a cyclonic flow. The photographic sequence reproduced in Fig. 2 reveals the spiral motion of the well-defined hook echo as it curled cyclonically inward to a center in the right rear quadrant of the parent cloud.

The dimensions of the small cyclone (mesoscale low) that apparently curled the hook into a tight spiral have not been determined from analysis of the weather observations, but the curvature of the hook and of spiral streamers imbedded in the parent cloud suggests a diameter of the same order of magnitude (10 miles) as that of the "tornado cyclone" discovered by Brooks (*4*) in 1949.

These radarscope photographs come at an opportune time, when meteorologists are becoming keenly interested in the spirally banded structure of weather phenomena at all scales. The spiral bands of hurricanes observed on radar, as shown in Fig. 3, are well known (*5–7*). These spiral bands extend in length up to 250 miles (*6*).

Recently Tiros I (experimental weather satellite) revealed that spiral cloud bands also exist around well-developed storms located outside of the tropics (*8*, *9*). In these storms the bands, separated by clear areas, range in width from several miles to a few hundred miles, and in length they range to about 1000 miles. Such a spiral band is shown in Fig. 4 in a photograph taken by Tiros of a well-developed storm centered over Nebraska at 3:30 P.M. EST, 1 April 1960. The center of the storm was marked by a circular cloud mass in the upper part of the photograph, with an extension of the spiral along a cold front trailing from the storm center to the south and southwest, as shown on the surface weather map of Fig. 4.

Striking similarities can be seen in these observations (Figs. 1–4) of cyclonically spiral bands associated with atmospheric vortices ranging in size from the small scale of a 10-mile hook echo of a tornado, through the medium scale of the 250-mile-long spiral band of a hurricane, to the large scale of the 1000-mile-long frontal system of an extratropical storm. The atmospheric processes which produce these bands are believed to be different at each scale, but the similarity of appearances may reflect some similarity of kinematics. To the extent that this may prove to be true, there is hope that increased understanding of any one of the phenomena will contribute to our progress in understanding the others (*10*).

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Electrical Responses of the Retinal Nerve and Optic Ganglion of the Squid

Abstract. Recordings were obtained from the retinal nerves and optic ganglia of intact squid, which were maintained in good condition by perfusing their mantles with sea water. Only "on" discharges were found in the nerves, whereas "on" and "off" discharges as well as spontaneous activity and tactile responses were obtained from the ganglia.

Several highly competent investigators (*1*), as well as one of us (E. F. M.), have repeatedly tried without success to record impulses from the retinal nerve fibers of cephalopod mollusks. There appeared to be two possible reasons for this lack of success: (i) impulses are not discharged in this nerve; (ii) the retinal nerve may be unusually sensitive to injury or ischemia produced after interruption of the circulation.

It has been suggested (*2*) that impulse propagation is unnecessary in short axons only a few space constants in length. It is entirely conceivable that the large electrical changes known since the time of Fröhlich (*3*) to take place in the receptors could be conducted decrementally in the optic nerve fibers, which are the axons of these cells, and retain sufficient amplitude to cause excitation in the optic ganglion.

Evidence of this mode of transmission in the squid's retinal nerve would furnish a concrete example of an important phenomenon which has long been postulated but has never been established by direct experiment.

It occurred to one of us (W. E. L.), in the course of bleeding squid to obtain hemocyanin for x-ray crystallographic studies, that it should be possible to maintain the squid in good condition by perfusing the gills with sea water while probing the retinal nerve with a microelectrode, and thus to determine whether conduction in this nerve takes place by the discharge of impulses or by electrotonic spread. A similar technique has been used for studying the giant axon in vivo (*4*).

In our experiments the squid (*Loligo pealii*) were placed on their backs, and their mantles were wrapped in a jacket of sheet lead. Two plastic tubes were inserted into the mantle through the valve on either side of the head. Sea water at 17°C flowed into these tubes and out the siphon, which could be deflected to one side by means of a lead hook to uncover the region over the optic nerve and ganglion. The tentacles were immobilized with a lead strap. An animal in good condition exhibited regular breathing movements and ejected a jet of water violently when stimulated.

Potentials were recorded between a glass-coated metal microelectrode (*5*), inserted into the head of the animal, and the lead jacket. A capacitance-coupled amplifier, dual-channel oscilloscope, and camera were used for recording, and an audio amplifier and loud-speaker were used for monitoring the experiment.

A stimulator comprising a tungsten lamp, electromagnetic shutter, neutral density wedge, and lens system was used to project a spot of light on the eye. A photoelectric cell was used in conjunction with one trace of the oscilloscope to indicate the duration of the stimulus.

Under suitable illumination the retinal nerves and optic ganglia could be seen through the transparent, cartilaginous "skull." A strong, steeply tapered electrode could be inserted manually through the skull, which then held it in place. Under these conditions impulse discharges from several units were recorded simultaneously. It was not possible to manipulate the electrode with sufficient precision to record from single units in isolation. It was also possible to punch holes in the skull with an 18-gauge hypodermic needle to permit the insertion of more fragile microelectrodes and still maintain the squid in good condition for an indefinite period.

To make certain of the exact location of the tip of the microelectrode in some experiments, the cartilage and muscle overlying the retinal nerve and ganglion were dissected completely away before insertion of the electrode. Results were identical to those obtained with an intact skull, except that survival time was only a few minutes.

As shown in the top trace of Fig. 1,

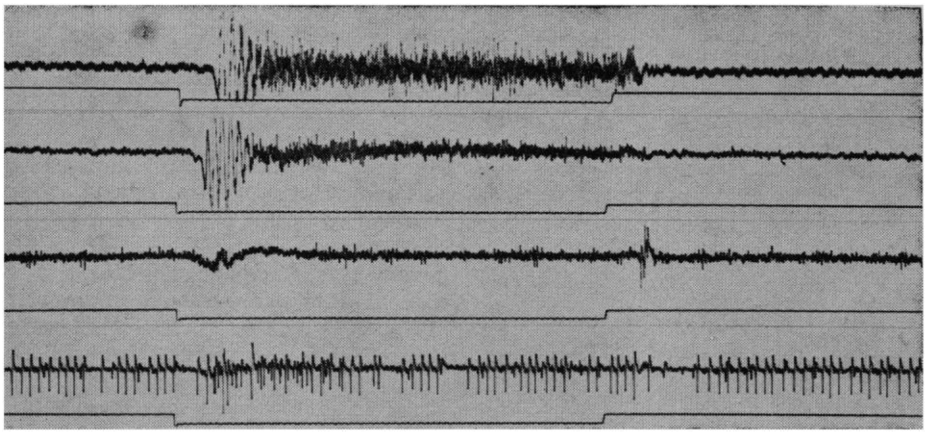

Fig. 1. Electrical activity of the retinal nerve and optic ganglion of the living squid. A glass-covered platinum 30-percent iridium microelectrode was applied directly to the surgically exposed nerve and ganglion. (Top trace) Electrode on nerve at point of emergence from retina; (2nd trace) electrode on surface of ganglion; (3rd trace) electrode penetrating ganglion; (bottom trace) electrode deep in ganglion. The bottom line of each trace shows the signal from the photoelectric cell; downward deflection indicates light on. Duration of stimulus, 0.51 second; amplifier coupling time constant, 0.001 second; amplitude of spikes in top record, approximately 500 μv.

the retinal nerve gave a discharge of impulses with a latency of about 0.05 second after the stimulating light was turned on. The frequency of impulses decreased within less than a second to a steady, maintained value and ceased abruptly after the stimulus was turned off. A damped train of slow oscillations appeared at the beginning of the discharge. These oscillations are of unknown origin and appear to be similar to those described by Fröhlich in the electroretinogram of *Eledone* (*3*), and by Wagner and Wolbarsht (*1*) in the octopus. They had many times the amplitude of the impulses from the nerve fibers, even though a millisecond coupling time constant was used in the amplifier to remove the slower components of the electroretinogram. No "off" discharges were found in the retinal nerve.

The discharge recorded from the surface of the optic ganglion (Fig. 1, second record) was identical to that recorded from the nerve and was presumably due to the fibers which cross the surface of the ganglion before entering it. Within the ganglion, both "on" and "off" discharges (third record) were obtained, similar to those found by Wilska and Hartline (*5*) in the optic lobe of *Limulus*. There was also a great deal of impulse activity within the ganglion, which was of spontaneous or undetermined origin (fourth record), though tactile responses were sometimes obtained. Obviously the two optic ganglia, which comprise the largest portion of the squid's central nervous system, are concerned with more than purely visual responses.

In these preliminary experiments (*6*) it was not possible to obtain quantitative information from single units, as has been done so successfully in *Limulus* and in the vertebrates. We only attempted to show that the retinal nerve of the squid discharges impulses in response to light and, in general, behaves as might be expected for the axon of a primary photoreceptor. We hope that others will be encouraged to make quantitative studies on the responses of the visual system and will solve the problem of keeping the microelectrode rigidly fixed with respect to the head, so that responses from single units can be recorded for an indefinite period. We also hope that our success in keeping the squid intact though immobilized for an indefinite period will encourage the study of the physiology of the circulation, the central nervous system, and the other sense organs of this intricate and highly organized animal.

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Factors in Phoretic Association of a Mite and Fly

Abstract. Combined rearing of the mite *Myianoetus muscarum* (L.), and the fly *Muscina stabulans* (Fall.) has revealed adaptations of the hypopus to a series of fly factors. These adaptations favor the mite's dispersal. Hypopi are attracted to the pupa by a volatile substance and cluster on the anterior end, from which the fly emerges.

Anoetid mites share with some other mite families a distinctive stage in the life cycle, the deutonymph, which is highly adapted for dispersal by insects. The deutonymph, or hypopus, is an alternative stage interposed between protonymph and tritonymph. Conditions eliciting its appearance are as yet poorly understood, and may involve genetic factors besides physicochemical factors of its environment. Adaptations of the deutonymph include increased sclerotization, reduction in leg size, anal suckers, and rudimentary mouthparts (*1*). A marked degeneration of the digestive tract of *Histiostoma laboratorium* Hughes has also been observed (*2*, p. 122). The hypopus of *Myianoetus muscarum* (L.) was first noted on the housefly in 1735 (*3*). Berlese (*4*) reared the adult from hypopi found on *Muscina stabulans* (Fall.), and recently Cooreman (*5*) redescribed the species. We know of no work in which this or any other species in the family has been raised with fly larvae for the purpose of studying phoretic behavior. This report describes a series of orientations of the hypopus of *Myianoetus muscarum* which are behavioral counterparts of the anatomical adaptations noted above.

Trapped flies bearing hypopi were placed in a fly cage and maintained on lump sugar and water. Maggots and mites were reared at 24°C on meat covered with moist sawdust. Oviposition and pupation of the fly also occurred in this medium, as well as the complete mite life cycle. As a prelude to pupation, the prepupa usually faces downward, and in this position begins to construct a cocoon of cemented sawdust. Presumably, salivary secretions constitute the cement, since the salivary glands are greatly distended in the prepupa, whereas in actively feeding maggots and newly formed pupae they are much smaller (*6*). The prepupa then inverts, completes the top of its cocoon, and pupates soon after. Inversion of the jar elicits immediate reorientation of prepupae. Noteworthy is the normal sequence of positive and negative geotropisms which occurs within the space of a few hours.

Clusters of hypopi which may contain thousands of mites are often found