they are all necessary." And though we are prone to consider the last determining condition for a process as its cause, in reality "a state or process is solely determined by the sum total of its conditions." Living material by virtue of its irritability adapts itself to changes in the conditions of its existence, by various manifestations with which we are familiar. "Life is the entire sum of the vital conditions."

A stimulus is every alteration in the vital conditions, being a stimulus only when considered in relation to the previously existing state. The alteration may be subliminal, minimal, submaximal, or maximal; it may be harmless or injurious; short, long or the initiation of a new condition which is to persist. Since there are certain internal vital conditions that are always undergoing change, as in development, and external vital conditions that may exist unchanged, and independent of the vital process, a suggestion is made that for practical purposes stimulation be defined as "every alteration in the external vital conditions."

Having achieved the new viewpoint (and indeed the word "new" might be omitted, for most of us have none), the reader follows through equally lucid discussions of the characteristics and effects of stimuli, of the process of excitation, of conductivity, the refractory period, fatigue, interference and states of depression, meeting old facts in unexpected places, watching isolated observations falling into line, and finding new meanings in all that is placed before him.

To suggest that the book be read for pleasure is perhaps apparently to belittle its importance. If so the fault lies in the general notion of the meaning of pleasure. But it is undoubtedly true that the biological scientist has few such opportunities for simultaneously pursuing happiness and acquiring merit.

The reviewer had almost forgotten to refer to the excellence of the translation, for which the author makes gracious acknowledgment. The reader will find it very easy to forget that the book was not originally written in English.

C. C. S.

REGENERATION OF ANTENNÆ

Some interesting results have been achieved by experiments, made and reported by H. O. Schmit-Jensen,[1] on the regeneration of severed antennæ of Phasmidæ. A rather large number of small and half-grown larvæ of *Dixippus morosus* had been insufficiently supplied with fresh vegetable food and thus cannibalism appeared among them, and a number were found with one or both antennæ or some of their limbs missing. A single specimen attracted attention because of one of its attennæ having regenerated like a little foot. After the following molt this organ had increased in size and became still more foot-like in form.

This case of spontaneous homœosis caused the author to cut the antennæ from fifty newly hatched and sixty half-grown *Dixippus* larvæ, all the larvæ being from unfertilized eggs. The antennæ were severed between the first and second segments or between the second and third, sometimes the left antennæ being cut and sometimes the right and in some cases both were amputated. When both were cut the specimens died. In some cases where the single antenna was severed there was no regeneration, only a knot developing. But often there was produced, not a small antenna, as one might expect, but a tarsus consisting of from one to the normal five segments complete with terminal claws with the ordinary arolium between them. In four cases a tibia was also developed. In young larvæ there seemed to be a distinct increasing development of the foot-like characters of the regenerated organ with each molt. After the first molt succeeding amputation there appeared only a short knob. The next molt produced a segment with evident claws and the third molt brings the organ into more perfect tarsal formation. Some of the more perfect tarsus-like regenerations are, as shown by figures reproduced from photographs, almost indistinguishable from an actual foot, some, as stated above, even having the tibiæ present. In the older larvæ the place of severance

[1] *Meddel. fra Dansk naturh. Foren.*, Vol. 65, pp. 113–134, Figs. 1–7 (1913).

appears to have some effect, as when the antennæ were cut between the first and second segments nothing but a knot developed but when the cut was made between the second and third segments a foot was regenerated.

A. N. CAUDELL

SPECIAL ARTICLES

A SECOND CASE OF METAMORPHOSIS WITHOUT PARASITISM IN THE UNIONIDÆ[1]

THE discovery[2] three years ago that the species *Strophitus edentulus* (Say) passes through its metamorphosis in the entire absence of parasitism placed that species in a unique position among fresh-water mussels. Since Leydig in 1866 solved the mystery as to the post-embryonic development of the Unionidæ in the discovery that the glochidia are parasitic on fishes, the announcement by Lefevre and Curtis seems to have been the first reported exception.

Lefevre and Curtis[3] in their investigations into methods of propagation of fresh-water mussels found that certain species of fish are more susceptible than others to infection by glochidia. In their operations a number of species of mussel were employed, but the commercially important species were chiefly confined to members of the subfamily Lampsilinæ Ortmann.[4] The fishes found adaptable to infection were the common game fish of the family Centrarchidæ. The fishes which did not take artificial infection were considered by them examples of specific immunity to infection by glochidia.

Following the work of Lefevre and Curtis considerable effort was made to carry through artificial infections with mussels of the genus *Quadrula* (Rafinesque, 1820) Agassiz, a group economically important because of their heavy shells. These attempts, employing the method of artificially infecting the common and readily obtainable game fish, met with little success. In 1912 I undertook the investigation of this problem. The previous negative results seemed to indicate that suitable fishes were not being used. It seemed probable that the parasitic glochidia, like other parasites, might be considerably restricted as to the species of host to which they were adapted. Working upon this theory I examined considerable numbers of fishes taken at large, with a view to finding those species that were carrying in nature the glochidia of *Quadrula* mussels. These studies supplemented by experimentation in artificial infection confirmed the chief postulate of the theory, namely, that there does exist a decided restriction as to species of hosts for the glochidia of some mussels. In the case of the warty-back mussel, *Quadrula pustulosa* (Lea), for example, I found infection restricted almost exclusively to the Channel catfish, *Ictalurus punctatus* (Rafinesque).[5] The investigation of these natural infections which has been taken up quite extensively by Mr. T. Surber[6] in the mussel investigations by the U. S. Bureau of Fisheries, revealed other points of interest. Among these was noteworthy the entire absence of evidence of infection by some common species. Such observations for a given species of mussel obviously indicate something unusual in the life history. One of the mussels for which I found no natural infection and for which none have been reported was *Anodenta imbecillis* (Say).

During the first part of last November I succeeded in securing several specimens of this mussel. These were all gravid, as is usually to be expected, since this species is hermaphroditic. Upon examining the contents of the marsupium of one individual I found that what at first glance I had supposed were mature glochidia were instead juvenile mussels with organs developed to the stage usually seen at the end of parasitism when the young

[1] Printed by permission of the Commissioner of Fisheries.

[2] Lefevre and Curtis, SCIENCE, Vol. 33, pp. 863–865, 1911.

[3] Bulletin of the Bureau of Fisheries, Vol. XXX., 1910 (issued 1912).

[4] *Annals of the Carnegie Museum*, Vol. VIII., No. 2, 1912.

[5] Howard, A. D., *Transactions American Fisheries Society*, 1912, pp. 65–70.

[6] "Notes on the Natural Hosts of Freshwater Mussels," Bull. Bureau of Fisheries, Vol. 22, 1912 (issued June 28, 1913).