figures indicate an aldobionic acid of formula $C_{12}H_{20}O_{12}$. In fact O'Sullivan's analytical data agree better with the requirements of the barium salt of an aldobionic acid than with the barium salt of a dibasic acid of formula $C_{23}H_{38}O_{22}$. It gives a strong naphtho-resorcin test and reduces Fehling's solution vigorously. On boiling with 12 per cent. hydrochloric acid, the correct amount of carbon dioxide is liberated and the glucose value, calculated from the amount of iodine consumed in oxidation, as well as the percentage of calcium found, corresponds to the requirements of a compound of formula $C_{12}H_{20}O_{12}$ containing one aldehyde and one carboxyl group.

Aldobionic acids are substances new to chemistry, and to date have been found only in the soluble immune substances produced by bacteria, *e.g.,* pneumococcus Types II and III, and by Friedlander's bacillus,[5] Types A, B and C.

It has been said that true gums are never formed except by the decomposition of vegetable tissue due to a diseased condition of the plant. Some authorities have claimed that this morbid process is the result of bacterial action,[6] and, if this is true, it is not surprising that an aldobionic acid would be found.

We have not as yet identified either the uronic acid or the sugar component of this aldobionic acid, but are at present engaged in the solution of the problem.

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VARIETY OF BEHAVIOR OF LARVAL TREMATODES

THE life cycle of most trematode parasites includes two free-swimming stages: the miracidium and the cercaria. The mature worm, parasitic with few exceptions in a vertebrate, produces eggs which develop into miracidia; these hatch out in water and then penetrate an invertebrate intermediate host, which is almost always a gastropod mollusk. From the point of entry the miracidium usually makes its way to, and lodges in, the hepato-pancreas or the gonad; here it metamorphoses into a sporocyst, the first of a series of parthenogenetic reproductive stages (daughter sporocysts or rediae or both) the last of which finally produces in large numbers a larva known as a *cercaria.* The cercaria of most species deserts the mollusk host and has a period of free-swimming existence which lasts at most several days. The tail of the cercaria, in many cases a highly modified larval swimming organ, is cast off at the beginning of post-larval development, when the cercaria penetrates the body of an intermediate invertebrate host, or, in a few species, the definitive vertebrate host.

The morphology of a great many cercariae has been more or less completely described, but no detailed studies have been made of their behavior, which is varied and is of interest from a number of standpoints. Observations and preliminary experiments made by the author on representatives of various groups of cercariae, chiefly fresh-water ones, from Illinois, Michigan, Missouri, Washington, and from Woods Hole and the Dry Tortugas justify the expectation that larval trematodes are an important source of experimental material, especially for a study of the responses of animals to changes of light intensity.

In so far as these larvae have been studied it has been found that the swimming behavior of each species is distinctive; the only time that preliminary observations failed to show differences between species was in the case of two which have only slight morphological differences. In most cases examination of living cercariae with the unaided eye, or with a hand lens, is sufficient to distinguish among the species found in a locality; but it is not true that species of furcocercous cercariae with long furcae may be thus differentiated, except by closer examination. From the standpoint of the parasitologist it will be interesting to determine in what ways the swimming behavior and the responses to stimuli normally encountered in nature play a rôle in the life history of the species.

Unstimulated swimming behavior. Locomotion is effected principally by vigorous movements of the extensile and usually very muscular tail. Some species swim almost, if not quite, incessantly from the moment of liberation from the host; but the greater number are intermittent swimmers. Among the species in either group considerable variations occur in swimming behavior. Some of these are described in this paper.

Among the *incessant* swimmers the individuals of one species swim close to the surface of the water with rapid and sudden changes of direction, while those of another species swim erratically throughout the container; in some species locomotion is very slow. The individuals of a few species aggregate in the most illuminated part of the container. In the *intermittent* swimmers a period of passive sinking alternates with a period of locomotion upward, usually in a more or less vertical path. During the period of passive sinking the individuals of most species are motionless, or almost entirely so; the length of this period gradually increases until finally the cercariae come to rest on the bottom. From this position, or during the period of sinking, they may suddenly swim

[5] Heidelberger and Goebel, *J. Biol. Chem.,* 74, 613 (1927); *ibid.,* 74, 619.

[6] G. Smith, *J. Soc. Chem. Ind.,* 23, 972 (1904).

upward, and then at times downward, or they may suddenly and erratically change the direction of their path. The rate of locomotion may be slow, but in most species it is relatively rapid.

In many species in which the cercariae are motionless during sinking or after they are at rest on the bottom, the form of the body and tail is characteristic of the species; many different shapes are assumed by the individuals of different species. At the moment of coming to rest the axis of the body may be at any angle with the horizontal; in one species the cercariae very quickly orient in a vertical position with the body down, while all individuals of another species may very slowly become thus oriented, or may sink in the chance position in which they came to rest. These variations are due to differences in the specific gravity of body and tail. Some species of cercariae swim with the tail directed forward and others with the body in advance; the former is the more common method. In a few species of furcocercous cercariae there may be a reversal of direction without any apparent change in the character of the rapid movements causing the locomotion.

Reactions to mechanical stimuli. To a stimulus occasioned by jarring the container, or by the touch of an instrument or of a swimming individual, some species of cercariae at rest immediately respond by swimming upward. In the case of others a short reaction time[1] intervenes between stimulus and response. In contrast with these, the individuals of some species while sinking may be vigorously struck by an instrument without causing them to resume locomotion or to change their characteristic shape.

Reactions to light. Cercariae of some species are strongly photopositive or photonegative, aggregating in the most highly illuminated or in the least illuminated regions of the container and returning rapidly to these regions when the container is turned. The individuals of other species aggregate less closely and return much less rapidly when the container is rotated. However, it is not this type of reaction but the variety of response exhibited by different species to change of light intensity, which is the most interesting aspect of the behavior of larval trematodes.

Reaction to decreased light intensity. In the case of larvae which swim intermittently a number of species have been found in which a shadow falling on cercariae, either while sinking or while lying motionless on the bottom of the container, results in their activation; in most cases an immediate response occurs, but in one among five species observed there was a reaction time of about five seconds (aver.). The response in either case is a resumption of locomotion, usually an upward swim. In other species, larvae at rest are not stimulated to swim by a decreased intensity of light: but those which are swimming suddenly stop, either immediately or at the end of a very short reaction time.

Only one of the few species of incessant swimmers observed reacted noticeably to a shadow; in this case a reaction time intervened between stimulus and response (about two seconds) during which all cercariae continued in locomotion and at the end of which they more or less concertedly stopped, and then sank. At the end of a period of inactivity, which lasted about as long as the reaction time, normal locomotion was resumed.

Reaction to increased light intensity. An increased intensity of light falling on intermittent swimmers during the interval of rest (sinking or on the bottom of the container) results, in most species, in the activation of the cercariae; in most species there is a definite reaction time preceding this response, which is usually an upward swim. Cercariae which are incessant swimmers are apparently not affected by an increased light intensity.

Reaction both to decreased and to increased intensity of light. Some species of intermittent swimmers, stimulated while at rest, respond by swimming upward either when the light is suddenly decreased or when it is increased. The individuals of one of these species respond immediately to a decreased light intensity (shadow); and if the shadow remains on the cercariae for less than three seconds there is also a response to the increased light intensity caused by the sudden removal of the shadow.

Although experiments have so far been largely of a preliminary nature it is thought worth while to call attention to this important source of material, especially for the study of the reactions to light. Cercariae in many ways constitute ideal material for such an experimental study. The molluscan fauna of the United States is very rich, and large numbers of cercariae may usually be obtained from a single infested snail host. They emerge from the snail and may continue to be liberated daily. These emerged larvae are all fully developed, and it is assumed that they are very nearly of the same age. During their brief free-swimming existence, usually of not more than 48 hours duration, they do not eat and hence the food factor does not enter into their behavior. For these reasons it is thought that cercariae constitute material that is at least as uniform as any which has been used for behavior studies.

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[1] The time from the application of the stimulus to the beginning of the response.