THE PROTOZOA OF LAKE ERIE.

same is true for these. Spirostomum ambiguum when stimulated contracts, swims backward, turns toward the aboral side, and swims forward. If touched with a spicule of glass at its anterior end it swims backward, away from the glass; if touched at the posterior end it likewise swims backward, therefore toward the glass. Stentor polymorphus when stimulated contracts, swims backward, turns to the right, then swims forward, the direction of motion having, as in theother cases, no relation to localization of the stimulus. Similar results, not yet published in detail, have been obtained with certain Flagellata, as well as with other Ciliata.*

Besides determining the general mechanism of the reactions of Paramecium, an extended study was made of the effects upon its activities of different chemicals. If into a preparation of Paramecia mounted upon the slide a drop of some chemical substance in solution is introduced, the Paramecia may either collect in the drop or leave it entirely empty. In the former case they show positive chemotaxis to the substance; in the latter case, negative chemotaxis. As to what might be called the mechanism of chemotaxis, the following was made out. The Paramecia are not attracted by the drop of substance into which they gather. They may graze the very edge of the drop without swerving a particle from their course so as to pass into it, But Paramecia when first brought upon the slide swim rapidly in every direction, so that many will quickly come by chance against the edge of such a drop. They do not react, but swim straight ahead-the substance in the drop not acting as a stimulus to produce the motor reaction above described. But on passing across the drop, the outer fluid does, after the Paramecia have been in the drop of the chemical, act as a stimulus to produce the motor reaction. The Paramecium therefore, on coming to the outer edge of the drop, swims backward, thus returning into the drop. It then turns toward the aboral side and swims forward (in accordance with the general scheme of reaction above described). It thus comes to the outer edge of the drop once more; reacts again, and this being kept up, is continnally prevented from crossing the boundary of the drop into the surrounding water. The same process is repeated for many Paramecia, until in time the drop swarms with the Infusoria, so that they appear to have been attracted into it.

In case of a substance in which the Paramecia do not collect at all, observation shows that the motor reaction (swimming backward, turning, and swimming forward) is produced when the Paramecia come against the drop from the outside; hence they are prevented from entering and the drop remains empty.

It was found possible to classify chemical compounds thus into two classes. On the one hand may be placed together those which do not produce the reaction when the Paramecia enter them, but throw the animals into such a physiological condition that they do react when they pass out of a drop containing the substance in question. In these the Paramecia, therefore, gather and are said to be positively chemotactic toward them. On the other hand are substances which produce the motor reaction as soon as the Paramecia come in contact with them, so that the animals do not enter

^{*} The reactions of a large number of Protozon have been studied since the above was written. In all of these the direction of turning was found to be determined entirely by internal factors, and to have no relation to the position of the source of stimulus. The direction of motion along the body axis, on the other hand, was found in a number of cases, for mechanical stimuli, to be determined by the localization of the stimulus. Loxodes restrum, for example, when tonehed with a glass rod at the anterior end swims backward; tonched at the posterior end it swims forward. For chemical stimul, however, the absence of my such dependence of the direction of movement on the localization of the stimulus was demonstrated. For details, see a paper by the author on "The movements and motor reflexes of the Flagellata and Cillata," in the American Jonrual of Physiology, January, 1900.