, there are no *secondary fontanelles* to be covered by the parietals, it is all one pyriform space.

The narrow walls and spurs between and around the nasal mucous membrane, exposing it largely in the chondrocranium (Plate 60. figs. 5 & 6), are largely supplemented by investing bones. The main pair are the nasals (Plate 61. figs. 2 & 4, *n.*); they are large bones, nearly semicircular, but their obliquely placed transverse margin is deeply notched

* Professor HUXLEY missed this bone in the adult (art. "Amphibia," p. 756). The unlooked-for "wings" to this part in the huge parasphenoid of the adult (Plate 62. fig. 2, *pa.*, *pa.s.*) struck me as abnormal, and led me to make inquisition in the young.

for the external nostril (*e.n.*). Their round hinder edge is overlapped by the frontals, and their outer edge, in turn, overlaps the marginal bones externally and the ethmo-palatine bar (a little) behind. The large anterior sinuous narial notch is of great interest, as it makes the nasal bone of *Pipa* the prototype of that of a "Carinate" bird. The hinder of the marginal bones is a "preorbital" (Plate 61. figs. 2, 3, 4, *p.o.*). It is not common in the Batrachia, but exists in *Rana pipiens,* and is well seen in *Clarias capensis,* a "Siluroid" fish; here it is a thin bony scale, broadest behind, and having its thin inner edge deficient at places, forming teeth and hooks; it helps to set bounds to the outer nostril. But the outside of the nostril (*e.n.*) is finished by a much smaller bone, the septo-maxillary (*s.mx.*); it is set on the narrow end of the last, and is a sigmoid rod, bending first outwards and then inwards; it ends in the front wall of the face in a blunt point; this is the bony element of the curious nostril-valve. Below, the chondrocranial framework, in front (Plate 60. fig. 6), is strengthened by flat bony splints, the premaxillaries and maxillaries (Plate 61. fig. 3, *px.*, *mx.*); these are extremely embryonic and simple, for they only lie on the under face of the chondrocranium. Their free surface is gently rounded; altogether they are thin and fibrous. The premaxillaries do not meet, yet, beneath the septum nasi, the form of each is an arcuate lobe, rounded within and sharp externally and behind; the outer edge has a round notch.

The convex edge of the premaxillary is overlapped by the projecting end of the maxillary. This latter bone is falcate, with distant serrations on its sharp inner edge, and it ends behind as a sharp point, a little in front of a similar point, the fore end of the pterygoid. The pterygo-palatine cartilage bows out beyond these styles. Below (figs. 3 & 7, *pa.*), the palatine style looks like a prop standing out between the parasphenoid and the maxillary.

The squamosals and the dentaries are the other investing bones. These have already been described; there is no quadrato-jugal.

The peculiar valves that protect the external nostrils are strengthened by cartilages within; these are the "upper labials," now at their highest development. They are best seen from above (Plate 61. figs. 4 & 5; Plate 60. fig. 8, *a section*). The most massive of these ($u.l^a.$) lies in the floor of the outer nostril; it is pedate and flattish in front and bulbous behind; the pedate expansion is largest externally. To the hinder bulbous part of this a second ($u.l^b.$) is articulated; it is larger and thinner than the first. Where it articulates with the bulb by a concave margin, there it is squared on its opposite edge. From thence it runs outwards as a narrow, somewhat decurved band, which ends on the upper lip in a point, from which point a sharp hook runs inwards towards the first cartilage. That is its outer end; its inner end runs forward from the squared part, and dilates into a bilobate process that lies against the fore front of the septum nasi. Also on the subnasal laminæ (*s.n.l.*) of the septum, where the trabeculæ retain somewhat of their primordial flatness, there is a small, seed-shaped, third labial ($u.l^c.$). Others than these I have not been able to find; and these are fullest at the ripeness of the embryo, and then waste away by the time the *Pipa* is adult.

All that remains of the hyoid arch (Plate 60. fig. 7) now is the fore end of the basi-hyobranchial bar (see in *Dactylethra*, Plate 58. figs. 4 & 5, *b.hy.*, *b.br.*). This part did not exist in the first stage (Plate 60. fig. 4); but the median bar has appeared with the disappearance of the "cornua," and already the metamorphosed branchials are the very true counterparts of what we see in the adult *Dactylethra* (Plate 58. fig. 5), save that the hyoid bands are gone.

Here the second basibranchial (*b.br.* 2) has now become cartilage (Plate 60. fig. 7, *b.br.* 2), and is, relatively, much larger than in *Dactylethra* (Plate 58. fig. 5, *b.br.* 2). In that species, as in *Pipa*, the first basibranchial is fenestrate, and the first and second branchials (*br.* 1, 2) are molten together and spread out into a large flat plate, pyriform here, oblong in *Dactylethra*. Here the third and fourth (*br.* 3, 4) branchials (their lower or hypobranchial ends) have formed the thyro-hyals, but they are not yet ossified as in the old *Dactylethra*. In *Rana temporaria* ("Frog's Skull," plate x. figs. 1 & 2, *th.*) there is no second basibranchial to underlie the larynx (*lx.*); and, seeing the relation of the second basibranchial of the Newt to its larynx, Professor Huxley has been led to doubt the correctness of my description (*op. cit.* p. 185) of these parts. *Pipa* and *Dactylethra* answer for me, for they possess both the median thyro-hyal of the Urodele and the paired thyro-hyals of the Anuran.

The remainder of this demonstration is by far the easier part, for the skull in the little ripe embryos had undergone the most striking and important changes. Its metamorphosis was fairly perfect, relative change of size or degree of hardening being nearly all that remained over to the growing *Pipa*.

Skull of Pipa monstrosa.—*Third Stage; the adult Toad.*

There can scarcely be a more remarkable skull than this; the sense of hearing would appear to be of more consequence to this Toad than that of sight, for the eyes are but little grown (Plate 62. fig. 1, *e*), whilst the organs of hearing are thrown out on long arms much as the eyeballs are thrown out in the Hammer-headed Shark. Therefore many things in the skull are contrary to what we find even in the nearest of kin, namely, the other tongueless kind (*Dactylethra*, Plate 59). The general appearance of the skull suggests the idea of a log-house hastily thrown together, and not a fitly framed structure compacted together with the utmost architectural care and skill. A little of the old cementing cartilage there is, and strong bands and sheets of fibrous tissue in places; but in the main it is made up of slabs, and planks, and bars, placed lengthwise, slanting, and across. These, moreover, look as though they were fresh from the tools of the hasty framer.

Behind (Plate 62. fig. 1–4, *oc.c.*) the occipital condyles have their faces turned the contrary way; they look outwards, and are unusually flat. The dense, stout occipital ring is all bony, save below (fig. 2, *b.o.*); for, true to its Batrachian character, it has a soft basioccipital. The great, outstanding occipito-otic "arms" are one single mass of bone, although on the under face there is a second transverse slab in front of the other and beneath it; this is, however, merely a part of the pterygoid (*pg.*). The exoccipital (*e.o.*), jagged and somewhat bowed, touches the quadrate (*q.*) outside; the prootic region of the bone (*pro.*) stretches to the far-off tympanic apparatus. Wedged in between the inner edges of the exoccipitals, we see an elegant, convex tongue of the parasphenoid (*pa.s.*, its old spike, Plate 61. fig. 3). From thence, by step-like notches and projections, this under slab gains its full breadth under the 5th nerves, and retains it until it gains the palatine "wings." Then it runs, with a rounded margin, rapidly inwards, and ends in the front spike, which runs a little under the septum nasi; this spike is split at its end. Under this part in *Dactylethra* there is a vomer (Plate 59. fig. 2, *v*), but, with Professor HUXLEY, I have failed to find one in *Pipa*.

At this part there are remaining tracts of cartilage, and the ethmoidal belt runs forwards, much narrowed at the septum nasi (*s.n.*), which is thick and rounded below and above; but not alate, except in front. The extreme flattening of the face has caused the septum nasi to be a very low wall, especially in front; in this type the depressed form attains its greatest degree in age, in *Dactylethra* in the embryo.

The small alæ of the septum (Plate 61. fig. 5, *s.n.l.*) are gone, but now there can be seen an azygous process projecting into the front wall, namely, the prenasal (*p.n.*); it is a rounded spike. The depressed septum becomes altogether almost rounded in front, and the alinasal folds (*al.n.*), as seen from beneath, might be supposed to grow from the lower margin of the septum; but they are its roof, but are a very short distance from the floor (compare Plate 60. fig. 6, *al.n.*, with Plate 62. figs. 7, 8, *al.n.*). Now, instead of showing a convex margin, emarginated slightly in the middle, the front is trifid, the middle projection being the spiked prenasal, and the lateral parts thick, cupped lobes, whose concave front face is beset with strong subcutaneous fibres. From this part they throw out, and run gently into the top of the septum within, whilst without they run backwards and outwards, as long, terete, nearly straight "cornua trabeculæ," which end beyond the inside of the prepalatine lobe (figs. 7, 8, *c.tr.*, *pr.pa.*).

The manner in which these trabecular bars have retained their primary recurrent form, and yet have merely become attenuated, is noteworthy (Plate 60. figs. 3, 5, 6, and Plate 62. figs. 7, 8, *c.tr.*). They now form nearly a right angle with each other, and one of less than 45° with the septum.

Here there is no "girdle-bone," the chondrocranium dies out a little behind the ethmoidal region, and the roof and floor meet at the sides (fig. 4). But the unossified cartilage binding the ethmoid with the palatine is guarded by a strong wing of bone, the palatine (*pa.*), which grows out from the angle of the parasphenoid. A vessel passes through the bone where this is given off, and there is an appearance of its former distinctness; this wing, we saw, was developed separately. The ethmo- and prepalatine (*eth.*, *pr.pa.*) regions are present, but the postpalatine bar has been absorbed: if the ethmopalatine had been segmented off from the ethmoid, as in the Common Toad, then we should have had the free antorbital cartilage of *Menobranchus* and *Proteus* (Plate 54. figs. 3, 4, *e.pa.*; and HUXLEY, "On *Menobranchus*," *op. cit.* plates xxix. & xxx. *A.o.*).

Here it curves forwards because of the original Batrachian form of this arch; there it has no prepalatine spur, and naturally grows backwards, as seeking its next segment the pterygoid. The long tape-like pedicle, and the stout, subconical otic process (Plate 60. figs. 5, 6, *pd.*, *ot.p.*) cannot be traced as distinct processes now; the former is lost, as a process, along the front of the outstretched otic masses; and the latter (*ot.p.*) may be seen as cartilage between the squamosal and the fenestra (figs. 1, 3, 4, 9, *sq.*, *pro.*). With this out-thrusting of the auditory mass the quadrate (*q.*) is carried from the head a great distance, and is, in its hinder margin, opposite the occipital condyles. Its own condyle (figs. 2, 3, 4, 9) is sinuous (cylindroidal), and much of its substance is ossified as a true quadrate bone, enclothed with the squamosal (*sq.*). The facet has a pyriform outline, with the narrow end looking forward and outward; its broad end is below and in front of the posterior margin of the quadrate bone. In front of and below the otic process, the pterygoid (*pg.*) passes forwards nearly at a right angle with the transverse otic masses. This front part of the pterygoid is a large, leafy bar, with oblique fibrous markings; it is narrower and thicker behind, broader and thinner forwards; the outer edge (figs. 2 & 4) is grooved and contains some unchanged cartilage, its inner edge is soft. This falcate part is grooved below for the jugal end of the maxillary (*m.x.*), which it largely overlaps; their overlapping ends are pointed. This fore part is the *shaft* of the hammer-shaped pterygoid; it joins the *head* in a curved manner, running inwards, and the inner part of the head is the longer. Where the inner part clasps the coalesced and undistinguishable pedicle, there is, proximally, an elevation of the bone; it then runs in and stops short suddenly, leaving exposed the roughly ossified pedicle and contiguous part of the auditory capsule. Further back it is longer and more splintery, and reaches one of the steps of the parasphenoid. Behind that spike there is another tract of rough inner bone, and then the long exoccipital; the two bones, externally, fit by a squamous suture. The short end of the "head" runs outwards and backwards, strongly clamping the inner face of the quadrate.

The free mandible (figs. 5, 6) is a strongly bent, rib-like structure; the condyle is also cylindroidal, and seen from above (fig. 5) it has a squarish outline, and is traversed by a concavity; it is obliquely set on the top of the inbent, solid "articulare" (*ar.*), which bends outwards beneath the condyle. The articulare runs to within a short distance of the chin, and is covered by the dentary (*d.*), which is two thirds its length; the transverse front ends of the dentaries form a fibrous symphysis, without an "os Meckelii;" the cartilage is almost entirely changed.

The auditory masses, as seen from above and behind (figs. 1 & 3), are, with their intermediate occipital arch, a most rugged and strong structure.

Already, in the ripe young (Plate 61. fig. 2), these parts were like small stony fruits, the occipital arch being thoroughly ossified by ankylosis of the exoccipitals above; but now it asks some care, if the parts are to be interpreted. The foramen magnum (fig. 3, *f.m.*), like the entrance of some stony cave, is surmounted by rough, projecting blocks of bone. The lower pair of these jutting snags overarch the 9th and 10th nerves (9, 10) in their passage. Above, these angular and jagged masses show the epiotic eminence (*ep.*); formerly (Plate 61. fig. 2) a gentle eminence covered the ampulla and arch of the posterior semicircular canal. Looking above (fig. 1) we see that the arches are now covered by three bony crests, and the interspaces are dug into deep fossæ; the whole bone being excavated, as in certain Osseous Fishes. The ridge covering the horizontal canal runs into the epiotic eminence behind; but in front it runs obliquely outwards as far as to the "tegmen." This crest overhangs the channel in which the "portio dura" (figs. 1, 3, 7), which has escaped from the "trigeminal" (leaves it at the foramen ovale), runs, once more free, along the grooved surface of the bone, to pass *over* the columella.

The vestibular portion of the membranous labyrinth runs outwards, and reaches the stapes in the postero-superior angle of the extended auditory mass.

The primary absorption of the cartilage for the fenestra ovalis (Plate 60. fig. 3, *fs.o.*) was below, and almost central; now the oval, funnel-like fenestra is in the centre of a thick ring of cartilage; it looks equally downwards and forwards, and its larger end, the *prefenestral fossa*, is below and in front. The cartilage above the fenestra belongs to the prootic region, that below it to the opisthotic; there is no *fenestra rotunda* as there is no *cochlea*. Fitting into this auditory funnel is the oval stapes; its inner part is a subconical wedge, its outer part flat; it is relatively small, but its outer face much exceeds that which closes the fenestra. The next part of this truly elegant apparatus is like a *flute-key*; it takes the same direction as the long axis of the stapes, namely downwards and forwards. Here let the reader compare the figure (9) with that of the auditory chain of the Pig ("Pig's Skull," plate xxxvi. fig. 3, *inverting* that plate). Here there is no interhyal (*i.hy.*), and the malleus exists in another form, namely, in the mandible; the stapes, also, has in the Batrachian no fenestrate crest. But the elegant, elbowed rod of bone, sticking, limpet-like, to the face of the stapes, and composed of two osseous centres, these correspond in both. The upper bone is the os orbiculare (*o.ob.*) or interstapedial (*it.st.*); the outer the long crus of the incus (*l.c.i.*) or the mediostapedial (*m.st.*): one difference there is, and not greater than is seen between *Bufo* (Plate 54. figs. 7, 8) and *Pipa*, and that is that the discoid part in the Pig is one centre, and the long crus another; here, in *Pipa*, the discoid part is one with the bar up to the "elbow," and then commences the other bone (*m.st.*). The body of the incus (*i.*) is represented in *Pipa* by a cartilaginous part, not anvil-shaped, but like the leaf of *Nymphæa*; and the short crus (*s.c.i.*) is here represented by a strong fibrous ligament. Another shorter ligament is seen on the underside of the columella; these attach the membrana tympani, "annulus," and extrastapedial to the front margin of the stout ring of cartilage that encircles the fenestra. If all this structure has an *artificial*, and as it were manufactured appearance, equally so has the part in which it is set. As in the common kinds, the squamosal (*sq.*) has a descending body and a double head; the posterior part of the head overlaps the tegmen and otic process, and on the anterior part of the head the drum-membrane and its ring are attached (see in *Bufo*, Plate 54. fig. 7). Here (Plate 62. fig. 9) the squamosal (*sq.*) is most carefully moulded over the front and outer face of the reverted oblong quadrate mass. It leaves the junction of the tegmen and otic process uncovered, has a scooped margin, where it binds against and then retreats from the stapedial encircling ring; it then, by steps, reaches the hinder face of the quadrate, leaving its margin uncovered, but it well enwraps it further forwards, down to the condyle, and round its front edge, ensheathing it by a beak-like folded plate. This is not all, for the middle of its outer face is hollowed into a valley which is bridged over by the columella; and this valley ends in front in an outstanding basin, suboval in shape, but apiculate, and with a fixed base. This *cochleate* process of the squamosal has its edges lined with the almost perfectly circular annulus, whose open part is traversed by the mediostapedial. The apex of the scooped squamosal process projects in front of the annulus; its cavity contains *air*, which it derives from the Eustachian tube, this part being built in the first postoral cleft, and utilizing, as it were, that old chink for these new auditory purposes. Behind the ethmoid, and in front of the auditory masses, the chondrocranium soon dies out; the parasphenoid has a bevelled upper edge, and the fronto-parietal slab has a raised and thick superorbital ridge, and a large, low, slanting orbital face (fig. 4, *pa.s.*, *f.*). In front the frontal dips into a thick *antorbital* process (figs. 1 & 4, *f.*), which is overlapped by the large nasal (*n.*).

This huge fibrous frontal is very *ichthyic*; it is divided into three processes in front, the antorbital and ethmoidal processes, the outer broad, and the inner sharp. In the very middle it is hollow, and from thence there run a small groove directly forwards, and a pair of deep grooves obliquely along the antorbital lobes. Behind there is a low thick ridge with crescentic scooping at its sides. Narrowing from the antorbitals it then sends out a short thick postorbital process; from that part the parietal region (*p.*) narrows, by steps, between the auditory masses, to overlie the occipital arch.

Half as much space is covered by the imbricating "nasal" wedges (*n.*); these are large, roughly triangular bones, with rounded corners and a notched outer margin; this notch, nearer the inner than the outer angle, is for the external nostril (*e.n.*). The nasals are gently convex above, and very fibrous. Running along their outer margin (figs. 1, 4, 7) we see under their edge the preorbitals (*p.ob.*) and the septo-maxillaries (*s.mx.*); the latter are now seed-shaped and flat, and bordered by the remains of the larger upper labial (*u.l.*); the former are flat, much larger than the septo-maxillaries, and ending behind in an inturned sharp hook. As the nasals meet above, in the front part (fig. 1, *n.*), so the premaxillaries meet below (fig. 2, *px.*); they, like the maxillaries (*mx.*), are entirely on the under surface. Together, the premaxillaries have the form of the letter W; they have each a pyriform outline, with a sharp stalk, the palatine process. A similar process grows from the maxillary (*mx.*), as this bone overlaps the premaxillary in front and joins it by a sinuous margin. The anterior part of the rounded and thickish outer edge of the maxillaries help the others to make a semicircular outline to the front of the face; but the maxillaries then bend in, and as gently bend out again where they have met the pterygoids. Their jugal process is a pointed spatula, which lies obliquely beneath the leafy part of the pterygoid, in its groove. The eyeball (*e*) just reaches, and a little overlies the junction of these bones (fig. 1). The "suborbital fenestra" is here finished in front by the maxillary; the cartilage is absorbed at that part.

The only important change to be looked for in the débris of the branchial arches would be the ossification of the thyro-hyal bar (Plate 60. fig. 7, *br.* 2, 3); this part had been removed in Professor HUXLEY's specimen.

Concluding Remarks.

In the prosecution of this special kind of research I am under the necessity of keeping to the driest morphological details, making comparisons from time to time of like parts in diverse types.

It was a good day for this work when Professor HUXLEY resumed his researches in the Amphibia (winter of 1873–74), for that gave rise to a discovery of the errors in my former paper on the Frog's Skull. Finding him thus engaged, and receiving his criticism, I gladly took up the amphibian types again, working as much as possible in concert with him, and especially reexamining all those points on which we differed at that time.

The result has been all but unanimity; and my own mind is still open to further modification of views, when evidence of any unsafeness of deduction or of incorrectness of observation shall be forthcoming.

Professor HUXLEY has acknowledged to me the extreme arduousness of this kind of work, and we both agree that the Amphibia, and the Anura or Batrachia especially, are the most instructive, albeit they present the knottiest problem of all the Vertebrata.

At present I defer giving any special summary: in the beginning of the present paper I have thoroughly sifted my older work, and it need not be done twice over. Here it is seen that the Frogs differ in important things from the Toads; the Toads that have *a tongue* from the "aglossal" types; and that the two types of tongueless Toads differ from each other in many instructive particulars.

Ready to follow this paper is one which will treat of the stages of the Bull-frog (*Rana pipiens*) and the Paradoxical Frog (*Pseudis paradoxa*); but to these I wish to add the Tree-frogs, the Bombinator Toads, and sundry other types of Batrachia, to say nothing of the Salamandrian or "Urodelous" Amphibia.

In my former paper (p. 202) I spoke of the light that the Batrachian skull sheds on that of the Mammalia; surely that assertion is not in the least belied by what is here written concerning the *marsupial*, *gill-less* young of the Surinam Toad.

I am not unaware that this kind of labour may seem to be the mere heaping up of details; to speculative minds, certainties and systems are demanded from the first; such certainties and such systems end in doubt and scientific confusion.

But I believe that when certainty has been painfully attained (although it be through much doubt and long-continued research), then a *system* will grow spontaneously, as a real living thing, and not as a mere human fantasy.

All the confusion arising from my mistaken view of the early coalescence of the upper part of the hyoid with the mandibular pier is now gone, and the cartilage which was supposed to be segmented off from that adhering half-bar, is seen now to become the cartilaginous *ear-ring*.

The important discovery, by Professor HUXLEY, of the *late* appearance of the "columella" was extremely confusing to me at first; it is now used as a key to unlock the most difficult "wards" of these organisms.

It is evident that we have in the Batrachian hyoid arch that which lays its hand, as it were, upon the hyoid arch of both Fish and Mammal, and will soon explain both. Although the stapes is not *segmented out* from the ear-capsule of the "Anura" (though it is so formed in the "Urodela," but formed later), yet it is *periotic* in nature, a hypertrophied and chondrified tract of the perichondrium of the auditory cartilaginous wall, just where that wall thins itself and opens towards the vestibule.

It appears to me that *Dactylethra* and *Pipa*, and even the Common Toad, by not cutting off the "interstapedial" as a distinct cartilaginous segment, but merely differencing it as a large, *even the larger*, shaft-bone, have shown that their "columella" is made up of a proximal "hyomandibular" and a distal "symplectic."

The ultimate disposal of the large cartilages of the suctorial mouth of the Tadpole (the "labials") has made the interpretation of the nasal capsule easy; we now know what has budded out from the trabeculæ (there are no distinct "paraneural" cartilages to the nasal sacs in the Anura), and what has been superadded to the labyrinth by the cartilages of the oral ring, in their metamorphoses.

Now that we know the structure of the cartilaginous skull when it is first fairly a "chondrocranium," and that the two myotomic masses are not accompanied at first by paraneural cartilages, but that the apices of the trabeculæ cling to the apex of the notochord, distinct at first, and afterwards becoming confluent with the "paraneurals"—all these things, being true, will lead to further truth.

Some of these things were seen by Professor HUXLEY long ago in the Newt, and lately in the Axolotl; and by me afterwards, as the result of the most difficult demonstration ever made by me in the early larva of the Common Toad.

Finally I may remark that not "old experience," only, is helping us, but new and more delicate means and appliances in our method of research.

DESCRIPTION OF THE PLATES.

PLATE 54.

Rana temporaria.—*Adult*.

Fig. 1. Fore part of endocranium (partially ossified chondrocranium), seen from above. $\times 6$ diameters.

Fig. 2. The same, lower view. $\times 6$ diameters. (In this and the next figure the outer bones are faintly shown.)

Bufo vulgaris.—*Adult.*

Fig. 3. Endocranium, seen from above. ×4 diameters.
Fig. 4. The same, lower view. ×4 diameters.
Fig. 5. Part of the same cranium, seen from the front. ×4 diameters.
Fig. 6. Part of the facial region (ectocranium), with labial; side view. ×8 diameters.
Fig. 7. Auditory region of skull, with upper edge partly pared away. ×4 diameters.
Fig. 8. Columella and stapes from the same; inner view. ×8 diameters.

PLATE 55.

Bufo vulgaris.—*Tadpoles and young.*

Fig. 1. Chondrocranium of a Tadpole, 4 lines long; 1st stage; upper view. ×40 diameters.
Fig. 2. The same, side view. ×40 diameters.
Fig. 3. Chondrocranium of a Tadpole, $5\frac{1}{2}$ lines long; 3rd stage; upper view. ×35 diameters.
Fig. 4. Chondrocranium of a Tadpole, 5 lines long; 2nd stage; half of lower view. ×35 diameters.
Fig. 5. Chondrocranium of a Tadpole, 8 lines long; 4th stage; part of lower view. ×20 diameters.
Fig. 5^a. Part of same region of fenestra ovalis. ×200 diameters.
Fig. 6. Chondrocranium of young Toad, 5 lines long; 5th stage; part of inner view. ×15 diameters.
Fig. 7. Part of the same. ×45 diameters.
Fig. 8. A view, like fig. 6, of a young Toad, 8 lines long. ×15 diameters.

PLATE 56.

Dactylethra capensis.—*Youngest Tadpole, whose total length was* $1\frac{1}{3}$ *inch.*

Fig. 1. Upper view of Tadpole; 1st stage. ×4 diameters.
Fig. 2. Lower view of Tadpole. ×4 diameters.
Fig. 3. Side view of Tadpole. ×4 diameters.
Fig. 4. Chondrocranium of same, upper view. ×10 diameters.
Fig. 5. The same, lower view. × 10 diameters.
Fig. 6. Mandibles and hyoid cartilages of the same. ×10 diameters.

PLATE 57.

Dactylethra capensis.—*Tadpoles* $1\frac{2}{3}$ *inch long.*

Fig. 1. Chondrocranium of Tadpole, upper view, 2nd stage. ×6 diameters.
Fig. 2. The same skull, seen from below. ×6 diameters.

Dactylethra capensis.—*Tadpoles at their largest size.*

Fig. 3. Chondrocranium of Tadpole, upper view; 3rd stage. ×6 diameters.
Fig. 4. The same skull, seen from below. ×6 diameters.

PLATE 58.

Dactylethra capensis.—*Tadpole: young and adult.*

Fig. 1. Hyoid and branchial cartilages of one side, from below; 2nd stage. ×6 diams.
Fig. 2. Cranium of young *Dactylethra* with large legs and tail; 4th stage. ×10 diams.
Fig. 3. The same skull, seen from below. × 10 diameters.
Fig. 4. Mandible and hyoid of the same skull. × 10 diameters.
Fig. 5. Hyoid and branchial arches of the adult *Dactylethra*, upper view. ×3 diams.
Fig. 6. Mandibular ramus of same, inner view. ×3 diameters.

PLATE 59.

Dactylethra capensis.—*Adult.*

Fig. 1. Chondrosteous cranium, with roof-bones removed; upper view. ×3 diameters.
Fig. 2. The same, seen from below. ×3 diameters.
Fig. 3. The same, side view. ×3 diameters.
Fig. 4. The same, seen from behind. ×3 diameters.
Fig. 5. Endocranium, front part, seen from above. ×3 diameters.
Fig. 6. The same, lower view. ×3 diameters.
Fig. 7. Auditory region of same skull; inverted view, with dislocated "columella." ×4½ diameters.
Fig. 8. Framework of auditory region; side view. ×4½ diameters.
Fig. 9. Front view of quadrate region, with projecting parts removed. ×4½ diameters.

PLATE 60.

Pipa monstrosa.—*Embryo ¾ inch long, and young (ripe), 6½ to 7½ lines long.*

Fig. 1. Embryo attached to yelk-mass; side view. ×5 diameters.
Fig. 2. The same; upper view. ×5 diameters.
Fig. 3. Chondrocranium of the same; lower view. ×15 diameters.
Fig. 4. Detached visceral arches of same; upper view. ×20 diameters.
Fig. 5. Chondrocranium of larger young *Pipa*; upper view. ×14 diameters.
Fig. 6. The same skull; lower view. ×14 diameters.
Fig. 7. Mandible and branchial arches of the lesser young *Pipa*; upper view. ×14 diameters.
Fig. 8. Section through nostrils of larger young *Pipa*. ×30 diameters.

PLATE 61.

Pipa monstrosa.—*Embyro and ripe young.*

Fig. 1. Orbital region of chondrocranium (embryo); upper view. ×20 diameters.
Fig. 2. Cranium of larger young *Pipa*; upper view. ×14 diameters.
Fig. 3. The same skull; lower view. ×14 diameters.
Fig. 4. Part of fig. 2; nasal region. ×42 diameters.
Fig. 5. The same, with investing bones removed. ×42 diameters.
Fig. 6. Part of fig. 2 (auditory region). ×42 diameters.
Fig. 7. Part of fig. 3 (ethmo-palatine region). ×42 diameters.

PLATE 62.

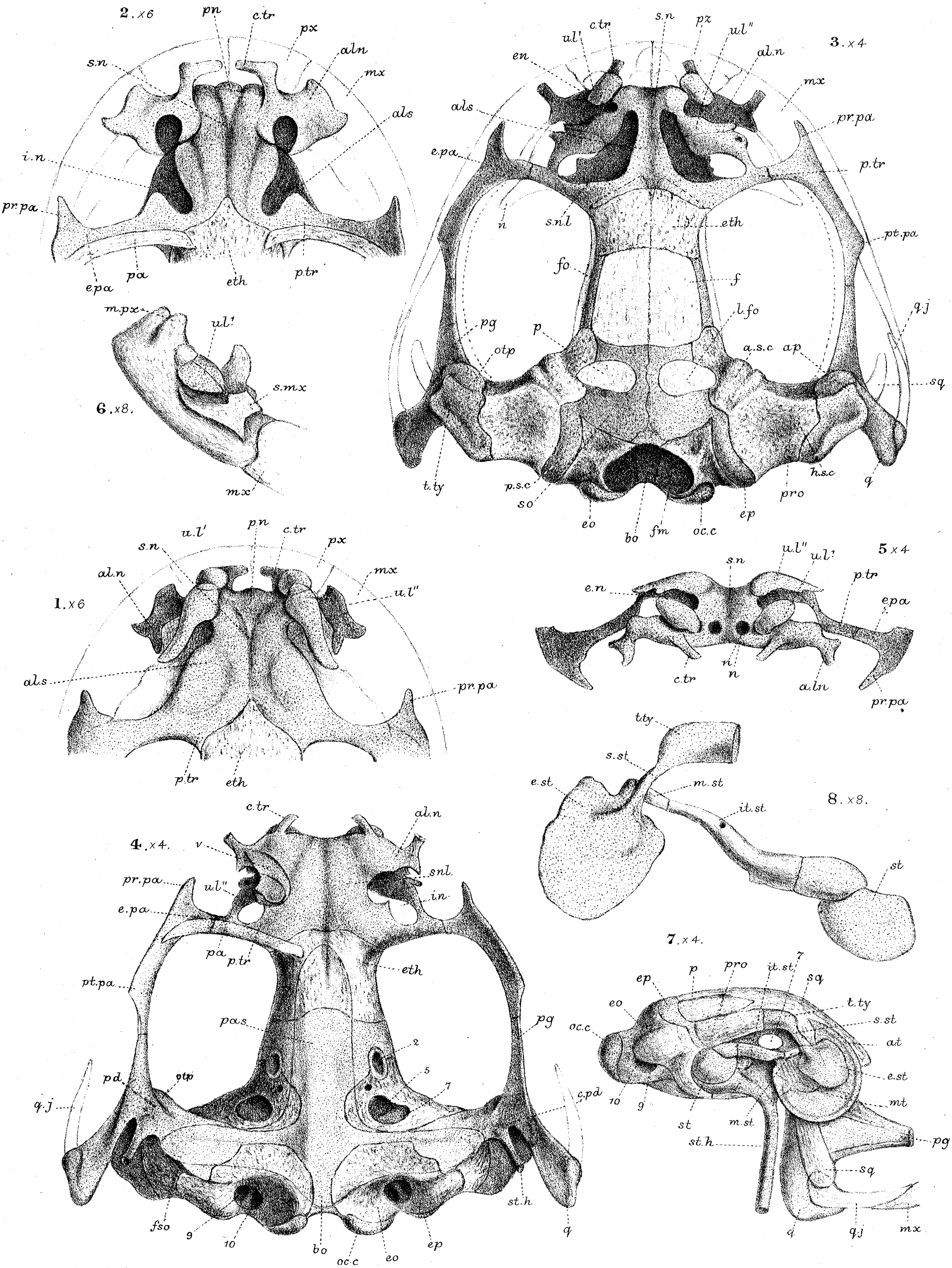
Pipa monstrosa.—*Adult.*

Fig. 1. Cranium; upper view. ×2 diameters.
Fig. 2. The same; lower view. ×2 diameters.
Fig. 3. The same; end view. ×2 diameters.
Fig. 4. The same; side view. ×2 diameters.
Fig. 5. Mandible; upper view. ×2 diameters.
Fig. 6. The same; side view. ×2 diameters.
Fig. 7. Fore part of skull, with investing bones in outline; lower view. ×2 diameters.
Fig. 8. Cranial elements of the same part; lower view. ×4 diameters.
Fig. 9. Temporal region of skull (part of fig. 4). ×6 diameters.

The *abbreviations* are the same in the present paper as in the last, with a few exceptions and a few additions. The terms "suprahyomandibular" (*s.hm.*) and "infrahyomandibular" (*i.hm.*) are dropped, as they were given under a misconception as to the nature of the parts. The first (*s.hm.*) has now to be lettered as the "annulus tympanicus" (*a.t.*), and the second (*i.hm.*) is known to be the pedicle of the mandibular pier (*pd.*). The special term "columella" (*co.*) is here added—also "preorbital (*p.ob.*), "prenarial ligament" or "lamina" (*p.n.l.*), "recurrent cartilage" or "lamina" (*rc.c.*), "otic process" (*ot.p.*), "thyroid gland" (*tr.g.*), "thymus gland" (*tm.g.*); the "quadrate *bone*" (*q.*) is here the "quadrato-jugal" (*q.j.*); the external valvular process of the nostril (*v.e.n.*) is here the "first upper labial" (*u.l.*).

In this paper the distal part of the "columella" is the "symplectic," and that term is erroneously applied to a part of the mandible in the former paper.

The nerves are also numbered somewhat differently, according to the new notation; the "portio mollis" is now the 8th, the "glossopharyngeal" the 9th, and the "vagus" the 10th.



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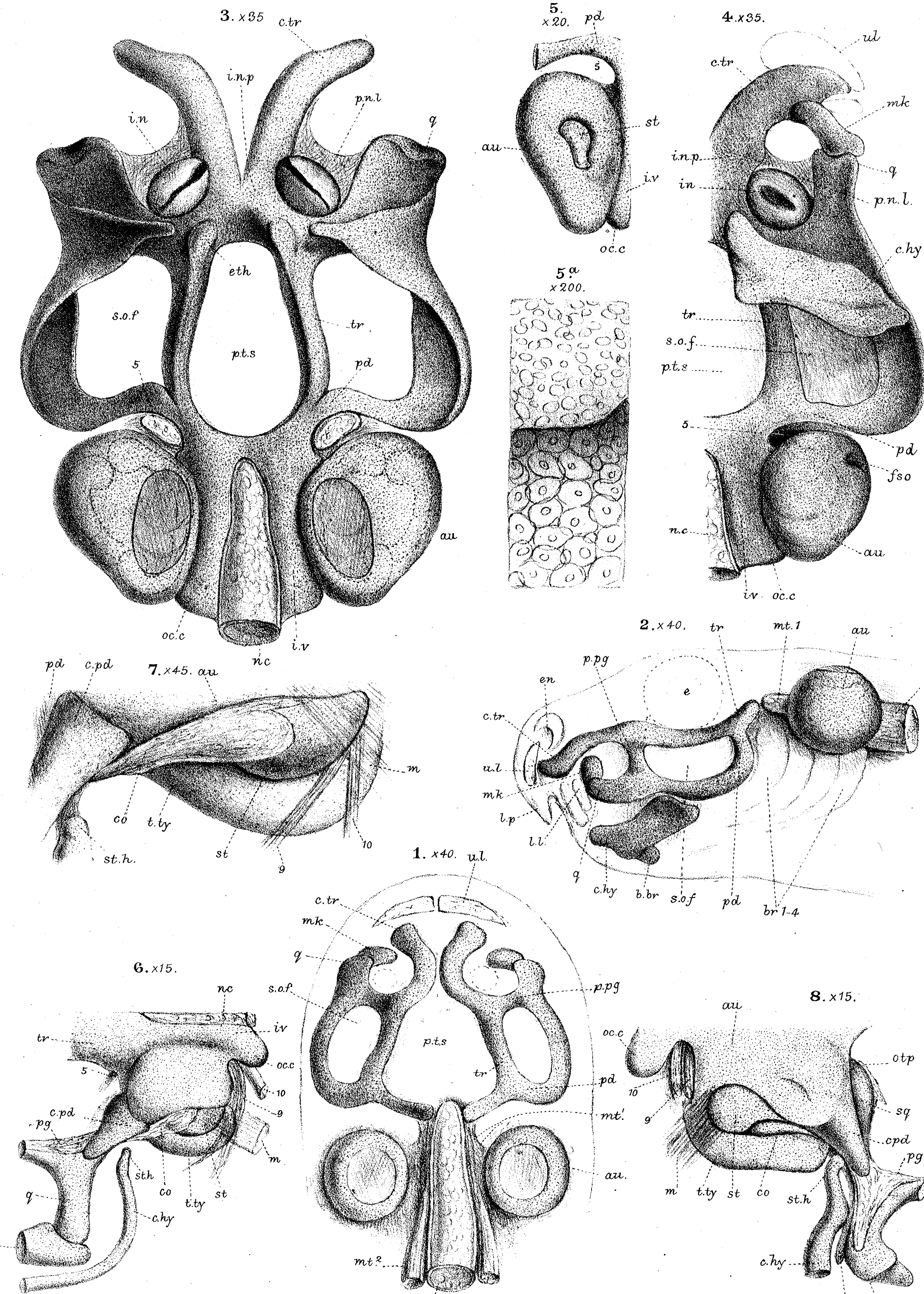
W. West & Co. imp.

Figs. 1—2, Rana temporaria. Figs. 3—8, Bufo vulgaris.



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W. West & Co. imp.

Bufo vulgaris.

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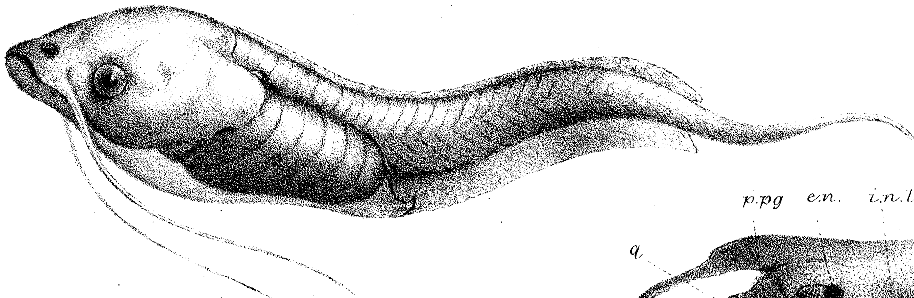

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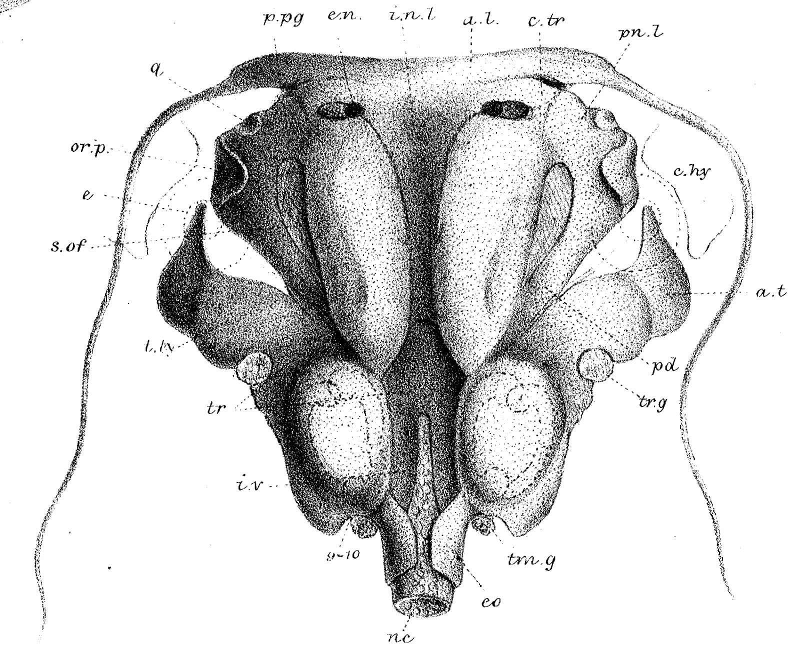

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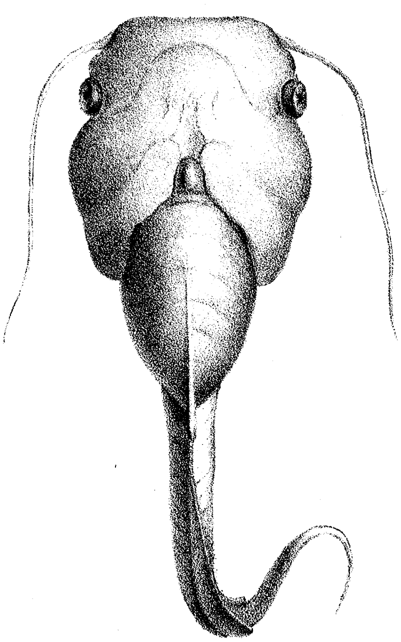

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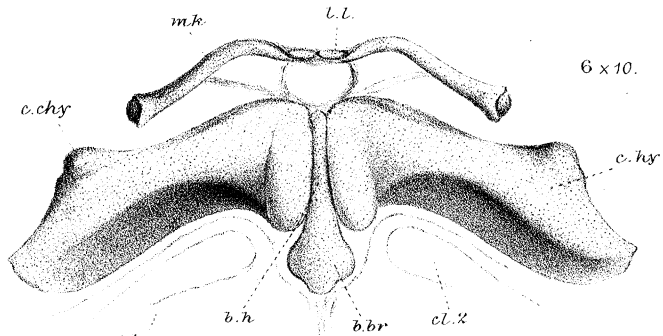

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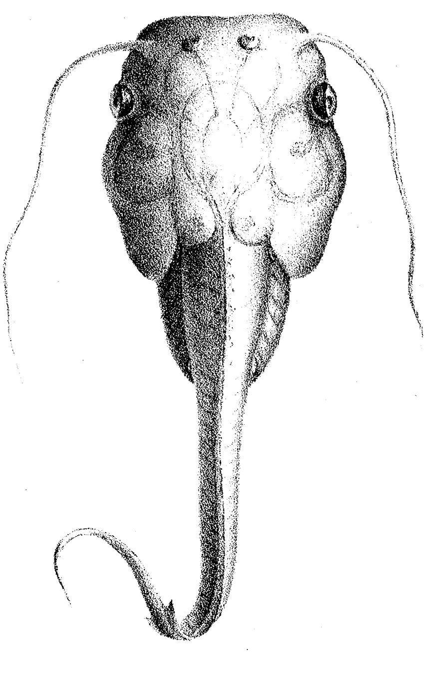

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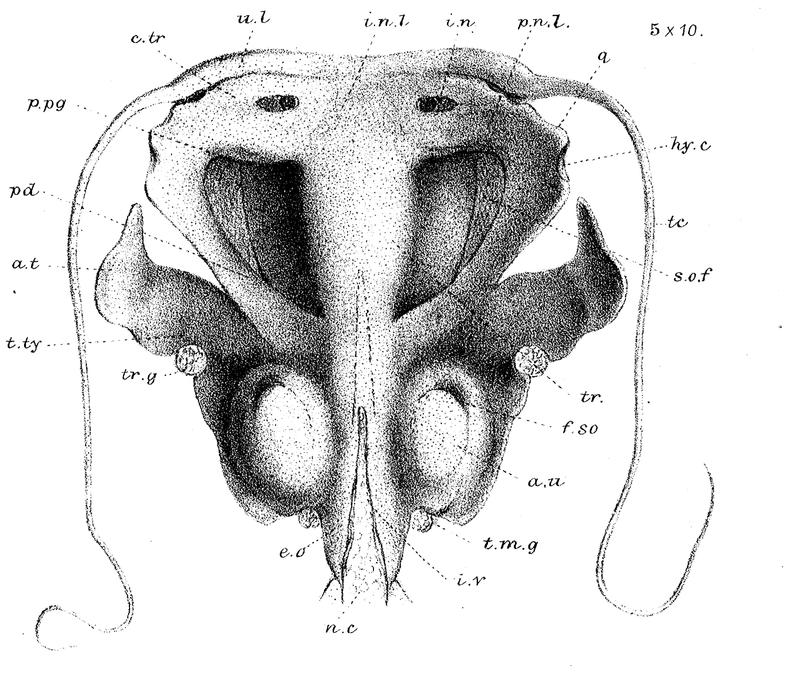

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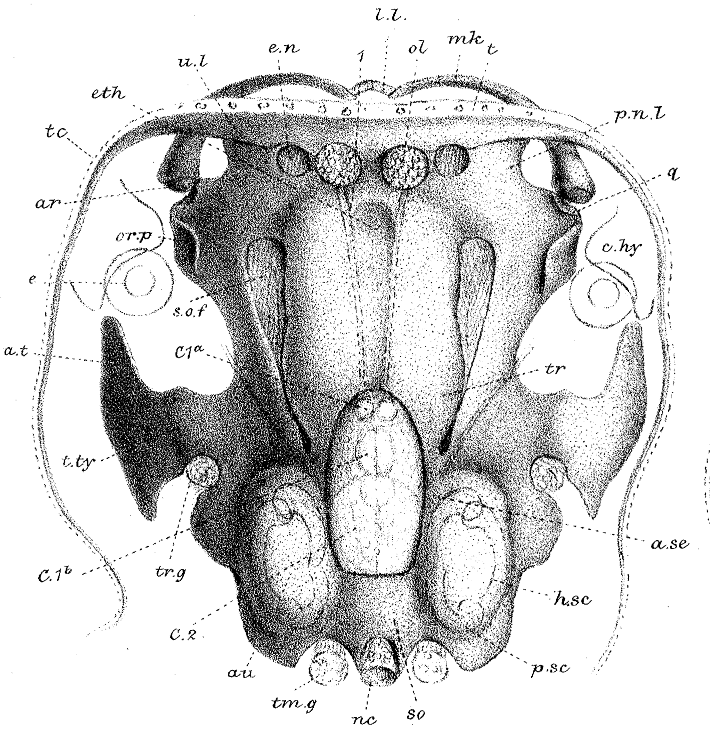
W. West & Co. imp.

Dactylethra capensis.

1 × 6



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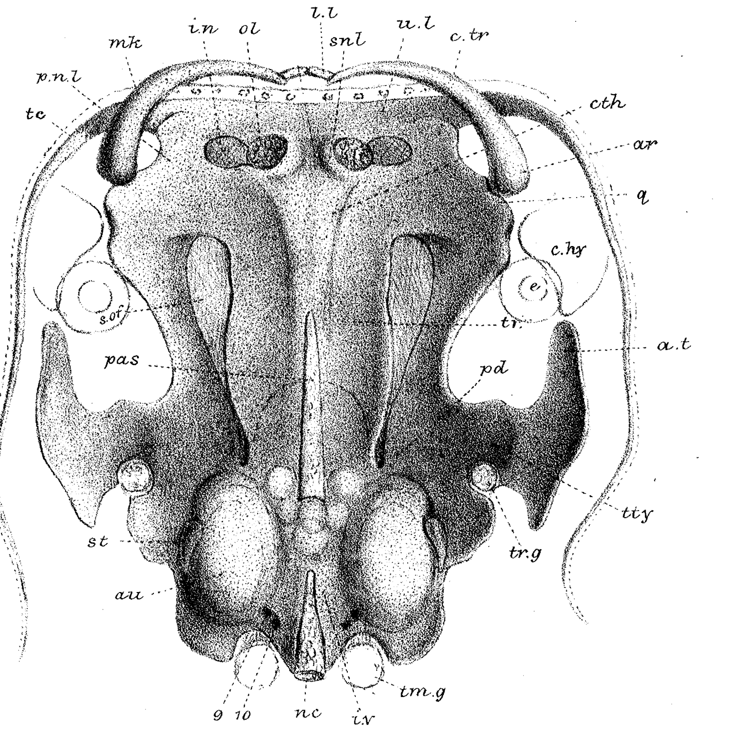
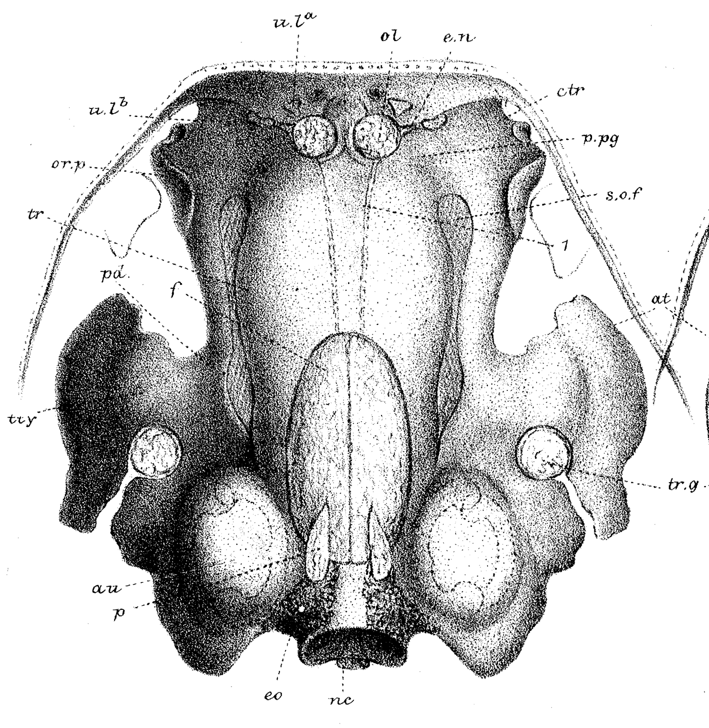


3 × 6



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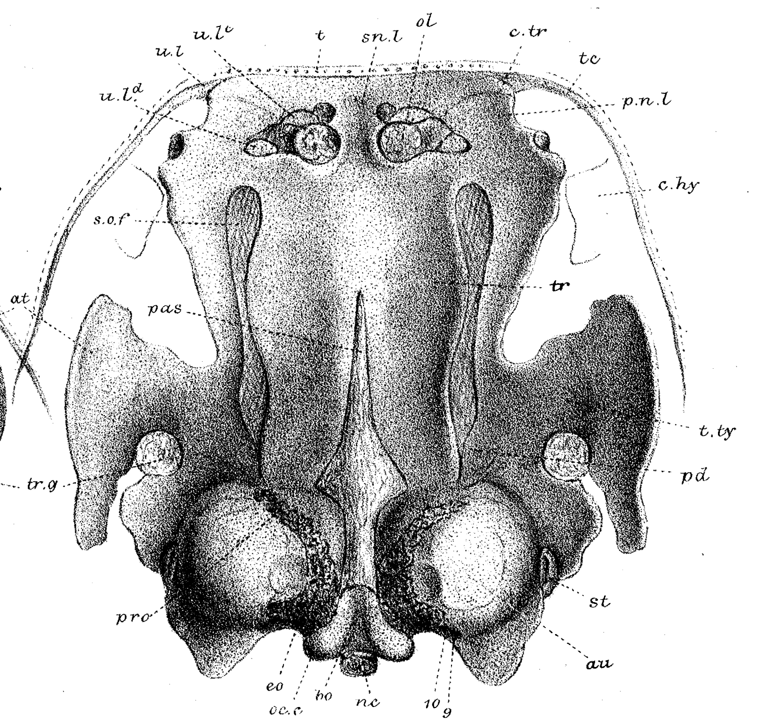
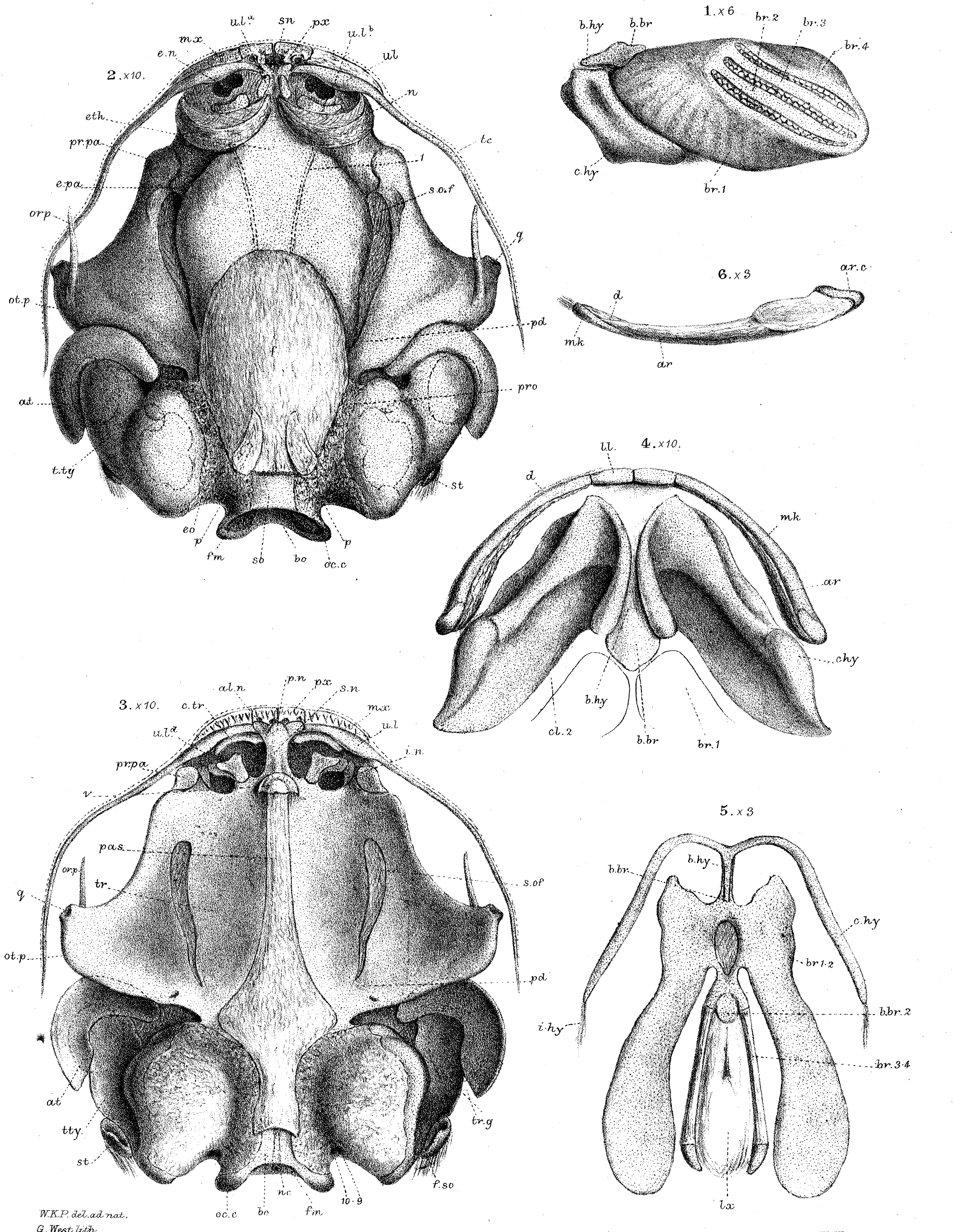


W. K. P. del ad nat.
G. West lith.

W. West & Co. imp.

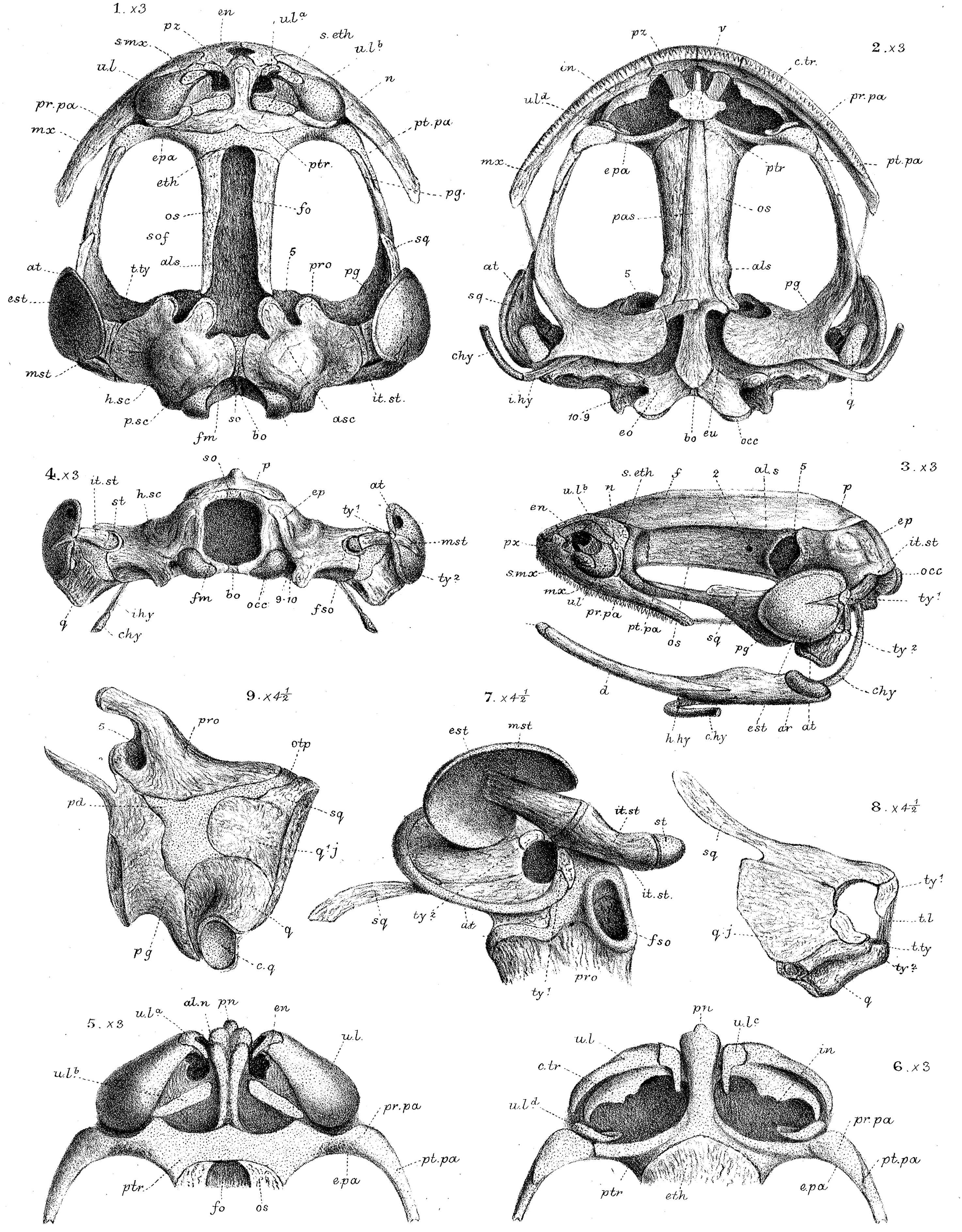
Dactylethra capensis.



W.K.P. del. ad nat.
G. West lith.

W. West & Co. imp.

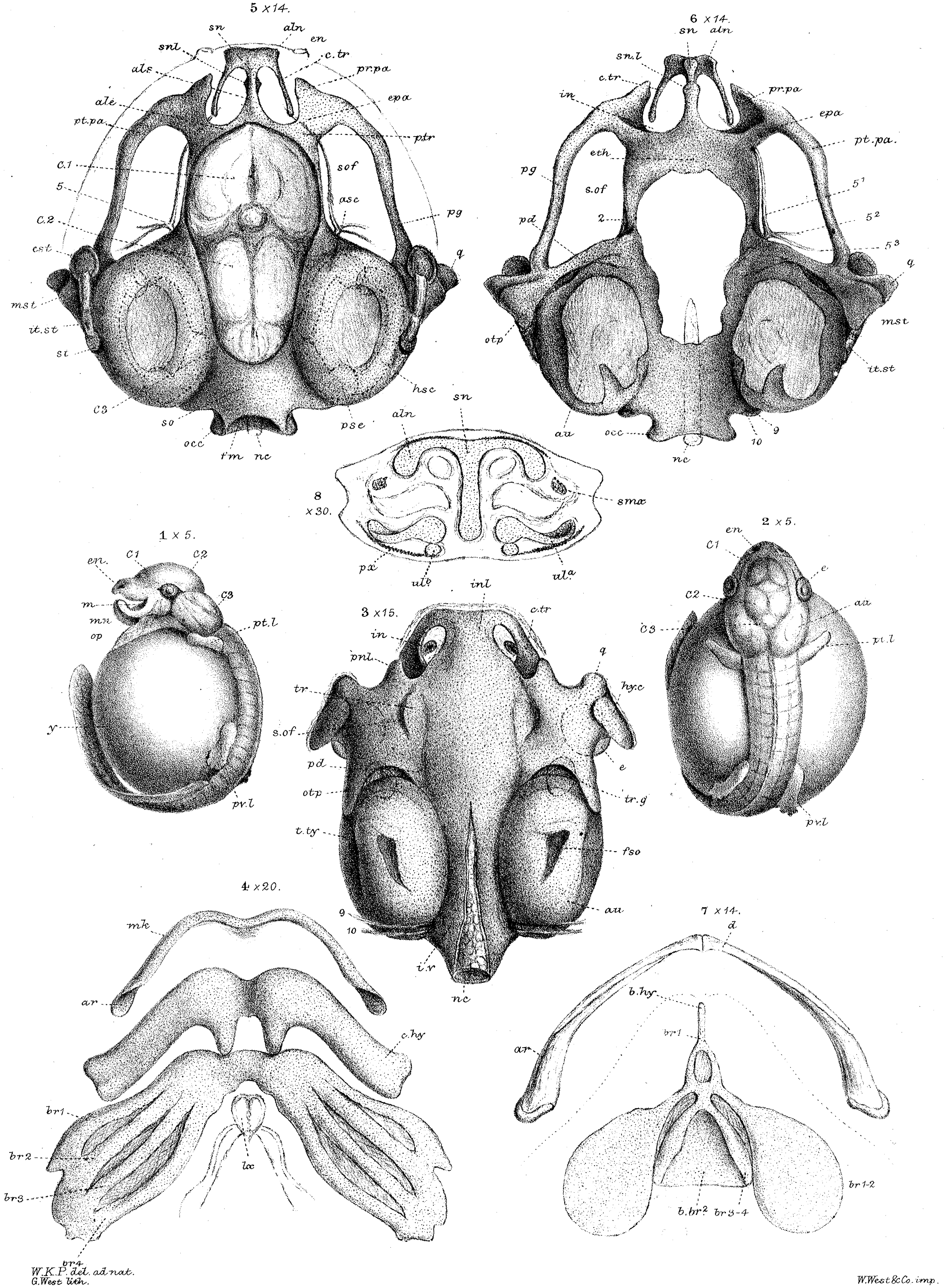
Dactylethra capensis.



W.K.P. del. ad nat.
G.West lith.

W. West & Co. imp.

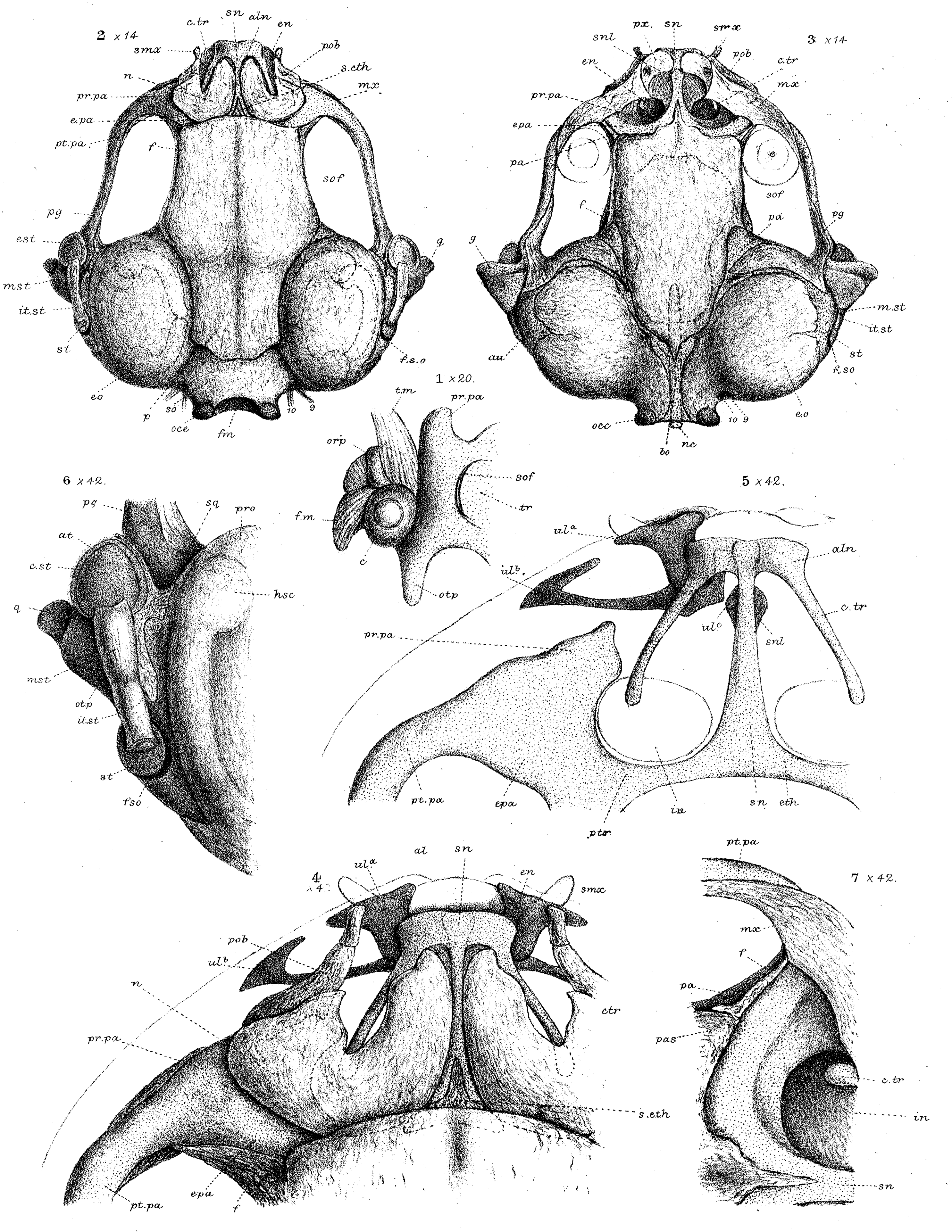
Dactylethra capensis.



W.K.P. del. ad nat.
G.West lith.

W.West & Co. imp.

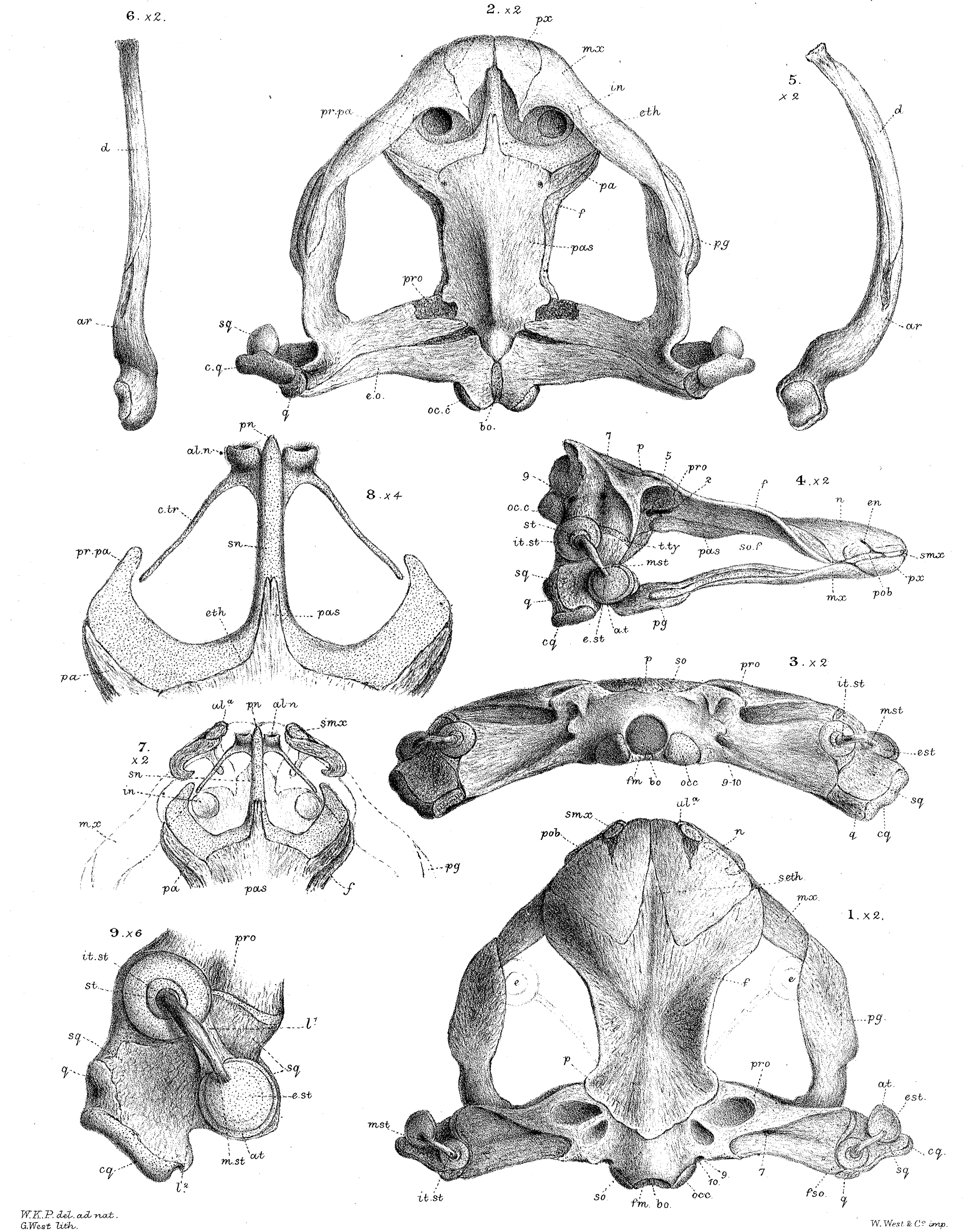
Pipa Monstrosa.



W.K.P. del. ad nat.
G West lith.

W.West & Co. imp.

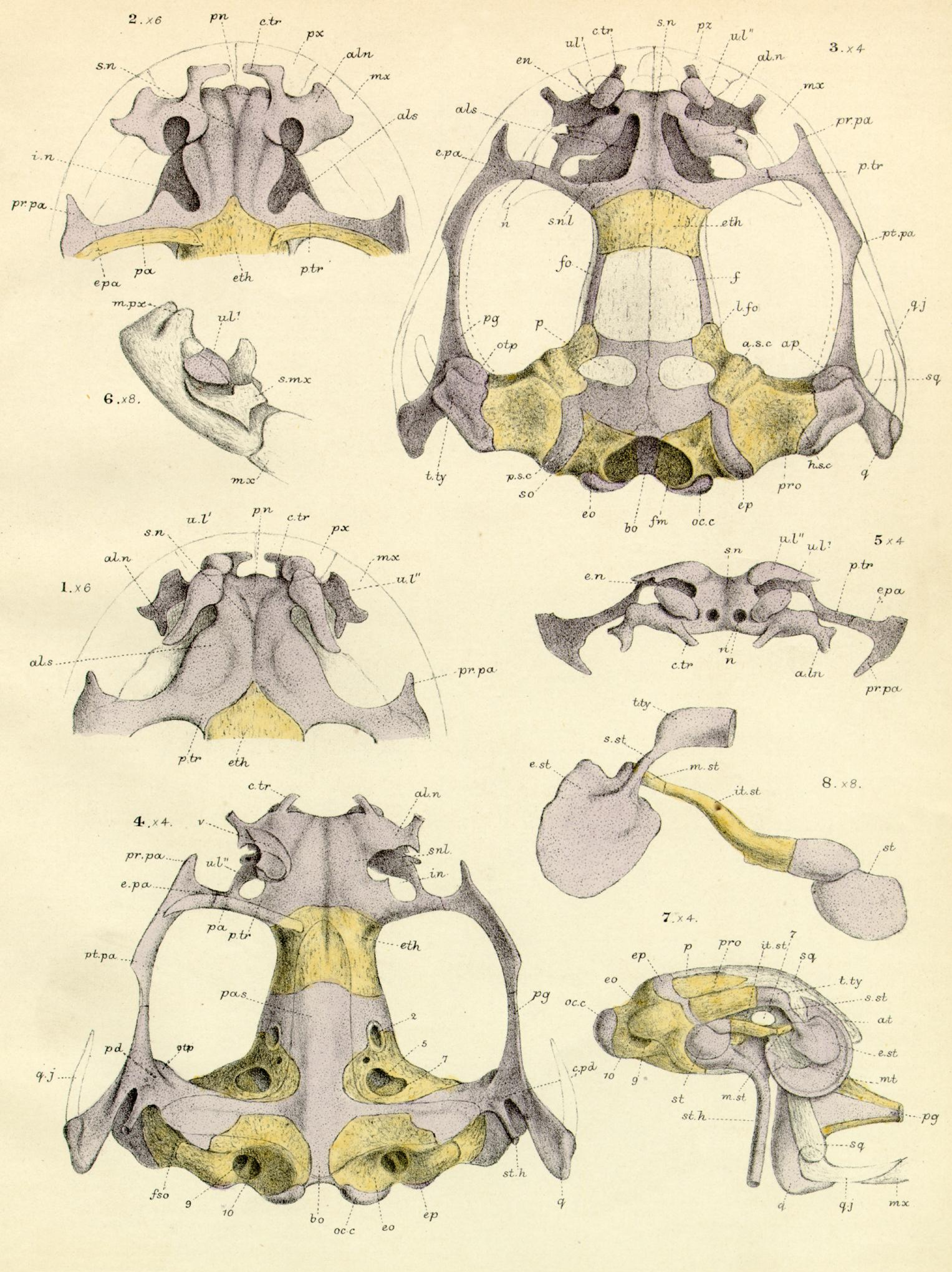
Pipa Monstrosa.



W.K.P. del. ad nat.
G.West lith.

W. West & Co. imp.

Pipa Monstrosa.



Figs. 1—2, Rana temporaria. Figs. 3—8, Bufo vulgaris.

PLATE 54.

Rana temporaria.—*Adult.*

Fig. 1. Fore part of endocranium (partially ossified chondrocranium), seen from above. ×6 diameters.

Fig. 2. The same, lower view. ×6 diameters. (In this and the next figure the outer bones are faintly shown.)

Bufo vulgaris.—*Adult.*

Fig. 3. Endocranium, seen from above. ×4 diameters.

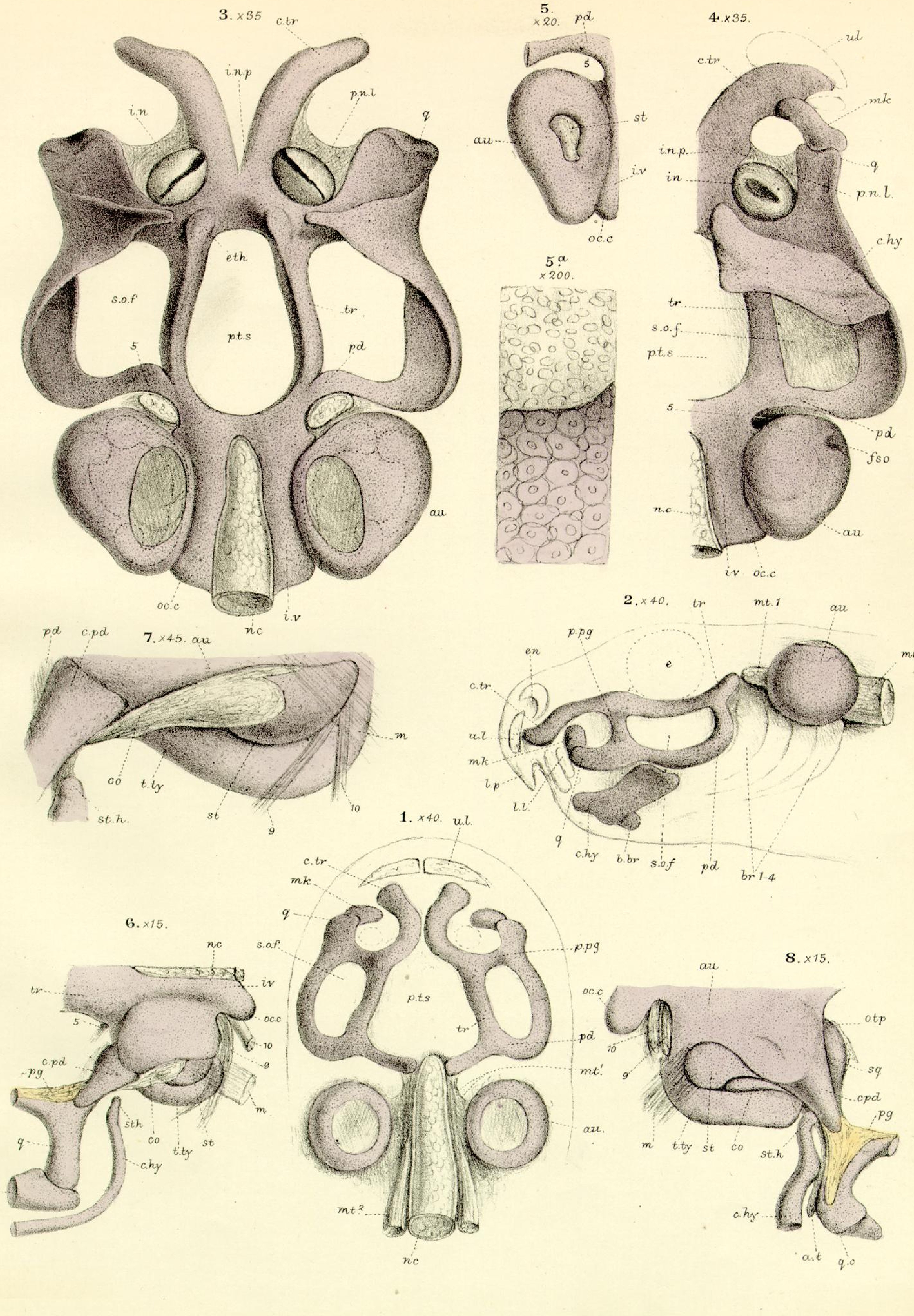
Fig. 4. The same, lower view. ×4 diameters.

Fig. 5. Part of the same cranium, seen from the front. ×4 diameters.

Fig. 6. Part of the facial region (ectocranium), with labial; side view. ×8 diameters.

Fig. 7. Auditory region of skull, with upper edge partly pared away. ×4 diameters.

Fig. 8. Columella and stapes from the same; inner view. ×8 diameters.



Bufo vulgaris.

PLATE 55.

Bufo vulgaris.—*Tadpoles and young.*

Fig. 1. Chondrocranium of a Tadpole, 4 lines long; 1st stage; upper view. ×40 diameters.

Fig. 2. The same, side view. ×40 diameters.

Fig. 3. Chondrocranium of a Tadpole, 5½ lines long; 3rd stage; upper view. ×35 diameters.

Fig. 4. Chondrocranium of a Tadpole, 5 lines long; 2nd stage; half of lower view. ×35 diameters.

Fig. 5. Chondrocranium of a Tadpole, 8 lines long; 4th stage; part of lower view. ×20 diameters.

Fig. 5ª. Part of same region of fenestra ovalis. ×200 diameters.

Fig. 6. Chondrocranium of young Toad, 5 lines long; 5th stage; part of inner view. ×15 diameters.

Fig. 7. Part of the same. ×45 diameters.

Fig. 8. A view, like fig. 6, of a young Toad, 8 lines long. ×15 diameters.

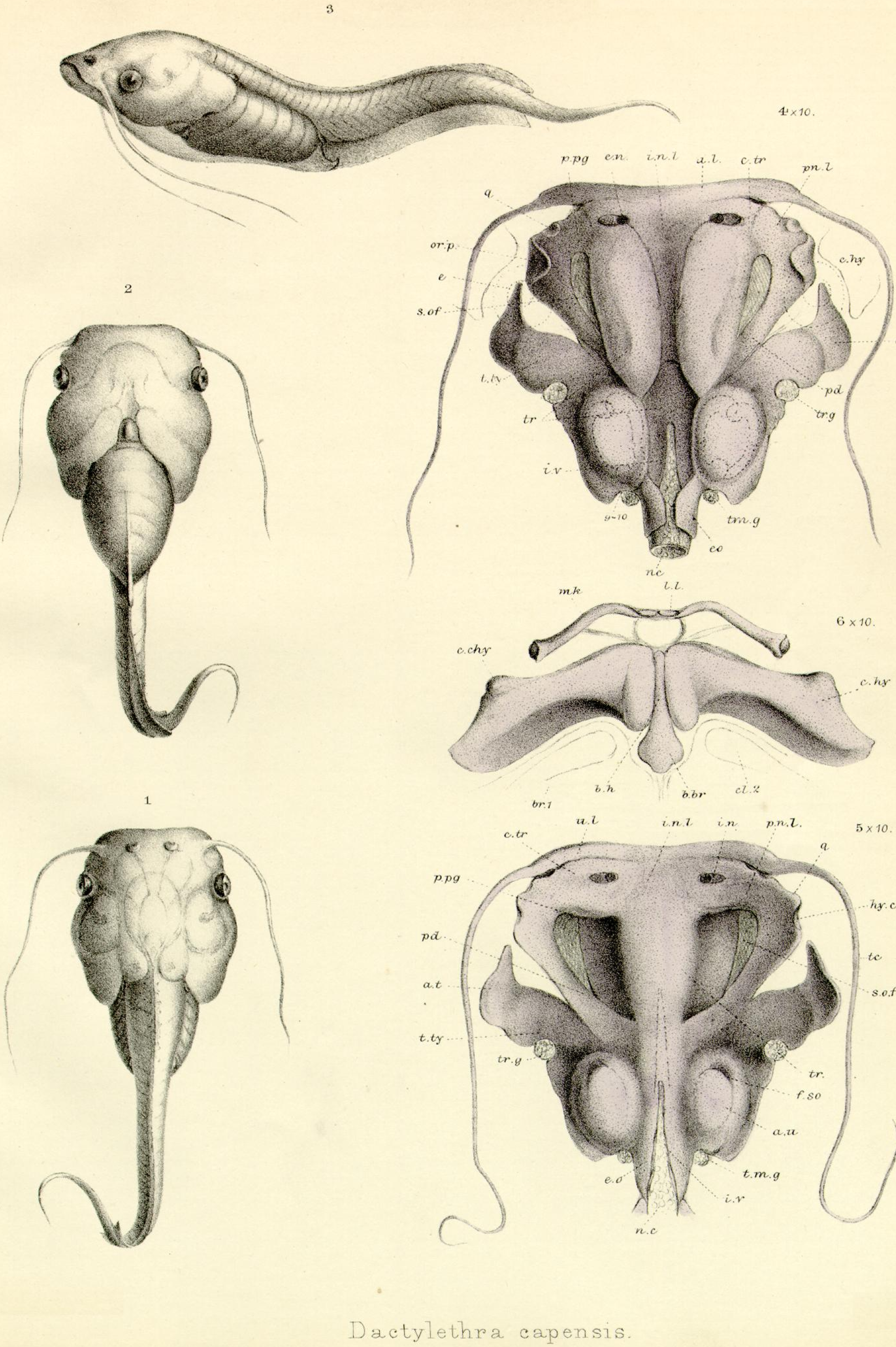
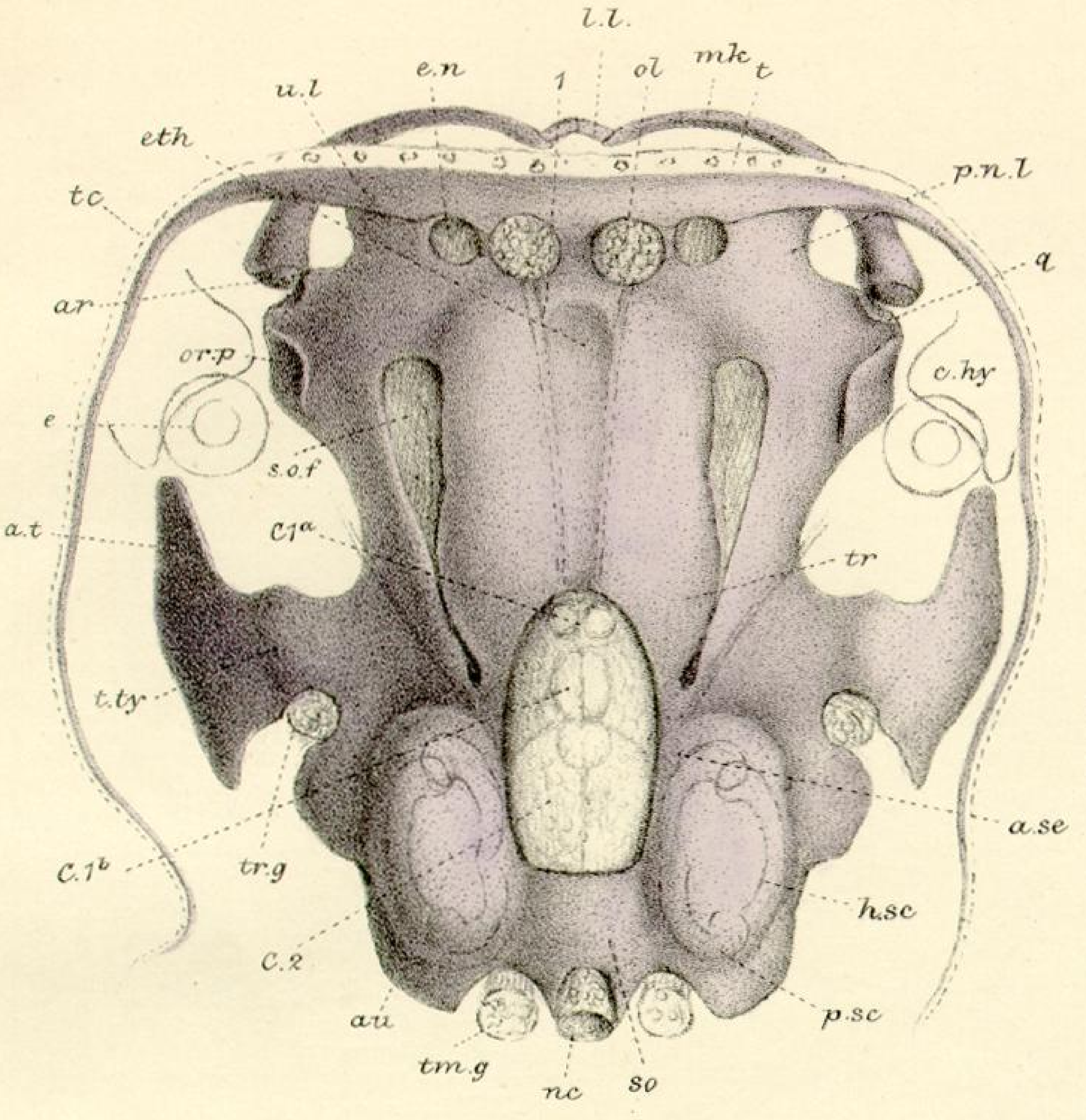


PLATE 56.

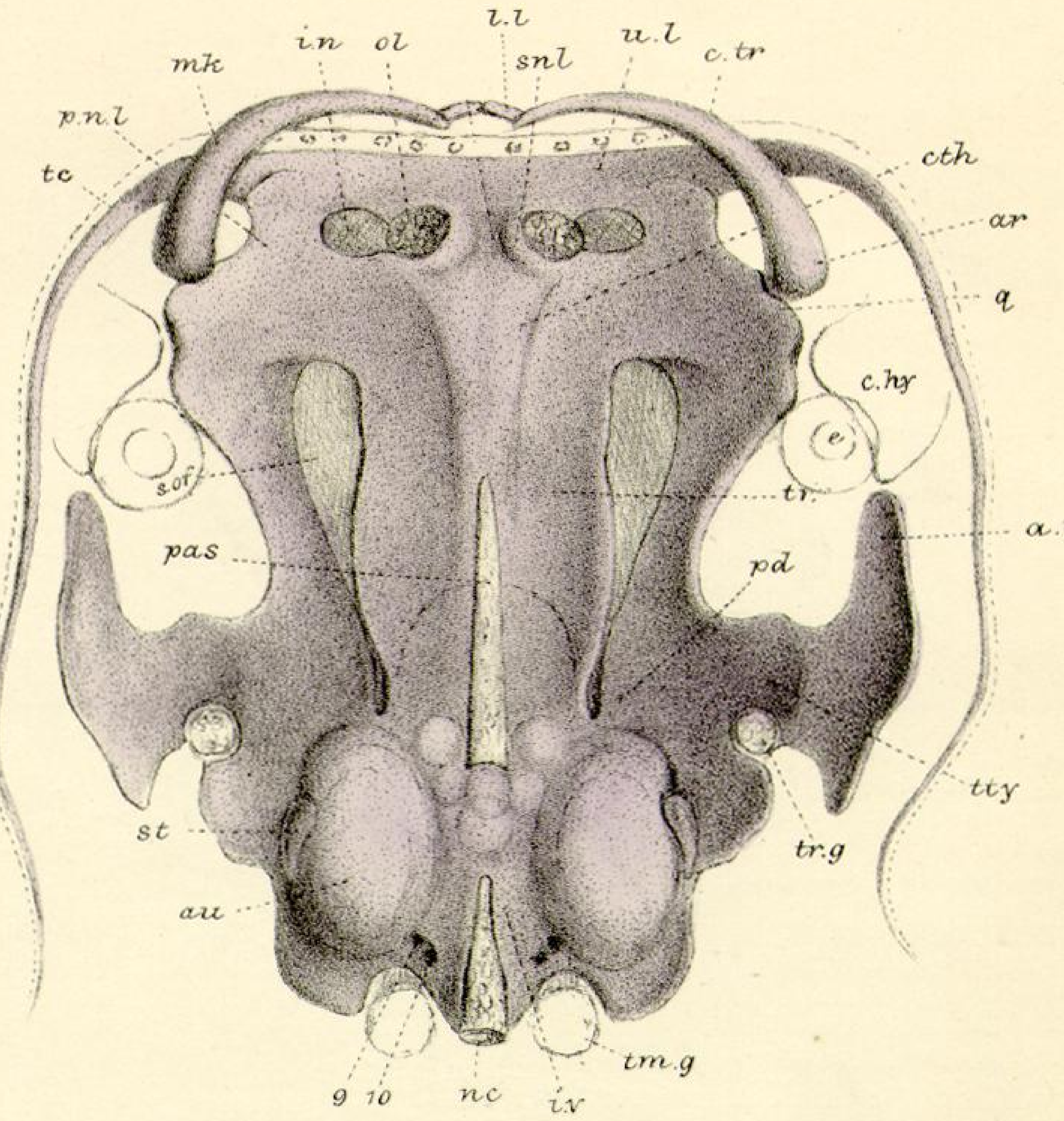
Dactylethra capensis.—*Youngest Tadpole, whose total length was* $1\frac{1}{3}$ *inch.*

Fig. 1. Upper view of Tadpole; 1st stage. ×4 diameters.
Fig. 2. Lower view of Tadpole. ×4 diameters.
Fig. 3. Side view of Tadpole. ×4 diameters.
Fig. 4. Chondrocranium of same, upper view. ×10 diameters.
Fig. 5. The same, lower view. × 10 diameters.
Fig. 6. Mandibles and hyoid cartilages of the same. ×10 diameters.

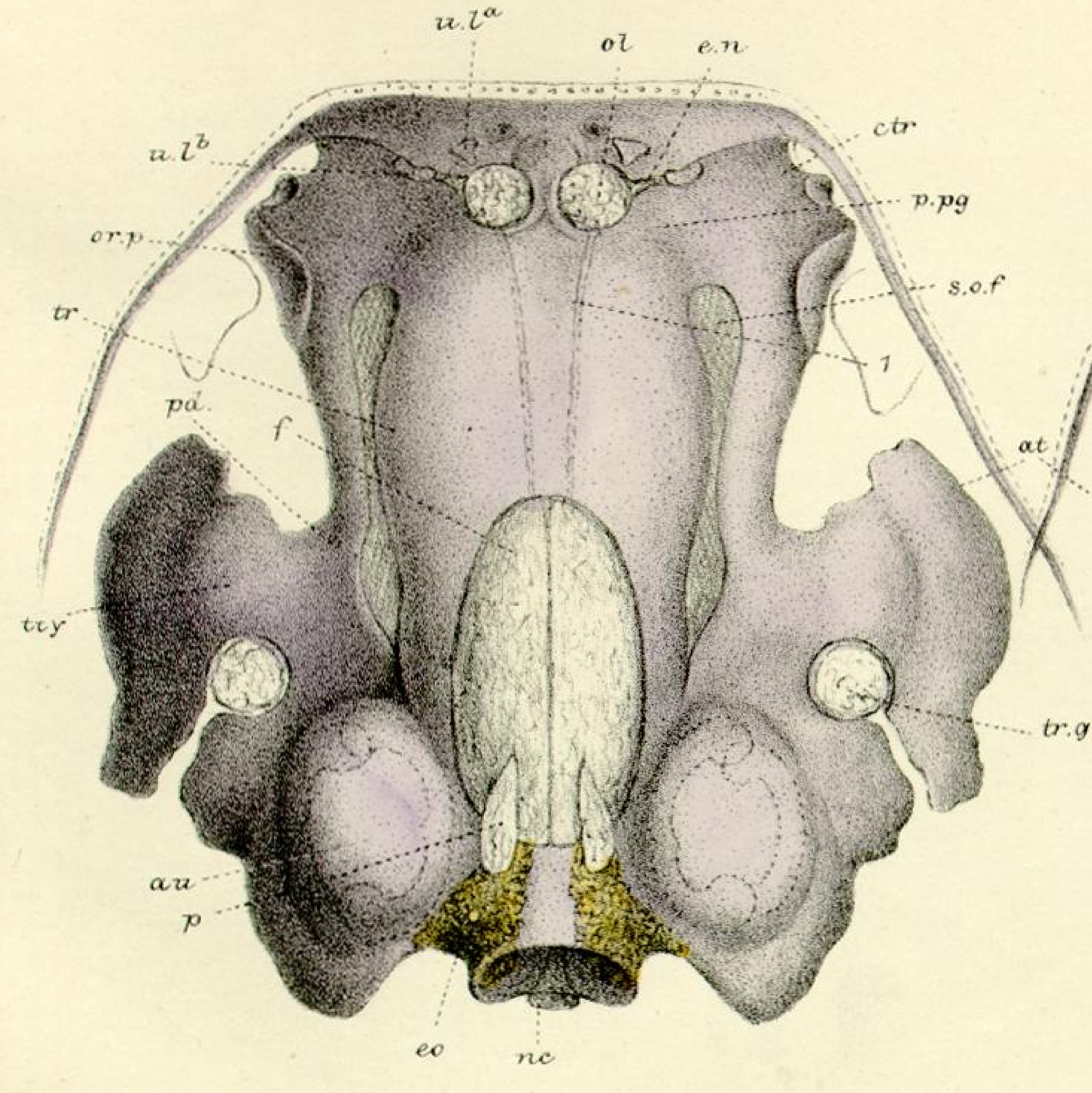
1 × 6



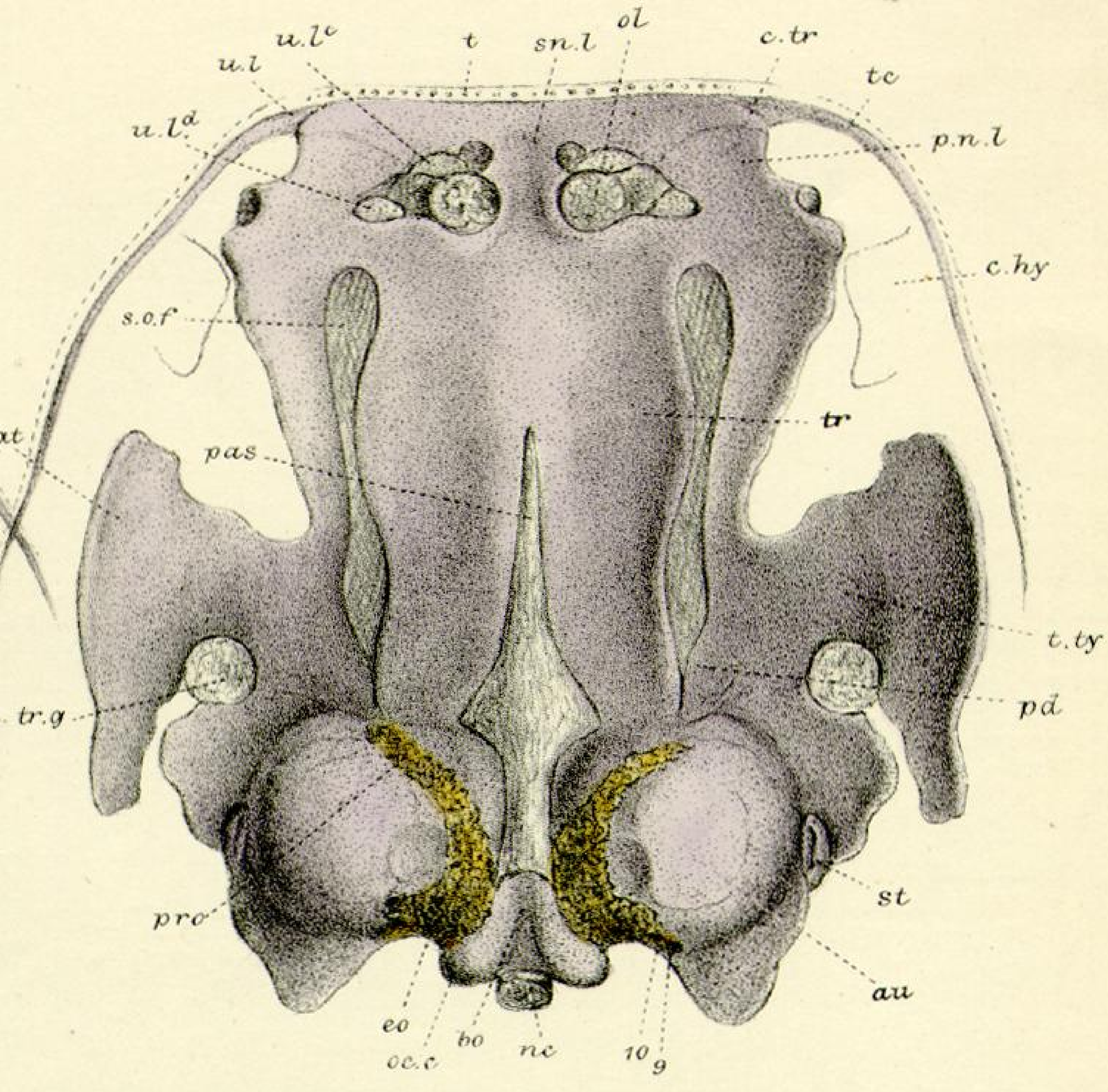
2 × 6



3 × 6



4 × 6



Dactylethra capensis.

PLATE 57.

Dactylethra capensis.—*Tadpoles* $1\frac{2}{3}$ *inch long.*

Fig. 1. Chondrocranium of Tadpole, upper view, 2nd stage. ×6 diameters.

Fig. 2. The same skull, seen from below. ×6 diameters.

4 z 2

Dactylethra capensis.—*Tadpoles at their largest size.*

Fig. 3. Chondrocranium of Tadpole, upper view; 3rd stage. ×6 diameters.

Fig. 4. The same skull, seen from below. ×6 diameters.

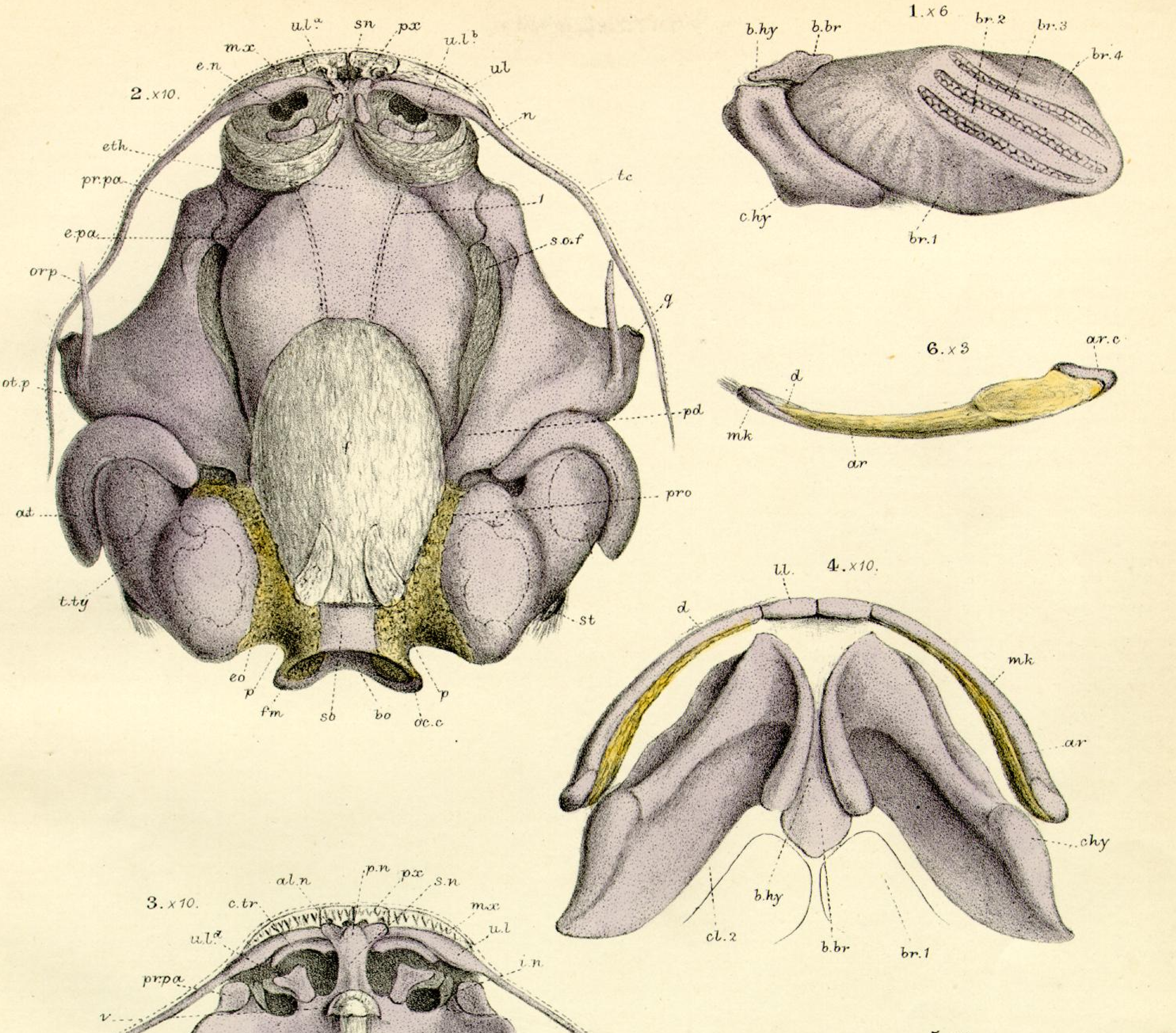


PLATE 58.

Dactylethra capensis.—*Tadpole: young and adult.*

Fig. 1. Hyoid and branchial cartilages of one side, from below; 2nd stage. ×6 diams.
Fig. 2. Cranium of young *Dactylethra* with large legs and tail; 4th stage. ×10 diams.
Fig. 3. The same skull, seen from below. × 10 diameters.
Fig. 4. Mandible and hyoid of the same skull. × 10 diameters.
Fig. 5. Hyoid and branchial arches of the adult *Dactylethra*, upper view. ×3 diams.
Fig. 6. Mandibular ramus of same, inner view. ×3 diameters.

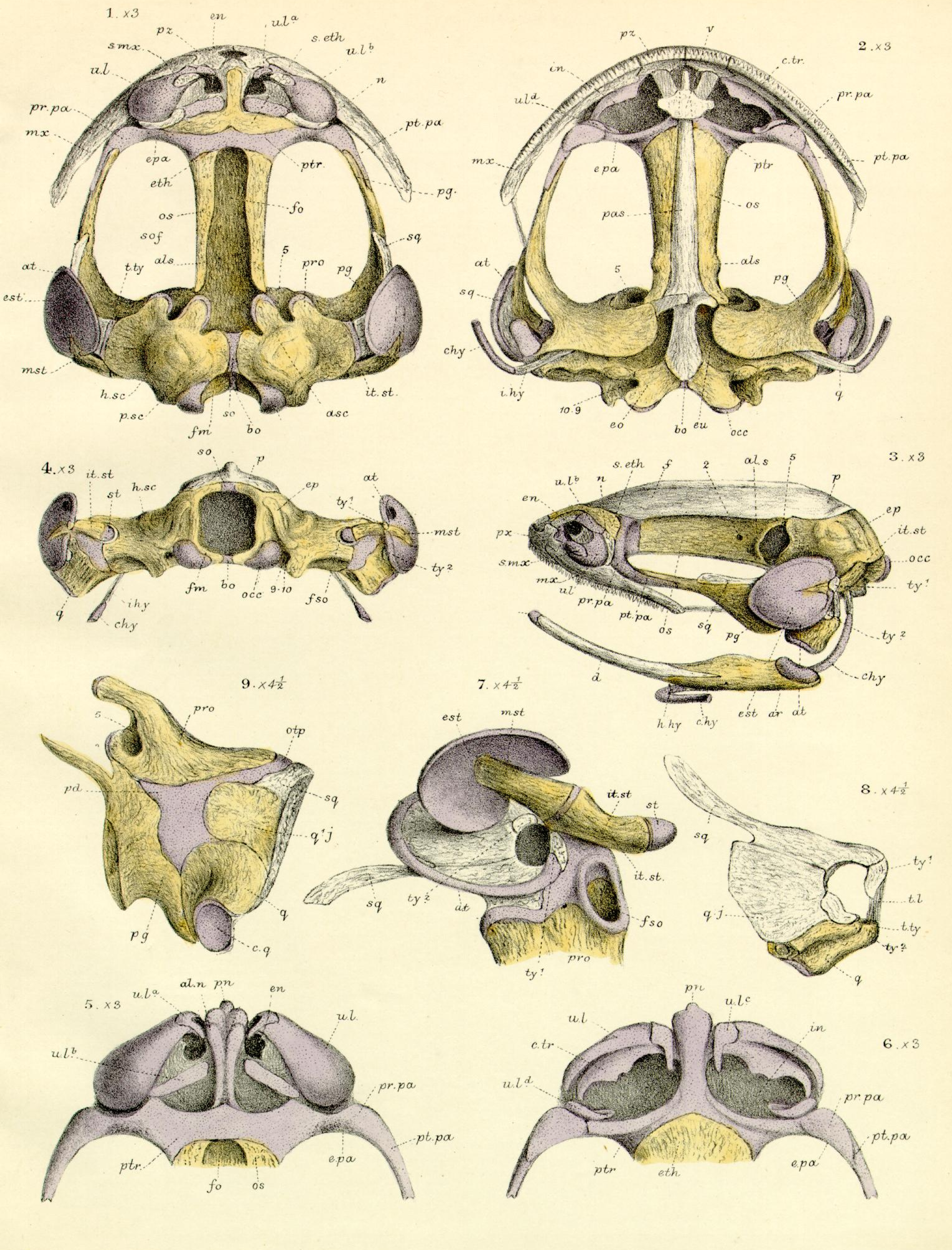


PLATE 59.

Dactylethra capensis.—*Adult.*

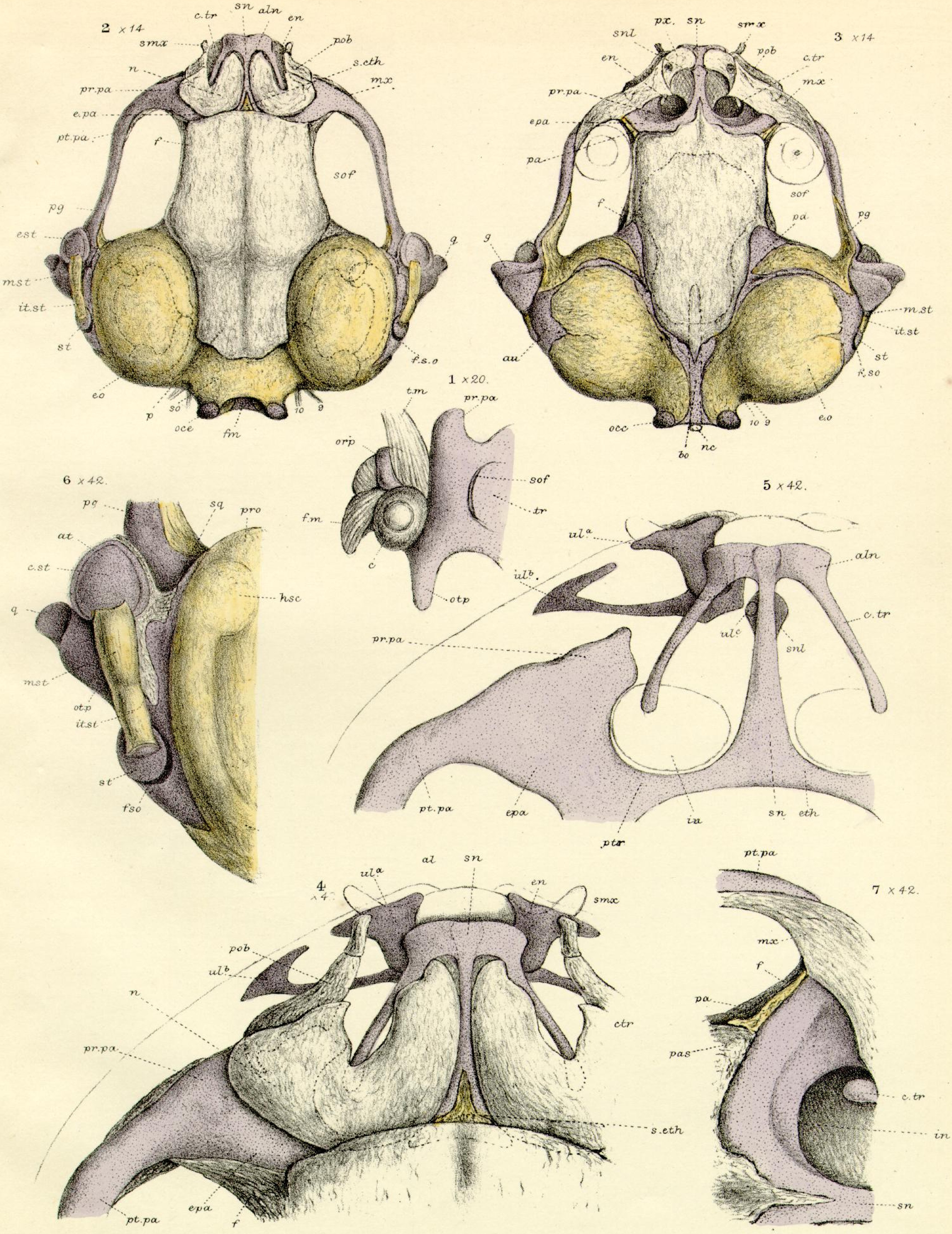
Fig. 1. Chondrosteous cranium, with roof-bones removed; upper view. × 3 diameters.
Fig. 2. The same, seen from below. × 3 diameters.
Fig. 3. The same, side view. × 3 diameters.
Fig. 4. The same, seen from behind. × 3 diameters.
Fig. 5. Endocranium, front part, seen from above. × 3 diameters.
Fig. 6. The same, lower view. × 3 diameters.
Fig. 7. Auditory region of same skull; inverted view, with dislocated "columella." × $4\frac{1}{2}$ diameters.
Fig. 8. Framework of auditory region; side view. × $4\frac{1}{2}$ diameters.
Fig. 9. Front view of quadrate region, with projecting parts removed. × $4\frac{1}{2}$ diameters.

Pipa Monstrosa.

PLATE 60.

Pipa monstrosa.—*Embryo $\frac{3}{4}$ inch long, and young (ripe), $6\frac{1}{2}$ to $7\frac{1}{2}$ lines long.*

Fig. 1. Embryo attached to yelk-mass; side view. ×5 diameters.
Fig. 2. The same; upper view. ×5 diameters.
Fig. 3. Chondrocranium of the same; lower view. ×15 diameters.
Fig. 4. Detached visceral arches of same; upper view. ×20 diameters.
Fig. 5. Chondrocranium of larger young *Pipa*; upper view. ×14 diameters.
Fig. 6. The same skull; lower view. ×14 diameters.
Fig. 7. Mandible and branchial arches of the lesser young *Pipa*; upper view. ×14 diameters.
Fig. 8. Section through nostrils of larger young *Pipa*. ×30 diameters.



Pipa Monstrosa.

PLATE 61.

Pipa monstrosa.—*Embyro and ripe young.*

Fig. 1. Orbital region of chondrocranium (embryo); upper view. ×20 diameters.

Fig. 2. Cranium of larger young *Pipa*; upper view. ×14 diameters.

Fig. 3. The same skull; lower view. ×14 diameters.

Fig. 4. Part of fig. 2; nasal region. ×42 diameters.

Fig. 5. The same, with investing bones removed. ×42 diameters.

Fig. 6. Part of fig. 2 (auditory region). ×42 diameters.

Fig. 7. Part of fig. 3 (ethmo-palatine region). ×42 diameters.

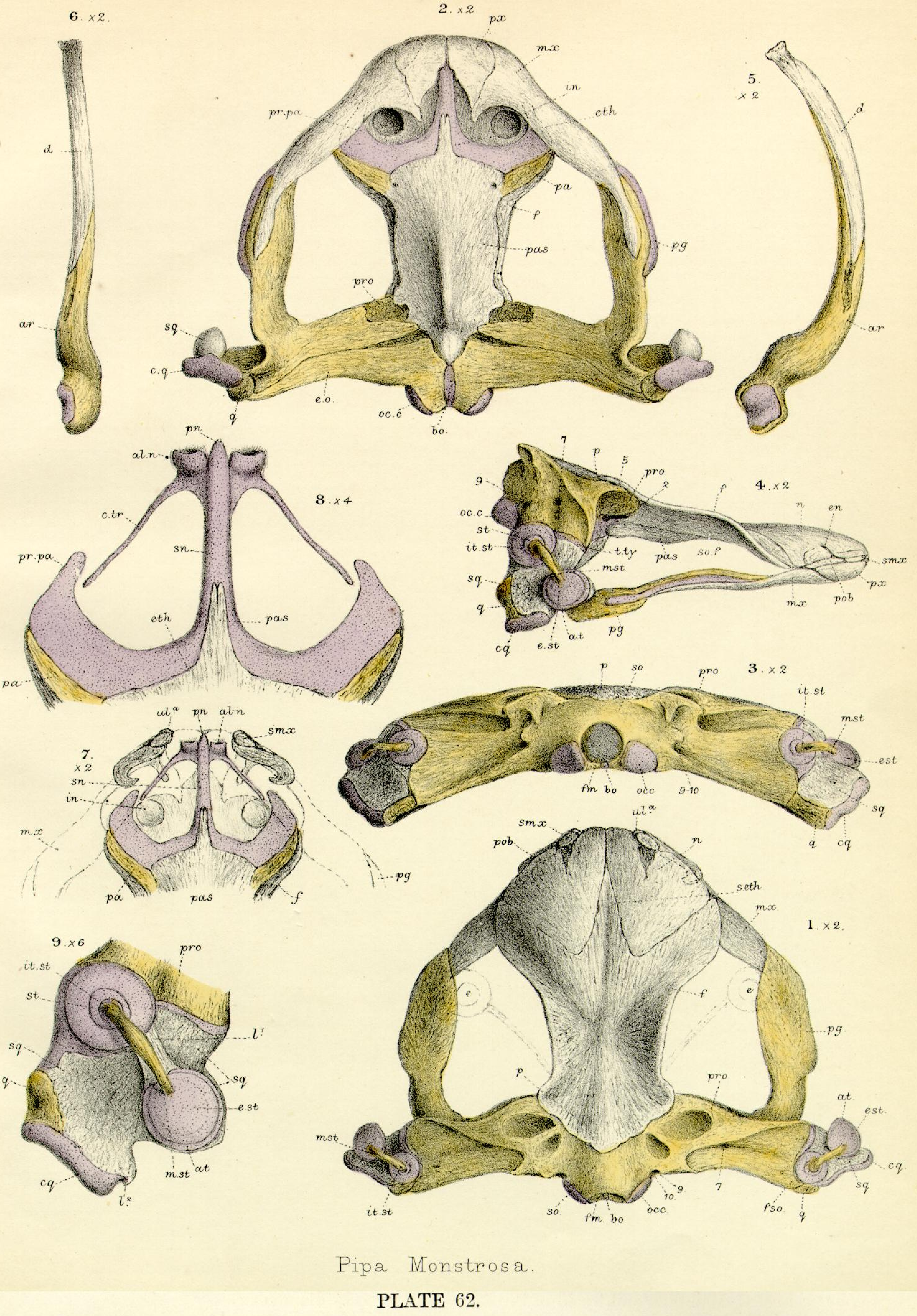


PLATE 62.

Pipa monstrosa.—*Adult.*

Fig. 1. Cranium; upper view. ×2 diameters.
Fig. 2. The same; lower view. ×2 diameters.
Fig. 3. The same; end view. ×2 diameters.
Fig. 4. The same; side view. ×2 diameters.
Fig. 5. Mandible; upper view. ×2 diameters.
Fig. 6. The same; side view. ×2 diameters.
Fig. 7. Fore part of skull, with investing bones in outline; lower view. ×2 diameters.
Fig. 8. Cranial elements of the same part; lower view. ×4 diameters.
Fig. 9. Temporal region of skull (part of fig. 4). ×6 diameters.