Observations of Behavioral Development in the Loggerhead Turtle
(Caretta caretta)

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The embryonic development of response in the loggerhead turtle (*Caretta caretta*) has specific implications for the problem of maturation of integrated behavior. The trunk of the loggerhead is housed in a shell which prevents the participation of gross trunk activity and mass-type movements in the adjustive behavior of the animal. The initial reactions of the animal in the egg stage of development, before the development of a body shell, have therefore been of spcial interest. In addition, a general survey has been made of the maturation of various reactions which are performed by the turtle in the course of embryonic development.

OBSERVATIONS

Nesting, fetal behavior development, and neonate activity of the loggerhead were observed in animals procured along the eastern coast of Florida. The female turtle deposits the eggs in the sand of the beaches in this area from late May to early August. Nests were located the morning after installation and marked for ease of relocation. Sample eggs were removed from the nests at specified later dates and taken to nearby quarters set up for observations. Eight nests were used in the study, from which 55 fertilized eggs were removed for observation. This sample represents about 5 per cent of the total number of eggs in the eight nests.

The female comes on the beach at high tide during the night. Leaving an unmistakable furrow and flipper path, she climbs above the high-tide level, excavates a hole about 24 inches deep with scooping movements of her rear flippers, and deposits a large number of eggs in the cavity (usually 75 to 150). After covering the eggs she partly camouflages the area by random movements and haphazard disturbance of sand, after which she returns to the sea. The incubation period of the eggs is 45–50 days in this locality. After hatching, the young turtles remain in the nest for several days, the exact time depending upon their mode of escape. They may emerge from tunnels dug by raiding sand crabs or by exits of their own making, effected by a slow milling about until the floor level of the nest is brought to the beach surface. Escape occurs at night or during the early morning hours.

In order to stimulate and observe the animals in the fetal stages, an opening was made in the eggshell after the turtle's position was determined and oriented for the operation. In the early stages the membranes supporting the fetus were not disturbed. Stimulation was effected by means of hair aesthesiometers mounted on rods. Specific areas were marked for stimulation and a standard procedure used in application of the hair stimulator. In making the observations the eggs were supported and their temperature maintained near that of the nest (86° F.).

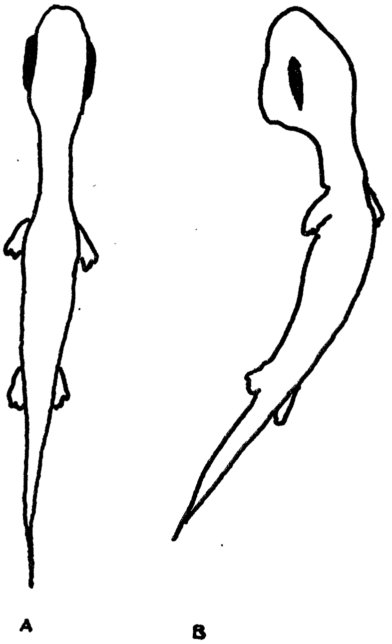

FIG. 1

The general results of the observed development may be summarized as follows:

Mass movement. Behavior responses of a spontaneous nature as well as stimulus-elicited reactions occur in the turtle fetus prior to the formation of a shell, which is evident at approximately 20 days. The earliest responses are seen at the 12th to the 14th day of egg life. These initial responses do not seem to involve limb reactions or specific responses of any sort, but are invariably a C-type twisting reaction of the entire body, which during that period has a relatively elongated (1–2 cm.), thin structure (Fig. 1a). This C-movement consists of a flexion of the body in its horizontal plane, head and tail areas moving toward each other, and a simultaneous twisting of the head in the same direction as the body flexion (Fig. 1b). The movement may involve twists to the right and return, to the left and return, or alternations of the two. Up to 12 or 15 individual twists were sometimes observed following a single stimulation or (apparently) spontaneous initiation of activity.

Early differentiation. Limb reactions occur clearly for the first time at the 18th to the 21st day of development. Even then, local responses are rarely, if ever, seen as independent of the still-occurring and more general C-response. These limb twitches follow immediately after, and are a part of, the C-response and may be most easily observed by stimulation of the limb itself. The C-response can still be elicited from any part of the animal, including the shell, but it is obtained more readily by application of the stimulator to the neck, eye region, and base of the fore flippers.

Specific responses. Beginning at about 22 days. specific responses of the eyelids, mouth, and head can be elicited by direct stimulation of those parts. A day or so later the limbs show a similar type of response, and the tail responds at 32 days. During this period the shell has become semirigid and insensitive to the stimulator. C-reactions and other gross movements drop out of the picture, but stimulations on one side of the animal give movements toward the stimulus locus as a rule, in a manner reminiscent of the true C-response.

Complex fetal behavior. Appearing first between the 26th and the 32nd days are several activities closely associated with behavior in the later normal sea environment. In the order of their appearance were found coordinated swimming movements, stimulus-directed activity (protective and avoidance), snapping, nystagmic head response to rotation, righting reactions, crawling, and finally, tropistic orientation toward the ocean.

Neonate behavior. Within a few hours subsequent to hatching the young loggerhead performs most of the basic reactions essential to continuance of life in an environment typical for this animal. Especially noteworthy are the abilities to escape from the deep nest, direct visual orientation toward and escape into the ocean, orientation in the sea toward deep water, and the abrupt occurrence of eating a few days after hatching. A series of observations indicated clearly that the ocean approach behavior is largely, if not entirely, a positive phototropism.

The first three patterns of conduct just noted occur when the animal is prematurely released from the egg. Within the intact egg the fetus is, of course, gradually filling the cavity so that movements are more and more restricted. At the age when complex fetal behavior was found to occur in the exposed egg, there is insufficient space available to the turtle in the intact egg to permit movements of the magnitude necessary for practicing the act. This is especially true of the front flippers, which are folded over the shell in the manner shown in Fig. 2. Notwithstanding this condition of restraint of the flippers during the later stages of development, these members are perfectly integrated in the total adjustment of the animal in swimming, crawling, righting, and avoidance reactions as soon as the animal is released from the shell either 8–12 days prematurely or at term. It would appear that in the loggerhead response repetition in embryo may be ruled out as a factor in the formation of integrated movements of the front flippers especially. These observations agree with the principal finding of this study, that the initial development of behavior in the loggerhead proceeds in terms of specialization of local responses within an evolving matrix of mass movements, which constitute basic behavioral patterns for the maintenance of integration of developing local movements.

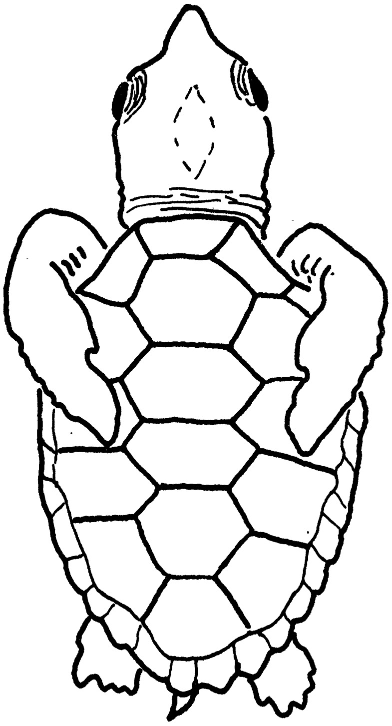

FIG. 2

A more detailed report of the present experiments and observations will be given elsewhere.

CONCLUSIONS

The behavioral development of the loggerhead turtle in the egg consists of an initial mass-type C-movement, the appearance of local response integrated with this pattern, and finally, elaborations of patterns of behavior subsequently adjustive in the terrestrial and aquatic environment of the animal.

The occurrence of a mass C-movement as a primary functional pattern of behavior is especially significant, since it establishes more firmly the role of mass movement in the development of response. The observations show that these initial, generalized movements occur in an animal which, within a very short time, is incapable of displaying mass trunk activity.

Observations show that behavioral maturation and integration in the turtle are not related to embryonic practice or repetition of response, but rather that they appear to occur as an outcome of physiological differentiation and specialization of more generalized movements in the maturation process.

Very generally, results indicate that in the growing loggerhead the specific local movements as well as adaptive coordinations of response are ontogenetically organized with reference to more primary and generalized patterns of behavior which constitute a matrix for subsequent evolution of response.

The Concentration of ^{39}K and ^{41}K by Balanced Ion Migration in a Counterflowing Electrolyte[1]

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It has long been suspected that isotopic ions in solution might differ in their migration velocities (*3*). The negative results obtained by Kendall (*2*) in the electrolysis of Li^+ and Cl^- ions through agar-agar dispelled most of the hope for an isotope effect of this type. Recently, however, a counter-current ion transport method has been developed which not only establishes the reality of this effect but also makes possible the continuous concentration of both $^{39}K^+$ and $^{41}K^+$ isotopes.

The basic principle of operation of the method rests in an imposed flow of electrolyte through the cell at a rate sufficient to reduce the net transport of K^+ ions to zero. Under this condition the faster-moving $^{39}K^+$ ions will make headway against the electrolyte stream toward the cathode compartment, while the slower-moving $^{41}K^+$ ions will be carried back toward the anode compartment.

Tiselius (*4*) has described a method based on a mass flow, which he designated as a "compensation movement" for the separation of proteins by electrophoretic migration. The separation takes place between a series of boundaries set up by the various proteins and is conducted at 4° C. to minimize convection currents in the solution. The experimental arrangement of Tiselius cannot be utilized for the concentration of isotopes, however, since the difference in mobility of the ions is small compared to the processes giving rise to remixing.

In the separation of electrolytic ions, where the transport can be looked upon as a small forward drift superimposed on kinetic agitation, it is necessary to reduce the rate of remixing in the electrolyte to a point below the rate of separation. Also, to obtain appreciable concentrations a multiple-stage process must be employed. Both these requirements have been met in the present experiments by carrying on the electrolysis in a fine-grained packing of uniform porosity. The packing not only reduces remixing to a minimum but acts as a fractionation column operating under total reflux. Packings have been made of sand, glass wool, cotton, glass beads, etc.

During the initial stage of the operation, the molar isotope transport equals the gain in concentration of the faster-moving isotope in the cathode compartment and is given by

$$\frac{I^+ \times t \times (\varepsilon - 1)\, N_1 N_2}{F} = \frac{V_c \times C}{1000} \cdot \frac{R_t - R_o}{(R_t + 1)\,(R_o + 1)} \text{ moles } {}^{39}\text{K} \qquad (1)$$

where I^+ = positive ion current before superimposing the counterflow, in amperes; t = time in seconds; N_1, N_2 = mole fractions of ^{39}K and ^{41}K, respectively; R = isotope abundance ratio, N_1/N_2; V_c = cathode volume, in milliliters; C = normality of electrolyte; and F = Faraday constant: 96,500 coulombs/mole.

The separation coefficient, ε, can be calculated directly from equation (1). The physical significance of ε is that it represents the ratio of the forward velocity of the faster to the slower isotopic ion. The minimum length of column required to obtain a separation of ε is the length of one theoretical unit, h. The over-all separation factor for a column of n theoretical units is given by

$$S_{t=\infty} = (N_1/N_2)_c / (N_1/N_2)_a = \varepsilon^n \qquad (2)$$

where c and a refer to the cathode and anode compartments.

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[1] A statement describing briefly the method and some early experimental results of isotope separation was submitted to the director of the National Bureau of Standards on 13 June 1941. Until recently it has been withheld from publication because of wartime security restrictions.

[2] At present with the U. S. Navy Department.