and amidic acids. But they may be, as I have pointed out, interpreted in another way. The question thus presented is accessible to experiment, being capable of solution in a variety of ways; and it appears useful to postpone further speculation upon this subject until it may be raised upon a broader experimental foundation.

II. "Additional Observations and Experiments on the Influence of Physical Agents in the Development of the Tadpole and the Frog." By JOHN HIGGINBOTTOM, Esq., F.R.S. Received Dec. 24, 1861.

In a former paper "On the Influence of Physical Agents on the development of the Tadpole of the Triton and the Frog," which the Royal Society honoured with a place in the Philosophical Transactions for 1850, experiments were detailed to prove that the ovum of the frog (the *Rana temporaria*) underwent its metamorphosis in the absence of light, contrary to the experiments of Dr. W. F. Edwards of Paris, related in his work 'On the Influence of Physical Agents on Life.'

My most satisfactory experiment was made in a rock cellar 30 feet deep, where no solar light ever entered; the mean temperature of the cellar was 51° Fahr.,—I believe, the lowest temperature at which the transformation could be effected.

The ova of the frog, just deposited, were placed in the cellar on the 11th of March, and on the 31st of October the first was fully developed in the form of a frog; while other ova deposited on the same day, which were placed in a shady part of a room at 60° Fahr. and covered with several folds of black calico, were fully developed on May 22nd, twenty-three weeks earlier than those in the cellar.

The experiment proved that the development of the frog depended upon the temperature, and not upon the presence of light. I found by other experiments that those in the light, and those deprived of light, were equally developed if placed at the same temperature. I observed that an excess of light retarded the development.

1. *On the Influence of Light on the Ovum.*

My former experiments not being parallel with those of Dr. Edwards, I was desirous of following his steps. Dr. Edwards says, in his work

above referred to, Part iv. chapter 15, 'On the Influence of Light upon the Development of the Body,' "This process, previous to birth, is generally carried on in the dark; there are, however, animals whose impregnated eggs are hatched, notwithstanding their exposure to the rays of the sun. Of this number are the Batrachians. I wished to determine what influence light independent of heat might exert upon this kind of development. With this view I placed some spawn of the frog in water in a vessel which was rendered impermeable to light by dark paper. The other vessel was transparent; they were exposed to the same degree of temperature, but the transparent vessel received the rays of the sun. The eggs exposed to the light were developed in succession; of those in the dark, none did well; in some, however, I remarked unequivocal indications of the transformation of the embryo."

Dr. Edwards does not mention the depth of water in the vessel in which he put the spawn of the frog, which he "rendered impermeable to light." If it were a few inches in depth, it would materially prevent the transformation of the embryo.

I commenced my experiment in a pool which had been the habitat of frogs (the *Rana temporaria*) for several years.

Experiment 1st.—I put a quantity of spawn, just deposited, into a box perforated with small holes, so as to admit a free current of water through it, and placed it about 3 feet below the surface of the water; all the ova perished.

The next experiments were made in an aquarium 20 inches deep, containing seventeen gallons of water at 60° Fahr.

Experiment 2nd.—A quantity of spawn was put into the water, which fell to the bottom of the aquarium; the spawn when first deposited by the frog, is specifically heavier than the water*. The ova enlarged as usual, but did not arrive satisfactorily through the branchial state; most of the ova appeared to undergo no change whatever.

* It is found that the frog usually deposits her spawn in shallow water, often close to the edge of a pool favourable to its development; at first it is very adhesive, and adheres firmly to the ground or weeds where it is deposited. The same condition may be observed when the animal deposits her spawn in an earthenware vessel. In this neighbourhood the deposition begins about the end of February or the first days of March, and continues fourteen or sixteen days, when the frogs quit the water.

Experiment 3rd.—Some spawn was placed 8 inches below the surface of the water; but none of the ova passed through the branchial state.

Experiment 4th.—A quantity of spawn was placed on rock work near the surface of the water. Nearly all the ova passed satisfactorily through the branchial state to the formation of tadpoles; each of the experiments was made at the same time and at the same temperature.

Experiment 5th.—A quantity of spawn was put into two round shallow dishes, each containing two pints of water, which were placed on the stand of the aquarium at the same time as in the former experiments; nearly all did well; and during the full branchial or fish-like state, great numbers of the embryos had placed themselves close to the margin of the water, forming a dark circle, with their branchiæ nearly exposed to the atmospheric air. They do not appear to feed during this period on the jelly—their first food; atmospheric respiration seems more needful than food for their existence for several days during their full branchial state*.

There are two distinct metamorphoses from the ovum to the full development of the frog: the first from the branchial or fish-like state to that of the tadpole; the second from the tadpole to that of a frog, —the first requiring for its existence a close approximation to the atmospheric air, the second requiring full atmospheric respiration, to which I shall hereafter refer.

The branchial state continues about nine days, from the first buddings of the branchiæ to their absorption. About the seventh day the branchiæ are absorbed on the *right side*, indeed so quickly that I have observed that scores have lost them during one night, whilst the branchiæ on the left side have apparently been perfect; but these in their turn become absorbed during the next day; the respiration of this newly formed tadpole now depends on the internal gills and

* The ova of the toad appear to be less tenacious of life than those of the frog. I have observed, when they are placed 4 or 5 inches below the surface of the water, they all die; but they live when the long jelly lines in which the ova are enclosed are floated on weeds, or on a network of sticks on the surface of the water. In my note-book on the tadpole of the toad in 1849, I found that after the gelatinous lines began to break up on the surface of the water, and the ova to separate from them, a number of the eggs undergoing the metamorphosis adhered to the sticks and weed, but those falling to the bottom of the vessel perished.

cutaneous surface. The gill-opening for the passage of water is very apparent on the left side, but there is none on the right.

2. *On the Influence of Light on the Tadpole.*

The experiments of Dr. Edwards indicate that a decided influence is exerted by light upon the metamorphosis of Batrachians, since, according to his statement, when tadpoles which had arrived at nearly their full growth were secluded from the influence of light, but supported with aërated water and food, they attained an extraordinary size, without undergoing any metamorphosis. The following is Dr. Edwards's experiment:—"I procured a tin box, divided into twelve compartments, each of which was numbered and pierced with holes so that the water might readily pass through the box. A tadpole (which had been previously weighed) was put into each compartment, and the box was then placed in the River Seine, some feet below the surface. A large number were at the same time put into an earthen-ware vessel, containing about four gallons of Seine water, which was changed every day; these tadpoles were at liberty to rise to the surface and respire air, and they soon went through their metamorphosis. Of the twelve placed in the box under water, ten preserved their form without any progress in their transformation, although some had doubled or trebled their weight. It should be observed that at the time when the experiment was begun, the tadpoles had attained the size at which the change is about to take place. Two only were transformed, and these very much later than those which, in the earthen vessel, had the liberty of respiration in air." Dr. Edwards concludes that the presence of solar light favours the development of form.

The situation in which Dr. Edwards placed the tadpoles, "some feet below the surface of the river" in his experiment, would inevitably prove unsuccessful in the full development of the frog. I have always found the transformation, both of the triton and of the frog, equal in the same temperature, both in the light and in the absence of light, if placed in shallow water; but during their metamorphosis they must be allowed to rise to the surface of the water to obtain air, or they become asphyxiated. I therefore placed stones in the vessel, and allowed them to leave the water for the purpose of atmospheric respiration.

The metamorphosis of the tadpole, when at its *full* growth, requires about fourteen days to bring it to the condition of a frog. About the termination of that period, the diminution of the body is so great, and also the absorption of the expanded caudal extremity is such, as to diminish cutaneous respiration. Respiration by the lungs becomes absolutely necessary to prevent the animal from becoming asphyxiated, which would be the case if it remained in the water—requiring then not an aquatic, but an atmospheric medium of respiration. It may be observed that after the tail is partially absorbed, leaving only a portion of the solid part, the asphyxiated state has commenced: the little animal, with open mouth, gasps for breath; but if removed into atmospheric air, the mouth is directly closed, and respiration is effected through the nostrils with perfect freedom; the animal is restored directly, jumps about and is lively.

3. *On the Influence of the absence of Light on the Tadpole and on the Frog.*

This time I commenced my experiments in three rock cellars, formerly only in one.

The cellars in Nottingham, cut out of solid rock, are most favourable for experiment; no solar light ever enters, and they are not subject to any great change of temperature. The deepest cellar is 30 feet deep, the mean temperature 51° Fahr.; the middle cellar is 18 feet deep, its mean temperature 53° Fahr.; the uppermost cellar 9 feet deep, mean temperature 56° Fahr.

June 11th. In each cellar I placed a shallow glazed earthenware vessel, containing two pints of water, with grass for chlorophyll for food, changing the water every second day. In each vessel I put twenty tadpoles, approaching the period of their metamorphosis, following the example of Dr. Edwards,—a much easier method than commencing with the spawn.

In the uppermost cellar ten were fully developed in the form of a frog on the 8th of September, and were on the stones, having left the water.

In the middle cellar ten were fully developed on the 22nd of September.

In the lowest cellar eight only had left the water, being fully developed on the 20th of October.

In the following year, July 1st, I made a similar experiment in

the same cellars, three weeks later. The tadpoles were of a large size. I obtained the same result,—the full development of the frog in the absence of light; but in this experiment I had another object in view, that of observing the growth and obtaining the exact weight of the tadpoles before, during, and after their metamorphosis into a frog.

Dr. Edwards said that in his experiment "the tadpoles attained an extraordinary size, doubling or trebling their usual full weight;" but he unfortunately does not mention any particular weight, or how long the tadpoles were preserved alive; in fact there is nothing definite.

During my several years of experiments I did not observe any remarkable increase of weight or size as mentioned by Dr. Edwards, although my first experiment was from the ovum to the full development of the frog, and the two last when the tadpoles were approaching the period of their development.

In my first experiment on the ovum, I never obtained a tadpole more than 8 grains in weight in the absence of light; but I found in a pool in the neighbourhood a number of tadpoles, some between 11 and 15 grains in weight; seven of them weighed 15 grains each. Of these large tadpoles I took twenty for my experiment, weighing altogether 264 grains, and averaging about 13 grains each. After their transformation the frogs weighed 93 grains, averaging about $4\frac{1}{2}$ grains each,—those of 15 grains in the tadpole state only weighing 5 grains as frogs, having lost two-thirds of their weight during their metamorphosis.

Subsequent experiments have been in accordance with the above.

III. "Note on Internal Radiation." By George G. Stokes, M.A., Sec. R.S., Lucasian Professor of Mathematics in the University of Cambridge. Received December 28, 1861.

In the eleventh volume of the 'Proceedings of the Royal Society,' p. 193, is the abstract of a paper by Mr. Balfour Stewart, in which he deduces an expression for the internal radiation in any direction within a uniaxal crystal from an equation between the radiations incident upon and emerging from a unit of area of a plane surface, having an arbitrary direction, by which the crystal is supposed to be bounded. With reference to this determination he remarks (p. 196), "But the