calibration of the strain-gauge transducer it was possible to calculate that the average force of contraction was 6.74 dy.

The ease of observation of *Dionaea muscipula* Ellis and its general availability make it a suitable object of further study of the excitation process. It should be studied with a view toward the relationship between permeability and transfer of intracellular ions with respect to its action potential.

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29 November 1960

Phylogeny of Priapulida

Abstract. The systematic position of the small invertebrate group, Priapulida, is uncertain. In more recent publications they are classified usually as pseudocoelomates in the division Aschelminthes. A histological investigation of *Priapulus caudatus*, a widely distributed species, reveals the body cavity to be a coelom, its lining a peritoneum. These features, and others, indicate the priapulids to be coelomates rather than pseudocoelomates. Unique morphology perhaps qualifies the group for the status of phylum.

In all members of the small invertebrate group Priapulida, certain basic organ systems are lacking, and other unusual structures are found. As a result, the systematic position of the group has been perhaps as uncertain as that of any group in the animal kingdom.

In the latest study of priapulid affinities, Lang (*1*) supports the popular view that the Priapulida are pseudocoelomates in the division Aschelminthes. In her treatises, *The Invertebrates*, Hyman (*2*) also places the priapulids in this position, and in a later volume (*3*) cites Lang's paper as additional evidence for inclusion of the Priapulida in the Aschelminthes.

Lang has listed numerous reasons to support his systematic conclusions. They are based in part upon his own histological investigations and in part upon those of others. He believes the more important reasons are:

(i) The dermomuscular tube of the Priapulida agrees histologically and topographically with those of the two pseudocoelomate groups, the Acanthocephala and the Kinorhyncha (Echinodera). (ii) In the Priapulida a very thin, structureless membrane, devoid of nuclei, lines the spacious body cavity. The same kind of membrane, positioned like a mesentery, holds the urogenital complex to the body wall. The membrane is structurally not a peritoneum, and thus the body cavity is a pseudocoelom. (iii) The excretory organs of priapulids, as well as of most pseudocoelomates, are protonephridia. Such organs are primitive; therefore, the body cavity they service is a pseudocoele. (iv) The proboscis apparatus is homologous in the Acanthocephala and Priapulida. (v) Kinorhynchid and priapulid nervous systems bear a striking similarity. (vi) The priapulid stereogastrula larva, first described by Lang (*1*), greatly resembles the acanthocephalan larva, and the earliest known kinorhynchid larva.

I have recently completed a histological study of *Priapulus caudatus*, one of the more widely distributed species, and have found considerable evidence indicating that the Priapulida belong with coelomates, rather than with the pseudocoelomates. The most important evidence follows:

(i) The dermomuscular tubes of both the Acanthocephala and Kinorhyncha (as well as of other pseudocoelomates) consist of syncytial tissues that exhibit relative nuclear constancy (*2*). The dermomuscular tube of *Priapulus caudatus*, however, consists of distinct tissue layers composed of discrete cells apparently of unfixed number. (ii) The membrane that lines the body cavity covers the numerous "coelomic" retractor muscles that extend between the body wall and the pharynx and covers the digestive tract and holds it to a pair of longitudinal spindle muscles. These muscles are dorsal and ventral to the gut and are free in the body cavity, except for their ends, which are attached to the pharynx and rectum. The membrane is always cytoplasmic with distinct enclosed nuclei (Fig. 1). As such it is structurally a peritoneum. (iii) Protonephridia, as found in the pseudocoelomates, are syncytial and lack nuclei in their flame bulbs, while the solenocytes of the Priapulida consists of discrete cells. (iv) The proboscis apparatus of the Acanthocephala is neither structurally nor functionally similar to the proboscis apparatus of *Priapulus caudatus*. (v) The nervous system of *Priapulus caudatus* has its main elements (circumpharyngeal nerve ring and ventral nerve cord) entirely within the body wall, in close contact with the epidermis, but distinct from it. In this way, and in others, it differs significantly from that of the Kinorhyncha. (vi) The first larval stage of both the Acanthocephala and Kinorhyncha shows extreme differences from the simple unciliated stereogastrula of *Priapulus caudatus*.

From histological examination, I have called the body cavity a coelom and its lining a peritoneum. Precise knowledge of the origin of the cavity and its lining will doubtless be revealed when embryological studies, still lacking, shall have been made. Solenocytic protonephridia are the most common form of excretory organs within the Pseudocoelomata, but they are not confined to these groups. Solenocytes are found in larval and in some adult archiannelids, polychaete worms, cephalochordates, and other true coelomates.

The presence, in these higher Meta-

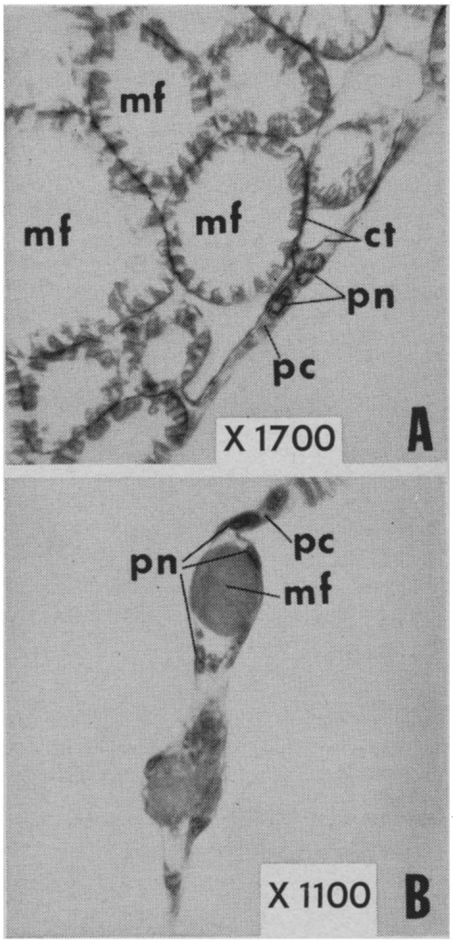

Fig. 1. (*A*) Cross section of a portion of a retractor muscle that extends between the body wall and the pharynx. Because of shrinkage the cytoplasm of the muscle fibers occupies only the peripheral portion (about × 1700). (*B*) Cross section of a portion of the mesentery between the digestive tract and a spindle muscle (about × 1100). *ct*, connective tissue; *mf*, muscle fiber; *pc*, peritoneal cytoplasm; *pn*, peritoneal nucleus.

zoa, of solenocytes structurally similar to those of *Priapulus caudatus* does not necessarily indicate a primitive organism but rather a retention of a primitive type of excretory system. To affirm homology for the proboscis apparatus of Acanthocephala and Priapulida, when embryology is unknown, is rash. The apparatus is different morphologically and functionally in both groups. The tissues present, as well as their arrangement, suggests that in the Priapulida it is probably derived, in part, from ectoderm, while in the Acanthocephala it is probably derived from mesoderm. The stereogastrula of *Priapulus caudatus* is unciliated and oval, and it consists of an inner syncytial cellular mass and an outer single layer of ectodermal cells (*1*). The priapulid stereogastrula is a simple postgastrula, while the earliest larval stage of the Acanthocephala and the Kinorhyncha are considerably more complex and advanced.

For these reasons a comparison is valueless. The larval stage of the Acanthocephala, described by Lang as possessing great resemblance to the stereogastrula, is in fact only a theoretical transitory stage in the development of the acanthor larva which does not pass through distinct blastula and gastrula stages. Simplicity of form is the greatest similarity of these three larvae, but this feature is common to the early developmental stages of all animals.

Histological evidence indicates that the Priapulida should be placed somewhere among the coelomate groups of animals. As vermiform coelomates, priapulids are unique. They possess a cuticle that is not only molted periodically through the adult life, but which has been determined chemically (*4*) and by x-ray diffraction studies (*5*) to be in part chitin. The caudal appendage, which is an extension of the coelom, and which is found in five of the six species in the "phylum", is unique. The Priapulida also possess an eversible proboscis. When all these factors are considered, the Priapulida are seen to constitute a very distinct group, perhaps deserving the status of phylum (*6*).

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13 January 1961

Human Vigilance and Operant Behavior

Abstract. The analysis of vigilance as operant behavior treats illumination (observing) responses as operants that produce signal-detections. Evidence is presented that the relationship is an artifact of the procedure, and that no vigilance factor is involved in illumination-responses.

Human vigilance, defined by the capacity to detect rare, near-threshold signals, shows orderly changes as a function of time at work, signal-to-noise ratio, and other conditions (*1*). For the psychologist it is an aspect of the general problem of attention or alertness. It is of special interest to the human factors specialist, because vigilance is a major performance factor in monitoring displays that signal the state of malfunction of automated equipment.

Holland (*2, 3*) proposed a technique for studying vigilance by using "observing responses"—that is, an observer's operations of a switch to illuminate the display—and showed that observing responses follow signal schedules the way other operants (*4*) follow reinforcement schedules. He also showed a good correspondence between observing response frequencies and detection frequencies. From this he concluded (*3*, p. 67) that "the detection data of vigilance studies may reflect the observing response rates generated by the particular schedules employed." The present report (*5*) tests this conclusion with a correlational analysis to determine the extent to which common factors govern variations in detection rates and observing response rates.

A paper by Baker (*6*), which appeared after the present work was completed, showed that observing responses, defined by photographic records of eye-fixations toward the display, did not behave as Holland's observing responses and were not correlated with detection rates. Rather than refuting Holland's argument, however, this result seems to us to indicate that such eye-fixations cannot be observing responses. Any reasonably defined observing response must, after all, result in a detection when it accompanies a signal. Baker's result suggests that one can appear to be looking at something without observing it. To avoid semantic confusion, Baker's responses should be called "eye-fixations," and Holland's, "illumination-responses," reserving the term "observing response" for an as-yet-unspecified act that accompanies the detection of a signal.

Signal-detections are, by definition, measures of vigilance, and our question is: are vigilance factors in signal-detections also present in illumination-responses? This can be answered simply by examining the correlation coefficients in an experiment in which the same observers perform a vigilance task twice, once with and once without the illumination-response requirement. A "vigilance" factor would be reflected in the expected significant positive correlation between signal-detections in the two performances (see *7*). If the same factor is also involved in illumination-responses, there should be a similar correlation between those responses and signal-detections in *both* performances.

The results of such an experiment are shown in Fig. 1. The apparatus used was a Mackworth-type clock (*8*) on which signals were 20° steps of the pointer that replaced 1/second 10° steps at programmed inter-signal intervals averaging 138 seconds and ranging from 52 to 203 seconds. Sixteen paid male undergraduates, working individually, monitored the clock during two uninterrupted 92-minute sessions on different days. One session required illumination-responses; in the other, the display was always visible. Order of the sessions was counterbalanced among observers.

An analysis of variance of detections for the two sessions (Fig. 1, D-1 and D-2) showed significant decrements with time and significant differences in over-all performance, but no significant order effects or other interactions. The decrements are typical of vigilance experiments (*1*), and the insignificant interactions indicate that introducing illumination-responses reduced the absolute number of detections but left the shape of the curve intact. The illumination-response curve (R-2) followed the detection curve (D-2). The latter result

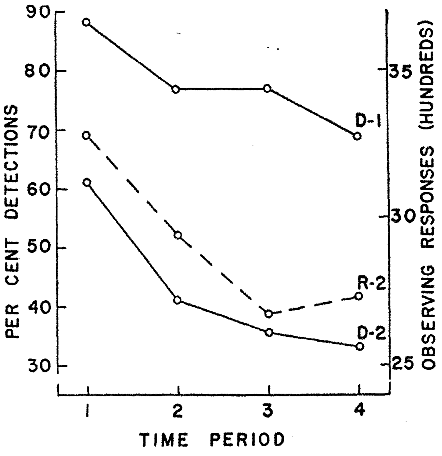

Fig. 1. Signal-detections and illumination-responses during four successive 23-minute portions (time periods) of continuous 92-minute vigils. D-1, signal-detections in session with externally illuminated display; D-2, signal-detections in session with display illuminated by observer's illumination-responses; R-2, illumination-responses (ordinate scale at right) during D-2 session.