Notes on the Batrachians of the Paraguayan Chaco, with Observations upon their Breeding Habits and Development, especially with regard to Phyllomedusa hypochondrialis, Cope. Also a Description of a New Genus.

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With Plates 28—32.

List of Batrachia collected by J. S. Budgett in the Paraguayan Chaco, 1897.

	Length.
I. Leptodactylus ocellatus, L.	120 mm.
II. Leptodactylus typhonius, Daud.	45 mm.
III. Leptodactylus bufonius, Boul.	55 mm.
IV. Leptodactylus pœcilochilus (Cope)	50 mm.
V. Phryniscus nigricans, Wiegm.	33 mm.
VI. Paludicola fuscomaculata, Steindachn.	40 mm.
VII. Paludicola signifera, Boul.	25 mm.
VIII. Paludicola falcipes (Hensel)	15 mm.
IX. Eugystoma ovale, Schn.	♀ 40 mm., ♂ 25 mm.
X. Eugystoma albopunctatum, Boul.	18 mm.
XI. Pseudis paradoxa, L.	50 mm.
XII. Pseudis limellum (Cope)	20 mm.
XIII. Bufo marinus, L.	150 mm.
XIV. Bufo granulosus, Spix.	50 mm.
XV. Phyllomedusa hypochondrialis, Cope	40 mm.
XVI. Phyllomedusa Sauvagii, Boul.	70 mm.
XVII. Hyla spegazinii, Boul.	80 mm.
XVIII. Hyla venulosa, Laur.	70 mm.
XIX. Hyla nana, Boul.	22 mm.
XX. Hyla phrynoderma, Boul.	43 mm.
XXI. Hyla nasica, Cope	28 mm.
XXII. Ceratophrys ornata, Bell.	120 mm.
XXIII. Lepidobatrachus asper, n. sp.	80 mm.
XXIV. Lepidobatrachus lævis, n. sp.	80 mm.

I. Leptodactylus ocellatus, L.

An extremely common frog, frequently found in the streets of Concepcion at sunset and on both sides of the river Paraguay.

At Concepcion, black markings on a greyish-green ground. At Waikthlatingmayalwa the ground is usually of a brighter green.

A triangular black spot at the back of the eyes is very constant.

The natives, who are Lengua Indians, name this frog Nukkmikkting, and use it largely for baiting their hooks. The largest measure 50 mm. from snout to vent.

The call is regularly repeated, beginning on a low note and ending on a high one, and is constantly heard in wet weather.

There is, however, another call, which is heard immediately after rain; this is a drumming like that of a snipe.

A large variety found in the Chaco is called by the Lenguas Yattnukkmikkting; these measure up to 120 mm., and are only found down in the swamps. I think this may be L. bolivianus.

II. Leptodactylus typhonius, Daud.

Not nearly so common as L. ocellatus; I procured only two specimens, though I saw a few others. These were all seen at Caraya Vuelta on the river bank. The general colour is lighter than ocellatus, the spots are more numerous and smaller, and there is a bright gold band on either side running from the eye to the hips.

It appears to be about the same size as ocellatus.

No Lengua name was obtained for it.

III. Leptodactylus bufonius, Boul.

Small brown frog with blackish spots above, beneath pale

yellow. Most inconspicuous on a background of earth. It is very agile and extremely shy.

In damp waste places on the outskirts of Concepcion I found it in great numbers, but very difficult to capture.

The call is a shrill sharp "ping" kept up constantly until approached, when it immediately ceases. The croaking of so many of them at a time produces an almost continuous sound.

Though only one specimen was secured, it was frequently heard on both sides of the river. This is probably the young form of L. bufonius, which grows to about the same size as L. ocellatus. I never detected large individuals of this form calling, and I am convinced that during the continuous calling described above the individuals about were of the small form almost entirely.

It would appear, then, that either young forms have the habit of calling to one another, or that there is a small and a large variety. Lengua name Ukksaliapertikk. In Lengua Uksaelia means a coin or disc. The name refers to the spots.

IV. Leptodactylus pœcilochilus (Cope).

This frog is much less common than L. ocellatus. It is of a more slender build; the toes are thin and long, especially the second toe. The markings are all in the form of stripes rather than spots. These are dark brown on a greyish-brown ground. At the side yellowish. One broad dark stripe runs down the back on either side at the edges of the transverse processes of the vertebræ. One specimen was found at Concepcion and one at Waikthlatingmayalwa.

I do not know if it has a native name.

V. Phryniscus nigricans, Wiegm.

This is a brilliantly coloured frog of toad-like appearance. The ground colour is black, and is irregularly spotted with

yellow, or sometimes with large yellow blotches on the upper surface. Beneath it is black, with scarlet blotches; the palms of the hands and the soles of the feet are scarlet.

The variety found at Concepcion had on the under surface scarlet blotches extending to the throat, while the variety found at Waikthlatingmayalwa had the scarlet confined to the lower part of the abdomen.

This form, too, had yellow blotches irregularly arranged on the back, while the Paraguayan form had small yellow spots more regularly arranged.

On the journey between these two regions I twice met with large numbers of small black frogs which seem to be of this species. They were characterised by their smallness, and by the absence of either yellow or red markings.

At the breeding season the males and females have a call which consists of two clear musical "pings," followed by a long descending "trill" like that of our British greenfinch. The eggs are laid in separate globules of jelly, which float freely on the surface of the water, and are heavily pigmented.

This frog, which at ordinary times is the slowest and most bold of frogs, is now active and excessively shy. Swimming rapidly between the blades of grass it climbs a tuft, and, dilating its throat, repeats its call, but if in the least disturbed it is suddenly gone. This change of habit is very remarkable.

The spawn is found in quite temporary pools in grassy ground; the development is excessively rapid. Segmentation beginning at 10 a.m., they were hatched and wriggling about by 7 a.m. the following day. They probably are washed down into deeper pools by the retreating waters, and for this purpose the manner in which the eggs are laid, i.e. in separate globules of jelly, seems especially suited.

The native Lengua name is "Pithpaya."

The eggs and larvæ do not seem to differ in any great degree from those of Rana. There is, however, a very large yolk-plug, which remains evident after the closure of the neural groove.

VI. Paludicola fuscomaculata, Steindachner.

This is the largest of the genus that I found in the Chaco. It is a short-limbed frog, with spreading slender toes and small head.

The upper surface is marked with characteristic marblings, which vary, however, greatly in colour. The metatarsal tubercles are large, horny, shovel-shaped, and black.

The peculiar cry which is so constantly heard in the neighbourhood of shallow pools, and resembles that of a kitten, is produced by the alternate inflation of throat and abdomen.

When fully inflated the frog appears to be the size of a golf ball, but, if startled, instantaneously shrinks to one fifth of that size, so that it seems to have vanished. It has also the power of ventriloquising.

In the spawning time it was found at night floating on the surface of pools in the distended condition, and crying to the females in a most mournful way. On coming to the surface it fills its lungs with a few gasps, greatly distending the walls of the abdomen, and then drives the air into the throat diverticula of the pharynx, causing them to become distended as the stomach collapses, and giving rise to a kitten-like cry.

The eggs are chiefly laid in January, and are found embedded in a frothy mass floating upon the surface of the water. The eggs themselves measure 1 mm. in diameter, and are without pigment and with extremely little yolk. They become free-swimming within from eighteen to twenty-four hours of the time of the first segmentation. When ready for hatching they wriggle their way through the froth to the water below, and hang into it from the floating froth.

In this rapidly hatching, free-swimming larva many of the processes of development are blurred, and as it were hurried over. The external gills never reach a high state of development. The cell layers are many cells deep and diffuse, and the involutions and evolutions are difficult to follow.

The natives call this frog "Zing Ye," which of course applies to the genus generally, for the species differ very slightly.

In this species the testes are much pigmented and lobulated.

Its food consists largely of water-beetles.

VII. Paludicola signifera, Boul.

This is considerably smaller than fuscomaculata, and is usually an olive-green on the back without conspicuous markings.

Its general habits seem to be the same as those of P. fuscomaculata, as also its cry. It is most agile. I put this species into a cage in which were many brightly coloured frogs, including Phryniscus nigricans and also Phyllomedusa hypochondrialis. In this cage was also a small grass snake. Hitherto it had taken no interest at all in the gaudy frogs in its cage; but as soon as the little Paludicola made its first spring, it was caught in mid-air by the snake.

VIII. Paludicola falcipes (Hensel).

Only one specimen found at Concepcion by the river side. Its toes are even, long, and slender. Many of the specimens in the British Museum are marked with one broad light band running from nose to vent. But by no means all have this, neither does it depend on sex. In the specimen which I procured this stripe is very much marked.

IX. Engystoma ovale, Schn.

This frog has a small head and pointed nose. The eyes are set far forward, and there is an encircling fold just behind the eyes. The fore-limbs are very small, and the general shape of this frog proclaims it at once to be a burrower. The skin is perfectly smooth. It is greenish brown above, yellow beneath, and a bright yellow band passes up the thighs and over the

vent. In the male this band is bright red. The male is somewhat smaller. The natives call it "Po it," being convinced that the cry which sounds to them thus proceeds from this frog. However, in each case that I tracked down, the frog calling with this cry I found a Leptodactylus ocellatus. The cry was heard everywhere, but I only found one male and one female.

I think the native boys were here mistaken again; they pointed out to me holes in the ground beneath fallen tree trunks, of the size of a cricket ball and lined with a froth containing white eggs and also tailed larvæ. The entrance to the whole was about a centimetre in diameter. This they said was the nest of the "Po it."

I reared some of the eggs, and one as far as the four-legged stage, when the young frog bore a very strong resemblance to a Paludicola, but unfortunately escaped from my tank before it had lost its tail.

Though the information obtained from the natives generally turned out to be fairly accurate, yet I feel sure that in some instances they were quite wrong.

To whatever frog these nests belonged, it is certain that they were a most ingenious contrivance for collecting water and keeping the eggs and larvæ at least moist, between the storms of the wet season. They were always found within the forest belts which lay on the highest ground.

I found with these larvæ that they would exist for a very long time in a small quantity of water without increasing in size, but that when removed to a tank they grew enormously, and very soon left the water.

These eggs were somewhat larger than the minute eggs of Paludicola, 1¼ mm., and pigmentless. As far as my investigations have gone these eggs develop much as Paludicola, though they are rather more heavily yolked.

X. Engystoma albopunctatum, Boul.

About half the size of E. ovale, and found under a heap of

decaying vegetation in the forest. Plum-coloured and very glossy above, and greyish with white spots below. One specimen found. Native name unknown.

(The specimens collected by Bohls, in Paraguay, are all brightly spotted above.)

XI. Pseudis paradoxa, L.

A water-frog never seen on land, and extremely shy. Though often seen floating in a shallow pool, it was caught with great difficulty.

In life most beautifully coloured with bronze, bright green, and black markings above; underneath a satiny sulphur-yellow, with brown spots on the trunk and brown stripes on the thighs. On killing, all the brilliant colours of the back turned to a dull uniform brown in a few minutes.

Though there were a pair of these in a pool all through the early part of the wet season, yet the pool did not contain any of the well-known gigantic larvæ with reference to which the frog is named.

No native name known to me.

XII. Pseudis limellum (Cope).

Small green frog abundant on the camelota leaves at Concepcion. Capable of changing its colour greatly from bright green to dull brown, underneath silvery. Two white streaks run backwards from the eyes. The call is a succession of sharp croaks or vibrations resembling the sound made by castanets. The throat is inflated for each series.

They hop quickly over the surface of the water, and perch on the camelota leaves and stems. They are enabled thus to hop on the surface of the water by reason of the very large webs of the hind feet. The tips of the toes also have dilated discs. Their food consists mainly of small fresh-water Gasteropods. Females larger than the males.

No native name known to me.

XIII. Bufo marinus, L.

The common toad of South America, up to 150 mm. in length from snout to vent. It feeds on all kinds of insects, and is very useful in helping to keep down the mosquitoes. One half-grown toad, sitting by one man's foot, picked off fifty-two mosquitoes in the space of one minute, flicking them up with his tongue as they settled.

This toad, which may be found in every shed or outhouse, is called by the natives "Pinnikk." Its call consists of three bell-like notes, the middle one being the highest. The parotid glands are enormously developed, and, if the toad is roughly handled, are discharged like squirts. When wet weather comes it hops out from its hiding-place, and proceeds to sit in a puddle, with its head out.

XIV. Bufo granulosus, Spix.

A very common small toad, found in great numbers near water after rain. Dark above, with black, brown, and greenish blotches, and a light vertebral line. Skin much tuberculated. Calls with a continuous bell-like tinkle, the vocal sac being greatly distended. A great deal of variety in colour.

Native name "Kelaelik."

This species forms the chief food of the two newly described species of Lepidobatrachus.

XV. Phyllomedusa hypochondrialis, Cope.

A brilliantly coloured grass frog, which I found breeding freely in the Paraguayan Chaco, about 120 miles due west of Concepcion (fig. 34). Above it is brilliant green, which may become brown, grey, or bluish at will; below granular white. The flanks are scarlet with black transverse bars, and the plantar surfaces are a deep purplish black.

The "Wollunnkukk," as it is called by the Lengua Indians, from the call of both male and female at pairing time, is extremely slow in its movements, and is active only at night. At this time, if it is seen by the aid of lantern as it slowly climbs over the low bushes and grass, it is very conspicuous, as shown in the figure. In the daytime, however, nothing is seen but the upper surfaces of the body as it lies on the green leaf or caraguata plant, and here it is most inconspicuous.

This small Hylid has a remarkable power of changing the colour of its skin to harmonise with its surroundings, and can effect a change from brightest green to a light chocolate in a few minutes. The skin is also directly sensitive to light; for if the frog is exposed to the sun while in a tuft of grass in such a way that shadows of blades of grass fall across it, on removal it will be found that dark shadows of the grasses remain on the skin, while the general colour has been raised to a lighter shade. Its food consists largely of young locusts. The ovaries on each side are divided into five distinct clusters. The rectum has a large saccular diverticulum, which is very heavily pigmented.

In the breeding season—December to February—this beautiful grass frog collects in considerable numbers in the neighbourhood of pools. During the night-time they call incessantly to one another, and produce a sound as of a dozen men breaking stones, well imitated by the native name "Wollunnkukk."

As regards the native names for frogs, most species had their separate names; for instance, two species so closely like one another as Leptodactylus ocellatus and L. bufonius had their names respectively "Nukkmikkting" and "Ukseliapertic," but with the Tree frogs it was not so. I could get no name for any frog with dilated discs but "Wollunnkukk," whether they had a call resembling this name or not, and whatever their form, colour, and size. I may mention also that they had no general name for frog, though they had a general name for bird and fish.

Breeding Habits.—On November 30th, 1896, I caught six of these frogs at the edge of a shallow pool late at night, and put them with some leaves in a tin until the morning. Next morning I discovered batches of white eggs, in masses of firm jelly, lying about at the bottom of the tin. I put some of these in water, and some I kept damp. Those which I put in water died immediately; those which I kept merely moist I watched segmenting and developing until December 5th, and preserved several eggs of each stage, but on this day the last of the embryos died, and I tried hard to get some more, and to find out how they were laid in nature.

On December 31st I discovered a small leaf overhanging a pool of water, and containing a batch of the Wollunnkukk eggs. At this same pool I found within the next three weeks about twenty leaves enclosing batches of eggs, in no case more than two feet from the water.

On January 15th I had an opportunity of watching the process of egg-laying. About 11 p.m. I found a female carrying a male upon her back, wandering about apparently in search of a suitable leaf. At last the female, climbing up the stem of a plant near the water's edge, reached out and caught hold of the tip of an overhanging leaf, and climbed into it. With their hind legs both male and female held the edges of the leaf, near the tip, together, while the female poured her eggs into the funnel thus formed, the male fertilising them as they passed (fig. 35). The jelly in which the eggs were laid was of sufficient firmness to hold the edges of the leaf together. Then moving up a little further more eggs were laid in the same manner, the edges of the leaf being sealed together by the hind legs, and so on up the leaf until it was full.

As a rule two briar leaves were filled in this way, each containing about 100 eggs.

The male hurried away immediately the laying was over, and he did not embrace the female except during the act of laying eggs. The time occupied in filling one leaf was three quarters of an hour.

Life History.—Development proceeds very rapidly; within

six days the embryo increases from 2 mm. (the diameter of the egg) to 9 or 10 mm., when it leaves the leaf as a transparent glass-like tadpole whose only conspicuous part is its eyes (fig. 30). These are very large and of a bright metallic green colour, so that when swimming in the water all that is seen are pairs of jewel-like eyes.

The newly hatched tadpole has also a bright metallic spot between the nostrils somewhat in front of the pineal spot. This is the point which touches the surface of the water when the tadpole is in its favourite position. Whether it is a protective coloration, or some mechanical arrangement for holding the surface, I cannot say.

The leaves containing the eggs are not always directly over water, and the newly hatched tadpole has often to make his way many inches to the water.

This migration to the water usually takes place during a shower of rain, when the larvæ tend to be washed into the pool, but they also assist themselves by jumping several inches into the air. They are intensely sensitive to light and shock.

During the embryonic development the jelly surrounding the embryo becomes more and more dilated by the growth of the embryo, and also by the accumulation of fluid within. Towards the close of embryonic life the embryo comes to lie quite freely within a membranous capsule.

The eggs are very heavily yolked, and some yolk persists until the tadpoles are ready to leave the capsule.

On the third day external gills are well developed, and the red blood-corpuscles may be seen coursing through them, and the heart beating rapidly. These external gills reach their highest state of development about the fifth day, when they extend beyond the vent, and are of course bright red (fig. 27).

The tadpole is hatched without a trace of yolk, the external gills have completely disappeared, there is a median spiracle, and the lungs are already clearly visible shining through the transparent body-wall (fig. 30).

The day after the tadpoles are set free, pigment begins to be developed about the head and upper surface of the body.

There is a conspicuous absence of pigment for some time over the pineal body (fig. 26).

Black pigment appears first, then green. At the end of about five more weeks the tadpole has begun to develop its hind limbs. During this period it has grown to a length of 8 cm. The upper surfaces are now a glossy green, beneath silver and rosy; the tail is still transparent, and the red blood-vessels give it a bright red colour (fig. 31).

At the time of the development of the hind limbs there is a very great accumulation of black pigment at the middle of the tail, especially below (fig. 31).

The tail is absorbed very rapidly up to this point; the final absorption of the proximal part of the tail is postponed for some days.

The young frog, having now grown both pairs of legs, leaves the water and betakes itself to the blades of grass close by (fig. 32).

Here it sits during the time of absorption of the remainder of the tail. When lying in the blade of grass, only the brilliant green upper surfaces are visible, and the tail helps to make the young frog still less noticeable by shading off the body, and causing it to become merged in the green of the grass blade.

The young frog at the close of its metamorphosis is two thirds the length of the adult frog, and at this time acquires the red flanks barred with black (fig. 33).

There is a certain stage in the life of this larva when it will not bear transferring from the pool to aquaria. If the larvæ are transferred at the time when pigment in the tail is just beginning to accumulate, that is when they are 3 cm. in length, they invariably die, though both younger and older larvæ stand the change quite well.

Development.

External Characters. — Segmentation is holoblastic, though not so regular as in Rana and most Batrachia (figs.

1—6). The blastopore is formed by a more general overgrowth of epiblast, and is from the first circular; it is only just before closure that it is possible to tell from an external view which is the anterior and which the posterior side of the pore (figs. 6, 8). It is quite during the last stages of gastrulation that the closing mouth of the gastrula swings up to the posterior edge of the egg. When the blastopore has reached this position it becomes pointed at the anterior end, and there can now be seen running forward from this point a groove showing unmistakably the line of fusion of the edges of the mouth of the gastrula (fig. 9).

Finally the yolk retreats, and a slit-like open blastopore remains at the posterior end of the pear-shaped neural plate (fig. 10).

While this fusion has been taking place the centre of gravity has been continually shifting; for along the line of fusion there is a greater accumulation of yolkless protoplasm, i.e. epiblast and mesoblast, than elsewhere. Yolk is heavy, therefore the fused edges of the mouth of the gastrula come to the upper side.

Finally the entire egg has rotated through 180°. The anterior end of the archenteron is now in the position that the posterior end occupied at the beginning of gastrulation. The area occupied by the neural plate has been formed chiefly by the downgrowth of the lateral and anterior edges of the blastoporic rim; however, the posterior edge here takes a greater share in gastrulation than in Rana, and in consequence the blastopore comes to lie not at the extreme posterior end of the archenteron, but further towards the middle, while the neural plate extends beyond the blastopore. The anus, however, makes its appearance at the extreme posterior end of the archenteron, far from the position now occupied by the blastopore (Sections II, III, *an.*).

The centre of the neural plate becomes slightly depressed, and here the blastoporic scar is seen running forwards from the edge of the blastopore along the whole plate as the "primitive streak" (fig. 11).

The neural folds now begin to approach one another at the anterior and posterior ends of the groove, but there is no well-marked anterior transverse fold (fig. 12).

Posteriorly the folds enclose the remains of the blastopore, which then opens only into the neural canal formed by the complete fusion of the edges of the two folds. A tail fold develops of a crescentic form encircling the posterior end of the neural plate, on the posterior convex side of which the anus is formed (Section III, *an.*).

Between the blastoderm and the egg membrane there is now present a considerable space, filled with a milky fluid (fig. 12, *sp.*).

When the neural folds have completely met, i. e. fifty hours after laying, then the anterior end of the neural plate expands to form the optic vesicles, and an elevation extends forwards from them, homologous with the so-called "Sense-plate" of Morgan. Behind the optic vesicles extending laterally and anteriorly on either side is seen the gill-plate or branchial fold.

Later this grows to completely encircle the sense-plate, which now shows a depression at the anterior end, the rudiment of the stomodæum (fig. 20, *Stom.*).

The right and left halves of the "sense-plate" thus divided are very conspicuous features at this stage in development, and for some time later. A little later they become formed into a regular pair of mandibular bars, which only just meet below the stomodæum (fig. 21, *Mnd.*).

In section they appear quite like the succeeding hyoid arches, which are very slightly developed, and also the larger first and second pair of branchial arches.

There is a total absence of suckers such as are borne behind the mouth in most Batrachian larvæ, and the embryo has now more the appearance of a young larva of Acipenser than of Rana.

The gill-plate in life appears as a single elevation on either side, but after fixing with appropriate reagents it may be seen almost from the first to consist of three branchial pouches of the pharynx; the two anterior of these alone persist. The

first pouch is between the hyoid and the first branchial arch. The second pouch is between the first and second branchial arch. The third pouch is between the second and third branchial arch (fig. 14, *3rd br. f.*).

The optic bulbs early begin to bud out from the fore-brain, and now just behind the gill-plate is seen the first rudiment of the pronephros, a slight but defined elevation tapering posteriorly; mediad to this are seen four or five mesoblastic somites (fig. 14, *mes. som.*).

The auditory vesicles are not easily visible until after the appearance of the external gills.

Up to this time the embryo has lain almost flat upon the surface of the yolk, preserving in all a spherical form; now, however, it begins to rise from the surface of the yolk, both anteriorly and posteriorly, but the yolk is still nearly spherical (fig. 15).

The eye-bulbs increase greatly in size, and are exceedingly large in comparison with what is found in Rana at a corresponding stage. The ocular muscles are developed very early, and the eye may be seen to be rotated by them on the fourth day of development. A very conspicuous feature of this stage is the dilated condition of the double gill-pouch (fig. 15). Viewed from the dorsal surface, the head region has now in outline the form of a trefoil.

The tail now begins to grow back from the surface of the yolk, the dilation of the branchial folds ceases, and in proportion to the latter the head portion increases greatly (fig. 16).

The first pair of external gills now may be seen budding out from the first branchial arch. Below the cleft post-oral region, formed from the sense-plates, the rudiment of the heart is clearly visible (figs. 21, 24, *ht.*).

In a side view, more or less transparent as in life, there are to be seen the heart, first pair of external gills, well-formed eye with conspicuous choroid fissure, auditory vesicles, somites, caudal notochord, and extended cloaca. The yolk-sac still retains its spherical form (fig. 24).

The changes in external form which now take place mainly

consist in the appearance of the second pair of external gills, which do not reach nearly so high a state of development as the first pair; also in the rapid growth of the first pair of gills, so as to extend beyond the vent as blood-red filaments through which the corpuscles stream along, propelled by the now rapidly pulsating heart (figs. 25, 27, 17—19).

A dense plexus of vitelline veins ramifies over the surface of the yolk, while the dorsal aorta and cutaneous veins give to the elongated tail a copious supply of blood (fig. 29). Indeed, so noticeable is this, that I am quite inclined to agree with Mr. Kerr's suggestion that the tail of this larva is an important organ of respiration. This view is further strengthened by my observation that in hatched larvæ the tail often remains motionless as a whole, while the extremity of the tail is kept rapidly vibrating. As the larvæ are not propelled by this motion through the water, I am tempted to think that the object of it is that a stream of water may be kept constantly running along the surface of the proximal part of the tail.

The operculum now grows down from the hyoid arch and encloses the gill arches. The external gills become rapidly absorbed (but I think that a study of the origin of the filaments of the internal gills shows them to be really of the same nature as the external gills), the stomatodæal aperture breaks through, and the young frog has reached the end of its embryonic life (fig. 26).

Internal Characters.—On account of the short space of time at my disposal it seems advisable not to attempt a continuous account of the internal phenomena of development, but merely to figure and describe sections illustrating some of the more important points of interest, leaving the fuller account for a future occasion.

Section I[1] passes transversely through the blastopore before the formation of the neural groove. The main points to be noted are the smallness of the archenteron, the absence of a

[1] The numbers here given correspond with those of the figures of Plates 31 and 32.

yolk-plug, the abundance of yolk, and the mesoderm extending only as far as the equatorial region of the egg.

Section II passes longitudinally through the blastopore (*bl.*), the walls of the neural groove being closed anteriorly, but not yet posteriorly. The points to be noted are the anterior position of the blastopore, the fusion of the embryonic layers before and behind the blastopore, and anteriorly the beginning of the first branchial pouch (*br. f.*).

Section III, a sagittal section of an embryo after the closure of the neural groove, showing the comparatively anterior position of the neurenteric canal (*n. en.*), the brain vesicles, the notochord not yet differentiated posteriorly, the archenteron, and anteriorly the branchial fold (*br. f.*) of the pharyngeal wall, which is continuous across the middle line; also posteriorly the depression which will later become the anus (*an.*).

Section IV is of the same series as the last, but further from the middle line, showing the large lateral cavity of the archenteron caused by the upraising of the branchial pouch (*br. f.*). The section also passes through the optic vesicle (*op. ves.*).

Section V is a transverse vertical section passing through the head region of an embryo in which the body of the embryo is just beginning to rise up off the yolk. To be noted are the regularly formed optic vesicles (*op. ves.*) and stalks, there being as yet no trace of the lens. Below is seen the pharyngeal region of the archenteron (*ph.*).

Section VI is of the same series as the last, passing between the optic and auditory region; it shows the single branchial pouch (*br. f.*) and the accompanying epidermal thickening.

Section VII of the same series, passing through the auditory region. There are seen in section the front end of the notochord (*N. ch.*), the auditory thickening of the epidermis (*Aud.*) and the rudiment of the pronephros being differentiated off from the general mesoderm (*Pn.*). There is seen also a faint indication of a neural crest (*N. cr.*).

Section VIII of the same series, passing through the posterior end of the archenteron, where it is seen to be constricted

into two portions, the upper being the opening of the neurenteric canal (*N. en.*), the lower the rudiment of the rectum (*Rect.*).

Section IX shows the fusion of the layers in the region of the neurenteric canal, and the separation of the latter from the rectum.

Section X of the same series, through the tail and vent, shows the opening of the neurenteric canal into the neural tube; also the fusion of the epidermis with the hypoblast at the anus (*An.*).

Section XI, a transverse vertical section quite at the anterior end of the head of an embryo, in which the first pair of external gills are beginning to bud. The section passes through the bottom of the stomodæum (*Stom.*), and obliquely through the mandibular arches at the point where they meet (*Mnd.*).

Section XII is of the same series, but further back, and on the right side in the figure passes through the centre of one of the eyes, showing the attenuation of the posterior wall of the optic cup (*Op. w. p.*) and the thickening of the anterior wall (*Op. w. an.*), the rudiment of the retina. The lens is also seen arising as a regular involution of the nervous layer of the epiblast, the epidermal layer (*l.*) remaining stretched across as a very thin membrane. The section also passes through the middle portion of the mandibular arches (*Mnd.*). The pharynx and pericardium are also cut through (*Ph.*, *P.c.*).

Section XIII of the same series passes through the centre of the opposite eye. The proximal parts of the mandibular arch are here cut through (*Mnd.*). The formation of the pericardium and heart, with its mesodermal membranous lining, is well seen (*P.c.*, *ht.*).

Section XIV of the same series passes a very little further back through the infundibulum, pharynx, and the two lateral extensions of the pericardium overlying the sinus venosus (*S. v.*).

Section XV is of a slightly older embryo, passing transversely through the eyes. The lens is now nearly completely

constricted off, and the back wall of the lens has begun to thicken and fill up the hollow of the lens (*l.*).

Section XVI is a sagittal section through the pineal eye of an embryo about two days before hatching. It shows the pineal stalk, still allowing free communication between the pineal body and the brain-cavity; this passage is now distinctly ciliated (*cil. st.*). Blood-sinuses are seen in front and behind.

Section XVII is a transverse section of an embryo just before hatching. It passes through the root of the first external gill (*Ext. G.*), and shows the developing first and second internal gills (*Int. G.*).

From this and similar sections there certainly does not seem to me to be any very marked difference in the nature of the external and internal gills.

As regards the development of the Pronephros and its duct, my sections indicate that there is considerable variation. Though by the time the external gills are developed there are invariably three nephrostomes, as in Rana, the first and third being lateral, the second dorsal, yet previously to this stage I find often only two nephrostomes, and in some instances two on one side with three on the other, and in one case but one. This seems to me to indicate that the pronephric tubules do not arise in the way usually described for Rana, namely, by the primitive pronephric groove becoming a closed tube and remaining in open communication with the cœlom at three points, but rather as a solid rod of mesoderm (Section VII), which later becomes hollow and acquires perforations into the cœlom, at first one, later three points—the nephrostomes.

In comparing the development of Phyllomedusa hypochondrialis with that of Rana, Bombinator, Pelobates, and other Batrachians with free-swimming larvæ, the first thing that strikes one as regards external characters is that, throughout, this embryo maintains a greater similarity to ichthyic forms, especially Ganoids, on the one hand, and to the Urodela on the other, than do the free-swimming larvæ of other Batrachians.

Again, we find this difference in general development of the young larva intensified in such forms as undergo a still more abbreviated embryonic development; for instance, in Paludicola fuscomaculata, where the embryonic development is shortened to something between twelve and twenty-four hours. All the points in which Rana appears to be a more modified form of development than Phyllomedusa are intensified, and the external characters are ill-defined. However, a minute comparison cannot yet be made until I shall have had time to study more carefully the details of development in Paludicola. The study of the internal anatomy leads to the same conclusion, namely, that in this protracted development we do not find the course of development distorted and blurred, but on the contrary every organ, so far as I can find, develops as in the ordinary frog, only more clearly and more definitely, and at the same time more as we see it develop in other great groups, Elasmobranchs, Ganoids, and the higher Vertebrates.

Take for instance the eye of a free-swimming batrachian larva, and compare it with the eye of Phyllomedusa. The evolution of the optic cup and lens is hurried over and blurred in the former, so that they are often difficult to trace, while here in Phyllomedusa it is as regular and diagrammatic as in any Vertebrate there is. Contrary to what we find in most Batrachia, the lens develops as an involution of a single layer of nervous epiblast rather than a mere thickening of that layer. In the free-swimming form the eye has been required to become functional as rapidly as possible, while here it has been suffered to go through its normal course of development in peace.

Take again the suckers of the free-swimming forms. They are evidently new adaptations without phylogenetic significance. Through the presence of these structures the form of the mandibular arches has become quite obliterated, while here in Phyllomedusa these would compare favourably with those of an Elasmobranch, reptile, or bird.

The peculiarly symmetrical gastrulation that this egg exhibits must be supposed, I think, to be the effect of a large

amount of food-yolk, as it can hardly be supposed that, at a stage previous to hatching in either mode of development, Phyllomedusa should be more primitive than the free-swimming forms.

I think the median spiracle may also be looked upon as a primitive feature.

The manner in which the branchial fold encircles the head reminds one strongly of Salensky's figure of Acipenser at a similar stage.

From the study of the development of Phyllomedusa, of which I have described the points of more general interest, I am distinctly inclined to think that we are not always warranted in attributing to alecithal free-swimming larvæ a greater biological importance, as far as retaining ancestral characters is concerned, than to heavily yolked embryos.

I think, moreover, that this is what we should expect, for from the time that the larva is hatched onwards it is subjected to the influence of natural selection.

Indeed, in this particular case of Batrachian development it would seem rather that the shortening of the embryonic period may be a specialised and not a primitive condition.

The fact that the majority of frogs have a shorter embryonic life does not seem to me to prove that the minority are the specialised forms in this respect. This particular mode of development is not confined to this species.

Von Jhering has described the oviposition of Phyllomedusa Jheringii, which agrees very closely with that here described. The eggs were laid between two or more leaves instead of being rolled in one, as with Phyllomedusa hypochondrialis. Von Jhering did not, however, work out the development of this species; in all probability it would not differ from this one.

This year S. Ikeda, of Tokio, has published an account of the oviposition in a species of Rhacophorus; from what he mentions of the appearance of the embryos which develop in a froth, much as is the case with Paludicola, I think the development of this form will be found to be quite like that of

Phyllomedusa; indeed, Professor Mitsukuri, who has seen them both, assures me that this is so.

To a paper by Gasser published in the 'Sitz. d. Kön. Ak. Marburg,' 1882, upon the development of the midwife toad, Alytes obstetricans, I have not yet been able to get access, but I feel quite prepared to find that it exhibits the same features that characterise the development of Phyllomedusa hypochondrialis.

XVI. Phyllomedusa Sauvagii, Boul.

This handsome tree-frog was brought to me in the Chaco, but I am not able to state anything about its habits.

XVII. Hyla spegazinii, Boul.

This fine Hyla was fairly common; I often caught or saw young specimens swimming from stem to stem of the Papyrus grass as we travelled through the reed-choked swamps. The full-grown specimens, however, were always taken either from palm tops just felled or from the trees overhead.

When caught in the water by daylight they were a bright light yellow, but at night they turned to a darker shade, and became marbled on the upper surface with brown markings. The full-grown specimens did not in this way become dark at night.

The largest specimens taken measured 80 mm. The eggs in the cloaca appear to be quite like those of Rana in size and colour, and are probably laid and reared in the same way.

One full-grown specimen I obtained in Central Paraguay on the Tibicuari, the rest in the Paraguayan Chaco.

XVIII. Hyla venulosa, Laur.

In life the markings are olive-green or grey upon a whitish ground. When taken from amongst foliage the whitish ground colour is suffused with green. It is a powerful and energetic frog, the large toe-discs having a tenacious sucking power.

The skin glands are strongly developed, emitting a very sticky white slime.

XIX. Hyla nana, Boul.

This small frog was abundant in the swamps, usually found by moonlight sitting on the broad-leaved plants of the swamp, and calling with a rather highly pitched scraping note.

The upper surfaces, as in H. spegazini, are light straw-colour by day, but brown by night. Flanks and underneath pigmentless.

XX. Hyla phrynoderma, Boul.

A light golden colour, shaded with darker above. The discs fairly strongly dilated. The skin is warty and extremely delicate, and it is not easy to catch one uninjured.

They are not common, but make themselves known by their constant call, which is just like the quacking of a duck. All the specimens I obtained were about the palm fencing and sheds.

XXI. Hyla nasica, Cope.

This is the most common Hyla in the Chaco. It is found everywhere, usually upon palm or palm fencing, where it is most inconspicuous.

Its call and habits are much like H. phrynoderma; the note is, however, somewhat lower. The colours are chiefly olive-green and brown, but the markings are variable. It is of more slender build than H. phrynoderma, the body being longer in proportion to the width of the head.

XXII. Ceratophrys ornata, Bell.

I obtained some half a dozen specimens of this curious and well-known South American frog, commonly known as the "Escuerso."

Its ferociousness is its most striking characteristic. If it is

approached to within two feet, it will make a vicious spring at one with its gigantic mouth wide open. If it succeeds in seizing any part of its tormentor, it holds on like a bulldog. The habit it has of distending its lungs to their fullest when teased has given rise to the idea amongst the Argentine people that if teased sufficiently it will burst.

It is perhaps needless to say that I was disappointed in my efforts to obtain this end. The Ceratophrys lives chiefly off other frogs and toads, but it is said also that it will seize and devour young chickens. The largest I saw was 120 mm. in length.

Lepidobatrachus, J. S. B. N. g.

Pupil horizontal. No vomerine teeth; transverse processes of sacral vertebræ not dilated. Large teeth in upper jaw; also two large teeth in dentaries of lower jaw. Tongue circular and free behind. Nostrils the most elevated portion of the head. Eyes close together, not more than the diameter of the eye apart. Fontanelles in the parietal region. Outer metatarsal tubercle very large. Great development of membrane bones in the head; width of jaw very great. Tympanum fairly distinct.

XXIII. Lepidobatrachus asper, J. S. B. N. sp.

Hind legs carried forward, toes reach barely to the eyes. Tips of toes horny. Skin of dorsal surface a dull leaden colour, much tuberculated and tough.

This frog lives continually in muddy pools. Its habit is to float with just the eyes and nostrils above the surface. If disturbed it slowly sinks to the bottom, leaving no ripple on the surface of the water. It feeds largely on Bufo granulosus.

XXIV. Lepidobatrachus lævis, J. S. B. N. sp.

This may possibly be the same species as the last, but

differs from it in the greater width of the skull, greater length of the hind legs, which carried forwards reach tip of snout, and in the skin being smooth, thin, and slimy, with the organs of the lateral line showing clearly upon it. Also the tympanum is larger and more evident. The tips of the toes do not bear horny caps as in the preceding species.

Below is a comparative list of measurements in millimetres in two specimens of XXIII and one specimen of XXIV.

		Total Length.	Hind Legs.	Width of Jaw.	Eye to Eye.	Eye to Ear.	Ear to Ear.
XXIII.	*a.*	80	62	34	4	8	24
	b.	70	60	33	3½	7½	23
XXIV.	*c.*	80	70	38	5	9	28

It is a source of great regret to me that I am obliged to abandon for the present my work in this direction. I have a considerable amount of material at my disposal of the developmental stages of several of the species of frogs, concerning which I have here merely stated the observations which I made a note of while yet in the Paraguayan Chaco. I sincerely hope that I may be able to return to this work at a future date.

Concerning the species Phyllomedusa hypochondrialis I should state that, although I have gone more fully into its development than others of my collection, here also my work has been cut short.

In concluding, I should like to say that I am very greatly indebted to Mr. Graham Kerr for the opportunity he afforded me of obtaining my material, and also for much help and advice in my work.

EXPLANATION OF PLATES 28—32,

Illustrating Mr. Budgett's "Notes on the Batrachians of the Paraguayan Chaco."

All the figures relate to the same species—Phyllomedusa hypochondrialis, Cope.

PLATE 28.

(See next page.)

PLATE 29.

The figures on this plate are all drawn under a magnification of eighteen diameters.

FIGS. 1—6.—Illustrating the character of segmentation. Figs. 1—4 are views from above; Figs. 5 and 6 from the side.

FIGS. 7 and 8.—Views of egg from below, showing diminution in size of the blastopore.

FIG. 9.—Egg seen from below, at a time when the blastopore is much reduced in size, and has nearly reached the level of a horizontal plane passing through the centre of the egg. From the pointed anterior end of the blastopore there passes forwards a distinct groove, indicating the line of fusion of the gastrula lips.

FIG. 10.—View of egg from above and behind, showing the continuation forwards of the slit-like blastopore as a faint groove along the axis of the medullary plate.

FIG. 11.—View of egg from above, showing neural plate and early condition of neural folds.

PLATE 30.

The figures on this plate are all drawn under a magnification of eighteen diameters.

FIG. 12.—View of anterior end of embryo, with well-formed neural folds. *Sp.* Space between embryo and egg membrane.

FIG. 13.—Similar view where the neural folds are arching over towards one another.

FIG. 14.—View of middle of trunk region of an embryo in which the pronephros has appeared on each side (*p.n.*). *Mes. som.* Mesoblastic somites. *3rd Br. f.* Position of third branchial pouch.

FIGS. 15—19.—Figures illustrating the further development in general form of the embryo.

FIG. 20.—View of anterior end of embryo, showing the first trace of stomodæum (*Stom.*).

FIG. 21.—Oblique view of embryo, showing the mandibular bars (*Mnd.*) and rudiment of heart (*ht.*).

FIGS. 22 and 23.—Views of anterior end of head, showing the fusion of the mandibular bars (*mnd.*) in the mid-ventral line.

FIGS. 24—26.—Side views of larvæ, showing the further changes in form up till the time of hatching. *Ht.* in Fig. 24, rudiment of heart. In Fig. 25 the external gills are at about their maximum.

PLATE 28.

(The explanation is given here as the figures run on from Plates 29 and 30.)

FIGS. 27—30 are drawn under a magnification of eight diameters.

FIGS. 31—35.—Natural size. It will be noticed that Fig. 35 has been wrongly orientated by the lithographer; the plant stem should be vertical.

FIGS. 27—29.—Side view of larvæ during the last day of intra-oval development.

FIG. 30.—Larva just after hatching.

FIG. 31.—Side view of larva at time of development of hind limbs, showing accumulation of pigment in the tail.

FIG. 32.—Young frog after leaving water.

FIG. 33.—Young frog after completed metamorphosis.

FIG. 34.—Pair of adults during the process of oviposition.

FIG. 35.—Adult specimen. This figure by comparison with Fig. 8 illustrates the extent of reflex colour change.

PLATE 31.

FIG. 1.—Transverse section through blastopore before formation of neural groove. *bl.* Blastopore. *ep.* Epiblast. *mes.* Mesoblast. *hyp.* Hypoblast.

FIG. 2.—Longitudinal vertical section of embryo with neural groove closed in anteriorly. *bl.* Blastopore. *An.* Depression marking position where anus will appear. *Arch.* Archenteron. *Mes.* Mesoblast. *Br.f.* Branchial outgrowth of archenteron.

FIG. 3.—Longitudinal vertical section of an embryo after the closure of the neural groove. *N.en.* Neurenteric canal. *an.* Anal depression. *Notoch.* Notochord. *hyp.* Hypoblast. *Br.f.* Branchial outgrowth of archenteric wall. *Ves* ^{I}, *Ves* ^{II}, *Ves* ^{III}. Brain vesicles.

FIG. 4.—Section parallel to the last figured, but more lateral in position. *Op. ves.* Optic vesicle. *Br.f.* Branchial outgrowth from archenteron.

FIG. 5.—Transverse section through head of an embryo which was just beginning to be folded off the yolk. *Op. ves.* Optic vesicle. *Ph.* Pharynx. *mes.* Mesoblast.

FIG. 6.—Section of same series as that shown in Fig. 5, through the single branchial pouch (*Br.f.*) and the ectodermal thickening accompanying it.

FIG. 7.—Section of same series through auditory region. *Aud.* Commencing auditory invagination of ectoderm. *N. ch.* Notochord. *Neur. cr.* Neural crest. *P.n.* Rudiment of pronephros.

FIG. 8.—Section of same series through posterior end of archenteron. *Rect.* Rectum. *N. en.* Neurenteric canal opening into this. *hyp.* Hypoblast. *N.ch.* Notochord.

FIG. 9.—Section of same series further back. *N.en.* Neurenteric canal. *Rect.* Rectum.

FIG. 10.—Section of same series showing opening of neurenteric canal (*N. en.*) into neural canal; also anus (*An.*).

FIG. 11.—Transverse section through anterior end of an embryo, in which the first pair of external gills were beginning to develop. *Stom.* Cavity of stomodæum. *Mnd.* Mandibular arch close to its junction with its fellow.

FIG. 12.—Section of same series passing through the rudiment of the eye. *Op.W.an.* Anterior layer of optic cup. *Op.W.p.* Posterior wall of ditto. *l.* Outer layer of epiblast passing continued over mouth of lens invagination. *Ph.* Pharynx. *P.c.* Pericardium. *mnd.* Mandibular arch.

PLATE 32.

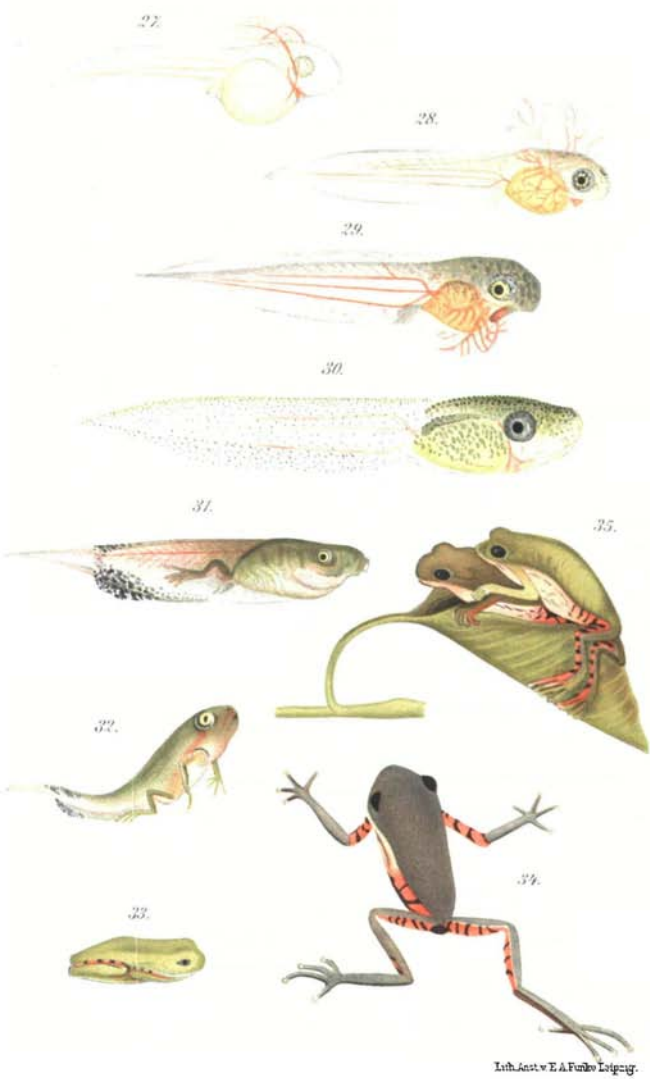
FIG. 13.—Section of the same series as that shown in Plate 31, Fig. 12. *mnd.* Mandibular arch. *ht.* Heart. *P.c.* Pericardium.

FIG. 14.—Section from same series through infundibulum (*Inf.*). *P.c.* Pericardium. *S.v.* Sinus venosus.

FIG. 15.—Transverse section through head of slightly older embryo, showing later stage in the formation of the lens (*l.*).

FIG. 16.—Sagittal section through pineal body (*Pin.*) of embryo about two days before hatching. *Cil. St.* Pineal stalk with ciliated lining. *Sin.* Blood-sinus.

FIG. 17.—Portion of transverse section of embryo just before hatching, passing through the origin of the first external gill (*Ext. G.*). *Int. G.* Internal gill.



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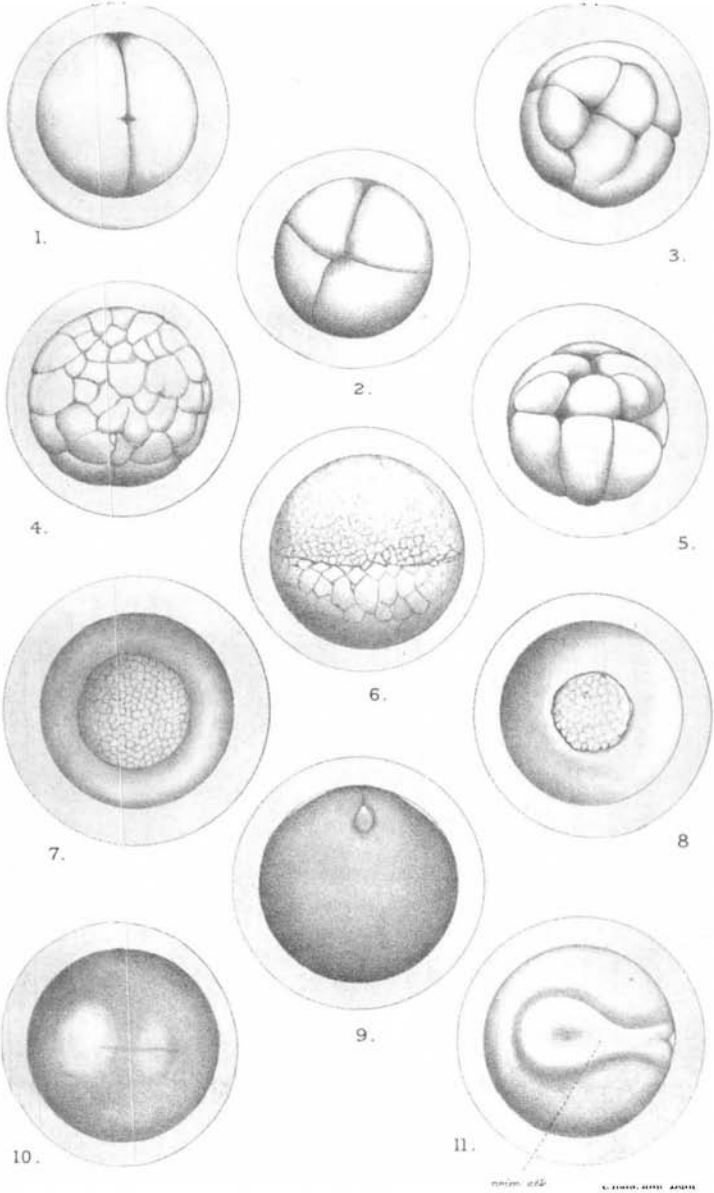
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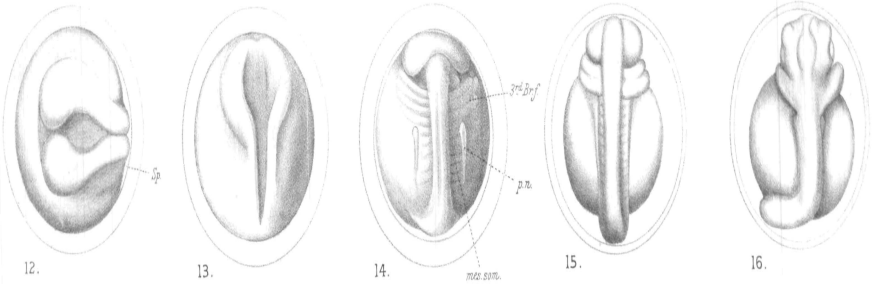

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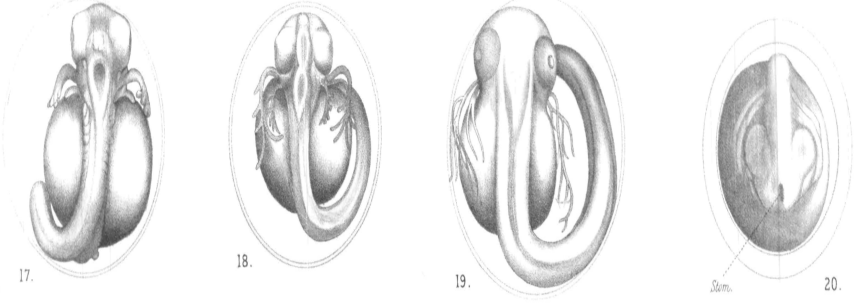

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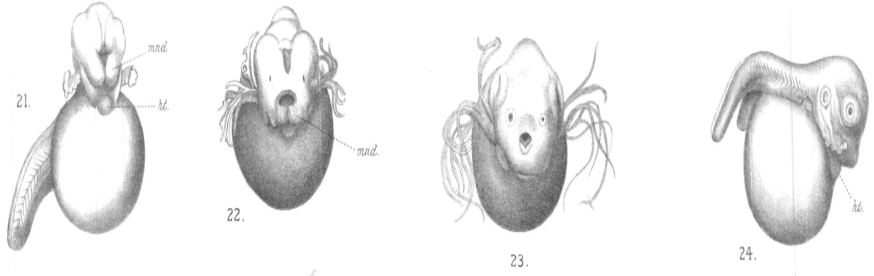

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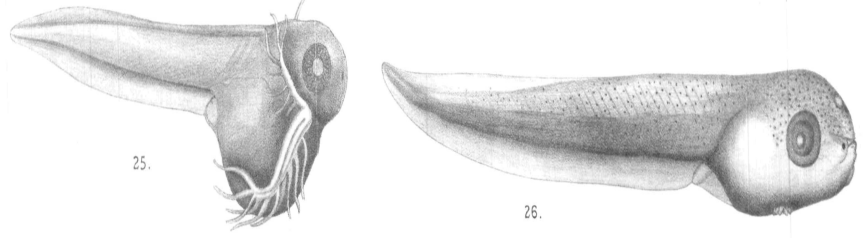

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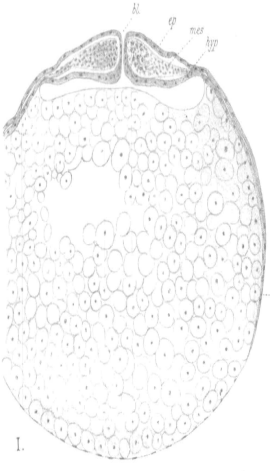

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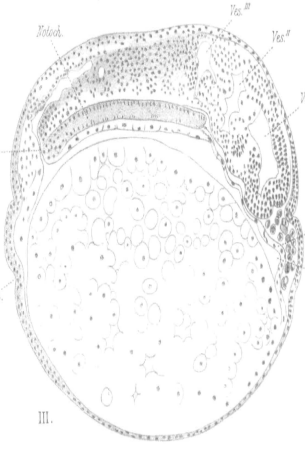

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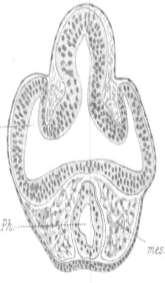

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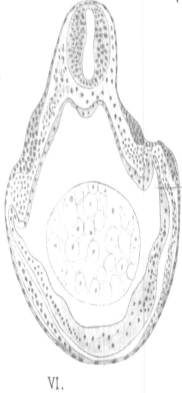

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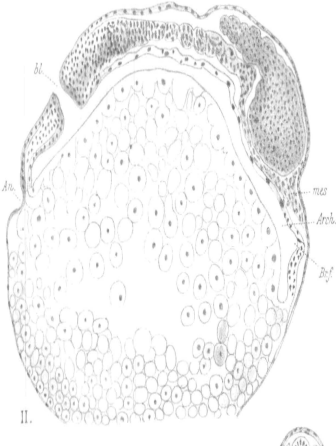

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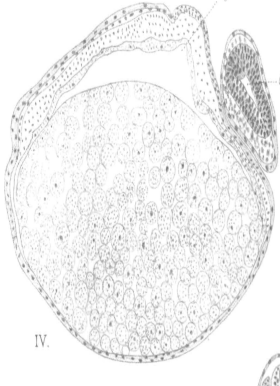

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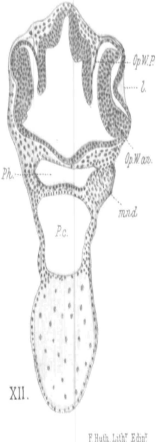

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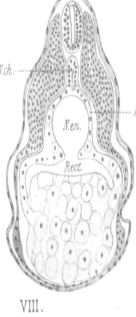

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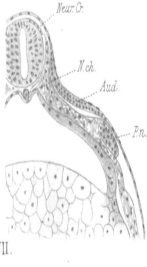

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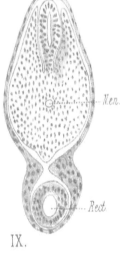

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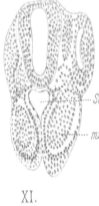

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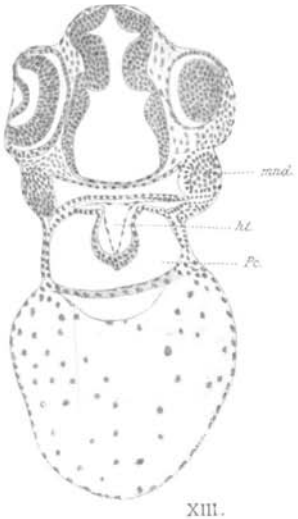

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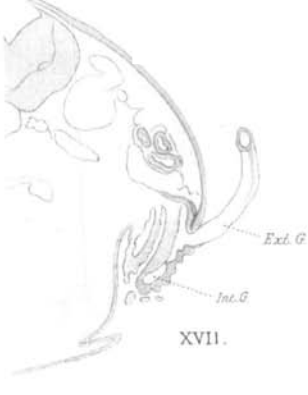

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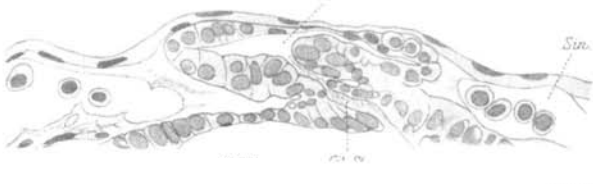

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