

CHAPTER XVI

EFFECTS OF TEMPERATURE AND OF LIGHT ON DEVELOPMENT

It has been long known that the rate of development within certain limits is dependent on temperature. The development of the frog's egg is very much retarded, or even stopped, in water at the freezing-point. In North America, *Rana temporaria* often lays its eggs so early in the spring that the water is afterward frozen. The eggs that are caught in the ice are generally killed, but those that lie in the water below often remain alive and will subsequently develop normally.

Hertwig ('94) has shown that the maximum temperature for normal development of the eggs of *Rana fusca* is about 25 degrees C. Eggs develop very rapidly at this temperature, and in twenty-four hours have reached a stage of advancement corresponding to that at the end of the second day for the average temperature of 16 degrees. A temperature of 25 to 30 degrees C. long continued, or a temperature of 30 to 35 degrees for a short time, injures the eggs; their development is arrested and many die. Eggs that have been partially injured by heat (after two or three hours at 30 degrees C. or after three to eight hours at 26 to 28 degrees C. and then brought into a normal temperature) continue to develop at a slower rate than eggs under normal conditions. The yolk-hemisphere of the egg is first affected, so that the cleavage-furrows do not appear in it. The injured or dead half of the egg lies below, and the segmented portion above.

Hertwig obtained similar results by cooling the eggs. Soon after fertilization the eggs were placed in water at zero C. and kept there for twenty-four hours. During that time they did not segment, but when brought back to a higher (normal) temperature, the egg divided into two, four, etc., blastomeres;

nevertheless, as subsequent development showed, the egg had been injured. Many of these eggs developed in the same way as did those kept at a temperature of 25 degrees C., *i.e.* the segmentation of the yolk-hemisphere was retarded.

Schultze ('95) has also made some experiments on the eggs of *Rana fusca* in which the eggs were subjected to a temperature of zero C. Embryos in the following stages of development were used: *stage A*, when the dorsal lip of the blastopore had just appeared; *stage B*, at the end of the "gastrula" period; *stage C*, embryos with closed medullary folds. Three days after these had been placed in a chamber at zero C. they were examined and found in the same stage as when put into the cold. Some of the eggs were then removed, and continued to develop normally at a higher temperature. After fourteen days in the cold the remaining eggs were examined. The eggs were still in the same stage as when put into the cold chamber, but those of stage C had died. The others developed normally when brought into a higher temperature.

Thus while Hertwig found that the eggs of *Rana fusca* were injured by only twenty-four hours at a temperature of zero C., Schultze saw that *certain stages*, at least, were not affected by fourteen days at the same temperature. It is to be noted that Hertwig put the eggs into cold water soon after fertilization, while Schultze used later stages of development.

Not only is the rate of development of the frog-embryo affected by the temperature, but also by *the kind of light* in which it develops. Schnetzler in 1874 compared the development of *Rana temporaria* in white and in green light. The conditions of the two sets of embryos were nearly the same except as regards the kind of light. The embryos developed much faster in the white light, and the tadpoles underwent sooner their metamorphoses. Yung ('78) made a much more careful and elaborate series of experiments in which the eggs and embryos were subjected to a series of different lights. Instead of colored glass, which is seldom monochromatic, Yung used solutions of different sorts. The eggs were placed in a vessel containing about 5 litres of water; this vessel was then placed in a larger vessel of the same form. A space of 5 to 10 mm. was left between the two vessels. This space was filled with

a fluid that allows only certain parts of the spectrum to pass through. The top of the dish containing the eggs was covered by an opaque lid. An alcoholic solution of "fuchsine c erise" was used to produce a monochromatic red light; a solution of potassium chromate for a yellow light (although this allows a little red and green to pass through); a solution of nitrate of nickel (which is perfectly monochromatic) for a green light; an alcoholic solution of aniline "bleu de Lyon" for a blue light; and an alcoholic solution of aniline violet for a violet light. Parallel experiments took place in the daylight ("white light") and in the dark. The other conditions were the same for all the aquaria; they had the same amount of water, the same extent of surface for a eration, the *same temperature*, and were placed in the same position before a window. Eggs of *R. esculenta* and of *R. temporaria* were used.

At the end of seven days it could be seen that the embryos in the violet and in the blue light were more vigorous and in a later stage of development than the others. At the same time the development in the red and in the green was retarded. At the end of a month the tadpoles were in good condition, and the following table shows their mean length in each aquarium.

LARVÆ OF *RANA ESCULENTA* AT THE END OF ONE MONTH.

| Violet. | Blue. | Yellow. | White. | Dark. | Red. | Green. |
|---------|-------|---------|--------|-------|------|--------|
| 27 | 24 | 22.8 | 23 | 19.6 | 19.1 | 15.1 |

The breadth of the embryos shows the same differences. It is interesting to see that in the red and in the green light the tadpoles were even less developed than those in the white light or even in the dark. The result of this series of experiments on *R. esculenta* agrees with other experiments made by Yung at different times, upon other species of frogs and upon other animals.