XXI. *Influence of Physical Agents on the development of the Tadpole of the Triton and the Frog.* *By* John Higginbottom, *Hon. Fellow of the Royal College of Surgeons of England.* *Communicated by* Thomas Bell, *Esq., Sec. R.S.*

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An opinion has been generally entertained by physiologists that the tadpole of the Frog, when deprived of *the influence of light*, cannot arrive at its full development, or assume the form of the perfect frog.

I made a series of experiments in different positions and degrees of temperature, but particularly in a rock-cellar thirty feet deep, where no solar light ever entered; this situation was also favourable in point of temperature, being

48° Fahr. from March 11th to May 15th.
50° to 54° Fahr. from May 15th to July 6th, and
55° Fahr. from July 6th to October 31st.

My first experiments were performed on the tadpole of the Triton.

Exp. 1.—I found the tadpole of the *Triton punctatus* more tenacious of life than that of the *Triton cristatus*. I commenced with placing a number of the ova, enveloped in blades of grass in the manner usual with this animal, in three open shallow vessels containing water. One vessel I placed in a room where the mean temperature was 60° Fahr., another in the open air at a mean temperature of 50°, and the remaining one in a deep rock-cellar at 48°.

In the temperature of 60° Fahr. some of the tadpoles escaped from the ova in fourteen days, those at 50° in twenty-one days, and those at 48° in the rock-cellar in twenty-one days.

Although the tadpoles in the cellar at 48° escaped as early as those out of doors, they did not afterwards increase in growth, whilst those in the room at 60° and in the open air at 50° became more developed, the former of these having the anterior extremities in thirty-nine days, the latter in forty-nine days, whilst those in the cellar had no appearance of an extremity at the end of sixty-two days.

Exp. 2.—On the 4th of July I made another experiment with the ova of the Triton in the rock-cellar at its maximum temperature of 55° Fahr. I placed a number of ova in that situation; the tadpoles escaped in due time, but, as in the former experiment, they did not proceed in their development, having no appearance of anterior extremities in 105 days, when they died for want of proper food.

Exp. 3.—On the 11th of August I put twenty-four tadpoles of the Triton in water,

in an earthen vessel enveloped in four or five folds of black calico, so as to exclude the light, the mean temperature of the room being 65° Fahr. I placed the same number under a shed where the mean temperature of the atmosphere was 60°, and a similar number in the deep, dark rock-cellar then at a constant temperature of 55°.

In six days several of the tadpoles in the vessel in the room at 65° and in the open air at 60° were dead, and on examination I found that their branchiæ were absorbed, and their opercula nearly closed, and I concluded that they had died of asphyxia. I now took the precaution to place a stone in the centre of each vessel, so as to allow the tritons to leave the water as they lost their branchiæ. Two days afterwards the top of the stones had a number of tritons upon them in the vessels in the room and in the open air.

All those placed in the rock-cellar retained their branchiæ, not one having left the water, although I had placed stones for that purpose. No more tritons died after the stones had been placed in the vessels, as they afforded them the opportunity of leaving the water when the branchiæ were absorbed.

In about twenty-one days afterwards, during the month of September, two or three had left the water and were on the stones placed in the vessel *in the cellar*, fully proving that the animal came to its full development in the absence of light, though this development was retarded by the low temperature of 55°.

Exp. 4.—On the 25th of August I deprived three tritons, one of an anterior, another of a posterior extremity, and the third of the tail. I put these into a vessel, which I enveloped in five or six folds of black-glazed calico so as to exclude the light, and placed it in a dark part of a room where the maximum temperature was 70° Fahr. As it was then the time of the year when the full-grown tritons leave the water, I placed a quantity of clay and flat stones in the vessel with a little water at the lowest part, in order to allow them to remain in the water or out of it.

In a month the amputated limbs had undergone the reproductive process; in one a miniature posterior extremity furnished with toes had been formed, in another the tail, and in fourteen days later the anterior extremity and the toes of the third were reproduced.

I now began a series of experiments on the Frog (the *Rana Temporaria*); this batrachian being more manageable in regard to food, and arriving at its full development in much less time than the Triton, the former only requiring about ten weeks, the latter about five months.

I commenced my experiments and observations on the Frog in March 1848, ascertaining accurately the influence of air, food, temperature and light, *from the ovum to its full development.*

On the Influence of the Atmospheric Air.

There are three modes of respiration in the tadpole of the Frog:—1st, the Branchial; 2nd, the Pulmonary; 3rd, the Cutaneous.

In the branchial state the body of the tadpole is very small, and at this period they flock to the sides of the vessel in which they are contained close to the edge of the water, nearly exposing the branchiæ to the atmospheric air, the lungs being as yet unemployed.

About a fortnight before the metamorphosis of the tadpole into the frog, its body is very large, and the cutaneous surface for respiration, including the tail, is very considerable; but when the development takes place, the body of the frog is again small, and there is not a sufficient surface for respiration, so that if the animal continues in the water, it becomes asphyxiated. Life then depends more on the pulmonary than the cutaneous respiration.

I found that the tadpole of the Frog soon dies in either aërated or boiled water if excluded from atmospheric air; those in aërated water live the longest; some of them I found at the top of the water, and on examination the lungs were observed to be inflated, whilst those tadpoles in the boiled water sank to the bottom of the vessel. Tadpoles put into boiled water exposed to the atmospheric air live as in aërated water.

2. *On the Influence of Food.*

The food of the tadpole is derived from two sources. The first is the gelatine of the ova, the second the plants growing in the water in which they are deposited.

1848.—On the 11th of March I put some spawn of the frog, newly deposited, into eight shallow earthenware vessels containing water; in four of them I added grass and duck-weed to serve as food for the future tadpoles, in the other four I put none. I observed in all the vessels that the tadpoles, after escaping from the ova, had about an equal growth, as long as any of the jelly-like substance of the ova remained; but after that was consumed, the tadpoles in the vessels where there was no grass were promptly retarded in their growth.

April 17th.—To prove whether the jelly of the ova was food for the young tadpoles, I separated a number from the jelly, putting the tadpoles in one vessel with water, and the jelly in another.

In thirteen days I found the tadpoles had not increased in size, and that some of them were very weak and nearly inanimate. On this day I placed them all with the jelly. In seven days the jelly was consumed, and some of the tadpoles had much increased in size, others of them had died from having been so long and at so early a period deprived of their *first food.*

After the tadpole has finished feeding on the jelly, nothing more is required for food than grass and duck-weed, the grass serving for food, the duck-weed both for food and as a shelter, and also probably yielding its influence as a living vegetable in the water. The grass is sufficient as food to produce the full development of the tadpole, which feeds upon the chlorophyle which adheres to the cells of the plant,

when the plant is in a state of decomposition, leaving the fibrous part. They generally feed on the under part of the plant with the abdomen upwards, owing to the position of the mouth.

I supplied the tadpoles with fresh water every third day, and with grass as often as necessary. In those vessels which were placed in the dark it was necessary to add grass more frequently, on account of the loss of the green colour it sustained in that situation.

I observed they did not feed so well at a low temperature. The life of the tadpole cannot be preserved very long with fresh water and air alone without proper food. I placed a number of tadpoles in eight vessels, of which four were excluded from the light, and four exposed to the light in different degrees of temperature; no food was put in any of the vessels after they had consumed the jelly. On the 11th of May, eight weeks and four days after the deposition of the spawn, the tadpoles remained very small, and the last of them died on that day.

The jelly appears to be quite essential as nutriment to sustain the early life of the tadpole. Had they been deprived of it, they would have died at a much earlier period, as proved by my former experiment*.

3. *On the Influence of Temperature.*

On the 11th of March 1848, I procured four round open earthenware vessels, each containing about three pints of water, and filled them about three parts full. In each I put a small quantity of the spawn of the frog just deposited, and I then placed them in four different degrees of temperature.

The *first* was placed near the ceiling in a shaded part of a room, where the mean temperature was 60° Fahr., six or eight folds of black-glazed calico being tied over it so as to exclude all light.

On the 20th of March (see Plate XXXII.) the tadpoles left the ova; on the 23rd the branchiæ were fully formed; on the 22nd of May the first was fully developed at a much earlier period than others placed in a lower part of the same room, exposed to the light at the mean temperature of 58° Fahr., and also earlier than in the pools.

The *second* was placed at the same time in a situation where the mean temperature was 56°. On the 20th of March, nine days after the deposition of the ova, the embryos were lengthened, indicating the head, body and caudal extremity, and lay in a curved position within the ova. On the 25th some escaped from the ova. On the 28th the branchiæ were fully formed, and on the 6th of April they were absorbed. On the 22nd of May the tadpoles had increased in size. On the 18th of August the first was fully developed.

The *third* vessel was put within a larger one and placed in the open air, on a shaded

* According to Mr. Brande (Philosophical Transactions for 1810), the jelly appears to be an intermediate substance between albumen and gelatine.

side of a house, and entirely covered with wood, so as to exclude all light, the mean temperature being 53° FAHR.

March 20th.—In nine days after the deposition of the ova, the embryos retained their globular form, but considerably increased in size.

On the 25th they had the elongated form within the ova; on the 31st they escaped. On the 4th of April the branchiæ were fully formed, and on the 11th they were absorbed. May 22nd, the tadpoles were increased in size. On the 28th of August the first was fully developed (see Plate XXXII.).

The *fourth* vessel I placed in the rock-cellar. The temperature was uniformly 48° FAHR. from the 11th of March to the 15th of May, 50° to 54° FAHR. from May 15th to July 6th, and 55° FAHR. uniformly from July to October 31st.

March 31st.—The tadpoles escaped from their ova on the same day as in that in the open air, the temperature being in the cellar uniformly 48° FAHR., in the open air 53° mean temperature.

On the 6th of April the branchiæ were formed, and on the 18th they were absorbed. On the 22nd of May the tadpoles were very small, but from that period to the 5th of September they grew much more rapidly. On the 31st of October the first was fully developed.

It will be observed (Plate XXXII.) that when the tadpole in the room was fully developed at the mean temperature of 60° FAHR., those in the open air were small at the mean temperature of 53°, but those in the cellar were smaller still, having been influenced by the low temperature of 48°; from March 11th to May 6th, when the temperature became constantly 55°, they advanced more rapidly in size until their full development.

November 17th.—Soon after this period the temperature in the rock-cellar was from 50° to 54° FAHR. for a month, and during that time there were no more tadpoles fully developed. One of them had three legs only; for upwards of three weeks the fourth leg could be seen distinctly under the skin when the animal moved, but it did not protrude.

All these results are displayed in Plate XXXII., in which the difference of temperature and its effects are registered.

4. *On the Influence of Light.*

With regard to the question of full development of the tadpole of the Frog in the absence of light, I am enabled by the most minute observation to state that it advances in growth equally well in the dark and in the light, and that absence of light has therefore no influence in retarding its development.

I have ascertained this by frequent experiments during the last two years; one experiment was made on an extensive scale.

I had six vessels with tadpoles, three exposed to the light in different degrees of temperature, and three from which the light was excluded.

At the first I was led to think the absence of light was even favourable to development, but I afterwards found that the difference depended on a slight increase of temperature owing to the vessel being covered. This fact is rendered obvious by the Plate, in which the temperature and absence of light are fully illustrated.

Nottingham,
February 5, 1850.

P.S. I made these experiments in 1848; they were repeated in the year 1849 with similar results.