recent, book; whether it will go promptly with our effective scientific literature may be doubted; it is not easily read by most biologists who, rather than mathematicians or physicists, must make it effective. Like many really new works it contains a great deal of the author's thinking and writing for a good many years. The fundamental idea is simple, namely, that the rates of change of certain variables x_1, x_2, . . . x_n are functions of the variables themselves and of certain parameters P_1, P_2, . . . P_m, that there will be an equilibrium situation (with respect to the time) for those values of the variables which make the rates of change zero, albeit this equilibrium situation may change with changing values of the parameters, and that if the variables differ only slightly from their equilibrium values there will occur a variation of those variables in time. Primarily it is the study of this well-known system of equations that concerns the author and the interpretation of the results when the variables and parameters represent quantities of biological significance.

The simplest case is the law of population growth, $dX/dt = F(X)$, it being assumed that the rate of that growth depends solely on the population. Here there will be equilibrium for those values of X which make $F(X) = 0$, *i.e.*, the population can maintain itself at any value X_0 such that $F(X_0) = 0$ because then $dX/dt = 0$ and there is no rate of change of population. One solution is $X_0 = 0$. If X is near zero we may expand F(X) by Maclaurin's series to a single term and have $dX/dt = aX$, which gives the Malthusian law of growth. Evidently, too, the population may be saturated at a value X_0 different from zero. In the neighborhood of this value we may expand by Taylor's series to find $dX/dt = a(X-X_0)$, where for stability a is necessarily negative, and asymptotic approach to the equilibrium value from above or from below. If we consider the two roots 0 and X_0 we may write $dX/dt = aX(X_0 - X)\varphi(X)$, and by neglecting φ (X), *i.e.*, by assuming it does not vary appreciably between 0 and X_0, we have the Verhulst-Pearl-Reed law of population growth—a law which the author shows does not hold for the growth of the rate in weight (Donaldson). By considering two variables in a similar manner one may discuss the interrelation of two populations, symbiosis, immunizing diseases, malaria-like diseases, parasitism, etc. Or by the further analysis of the growth function of a single variable one may derive certain demographic relations and conceptions which have been introduced by the author and used by him as a means of research on human populations.

From this brief discussion I intend to imply what I believe to be a characteristic of the book, namely, that it is fundamentally mathematical rather than physical biology, that it portrays the workings of a mind more mathematical than physical. Certainly physical biology should include a great deal about the theory of dimensions, about surface tension, etc., indeed much of the point of view and of the sort of material which may be found in d'Arcy Thompson's "Growth and Form." There seems to be in the book almost none of the sort of thinking that a physicist does. I do not particularly object to the author's choice of a name for his book; it is all right if you understand it; I am merely trying to point out that what some might expect to find under the name is conspicuous by its absence. Gibbs did not call his great work physical chemistry, and if he had, a contemporaneous reviewer might have made observations not dissimilar to mine above. And, by the way, although Lotka undoubtedly knows his Gibbs, even the "Statistical Mechanics," and often gives a type of reasoning very familiar to students of Gibbs, there happens to be no mention of that great name in the Index of Names which appears to list more than 400 persons as cited in the text. And again, by the way, if one will look at that list of names and examine the text to see how intimately ideas from very many of them are interwoven to carry forward the author's own thought, one can not but realize the long time and deep study and varied reading required to bring oneself to a position where he could contemplate writing such a book.

Although the main underlying thought may be mathematical, there is much general philosophy of science and much general descriptive material to be found in this work, much that is as easy to read as it is interesting and instructive, not a little perhaps which is of no great importance to the work as a whole. The author knows how to write, not only in detail but in a broad way, how to lighten heavy reading with description, to intersperse chapters weighty in mathematical formulas with those entirely free of them. And what a mass and variety of material he has thus put together! It would be quite out of the question for a single reviewer either to do it justice or to point out whatever defects of judgment it may contain.

EDWIN B. WILSON

SPECIAL ARTICLES

THE ANTI-COAGULATING ACTION OF THE SECRETION OF THE BUCCAL GLANDS OF THE LAMPREYS (PETROMYZON, LAMPETRA AND ENTOSPHENUS)

THE function of the paired buccal glands in the lampreys has for a long time been a puzzle to zoologists. There is no sign of them present in the larval or ammocoetes stage; and they appear as wholly new structures on transformation. Their ducts open in the floor of the sucking mouth near the rasping tongue (fig. 1).

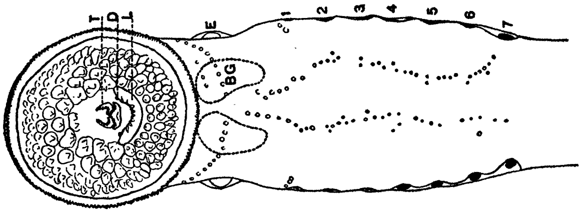

FIG. 1. Ventral view of the head and branchial region of a Lake Lamprey to show the position of the buccal glands and the opening of their ducts. BG. The bean-shaped, buccal glands at the level of the eyes (E). T. The rasping tongue. D. The duct-opening of the left buccal gland. L. The infraoral lamina. 1, 2, 3, 4, 5, 6, 7. The seven branchiopores or gill openings on the left side.

The wall of the sac-like gland is considerably folded and lined by a glandular epithelium. It is thus a combined secreting organ and a reservoir. Furthermore, for about three fourths of its circumference it has a special constricting capsule of striated muscle. In this respect it resembles the poison glands of snakes.

From the relation of the glands with the mouth, they are frequently spoken of as salivary glands, but their structure is not at all like ordinary salivary glands, and no proof has ever been given that the secretion has any digestive action.

At the only stage when these glands are present, the food of the lampreys is proteid in character, and consists almost wholly of blood from the fishes they prey upon, as one can see by examining the intestinal contents. Occasionally one may find traces of muscle or of other tissues torn (fig. 2) from its victim by the rasping tongue, but the main mass of the food as found by our many examinations has always been blood.

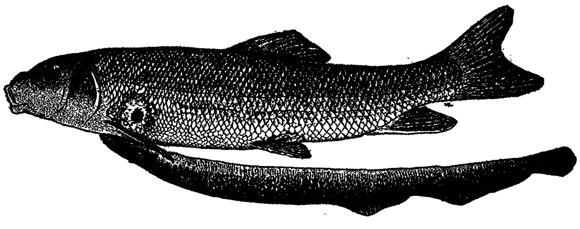

FIG. 2. Lake Lamprey attached to a fish. Above the pectoral and ventral fins are scars showing where other lampreys had made ragged openings with their rasping tongue.

In studying the structural arrangements of the lampreys for taking food it will be seen that the opening of the oesophagus is relatively small, and in Lampetra and Entosphenus especially, it is covered by a kind of grating. That is, the anatomical arrangement is adapted to the ingestion of liquid food. It is well known that the blood of fishes when it leaves the blood-vessels and comes in contact with the wounded tissues, clots very quickly. This is of course of great advantage to animals living in water, but it has two great disadvantages for the lampreys: It would not be so easy to swallow the clots as the liquid blood on the one hand, and on the other the clotting would tend to close the openings in the torn blood vessels and thus shut off the supply of food for the lamprey.

With this knowledge in mind, and remembering that the leech and the vampire bat have a secretion which they pour into the wounds they make in animals to prevent the blood from coagulating, it occurred to us that the lamprey's buccal-gland secretion might serve the same purpose.

Fortunately, by the aid of friends, a lake lamprey with the intestine full of blood was obtained, also some brook lampreys (Lampetra) early in the breeding season, and some of the secretion from the Pacific Coast lamprey (Entosphenus). Finally, by personal effort, many examples of the lake lamprey were caught when spawning. In all cases the secretion was obtained by aspirating it from the sac-like glands with a hypodermic syringe.

To test the hypothesis, the buccal-gland secretion of the lake lamprey was mixed with the blood of a bony fish (Amiurus), such as the lamprey often feeds upon. It entirely prevented the coagulation of the blood if in sufficient quantity. If the relative amount of blood was too great, the coagulation was delayed, but the fibrin filaments appeared in the end. In all cases the gland secretion tended to distort the red corpuscles and to haemolyze them. If the secretion was in excessive amount it extracted the haemoglobin very quickly, and in some cases seemed to destroy the corpuscles entirely, leaving only a granular mass. If the blood from the heart was put directly into the gland secretion, clotting did not occur and the corpuscles settled, leaving a straw-colored serum on top. Furthermore, when the buccal-gland secretion of a lamprey was mixed with its own blood, coagulation was prevented.

The buccal-gland secretion of all the lampreys when mixed with human blood delayed or prevented the coagulation. If a sufficient amount were used, no fibrin ever appeared, but if a smaller relative amount were used the clotting was delayed, but the fibrin filaments finally appeared, thus resembling the action on fish blood.

For all of the experiments, the dark-field microscope was used. In this way the minutest amount of fibrin could be detected. The action was tested upon human blood from many different racial stocks—English, Norwegian, Dutch, Hebrew, etc. The action was uniform in all cases.

There was one striking difference between the action of the buccal-gland secretion of the lake lamprey (Petromyzon marinus unicolor) and that from Lampetra and Entosphenus. With the lake-lamprey secretion the human red corpuscles were prevented from forming rouleaux, but with the secretion from Lampetra and Entosphenus, the red corpuscles did form rouleaux although the fibrin formation was prevented as with the lake-lamprey secretion. In this respect, the Lampetra and Entosphenus secretion resembled the action of the sample of hirudin from the leech with which we experimented.

It is hoped that a full account of the development and structure of this interesting organ and the action of its secretion can be published with full illustrations in the near future.

Simon H. Gage
Mary Gage-Day

Cornell University

EQUATION OF ELECTRONIC CONDUCTION IN UNI-POLAR NON-METALLIC FILMS

The equation for variation of current flowing through a uni-polar non-metallic film due to electronic conduction when the film is in intimate contact with a metal can be derived by the use of Poisson's potential equation, in a manner similar to the method used by Langmuir (*Phys. Rev.* 1913, II, p. 453; *Gen. Elec. Rev.* 1915, p. 330) in studying the effect of the space charge on the emission of electrons from hot filaments.

In the simple case of an infinite plane emitting surface and an infinite parallel conducting plane, we have from Poisson's equation

$$\frac{d^2 E}{dx^2} = -4\pi\varrho \qquad (1)$$

where E is the potential due to the space charge at point x along a line perpendicular to the planes, and ϱ is the volume density of the space charge. Consider a current flowing from the metal through the film in such intimate contact that electrons emitted from the surface of the metal penetrate into the film. If the concentration of free electric carriers in the non-metallic film is normally so small that it can be neglected, then at the boundary between metal and film we can then write $E = 0$, so that, neglecting any initial velocity of electrons emitted from the surface of the metal, we can write for the kinetic energy,

$$\frac{1}{2} m V^2 = Ee \qquad (2)$$

where m is the mass of an electron, e is its charge, and V is its velocity under the point potential, E. The current, I, flowing through the film can be written as

$$I = V\varrho A \qquad (3)$$

where A is the area of the film. Eliminating V in these equations and substituting in Poisson's equation to eliminate ϱ we obtain

$$\frac{d^2 E}{dx^2} = \frac{4\pi I}{A}\sqrt{\frac{m}{2Ee}} \qquad (4)$$

the space charge, ϱ, being taken as negative on account of the negative charge of the electron. Integrating this equation subject to $\frac{dE}{dx} = 0$ when $E = 0$ gives

$$\left(\frac{dE}{dx}\right)^2 = \frac{8\pi I}{A}\sqrt{\frac{2mE}{e}} \qquad (5)$$

Integrating a second time, and solving for the current, we have finally,

$$I = \frac{A}{9\pi}\sqrt{\frac{2e}{m}}\,\frac{E^{3/2}}{x^2} \qquad (6)$$

Considering the flow of current in the opposite direction, *i.e.*, from film to metal with which it is in intimate relation, the emission of electrons from the film contact electrode is very feeble; first, because the two are not in intimate relation, and second, because of its reluctance to part with electrons. In this case the same form of equation as given in (6) will hold.

Insufficient data are available to verify the coefficients of equation (6). Furthermore equation (2) holds only for film thicknesses less than the mean free path of the electron so that collisions do not affect the velocity of the electron. It is therefore best to write the equation in the form

$$I = kE^{3/2} \qquad (7)$$

for given dimensions of the film and for a given temperature. The constant, k, may then be determined empirically.

The form of equation (7) may be tested from data obtained experimentally by Grondahl (*Jour. A. I. E. E.*, March, 1927, p. 216), who has made measurements on the current flowing in both directions through a copper oxide film on a copper disk. The observed values of I_1 and I_2 are compared with