MEMOIRS OF THE COLLEGE OF SCIENCE, KYOTO IMPERIAL UNIVERSITY, SERIES B,
Vol. VII, No. 4, Article 7, 1931.

Notes on the Behavior of the Common Japanese Newt, *Diemyctylus pyrrhogaster* BOIE.

I. BREEDING HABIT.

By

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With Plate XV and 17 Text-figures

(Received Oct. 5, 1931)

The breeding habits of two Japanese urodeles were observed by K. KUNITOMO (1910, *Hynobius nebulosus*) and M. SASAKI (1024, *Hynobius lichenatus*). On the common newt, *Diemyctylus pyrrhogaster* BOIE, however, there are only a few reports, such as those by T. IWAKAWA (1889), E. ZELLER (1905) and J. OYAMA (1924), so that remains much to be found out about this species. It may be profitable, therefore, if I record some facts ascertained during the observations which I carried on for three years under the supervision of Prof. T. KAWAMURA in the zoological institute and the hydrobiological station of the Kyoto Imperial University and also in the natural habitats of the animal at various places.

I. Chief Sexual Characters at Ordinary Times.

The sexual differences in the external characters have already been described by T. IWAKAWA (1889), L. STEJNEGER (1907) and more recently by T. UEKI (1930) and K. TAGO (1931). I have to add the following facts for comparison.

(1) The whole body: The female is larger than the male. The total length of the mature male is about 85 to 105 mm, seldom more than 110 mm., while that of the female ranges from 100 to 120 mm., often being more than 130 mm. That is, in the total length, the female is larger than the male by 10 to 20 %. With regard to the gross body weight, UEKI (1930) has shown that the male weighs 6

gms. and the female 10 gms. on the average. The same is true in *Necturus* (BISHOP 1926), but in *H. lichenatus* the female is a little smaller and more slender than the male (SASAKI 1924).

(2) Dermal glands : In the development of the dermal glands remarkable differences are shown between the sexes, especially :—

A. Parotoid gland : well-developed in the male ; a large, prominent, compressed, flap-like process roughly triangular in shape behind the eyes on each side, almost continuous with a dorso-lateral ridge (Figs. 1 and 2).

B. Globular gland : a large, smooth, globular gland on each side of the neck at each end of the gular fold in the male (Figs. 2 and 3).

C. Scapular gland : a somewhat smaller and flatter but well-defined circular gland above the insertion of the fore-leg, between the latter and the dorso-lateral ridge, is observed in the male, but is not marked in the female (Fig. 1).

D. Glandular ridges : a vertebral ridge and dorso-lateral and ventro-lateral ridges on both sides are distinct

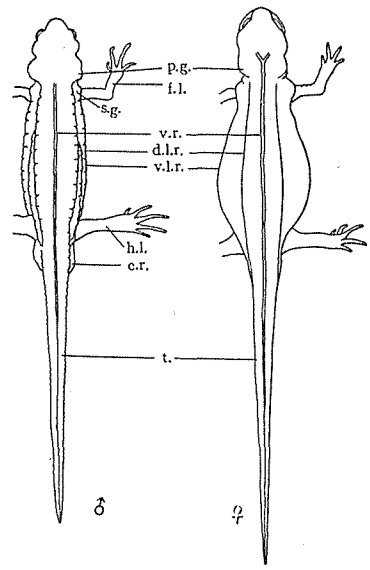

Fig. 1.

A dorsal view of *Diemyctylus pyrrhogaster*. c. r. cloacal region. d. l. r. dorso-lateral ridge. f. l. fore limb. h. l. hind limb. p. g. parotoid gland. s. g. scapular gland. t. tail. v. l. r. ventro-lateral ridge. v. r. vertebral ridge.

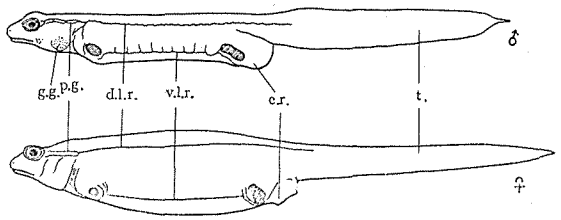

Fig. 2.

A lateral view, (the limbs being cut off near their bases). g. g. globular gland.

in the male and so the section of the trunk is pentagonal in shape, just like a Japanese chess-man, while in the female only the vertebral

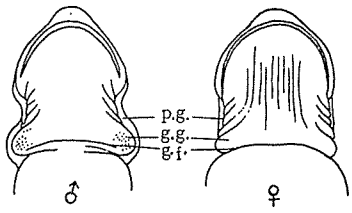

Fig. 3.
A ventral view of the head.
g. f. gular fold.

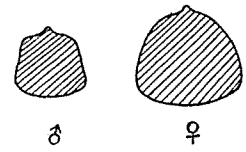

Fig. 4.
A section of the trunk in the breeding season.

ridge is clear and the section of the female trunk shows a shape like the section of a chestnut (Fig. 4).

(3) Cloacal region: The male having a cloacal gland, the cloacal region is a large, globular swelling, the surface of which is coarsely pustular. The vent is a longitudinal slit with a pair of papillae on each side near the posterior end of it. In the female the cloacal part forms a compressed elevation, narrow laterally and wide longitudinally (Figs. 2 and 5). In many salamanders a papillary protuberance like this has been observed at the cloaca.

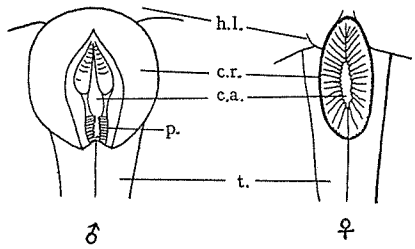

Fig. 5.
Cloacal region, (postero-ventral view).
c. a. cloacal aperture. p. papillae.

(4) Skin: In the female, the surface of the blackish brown skin, excluding the red belly, is rather beady than pustular, and somewhat smooth, while in the male it is coarse and rugose with many transverse wrinkles, particularly on the lateral ridges.

(5) Legs and digits: All the limbs of the male are relatively longer than those of the female, and so are the digits; for instance, the longest toes (the third) in both sexes measure about 6.5 % (male) and 5 % (female) of the total body length, according to UEKI. In thickness, the hind limb much exceeds the fore limb, especially in the male. The limb is the clasping organ of the male in the mating period.

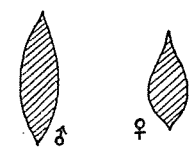

Fig. 6.
Sections of the tail cut at one third from the base.

(6) Tail: The tail of the male is strongly compressed dorso-ventrally and has a fin above

and below along the median line. The filament is of the same height throughout its length, so that the outline of the tail shows two lines nearly parallel and suddenly tapering near the end of it. In the female the fins are totally absent and the narrow tail as a whole tapers gradually to the end (Figs. 2 and 6).

The swimming of the newt is chiefly effected by lateral propulsion by the tail in both sexes. But in fear or in case of accident the male and the female bend their tails differently; the male bends it acutely and complexly, as in the mating, and the female, obtusely. Thence we can distinguish them readily by agitating the water. The relation between the lengths and weights of the various parts of the body have been detailed by UEKI (1930).

II. Special Features in the Breeding Season.

The Male.

(1) Special development of the glands: All the glands of the male develop remarkably in this season, especially on the parotoid gland the enlargement of the globular fold is obvious, and the development of the cloacal gland is accompanied by increase of the cloacal swelling. According to UEKI, the percentage weight of the cloacal gland is .67% in July and 3.05% in November. At this season the skin of the male is very soft to the touch owing to the secretion of these glands.

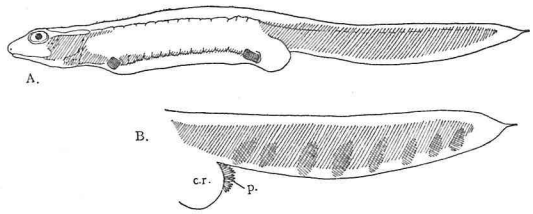

Fig. 7.

Colouration, (side view). A. Entire body. B. Caudal portion with protruded cloacal papillae showing many black spots.

In *Diemyctylus viridescens* W. A. HILTON (1902) observed a series of three to four small pits along the side of the head just behind the eye, and described the differences in the two sexes and in different stages of maturity. We can not find these depressions in our newt, but the parotoid gland has many small pits on the surface, and so on the globular gland. These organs are same in their position in the

body, in their secretory function and also probably in structure. They appear to me to be homologous.

(2) Colouration. The male in the breeding time shows a special colour on the body, a whitish blue or violet shade along the border between the dark skin of the dorsum and the red belly. This nuptial colouration expands from the hinder parts of the eyes and mouth to the parotoid and globular glands in the head, stretches along the ventro-lateral ridge in the trunk and spreads over almost all the surface of the tail excepting the filamentous appendix. The red belly with black mottlings on it and the underside of the limb are also tinged with whitish blue. Besides this, in some males, there appear black spots, seven or eight in number, on both sides of the tail. Such

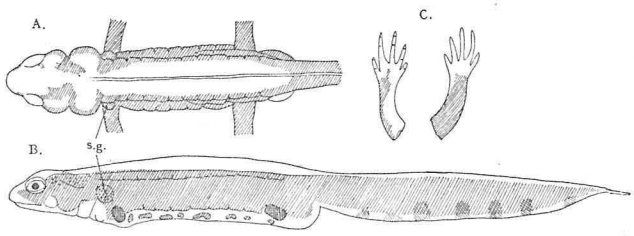

Fig. 8.

Nuptial colour of a male extending extraordinarily over parts of the body. A. dorsal. B. lateral. C. left hind leg, (dorsal and ventral).

colouration does not appear suddenly at the beginning of the breeding season, but gradually in the early autumn not long after its disappearance with the ending of the preceding breeding season, or it is kept all through the winter, and then becomes brighter in spring. That is, the pale colour is absent only in the summer.

The nuptial colouration of this species resembles that of *Triton cristatus*, but there is not such a nuptial dress or crest as in the latter or in *Diemyctylus torosus*. Also there is no special clasping organ in the breeding season, such as the wart-like elevation or the patch on the hind leg, or the black cap at the tip of the toe that are observed in *D. viridescens*, *Hynobius lichenatus* and *D. torosus* respectively.

The Female.

(1) Swelling of the abdomen caused by the development of the ovary and the maturation of the ovum.

(2) Enlargement of the cloacal elevation; but on the underside of

it there can not be seen the "warzenähnlich rauhe Scheibe" which appears in *Triton taeniatus*.

Some remarkable facts in regard to the behavior are to be seen at this period, for instance:

(1) The female becomes greedier and more omnivorous than the male.

(2) Both sexes prefer shade to a sunny place at this time.

III. Sexual Ratio.

The numerical ratio of the sexes is about 1/1 as far as I have been able to estimate it from a fairly large number of individuals reared from eggs in aquaria, but in the specimens collected from natural habitats, the sexual ratio is variable, the females being mostly superior in number to the males, sometimes more than three times as numerous, while in the breeding season the males greately exceed the females. At this season the individuals swimming on the shaded surface of water are mostly males, a female being sometimes seen creeping on the bottom near the edge of the pond or ditch, followed by a few males. Some females may swim near the surface entangled with several males but by no means very commonly. The female retires beyond the reach of our sight and hands in the breeding season. This is interesting since a similar habit is mentioned in *Necturus* by EYCLESHMER (1906), in *Cryptobranchus alleghaniensis* by B. G. SMITH (1907, 1912) and in *Hynobius lichenatus* by M. SASAKI (1924).

IV. Breeding Migration.

Two methods of hibernation are found in this species in nature: 1. The animals migrate to land and hide themselves under various substances such as decayed leaves, stones and other objects on the damp ground which protect them securely from injury by frost, snow and drought. 2. The animal does not go ashore but buries himself in the mud or rubbish at the bottom of the pond. The latter way is seen also in aquaria. In many cases the breeding ground is the natural habitat till hibernation. After each winter we find the newts under water at 7°–8°C. in the middle of March, but since they are nocturnal, I have never been able to observe such facts as BLANCHARD reported in the case of *Ambystoma maculatum* (1930). Recently K. TAGO has reported on this matter in the case of our *Diemyctylus* (1931). "The male", he says, "comes to the breeding pond in advance of the female and for spawning the latter migrates during the night

or in the rain", but he does not seem to have distinguished the mating from the spawning. The mating takes place even in the open water, but the spawning always in a shaded sump or drain with water plants in it. Then the migration begins and this is partly the reason why the sexual ratio in open water is male>female in number in this season, as mentioned above.

V. Mating Habit.

(1) Courtship.

For the most part urodeles are fertilized internally, and this is so in the Japanese newt. Copulation is carried on in the water. It is almost impossible to observe fully these habits in any natural pool inhabited by the salamander, so that the following observations were made in aquaria.

A male and a female which have been kept apart for several weeks are brought together in a glass vessel. When the animals thus disturbed return to the calm normal state, the courtship performance of the male begins. As soon as the male becomes aware of the presence of the female in his neighbourhood, he approaches her, and then smells her body keeping the tip of his snout close to her snout or cloacal region. When he has made sure it is a female, his cloacal aperture opens and the papillae come out (Fig. 7–B). He moves along in the same direction as the female with his body sidelong to her front, and prevents her from moving forward by pressing her snout down with his fore-leg or putting it under her snout and by bending his head to hers. At the same time he fixes himself in position by clasping her with the hind leg on the same side, stretching it to her armpit over her back. Then he bends his tail to her side and propagates rapid, delicate undulations to right and left from the root to the tip of the tail just above her back. This half-stroking and half-fanning motion of the tail undoubtedly serves to send the secretion of the cloacal gland to her

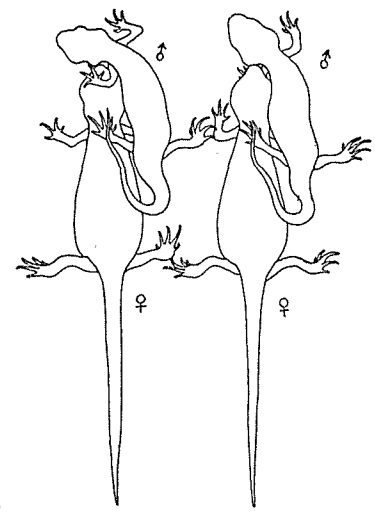

Fig. 9.
The sexes in "Vorspiel".

snout and to stimulate her to sexual excitement by means of this odour, having regard to the extraordinary development of this gland in the mating season. At this time his cloaca is widely distended, with numerous white papillae protruding which remind us of the expanded tentacles of a small sea-anemone. This special act of courtship of the male has been called "Vorspiel" or "Liebesspiel" by German authors. The fanning motion lasts one or two seconds and is repeated several times rhythmically at short intervals until the female darts away from his grasp as if she hates it, or else responds to his courtship. As she begins to move in spite of his strenuous inhibition, the male, ceasing the action, follows her and goes around her persistently to make a courting demonstration by which he seems to endeavour to send her a renewed stimulation. Then he repeats the "Vorspiel" again and again on her back. Comparing this with that of *D. viridescens* described by JORDAN (1891), it is different in that the male vaults just upon the female after a stealthy approach and the fanning motion of the tail is kept up alternately, first on one side and then on the other. It is merely a "Vorspiel", and I do not find any spermatozoa in the water nearby. In the ordinary case this action of the male is repeated continuously, but occasionally the male leaves her and shows quiet indifference, withdrawing the cloacal papillae entirely, then after some minutes or hours he sets to work again. Usually, nothing further happens in the aquarium; in the worst case I kept watch for ten hours or more in vain. During these the female is quite indifferent, and shows no peculiar manner actively. Usually she darts away from him after a while. The mating instinct is seldom displayed in action in our sight. The course goes on only when the female is so pubescent that she responds at once by pushing her snout lightly against his shoulder in the "Liebesspiel". Occasionally a female halts by her suitor and shows a slow tail-fanning movement similar to his, as if it had come to her turn. Although this is uncommon it may appear in some special individuals.

The male repeats the importunate action of courtship until the female responds to it. The duration varies according to her responses. At times, it happens that the male irritatingly bite her body at the parotoid gland or the tail, but except for this I never saw such cruel rough usage as was observed by *D. viridescens* (JORDAN 1891).

As soon as the female complies with his amorous intention, the male releases her and creeps very slowly along her front with his tail raised at the root and higher up at the end, and turning gently

to right and left in a somewhat snakelike movement accompanied by a delicate quiver in all its length. It resembles what E. ZELLER (1905) described in other Tritons, a "hakenförmig umgelegten Schwanz". The female follows just behind him, her snout coming nearly in contact with his tail and his opened cloaca (Fig. 10). Thus one behind the other they creep on a distance of about ten cms. All at once he opens his cloaca to the extreme so that the inside of the cloacal chamber, shaped like a round dish, comes into view, and the papillae are protruded on both sides of the brim of it, while at the same time a wormlike sperm-mass comes out from the inner part of it (Fig. 11).

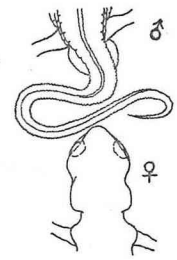

Fig. 10.
Both sexes in the copulation. Show partially the tail of the male and the head of the female.

If all goes well, the mass of semen, submerging towards the bottom of water, hangs on to the vent of the female, which follows closely. The male continues to creep on a distance of a few centimetres, then he deposits a second mass. In this way a male discharges as many as three or four masses consecutively.

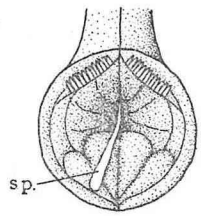

Fig. 11.
The opened cloaca of the male, discharging a sperm-mass, (hind view). sp. spermatozoa.

The sperm mass is somewhat like the nematode worm, *Enterobius* in shape, size and colour, that is milky white, about 0.5–1 mm. thick and 5–6 mm. long. It is neither twisted like that of *Triton taeniatus*, nor covered with any membrane; it is merely a pure accumalation of numerous spermatozoa which tends to become spherical in shape gradually after a few minutes. A very important point is that I could never find a spermatophore such as E. ZELLER (1905) observed in many European and American tritons and in our *Diemyctylus pyrrhogaster*, the structure of which he showed in detail by pictures. In my observations made in the past three years I have never come across any "Samenträger". The animal always deposits sperm masses alone. ZELLER says of his materials "In den Besitz des *Triton pyrrhogaster* bin ich durch die Freundlichkeit von Herrn Dr. W. Wolterstorff in Magdeburg gekommen". I suppose it may have been confused with some other species in passing from the collector to him.

The spermatozoa are not taken up by the female but adhere

mechanically to her cloacal region and by virtue of their own activity, pass up between the tightly closed cloacal lips. In the course of mating, a female creeps along straight just behind the male and her cloacal region, swollen more than usual, reaches down nearly to the bottom. This serves to increase the possibility of "Sichanhängen der Samenmasse". But I have never seen any female provided with "die warzenähnlich rauhe Scheibe welche die untere Fläche des weiblichen Kloakenwulstes bildet". The underside of the cloacal region of the female is somewhat rugose like the other parts of the skin and I have never seen its "auffallende Entwicklung während der Brunstzeit", as happens in *Triton taeniatus* (ZELLER, 1891). On the other hand, the end of the sperm-mass which leaves the male cloaca last is so adhesive that it clings to the cloaca and comes out at the same time as the next deposition. This thinner end of it sticks to the lower part of the female cloaca naturally in her forward movement, and then the adhesion extends gradually to the other end. At this time the slender sperm-mass hangs over the longitudinal slit of the cloaca (Fig. 12). Although this is called "Samenaufnahme", being a mechanical contact, many failures occur. If the water is disturbed by the animals or if the female does not creep straight along, the sperm-mass remains on the bottom not touched at all by the female or it comes in contact with other parts of her body. In the latter case, it often adheres to the belly or the inner side of a hind leg, and does not move toward the cloaca spontaneously, but remains at the same spot on the skin for several hours in spite of the female's attempts to scratch it off by her mouth and a fore leg. In the former case or if the sperm-mass is removed from the female body into the water, it is deposited on the bottom, becoming a ball, and never adheres to her body, but is lost in the mud. It is often eaten by the animals in aquaria. I should think that a considerable number of the sperm-masses can not fulfil their mission in my aquarium owing to its confined space, but it is possible that in the natural pond the number of failures is not very large.

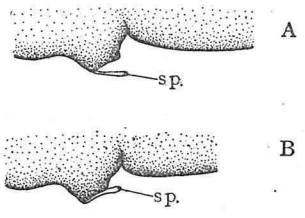

Fig. 12.

The adhesion of the sperm to the cloacal region of the female. A. partially. B. totally. sp. spermatozoa attached to cloacal opening.

When no sperm-mass attaches itself to the cloaca after her following, the impatient female occasionally bites at the tail moving before

her eyes. The male stops a while, then begins to discharge again, but frequently he darts away as if frightened by it.

The spermatozoa which stick to the cloaca of the female in a mass, pass through her closed aperture, enter the cloacal chamber and find their way to the receptacula seminis probably by means of a positive chemotaxis. At least it takes over an hour for them to disappear entirely out of sight. Considering this fact and also in my observations, a female takes up only one sperm mass at a mating although the male deposits 3 or 4 masses continuously. No case is seen in which a female takes up 2 or 3 masses and they fuse in a mass as in ZELLER's description. When a female bears a mass on her cloaca, usually she swims away and the male, not aware of her flight, continues his discharge and wastes the masses as if she were following him. But as soon as he finds this out, he swims after her, and repeats the action of courtship again. The female, nevertheless, does not respond, or at least not till the spermatozoa have completely entered her cloaca. In this case the excited male often bites at her body too.

In this way the mating is carried thorough. How many times one male or female mates in a season, is unknown. The appetite decreases remarkably in both sexes at this period.

(2) Receptaculum seminis.

The spermatozoa are kept in receptacula seminis by the female. S. YAMAGIWA (1924) described the urinogenital system of *Hynobius lichenatus* and *Diemyctylus pyrrhogaster*, but did not pay attention to the Rec. sem. They are many glandular "Schläuchen" buried in the dorsal and lateral walls of the cloacal chamber and a few in the ventral. They are long and slender tubules, round in transverse section, running rather obliquely from the antero-dorsal to the postero-ventral position, and the anterior end is blind, reaching nearly to the muscle, while the other end opens in a narrow path to the cloacal chamber in the anterior half of it, but it does not open just behind the mouth of oviducts and in the posterior half of the cloacal chamber. These ducts are branched many times and in one transverse section we can find about 40 to 50 canals filled with "Samenfäden" (Fig. 13). Highly magnified, this canal shows a "Lumen" surrounded with glandular cells mostly 20 to 30 in number and spermatozoa exist in it, sometimes with their heads thrusting into the intercellular space (Fig 14.). We can easily distinguish these flat "Drüsenzelle" of the Rec. sem. from the "Cylinderepithel" of the cloacal chamber.

Besides this the spermatozoa are found in the cloacal chamber and in the mouths of the oviducts where two ducts are close to each other and jut out into the cloacal chamber with some swelling, and never go up into the oviducts.

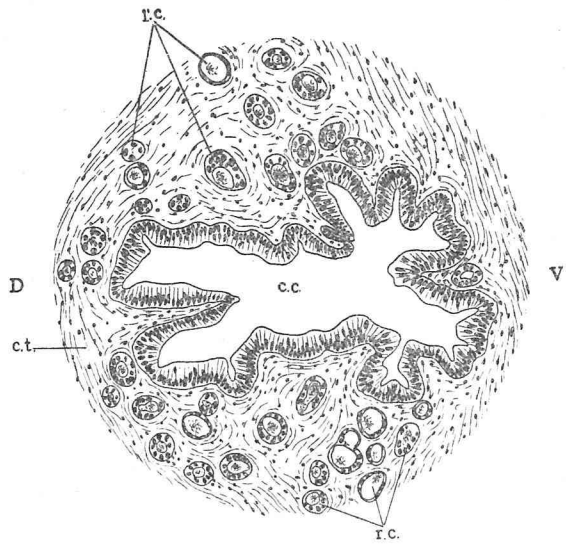

Fig. 13.

Receptacula seminis in the female cloaca, (transverse section). c.c. cloacal chamber. c.t. connective tissue. r.c. receptaculum seminis.

In regard to the Rec. sem. of *Diemyctylus viridescens,* JORDAN (1891) has stated that "the spermatozoa are not inside the mouth of the oviduct, as might be expected, but are closely packed in the ducts of two groups of gland-like structures situated in the cloacal wall just below the entrance of the oviducts". There are also two groups of the ducts in our newt, but only one group functions as Rec. sem., while the other paired one running through the dorsal wall of the cloaca, branching again and again, goes into the kidney and does not contain any sperms in its interior. I have found in many individuals some spermatozoa inside the aperture of the oviduct, but never very deep in the tube. No spermatozoa were found in microtome-sections of the oviduct, so that it is questionable whether the spermatozoa do really go up inside the oviduct or not.

The spermatozoa which enter the chamber in the mating are kept securely in the "Samentaschen" and coming out of it, arrive at the

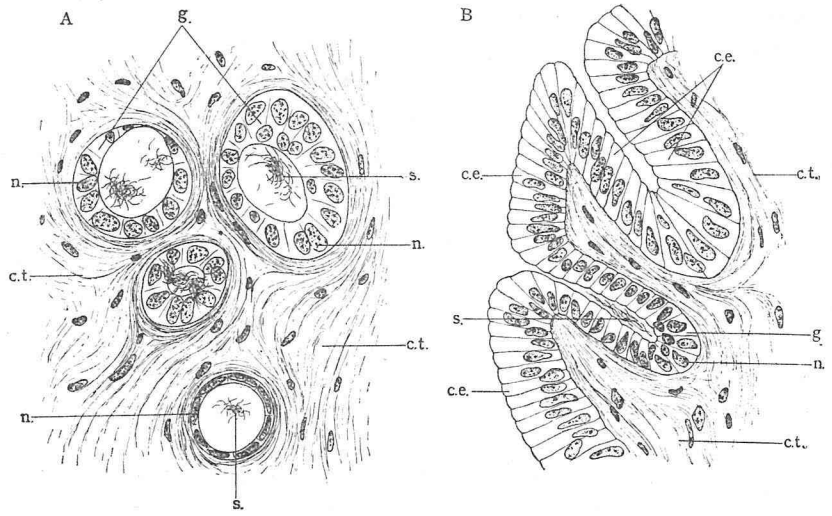

Fig. 14.

Receptaculum seminis. A. Transverse section. B. Orifice. c. t. connective tissue. c. e. cylindrical epithelium of cloacal chamber. g. glandular cell of Rec. sem. n. nucleus. s. spermatozoa.

ends of the oviducts when the ova come into the ducts, and then fertilize them in passing through there or in the cloaca if my deductions are correct.

In 1929 a female which had separated from the male on 18th November in the previous year, laid seventeen eggs in the aquarium from 25th April to 28th May and fourteen of them hatched normally. In this case the zoosperms had been preserved in the "Samentaschen" of the female for 190 days, at least. Such a case happens not seldom, that is, the spermatozoa are not only kept alive in the Rec. sem., but also fed there.

In Urodela there are two cases; one is external fertilization after spawning which occurs in *Hynobius* and others like the amplexation in Anura, and the other is internal fertilization by means of a special organ "Receptaculum seminis" as in many *Diemyctylus* and *Salamandra*, also in *Nectulus* and *Geotriton*.

(3) Period of Mating.

The animals begin to mate about the same time as their activities recommence soon after hibernation. The period varies with the climatic conditions, but in the middle parts of Japan it ranges from the end of March to the middle of May, occassionally to the first of June.

The mating goes on when the temperature of the water is between 8° and 15°C. and it occurs even at 18°–19°C. among individuals. The most favourable time is April. The copulation is carried on at any time in the day at this season both in the sunshine and in the shade.

(4) Autumnal Mating.

An autumnal mating takes place naturally in this species. In the male the nuptial colouration and the special development of the glands are mostly absent only in the summer, and appear at the beginning of the autumn, as has been adverted to already. I have on several occasions in November and in the other autumn months seen pairs engaged in the preliminary "Liebesspiel" in aquaria and in the natural habitats. But it is not so common and frequent as in spring. No doubt it occurs only sporadically and incidentally in some individuals.

Such an autumnal mating is noticed widely in Urodela, i. e., in *D. viridescens* (ZELLER 1890, GAGE 1891, JORDAN 1893) and in *D. torosus* (RITTER 1897). It is said that in *Salamandra maculosa* the same females reproduce regularly twice a year, in spring and in autumn, and in *Necturus* autumnal mating alone takes place (BISHOP 1926).

VI. Oviposition.

(1) Action of Egg-laying.

The newt is oviparous. At first the gravid female seeks a water-weed in a quiet place where she will not be disturbed by others, and creeping along the stem of the plant, she reaches a suitable leaf for laying. She then bestrides the chosen leaf, clasps it with her hind legs and presses it closely around her cloaca. As the upper part of the body and the fore-legs are free in the water, she often fails to do what she wants, the leaf comes out from between her legs, and she wanders from plant to plant to select another leaf. The leaf being held tightly close to the cloacal prominence by the legs, it makes an angle, forming a V-shape which completely hides her cloaca (Fig.

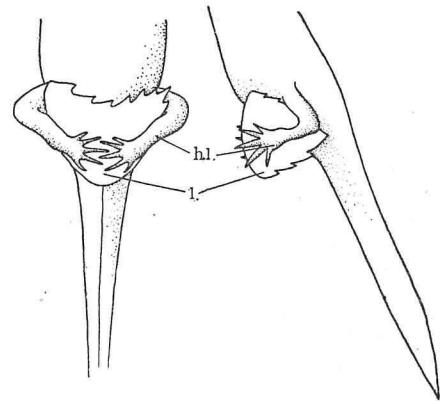

Fig. 15.
Female in oviposition. h.l. hind leg. l. leaf.

15). She remains motionless for about three to five minutes, during which time an egg is laid inside the V-shaped angle. Then she pushes her hind legs downward holding the leaf between them, so that the sides of the leaf are pressed together with her soles and glued to each other by the gelatinous secretion poured out of the cloaca (Fig. 16). The egg is thus completely wrapped in the leaf, when she swims away without looking round to see it. The eggs are laid singly as a rule, but occasionally two or three may be deposited successively, in a gelatin. This newt differs from *Hynobius* and others which lay many eggs in a bunch or an egg-sac on an object such as wood or stone submerged in the water. I have observed a female begin to lay an egg twenty minutes after spawning the preceding one, but this is the shortest interval that has come under my notice; usually the time elapsing between the deposition of two eggs is considerably longer than this.

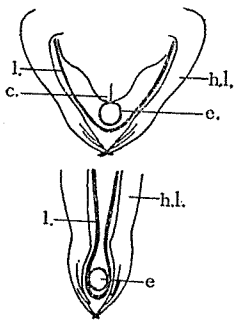

Fig. 16.

Sections which show the stages in oviposition. c. cloaca. e. egg.

(2) Place of Spawning.

They spawn in shallow, quiet water they dwell, such as ponds, swamps, pools, or road-drains, never in running water. The egg is laid near the surface of the water, at the deepest within 10 cms. under the surface; this is probably for the sake of light, high temperature, and good change of water. It is always laid in the shallow parts in spite of the danger of a fall in the water-level. I have often seen many eggs dried up on plants in swamps in the air. They like shade more than the direct light of the sun.

The plants on which they select to lay are commonly water weeds such as *Oenanthe stronifera*, some species of *Hydrocotyl*, *Viola*, *Ranunculus*, *Artemisia*, *Phalaris* and *Polygonum*. If they can find no weeds in the water, they occasionally lay on the leaves of plants growing on the bank and hanging their branches down into the water, such as *Milletia japonica* and *Rosa multiflora* etc. In aquaria they lay on *Nymphaea tetragona*, *Ceratophyllum demersum*, and even on decayed leaves and on pieces of paper put in for experiment.

They choose a soft, small leaf, as easy to bend as possible, and spawn on a leaf as above mentioned or between a stem and leaves, and often between two leaves, when the leaves are thick and hard.

If the leaf is long and slender they fold it again and again, and then many eggs are laid singly here and there on it. If it be large in size, they turn up the edge. Mostly they lay on the upper surface of a leaf. When *Ceratophyllum* is the plant chosen, the animal gathers in the leaflets with her hind legs, presses them against her cloacal region and lays an egg in the tangle of these shoots, just as in the cases described by JORDAN (1891) and GAGE (1891) in *D. viridescens*.

(3) Period of Oviposition.

Usually about a month elapses between the mating and the deposition of eggs. In aquaria the oviposition extended from May 10 to July 4 in 1928, May 15—July 2 in 1929 (Fig. 17) and in 1930 April 10—July 8 (earlier than in the other years owing to exceptional warmth at the season) and in 1931 April 17—June 29. The water temperature for spawning ranges between 14° and 20°C., higher than that of the mating by 4° or 5°C., so 16° or 17°C. is the optimum. For the most part she lays at dawn, but often in the daytime. The largest number of eggs laid by a single female in captivity in one season in the course of my observations was 324; that was this year. OYAMA (1924) reports that he counted over two hundreds.

Captivity has an influence on spawning, but only for a short time. A few days after being captured the animals lay as usual even in a small vessel. Spacial sense is negligible; the chief factor is the temperature. Females in my room warmed by a stove laid many unfertilized eggs on the bottom of the vessel in the middle of March. Rain has no effect on oviposition, unlike in *Ambystoma* (BRANCHARD 1930).

The newt eats its own eggs when hungry. We often see the leaves of the plants used for egg-laying harmed by mere biting of them in the breeding season. Last autumn I found many leaves of *Oenanthe* injured by the newts in my aquaria. From this I have recognized that spawning had taken place though I had not witnessed it. Having regard to the fact that in that month the atmospheric temperature rose again after some cold days with frost on the ground, it may have happened through an error of instinct probably, before hibernation.

(4) Relation between Mating and Oviposition.

In the natural condition, spawning is caused by maturation of the ova owing to rise of the temperature after mating. But it is an error to suppose that they often, without copulation, lay many unfertilized eggs merely because the temperature is high. The vast majority of the females which are separate from the males do not

lay even when the temperature has risen enough for the purpose, but spend a full season without one egg-laying. They have many ovarian eggs in maturation, but we can not find any ova in the oviducts. After the first mating in a season, when the temperature rises enough, they begin to bring the eggs into the oviducts and to lay. It takes at least over two days. The temperature merely serves to mature the ova, and it is a necessary condition, but not sufficient for oviposition. The ovulation i. e. the discharge of ova into the oviducts, is due to the stimulus which is brought only by the presence of spermatozoa. Considering the whole course of the breeding, it may be said that the female is quite passive in the sexual activities and able to do nothing unless the male courts her. At least a duration of two days intervenes between the copulation and the first oviposition by the same individual even if the temperature is favourable.

VII. Egg to Hatch.

The embryo of the newt was studied by J. OYAMA, who recently published the "Normentafel" (1930). Eggs kept in the laboratory hatch in from twenty to thirty days, twenty-five days on an average, depending upon the temperature. The dates of the first hatching out in aquaria were 4th June in 1928, 5th June in 1929 (Fig. 17), 10th May in 1930, and in 1931 15th May, ending on 16th July. Undoubtedly, as with many other animals, the date of development of the embryo is subject to considerable variation, depending upon the varying temperature of the water in which they are contained. Last year the eggs deposited on April 10 hatched on May 10—18 taking 30—38 days, but those deposited on July 8 and hatched on July 24 took only 16 days.

There is no nursing habit in this newt. They even eat their own eggs when hungry.

VIII. Larva.

(1) Form of Larva.

The larval form has been described by IWAKAWA (1889) and OYAMA (1923, '24, '26, '30). The newly hatched larva, which measures 10–12 mm. in total length, has three pairs of external gills and a pair of balancers on the ventral surface of the head as in many other urodeles. The tail-fin extends along the back almost to the head as a dorsal crest. At this time the fore-limbs are merely short rods provided with three toes as buds, and there is a considerable amount of yolk on the

ventral side of the body. In the course of a week after hatching, the fore-legs grow rapidly and begin to perform their function, while the balancers shrink gradually until they disappear, and the hind legs begin to grow. It follows the general rule applying to the larvae of the Urodela.

(2) Metamorphosis.

In the ordinary case the metamorphosis takes place during summer, from the middle of July to the end of August, mostly in a month after hatching. It is expressed by absorption of the external gills, by atrophy of the median fin and by a change in the pigment pattern. The transformation has been studied by J. OYAMA (1923, '24).

Neoteny, which occurs in many other urodelans can not be seen naturally, but it is possible to preserve the larval character over winter in certain conditions in the laboratory.

The newly metamorphosed individuals, 30–50 mm. in length, leave the water and seek shady and damp places. These young and immature newts are not to be caught in water even by using a net with very fine meshes. They hide themselves under the stones and logs on the shores of the pond, and thus pass securely the most critical period in their life. But it is quite possible for them to keep alive and healthy without leaving the water, differing in this from *D. viri-*

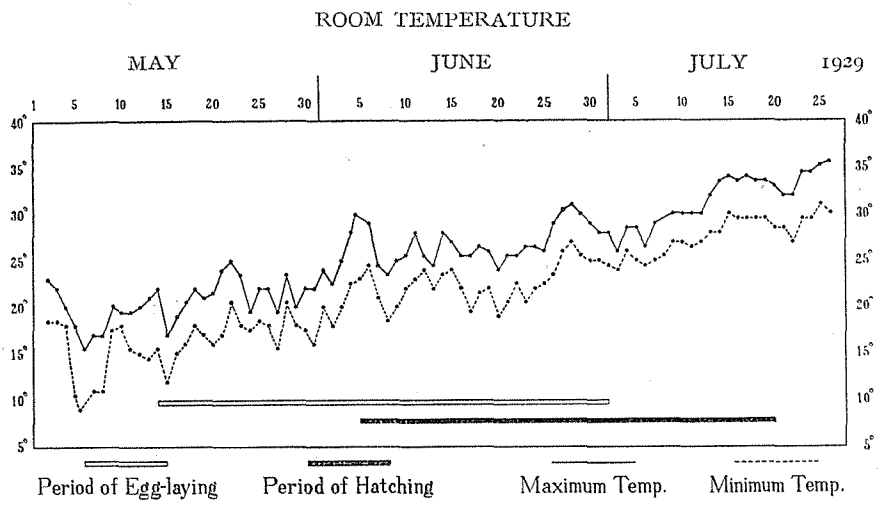

Fig. 17.

Periods of egg-laying and hatching of the Japanese newt observed in a green house aquarium of the Zoological Laboratory in Kyoto.

descens (JORDAN 1891) and *D. torosus* (RITTER 1897) which drown when they can not land.

(3) Period of Maturity.

The red colour on the belly, which gives them the name of *pyrrhogaster*, appears gradually after they have undergone the metamorphosis and becomes fiery red as the body grows in the second year. It is most beautiful just before sexual maturity, and is clearer in the female than in the male.

It takes three years for this newt to attain sexual maturity, shorter by half than *Necturus* (BISHOP 1924) which takes 6 or 7 years. We can not find in this species any dimorphic males such as terrestrial and aquatic forms which are stated to occur in other species of *Diemyctylus*.

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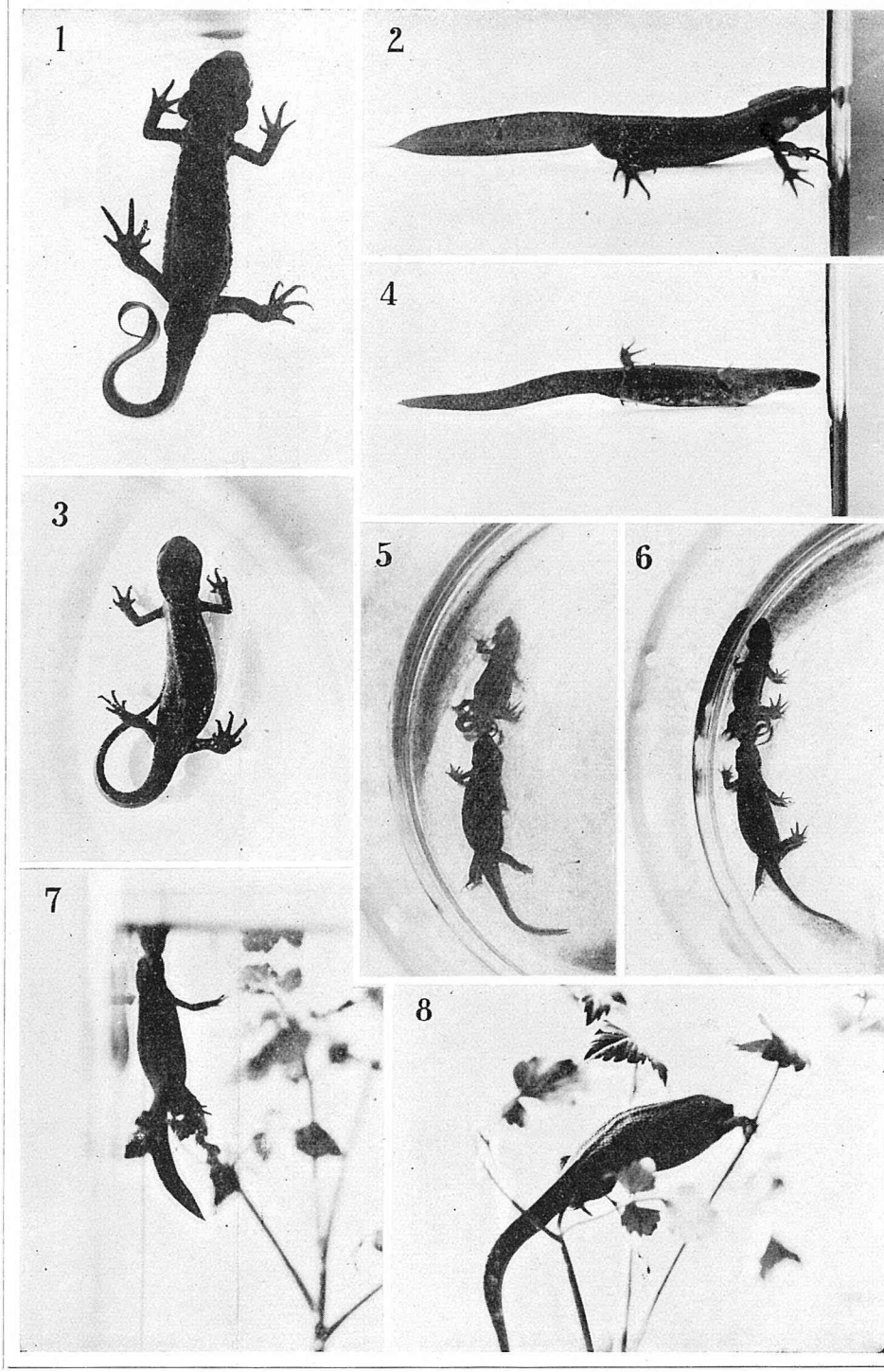
EXPLANATION OF THE PLATE.

Fig. 1. A mature male, dorsal view. Fig. 2. Do, lateral view.
Fig. 3. A mature female, dorsal view. Fig. 4. Do, lateral view.
Figs. 5 and 6. The two sexes in copulation.
Figs. 7 and 8. A female in oviposition.



Y. Tsutsui.