genus, it is possible to avoid the inconsistency of having polyphyletic genera, but only at the expense of considerable practical confusion. By going to the other extreme and dividing *Megascolex* into as many genera as there are probable lines of descent, we employ a logical method, but have before us a series of generic units which are extremely difficult to distinguish or define. We may suppose that posterity will on the whole prefer the second method, and will remove what would now be ambiguities by more intensive morphological and biological studies. In one case, Col. Stephenson states the dilemma very clearly. The genus *Plutellus* has given rise to a group called *Fletcherodrilus* by the fusion of certain paired structures. The morphological deviation is considerable, but if *Fletcherodrilus* is recognized, it has to consist of two speeies, which have arisen quite independently from *Plutellus* in India and Australia respectively. It is here assumed that *Fletcherodrilus* must be based wholly on the characters mentioned, but very likely some author will find other characters in the Indian species (*P. palniensis*), and will make it the type of a new genus.

It will be readily seen that the work is of interest to all biologists, whether they have occasion to study Indian worms or not. It contains a very excellent account of the general features of these animals, and full directions for their study. Were the reviewer possessed of adequate funds, he could think of no greater service than to make possible the publication of a Fauna of North America on the same lines as the Fauna of British India. We have the men who could write the volumes, given time enough. We certainly have the resources for publication, could they only be diverted into such productive channels. The volumes on the Indian Fauna, published by authority of the government, are reasonably condensed, yet full enough to supply the information desired. They are well printed and contain many illustrations. The style of publication is not extravagant and they are accordingly sold for a very moderate price. It is not unlikely that a North American series, thus conceived, would pay its way. It would, however, need an initial subsidy, as in the case of the much more condensed and far less adequate North American Flora, which is now or was recently self-supporting.

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UNIVERSITY OF COLORADO,
Boulder, Nov. 28, 1924

Maker, Man and Matter. Thread of Life Series I. By PIERSON WORRALL BANNING. International Book Concern, Los Angeles, California.

THIS is a volume of fantasy, purporting to deal with facts, of the type termed by Fechner, "cuckoos' eggs laid in the nest of science." It describes the development of the earth from the time when it was rolled out flat and inhabited by the first of the "four root races," invisible, boneless, sexless and ubiquitous, up to the year 7120 B. C. The period of the first root race (which followed the condensation of the whirlpool nebulae accomplished by electrons in the vortex of energy) lasted, we are told, 575,377,000 years. With the second root race, the hyperborean continent gradually extended towards the equator, forming, about 500,000,000 B. C., the continent of Lemuria inhabited 200,000,000 years by the third root race. The fourth root race began on the "lost Atlantis" nearly a million years ago, this continent breaking up, 100,000 to 200,000 years ago amid shocking episodes. It is to be succeeded by the new continents of Numerica and Nulantis, and so on. The book leans heavily on quotations from Blavatzky, Besant, Donnelly and other noted sciosophists treated as scientific authorities. Baron Münchhausen is, however, not even mentioned.

It is, in fact, an expanded fairy tale, conceived and told without genius or charm of any sort.

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SPECIAL ARTICLES

NOTES ON THE OLFACTORY AND OTHER PHYSIOLOGICAL REACTIONS OF THE CALIFORNIA HAGFISH[1]

POLISTOTREMA STOUTI is an interesting representative of the Marsipobranchii, the lowest of the vertebrates save amphioxus. The species is found in abundance in the waters of Monterey Bay and has held the interest of systematists (1), anatomists (2), morphologists (3), embryologists (4), and physiologists (5) since the opening of the Hopkins Marine Station of Stanford University in 1892 on the rocky Point Aulon on the south shore of Monterey Bay. No less than five young investigators of the station in the early years, all now prominent in science and in medicine, made extensive anatomical studies of the hagfish with drawings adequate for publication. Actual anatomical publication was first accomplished for the circulatory system by Dr. C. M. Jackson (2) under the inspiration of Professor Howard Ayers.

Nothing was known of the embryology of the hagfish until the eggs were found and identified in 1893. Even then many of the eggs obtained through an intelligent and shrewd Chinese fisherman, Ah Tak, were decomposed or partly digested. Ah Tak claimed

[1] From the Hopkins Marine Station of Stanford University and the University of Missouri.

that he obtained the egg specimens from the alimentary canals of the males. The first living embryos were secured by Professor Geo. C. Price. It was these specimens that afforded the basis for his classic papers on the development of the pronephros of the hagfish. Once it was known that eggs of the hagfish had been discovered in Monterey Bay morphologists came from near and far to secure them. Professor Bashford Dean (6), of New York, and Dr. E. Doflein (7), of Germany, came for hagfish embryos alone. The Chinaman Ah Tak levied heavily for contributions to his bank account, but the scientists thereby secured some priceless embryos out of many predigested and addled specimens (8). However, even now it is not fully known just when the hagfish spawning season is at its height nor how and where the eggs are disposed in the spawning act.

Physiologically the hagfish is extremely interesting. In the first place it is blind. There are rudimentary eye spots, but there is not the slightest recorded evidence of sensitiveness to light. The adult skin is continuous over the eye spots, though the area is characterized by the absence of skin pigment. The rudimentary eyes themselves are imbedded in pits in the cartilage of the head skeleton.

In compensation for the blindness, it would seem, there is great sensitiveness both to physical contact and to chemical stimuli. Observations show that when at rest the individual hagfishes habitually lie coiled in a spiral on the bottom of the aquaria and presumably on the sea bottom when free. They coil both clock-wise and anti-clock-wise, but always with the tail inside and the head on the outside of the spiral. This brings the nostril and the two short tentacles free to react to whatever may disturb. The slightest touch of the tentacles or of the skin about the head, however gently, produces the most prompt reaction. The head is withdrawn vigorously and for a distance of as much as one third to one half the length of the fish, which then immediately swims away. The reaction is equally prompt whether the hagfish is coiled and quiet or actively swimming about.

Contact with odorous substances is facilitated by respiration which is carried on by the musculature of the head and of the branchial pouches. These together act like a pump to draw water in at the one nostril and drive it out at the branchial pores or gill openings. A valve-like fold, a sort of soft palate, guards the posterior end of the nasal cavity, preventing a return of water through the inhalent nasal tube. It is assumed that this mechanism carries odorous particles to the olfactory apparatus. It is certain that the fish responds promptly and definitely to the presence of soluble chemical substances.

To test the olfactory reaction, a bit of food, a slice of sardine, was dropped into an aquarium, the bottom of which was covered with quiet and resting hagfishes. Instantly there was the greatest commotion. Hagfishes began to uncoil all over the aquarium. Those nearest the bait were most active. They swam at once along the trail through the water taken by the bait and seemed to search for it, apparently guided by chemical sense. When at last one individual came in contact with the bait the bait was seized and swallowed. When a whole sardine was offered to these hungry hagfishes, all in the aquarium were soon in active motion. The first to touch the bait at once rasped off the flesh by a quick movement of protraction and retraction of the corneous teeth of the mouth plate. Another individual by biting out the abdominal wall quickly bored or cut its way into the interior of the bait until several inches of the hagfish's head were buried. The rasping reactions continued until the flesh was removed from the skeleton of the bait. The entire reaction is a splendid illustration of the chemical guidance of a blind carnivorous and parasitic fish.

The impelling and far-reaching effect of this chemical tropism, for such it may be called, is well illustrated by our methods and the success in trapping the hagfish studied in this report. A five gallon tin oil can was punctured with a number of small holes just adequate to admit the passage of a hagfish. The roughened edges turned within acted to retard exit of the fish. A liberal amount of dead fish for bait was placed within the can through a trap door. The door was securely closed and the baited trap lowered to the bottom of the bay about one hundred yards off shore from the station. In the most favorable catch the trap was completely filled with hagfish. Some escaped during the drawing of the trap to the surface, but a total of sixty-seven specimens were secured from this one haul.

Incidentally, the number of hagfish attracted to this baited trap illustrates the difficulties of the commercial fisherman who undertakes to use set gear in Monterey Bay. The high percentage of netted fish lost by the destructive attacks of the hagfish have discouraged and destroyed set gear fishing (Jordan and Evermann (1)).

The California hagfish is one of the few animals that possesses more than one heart. It is known generally that the eels of the rivers of the Atlantic seaboard and of the Mississippi Valley have, in addition to the usual systemic heart, a contractile vascular organ in the tail on the caudal vein. The hagfish, however, has three hearts. One is the systemic heart in the usual relations to cardinal veins and ventral aorta. It has the anatomical structure typical of fishes. The portal venous system also has a heart with incoming and outgoing vessels all adequately provided with valves to insure a one-way course of the blood (Jackson (2)). The third heart is the so-called caudal heart. This is a true pump supplied with valves and located at the beginning of the caudal vein. In fact, it is a bilaterally symmetrical or double heart, each half collecting blood and lymph from the subcutaneous sinuses of the corresponding side of the body (Greene (5)). The caudal heart varies from the systemic and the portal hearts in that the walls of the cavity itself are not contractile. The power that contributes the energy for the caudal pump is a pair of striated or skeletal muscles differentiated out of the great lateral muscles of the region. Like all skeletal muscles, these are controlled by spinal nerves and by a rhythm inherent in a definite spinal center (4, 5). In its coordinative nerve control the caudal heart of the hagfish is unique, for the portal heart and the systemic heart are both without nervous regulation (5).

There are still many facts of the biology and natural history of the hagfish to be determined. The living collections maintained at the Steinhart Aquarium of the Golden Gate Park in San Francisco may add to a fuller knowledge of facts. This blind primitive form is indeed replete with morphological, embryological and physiological interest to both student and investigator.

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CARBON MONOXIDE, A PRODUCT OF ELECTROLYSIS

PHOSGENE has for some reason always been regarded as a non-ionizing solvent, and this view was given support by the observation of Beckmann and Junker, in a study of the ebullioscopy of phosgene solutions, that organic acids dissolve in it as double molecules, while their anhydrides dissolve as simple molecules, a phenomenon that has been observed for non-ionizing solvents such as benzene.

The ease with which solutions of aluminium chloride in phosgene react with metals, metallic oxides, sulfides, carbonates, etc., however, led me to believe that these reactions were of the ionic type, and that the solutions contained ions and would therefore conduct electricity. The experiment verified the prediction, and conductivity measurements have shown that, while phosgene itself is a very poor conductor, the specific conductivity of the solution of aluminium chloride in phosgene increases with the concentration until the more concentrated solutions conduct nearly 100,000 times as well. Mr. Russell Timpany, working in this laboratory, has measured the conductivity of redistilled technical phosgene, and has obtained the value $.007 \times 10^{-6}$ for the specific conductivity at 25°.

The products of electrolysis were not collected separately, but the gases evolved from a cell connected in series with a copper voltameter were evolved under mercury, the surface of which became blackened, showing the presence of chlorine; a solution of sodium hydroxide, over the mercury, absorbed phosgene, which was present in the evolved gases by virtue of the vapor tension of the solution, and the unabsorbed residual gas was collected in a gas burette filled with sodium hydroxide. Analysis of this gas showed it to be carbon monoxide (characteristic combustion and absorption by cuprous chloride). The volume of the gas collected, however, was only 65 to 75 per cent. of the volume calculated according to Faraday's law from the weight of copper obtained.

This is undoubtedly due to the fact that carbon monoxide and chlorine in the light readily combine to form phosgene, so that under the experimental conditions employed a certain proportion of the gases evolved would inevitably recombine to form phosgene. Furthermore, Plotnikov has shown that when a mixture of these gases is bubbled through a solution of aluminium chloride in chloroform, the solution contains phosgene; it would seem reasonable to suppose that the same combination might occur in the presence of aluminium chloride in phosgene solution.

It has been shown, then, that phosgene is a weakly ionizing solvent and that when the solution of aluminium chloride in phosgene is electrolyzed, car-