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THE AUSTRALIAN NATIONAL UNIVERSITY

RESEARCH SCHOOL OF BIOLOGICAL SCIENCES

DEPARTMENT OF NEUROBIOLOGY

ANNUAL REPORT - 1974

Professor:

George Adrian Horridge, M.A., Ph.D., Sc.D. (Cantab), F.A.A., F.R.S.

Senior Fellow:

David Cartner Sandeman, M.Sc. (Natal), Ph.D. (St. Andrews)

Research Fellows:

Eldon Edward Ball, A.B.(Stan.), Ph.D. (Calif.)
Christopher Michael Bate, B.A. (Oxon.), Ph.D. (Cantab)
Jeffrey Lewis Denburg, B.A. (Amherst Coll.), Ph.D. (Johns Hopkins)
Keiichi Mimura, M.D. (Nagaski)
Harald Albert Nocke, Dr.rer.nat. (Cologne)
Yasuo Tsukahara, M.D. (Sendai, Japan)
David Young, B.A. (Oxon.), Ph.D. (Wales)
Jacob Israelachvili, B.A., M.A., Ph.D. (Cantab). Joint appointment with RSPhysS.

Postdoctoral Fellows:

Peter Fraser, B.Sc., Ph.D. (Aberdeen)
Simon Barry Laughlin, B.A., (ANU), Ph.D. (Cantab.)
Caryl Hill, Ph.D. (Melb.) (from November)
Gert Stange, Dr. rer. nat. (Göttingen)

Visitors:

Gerald Silvey, B.A. (St. Mary's College, Calif.), Ph.D. (Miami)
Robert L. Seecof, B.S., (C.C.N.Y.), M.A., Ph.D. (U. Texas) (from Sept.)
Kenneth Hill, Ph.D., (Melb.) (from November)

Research Assistants:

Martin Wilson, B.Sc. (Bristol), Ph.D. (Cantab.)
Miriam McLean, B.A., (Am.Univ.Wash.D.C.), M.S. (Howard Univ.), Ph.D. (Univ. Wash.)
Willi Ribi, Dipl.Biol., Dr.sc.nat. (Zurich)

RESEARCH WORK

There are four main lines of research in the Department generating interaction at two levels, within groups working in the same area, and between groups educating each other and hopefully sparking off new ideas between their areas of main advance. The most sharply defined area of interest is the analysis of statocyst and visual coordination by the brain of the crab Scylla, by Drs Sandeman, Fraser, Silvey and two postgraduate scholars, Messrs Dunn and O'Brien. Secondly, there is an association between Drs Ashhurst, Ball, Bate, Denburg, C. Hill and Seecof, with interests in the growth and biochemical differences of insect neurons, and how they become connected with the appropriate muscles or other neurons. Besides these is a small group consisting of Drs Laughlin, Mimura, Tsukahara and Wilson with two scholars Leggett and Via, recording from the primary photoreceptor cells of insect and crustacean eyes. Also concerned with vision are a number of specialists with quite different techniques. Dr Ribi and scholar Sharma on anatomy and connections of the optic neurons, Dr Israelachvili on basic physics of photoreceptor membranes, and Professor Horridge who has been concentrating this year on a broad survey of compound eyes. The highlight of a vigorous interaction with the Department of Applied Maths was the working conference on Receptor Optics at Darmstadt in October, where 8 members and past members of Neurobiology collected. The fourth group, Drs Ball, K. Hill and Young continue their analysis of hearing and sound production by a number of insects of great interest that are available only in Australia. Besides the above, their are two scholars, Simmons and Whitington, working on motoneurons of central nervous system and Dr Stange who continues his analysis of the smelling of carbon dioxide by bees and blowflies.

It is important to stress that, as a result of the timing of appointments in the department, almost everything in the 1973 report for Neurobiology applies equally well to 1974, but a more noticeable turnover will take place in 1975. At present the department is too diverse, as shown by a tendency to divide even for small-group seminars.

Control of walking in the cricket (E. Ball and C. Vilcins)

The cell bodies controlling walking in the cricket have been determined using the cobalt chloride technique. The pattern of these cell bodies is very similar in all three of the thoracic ganglia and is also similar to the patterns thus far examined in other orthopteroid insects.

Strike control in the praying mantid (E. Ball)

The goal of this study is to investigate the relationships between a small number of nerve cells as they interact to produce the rapid strike by which praying mantid captures its food.

(1) The morphology of the prothoracic ganglion-mass has been reconstructed from serial sections and whole mounts to establish the location of the larger neuron cell bodies in the prothoracic ganglion. Cell bodies controlling the leg musculature have been determined by filling the appropriate nerves with cobalt chloride from the periphery.

(2) Anatomy of the prothoracic legs - A detailed study has been made of the muscles and skeletal structures of the leg in an effort to determine the mechanics of the system.

(3) Physiology - Simultaneous recordings have been made from up to 4 muscles during the strike. However, much remains to be done on this part of the study since ideally all possible combinations of muscles should be recorded from repeatedly.

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(4) Sensory Input - The structure, function, and role in strike control of the sensory hairs on the inside of the prothoracic femur is being investigated.

Studies on the auditory system of the cricket (D. Young and E. Ball)

Morphological studies on the structure and development of the auditory system of the cricket have been completed. On the basis of physiological results to date it appears that although preadult animals are sensitive to substrate - borne vibrations they are not sensitive to air-borne sounds. Present research involves quantification of the changes in sensitivity of the auditory system during development and an attempt to explain the apparent insensitivity of pre-adult animals to air-borne sound.

Analysis of the crab statocyst and its central projection (D.C. Sandeman, P. Fraser and G. Silvey)

Movements of the crab eyestalk can be generated by the input from the semicircular canals of the statocyst as well as the visual system. The central transformation of angular accelerations to produce the final eye movements is studied using isolated eye-brain preparations of the crab. The dynamics and anatomy of the angular acceleration receptors themselves in the statocyst is the interest of research scholar Mr. P. Dunn. Deeper within the brain, we have found that impulses from these receptors are transmitted to the optic lobes and the possible influence of this on the incoming visual information is being studied by Mr. O'Brien. The study of crab eye movements assumes more and more interest as quite remarkable parallels are found to exist in the control mechanisms of the movable eyes of all animals which have them. The central brain mechanism for the generation of the characteristic slow and fast phases of nystagmus may well turn out to have a common basic theme. It is probably easier to establish this theme in the lower animals than in vertebrates because the brains of the lower animals' contain fewer nerve cells and withstand isolation.

Optokinetic eye movements in the crab (D.C. Sandeman)

The study of the optokinetic system in the crabs has been hindered by the lack of information about the activity of central interneurons related to the response. Dr. Sandeman spent 6 months study leave at the Zoological Institute in Darmstadt working with Dr. J. Kien and J. Erber, to develop a preparation in which the activity of interneurons could be observed in an intact animal and directly correlated with the eye movements. The attempt was rewarded with the discovery of 3 classes of optokinetic interneurons which are specifically activated by optokinetic stimuli and which fit all the criteria necessary to establish them as part of the optokinetic system. The characteristic responses of the different classes of interneurons provides a possible explanation of the long delays which occur between the activation of parallel muscle systems in the eye. The interneuron responses also give an insight into the ability of the crab to respond to a wide range of angular velocities and also of the possible effect upon the visual input of a fast phase of nystagmus.

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Crab oculomotor system (G.E. Silvey and D.C. Sandeman)

The neural mechanism by which crabs produce compensatory eye movement to yaw rotation of the body has been analysed. Crabs move their eyes in phase with, but in opposite direction to, a sinusoidal yaw rotation of their bodies at frequencies upward to 0.1Hz. These eye movements to angular movements of the body are mediated by the thread hairs of the horizontal canal. These hairs, which are innervated by bundle IIA of the antennular nerve, are excited by acceleration and reach their peak firing frequency during maximum velocity of the rotation. The sensory neurons which innervate these hairs synapse directly with the oculomotor neurons that innervate the antagonistic pairs of muscles which move the eyes in the horizontal plane. One set of sensory neurons in each statocyst responds to clockwise rotation, another set to counterclockwise rotation and these appear to make correct connections to the motor neurons which drive the eyes in counter-clockwise or clockwise directions respectively. Peak firing of these motor neurons coincides with peak discharge frequency of the sensory neurons. This means that the statocyst performs one integration at a change in body position, integrating the acceleration component of the change to an input signal that detects velocity. The motor neurons respond directly to this signal, leaving the muscles and mechanics of the eye to integrate velocity information to a change in eye position. Of particular interest is that brain interneurons are not needed for integration; any central integration is performed by the motor neurons alone.

Embryogenesis of locust nervous system (C.M. Bate)

A preliminary survey of embryogenesis in Chortoicetes terminifera has been followed by a more thorough investigation of the embryonic nervous system of Locusta migratoria, an animal which is larger, and more easily cultured. At 30° C embryonic life lasts 15 days. At 144 hours blastokinesis occurs, by which time the overall pattern of the nervous system is established. We have confined our attention to the events preceding blastokinesis and to the mesothoracic ganglion in particular. The investigation has developed along several lines (1) the pattern of central nerve fibres established in early embryogenesis; (2) the fine structure of developing neurons (3) the first appearance of inwardly growing axons signalling the differentiation of neurons in the peripheral as well as the central nervous system; (4) incorporation of labelled thymidine into embryos to establish the birthdays of identified neurons in the adult nervous system; (5) experimental manipulation of neuroblasts.

Differentiated neurons in the adult system are the progeny of lateral and median neuroblasts in the embryo. Axon outgrowth from the cell groups established by the unequal division of the neuroblasts and subsequent divisions within the group begins at 83 hours in the mesothorax. By 100 hours a characteristic pattern of longitudinal connectives, transverse commissures and segmental neuropiles is apparent. The earliest date at which axon branches have been seen is at 115 hours, at the junction of connectives and commissures, but serial sections, of ganglia at earlier stages will likely show that axon branching occurs considerably earlier.

In the light microscope the early growing axons appear in a meshwork of filopodia. These processes, the axons and their parent cells

●ve the structural characteristics of differentiating neurons as previously described for various embryonic and cultured preparations. Sca like protrusions of the cell body and the axon itself are common in the embryonic nervous system, filled with electron lucent vesicles with a diameter of about 1,500 A. These are similar to the 'growth cone vesicles' previously described in a number of developing vertebrate nervous systems. They are not however associated with growth cones' and are to be found in a variety of other embryonic cells in the locust. They are probably a characteristic of rapidly growing cells in general rather than embryonic neurons in particular. Gap junctions are found between adjacent cells but it is not clear whether this relation is restricted to the progeny of single neuroblasts.

Inward growing axons have been found in electron microscope sections of the base of the embryonic, antenna at 96 hours. Extending this investigation to the mesothoracic limb bud we find a few centripetal axons at the base by 120 hours. Axon ingrowth therefore begins at the latest shortly after axon outgrowth in the central nervous system, and many hours before differentiated sense organs appear in the periphery. It is hoped to confirm this finding of an early differentiation of sensory neurons by incorporating tritiated thymidine into the embryo before blastokinesis. Using a modification of a technique previously used with Drosophila embryos, it has been possible to incorporate labelled thymidine into embryos at stages later than 70 hours. The main aim of these autoradiographic experiments however is to establish the sequence in which the prospective adult neurons are budded off from the embryonic neuroblasts.

Left/Right Inversion of cockroach ganglia (C.M. Bate)

Experimental animals with rotated ganglia in each of the three thoracic segments have been assayed by retrograde iontophoresis of cobalt chloride for the regrowth of nerves into the limps. In every case axons from inverted ganglia fail to grow back to their side of origin. They innervate the nearest available limb which subsequently develops coordinated movements.

Biochemical basis of neuronal specificity (J. Denburg)

The type of neuronal specificity studied is that between motoneurons and muscles determining whether synapses will form between them. It is assumed that this specificity is a reflection of specific interactions between macromolecules on the cell's surface. In the cockroach, Periplaneta americana. This system exhibits great specificity which can be studied at the level of identified cells. One experimental approach is to examine biochemical changes in the motoneurons while they regenerate after having their axons cut, looking particularly for an increase in synthesis of some macromolecules responsible for the growth of the axon and the reformation of a specific synapse. Cutting all the motoneurons leaving a thoracic ganglion produced no change in the rate or pattern of protein synthesis when the entire ganglion was analysed. This may indicate that there is no change in protein metabolism during regeneration of the neuron or that the changes in the motoneuron are too small to detect when the entire ganglion is studied. To examine the latter possibility, techniques such as autoradiography and microgel electrophoresis are being adapted in which protein synthesis can be examined in single identified neurons. In addition, sufficient data

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have now been obtained on the protein metabolism of ganglia regenerating in vivo to make a comparison with that of ganglia growing axons in vitro.

The other cell involved in these specific interactions, the muscle, is perhaps more amenable to biochemical study. In the cockroach there are muscles whose fibers are all innervated by the same neuron. It was observed that each muscle innervated by a particular neuron had a characteristic pattern of proteins on gels after electrophoresis. In muscle fibers innervated by two neurons, the proteins characteristic of both neurons are found. Studies are being done to determine whether these differences in protein pattern are a product of the innervation of the muscle by the neuron (a trophic interaction) or whether they are intrinsic to the muscle and serve as identifying labels for nerve recognition.

To identify macromolecules involved in specific synapse formation, another approach being attempted is the use of immunochemical techniques for observing complex formation. These are usually used to characterise antigen-antibody complexes but may equally be applicable to the identification of complexes between mocromolecules from nerve and muscle.

Control of Equilibrium in the Crab (P.J. Fraser)

The equilibrium system of the crab Scylla is being investigated at the level of a large interneuron (giant fibre 5) connecting brain and thoracic ganglia. Statocyst input from thread hairs and free hook hairs has been extensively studied. Thread hair receptors which respond to one direction of fluid movement in the vertical canal of one statocyst contact the cell directly. During rotation of the crab, the bilateral systems of canal, thread hairs and interneuron abstract orthogonal components of the rotation and effect the first integration of the angular acceleration. Free hook hairs from both statocysts provide input to one fibre 5 as shown by spikes in response to rotation of the antennule at high frequencies (up to 100 Hz.) after cutting the thread hair nerve. Leg proprioceptor input from the thorax and a central 'command' input involving the optic lobes have been shown to converge separately on to fibre 5. These inputs are now being investigated more quantitively. In the whole animal, statocyst, leg and central inputs sum to give a complicated output. One overt output which can be evoked on experimental stimulation of fibre 5 is the righting reflex. Study of one interneuron thus yields an analysis of a complete behaviour pattern from sense organ to muscles.

Statocyst and nervous system morphology has been investigated in several families of crabs with different life styles. Preliminary results indicate that two components of the equilibrium system (statocyst morphology and relative size and occurrence of fibre 5) are relatively constant in all crabs.

Angular sensitivity of the light and dark-adapted locust compound eye (M. Wilson)

The structure of the locust ommatidium is being reinvestigated by electron microscopy (with P. Garrard) and an exact reconstruction of the pattern and combinations of photoreceptors is in preparation.

The spectral and polarization sensitivity of the 8 photoreceptor cells in an ommatidium are being investigated with two techniques: intracellular recording from single receptor cells, and selective light adaptation followed by examination in the electron microscope. Electrophysiology has also been used on the light and dark-adapted photoreceptors, showing that the locust receptors have better acuity than was previously thought, an acuity in fact that comes close to the theoretical limit set by the diffraction of a lens of the diameter of the facets of the eye.

The orientation of photopigments in the invertebrate rhabdom (J. Israelachvili and M. Wilson)

This work is directed to understanding the consequences on absorption of the tubular form of the membrane in which invertebrate photopigments lie. The first stage was a theoretical study of the effects of orientation of the visual pigment and an effort is being made to visualise rhodopsin molecules with the electron microscope and to alter the properties of the receptors by appropriate adaptation with coloured and polarized light.

Photoreceptor theory (J. Israelachvili)

The past year's study was mainly theoretical work on the physical and optical properties of visual photoreceptors, with particular attention to the receptor membrane and its photopigments. The aim is to interpret experimental data (birefringence and refractive index studies, polarization sensitivity studies, etc.) in terms of the photoreceptor structure and the distribution and orientation of its photopigments inside the photomembranes.

Other theoretical work on the general protperties of membranes, hydropholic interactions, and intermolecular forces in biological systems is in progress jointly with the Department of Applied Mathematics.

Visual signal processing in dragonflies (S.B. Laughlin)

Dragonflies are aerial predators and require a compact, accurate and sensitive visual system for tracking their prey. Intracellular recordings from the photoreceptors and second order interneurons allow us to examine how the visual signal is extracted from the pattern of incident light and is processed in the first optic neuropile, the lamina.

The receptors set up a mosaic of signals representing the spatial distribution of intensity. In the lamina there is a mechanism which increases the signal-to-noise-ratio of each mosaic element, emphasises intensity changes, sharpens the signal by lateral inhibition, and gives a measure of contrast that is independent of the average brightness of the visual field. In this respect the second-order interneurons of dragonflies resemble their counterparts in the vertebrate retina, suggesting that at a peripheral level the problems of vision are formally equivalent and involve the sharpening-up of the receptor signal and a matching of the amplification of the visual signal to the average brightness of the environment. Current research is concentrating on the neural basis of light adaptation and sensitivity control in receptors.

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Throughout the year the valuable collaboration with Dr A.W. Snyder's group (Applied Maths. IAS) has continued. Several optical properties of insect photoreceptors have been examined. In particular we have analysed the roles that membrane form and chromophore orientation play in determining the quantum capture of photoreceptors. Work in this field is continuing.

"Bumps" of the retinula cells of the fly (K. Mimura)

Retinula cells (1-6) of wild type Lucilia cuprina have two spectral sensitivity peaks, near 350 and 490 nm of almost the same height. In order to solve the problem of whether there are one or two pigments per cell, the miniature potentials or "bumps" which are inferred to arise from single photon absorptions, have been investigated with mainly 333 nm and 500 nm light. The miniature potentials in response to 333 nm low intensity stimulation were relatively larger in amplitude and shorter in duration than those caused by 500 nm photons. Therefore it is inferred that the two peaks of the fly spectral sensitivity curves are caused by different processes which yield distinct bumps.

Effect of wavelength upon angular and polarization sensitivity of the fly's eye (K. Mimura)

The angular sensitivity and polarization sensitivity curves of retinula cells (1-6) of wild type Calliphora stygia were investigated. The angular sensitivity curves were narrower when measured at 333 nm (mean 2.25° in the vertical plane and 2.39° in the horizontal plane) than at 500 nm (mean 1.81° in the vertical and 2.93° in the horizontal). This is mainly explained by the narrower Airy disc at the shorter wavelength.

The direction of the ε-vector plane for maximum polarization sensitivity with UV light was different from that to green light. Angular differences were mainly scattered between 30° and 90° in anticlockwise direction but a few cells showed differences of about 30° in clockwise direction looking out from the eye. Polarization sensitivity curves were constant through the range of UV with a sudden transition to different curves in the green range. These results cannot be explained by two pigments, one of which has molecules at an angle to the microvilli, and therefore it is inferred that the fly rhabdomeres are twisted, with the two visual pigments in different parts of the rhabdomere. The explanation of the variability between cells then lies in the different amounts of twist in the different types of cell 1-6.

Neurons of the insect optic lamina (W. Ribi)

Light microscope studies using selective and reduced silver impregnations and EM techniques (normal and Golgi-EM) give comparative information about the neuropile of several insect species. Fibres are followed from the base of the retina through the first optic ganglion or lamina. The enormous morphological variations between different neurons in the first synaptic region make it possible (i) to characterize the single axon types that come from the retina or the second optic ganglion to the lamina and also the second order neurons which originate in the first optic ganglion and (ii) to recognize a projection pattern between the receptor axons and the second order neurons in the lamina.

Culture of cockroach neuromuscular elements in vitro (R. Seecof)

Insect neurons and muscle cells will grow in vitro and establish neuromuscular junctions. Culture of appropriate neurons and muscle cells should provide information that cannot be obtained readily from studies of intact insects.

David Young has shown for cockroaches after nerve transection that individual motoneurons will re-establish connections to the muscles they normally innervate. During regeneration, proper connections are achieved either through directed growth or through random growth followed by utilization of successful axon branches. Either sequence implies recognition between neuron and muscle types.

Preparations of selected motoneurons and target muscles will be made in vitro and monitored for successful axon regeneration and neuromuscular junction formation. Such preparations should yield a description of axon regeneration and eventually prove useful for characterizing the biochemical specificity of the recognition phenomenon.

Insect rhodopsin and phototransduction (Y. Tsukahara)

Vertebrate visual pigment (rhodopsin) is bleached when it absorbs light and must be regenerated chemically. Invertebrate visual pigment is changed by light to another pigment (metarhodopsin) which is isomerized back to rhodopsin by longer wavelength light. New findings in fly are (1) the sensitivity of the single receptors are not proportional to the concentration of rhodopsin and (2) the receptor after-potential is suppressed by the metarhodopsin activation. The spectral sensitivity of this potential is the difference spectrum between rhodopsin and metarhodopsin. (3) At intermediate wavelengths, when the after-potential is measured as the response, a full range from zero to saturation is covered by a range of monochromatic intensities of less than one log unit. The after-potential therefore cannot be the simple effect of the isomerization of one pigment. These studies are leading a new interpretation of the transduction process in insect eyes.

Physical and physiological properties of the tettigoniid ear (H. Nocke)

The physiology of the tettigoniid ear was first studied by Autrum (1940) who based his theory on the assumption that sound only acts the outer surface of the 2 eardrums. In classical anatomical studies (Graber, 1876) it had already been suggested however, that sound might reach the sensory structures via the tympanal trachea which runs from a spiracle in the thorax down the leg to the tympanal organ in the tibia. Since Autrum's theory can not explain many recent behavioural experiments on the acoustic orientation of the Tettigoniids, the physiology and physics of the tettigoniid ear have been reconsidered in these experiments using physiological methods.

It has been found that the tympanal trachea functions as a resonator which largely determines the physiological properties of the ear. The resonator tunes the tettigoniid ear to the species own song, and lowers its hearing threshold to extremely low values. An important property of the ear is its directional sensitivity; the female can locate the male over distances of up to 0.5 km. Our

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present picture of the directionality of the tettigoniid ear has largely been determined by Autrum's experiments, which are based on sound acting on the outer surface of the eardrum. My experiments show however, that the directional properties of the ear are only determined by sound acting on the tympanal spiracle. The ear is most sensitive if the spiracle points towards the sound source and least sensitive if it points away from it. The directionality disappears if the spiracle is closed artificially. Similar results are also available for the cricket ear (Teleogryllus commodus). These findings are in excellent agreement with recent behavioural experiments on the acoustic orientation of crickets, which could not be explained with the old hearing theories.

Transduction mechanisms in insect CO_2-receptors (G. Stange)

In continuation of the work on primary mechanisms involved in the detection of CO_2 by the honeybee, an attempt has been made to test CO_2-receptors in other insect species for which the ability to detect CO_2 might be important. Electrophysiological recordings from beetle larvae, ants and termites have been unsuccessful so far, but in the sheep blowfly Lucilia cuprina a CO_2-receptor was found which shows similarities to the honeybee CO_2-receptors in some aspects, but differences in others. The receptors in both species have similar sensitivities, and they respond to a variety of lipid soluble gases which also act as general anaesthetics. The efficiency of those stimuli increases with their lipid solubilities, but small size of the molecules is also important: Within the series of homologous n-paraffins the effect increases with chain length, towards pentane in the honeybee and butane in the blowfly; higher homologues have no or only a very weak effect. There are two differences in the response properties of both receptors: the anaesthetic stimuli, which cause an inhibitory response in the honeybee receptor, have an excitatory effect in the blowfly, and in the blowfly the effect of the carbonic anhydrase inhibitor acetazolamide is much smaller than in the bee.

It has been the subject of frequent discussions, whether kinetic properties of chemoreceptors such as the saturation and latency behaviour are determined by a primary acceptor system according to the mass action law, or whether later steps in the transduction chain are rate limiting. The results from both types of CO_2-receptors indicate that the second possibility applies, similar to the situation in visual receptors: A primary acceptor system, which is highly specific to CO_2, does not saturate within the dynamic range of the receptors, and also the intensity dependence of latencies is determined by later events and not by the primary interaction between stimulus and acceptor, which is very fast.

Anatomical aspects of sound production and reception in Cicadas (D. Young)

As part of a continuing project on sound production and hearing in cicadas, the detailed anatomy of the relevant sense organs has been studied this year. Three specialised nerve organs associated with the sound production system have been described in this study:-

(1) The tymbal organ is connected to the lower anterior margin of the tymbal;
(2) The tensor organ is connected to the special protuberance bearing the origin of the tensor muscle;
(3) The detensor organ is connected to the cuticle near the inner margin of the tympanum but is quite separate from the auditory organ. These sense organs contain an exceptionally large number of sensillae, up to 1300 in the tymbal organ, which is the largest of the three. All three organs belong to the distinct arthropod type of mechanoreceptor termed chordotonal organs. Each sensillum consists of the sensory cilium, a scolopale cell (containing the specialized sensory ending, the scolopale, has been examined by electron microscopy and its distinctive features described.

The auditory organ is also being studied anatomically. Its exact location within the auditory capsule has been described, in preparation for physiological studies. The auditory organ contains a complex array of individual receptors, about 1500 in number. The exact pattern of this array and the fine structure of the receptors is being analysed.

Regeneration patterns of cockroach motoneurons (P. Whitington)

In an earlier study it was shown that cockroach motoneurons regenerate very specifically to their own muscles and to no others. This process is now being examined in more detail to see to what extent branching patterns and physiological properties are constant after regeneration.

Anatomy of insect nervous system (V. Sharma)

Following a preliminary study on the anatomy of the Dragonfly nervous system which is about to be completed, a detailed account is being prepared of the neuronal anatomy of the lamina of the locust. The intention is to provide the anatomical background for physiological work on the same system. Only with complete anatomical details of the component neurons and their synapses is it possible to attempt to understand the processing of visual information.

Statocyst interneurons to the crab optic lobe (B. O'Brien)

Interneurons in the crab optic lobe carry information on position and movement of the whole animal from the brain to the optic ganglia. As there are no known motoneurons in these ganglia the positional information must be integrated with either visual information or with other mechanoreceptive input and returned to the brain. According to earlier reports, the visual horizon of some interneurons of the optic ganglia is altered by the input from the statocyst. This is called space constancy. An attempt is being made to demonstrate which parameters of spatial orientation detected by the statocyst are important for the space constancy effect.

Central neurons of dragonfly flight system (P.J. Simmons)

Activity is recorded in pairs of identified motoneurons in insect ganglia with the aim of discovering mechanisms underlying patterning of behaviour. The reason for recording from pairs of motoneurons simultaneously is that common inputs and correlations between them can be seen, so that the system regulating output of the motoneurons can be inferred. Australia has a number of large insects that should be amenable to this kind of analysis. Present efforts are concentrated upon parts of the flight system of the dragonfly, Hemianax papuensis, with particular attention to the mechanism of flight control and of respiration during flight.

Physiology of the statocyst receptors of Scylla (P.A. Dunn)

Physiological responses, dynamics and ultrastructure of the sensory hairs and nerves are being studied to elucidate the equilibrium function of the statocyst of the crab, Scylla serrata.

Crab vision (L.M.W. Leggett)

Although the insect eye has been extensively used in basic vision research, the similar compound eye of the crab is relatively unexplored, especially at receptor and early integrative sites. Intracellular records have been made from the crab retina and these show that, in the two species studied, vision is monochromatic, of similar acuity to the best insect eyes, and that the polarization sensitivity is the highest so far observed in the visual receptors of any animal. The normal experimental insects have receptors with a number of visual pigments and low polarization sensitivity (except in a small percentage of specialised cells). The crab response characteristics contrast greatly with these. This difference may simplify the analysis of visual integration in crab optic interneurons, from which recordings are at present being made.

Receptors and integration in insect visual system (S.E. Via)

The compound eyes of dragonflies are divided into dorsal and ventral areas easily distinguished by a difference in colour. Spectral sensitivity of receptors also differs between these two areas. The dorsal retinula cells and second order cells of the lamina are being examined electrophysiologically to determine colour types so that properties of interneurons which are excited by both sets of inputs can be studied.

Other activities

Dr Ball spent seven weeks in Papua New Guinea continuing his studies on biological colonization of a newly-created volcanic island and on the biogeography of New Guinea lakes.

Dr Denburg presented a public lecture entitled "Drugs and the Chemical Manipulation of States of Consciousness" as part of the Man the Manipulator lecture series presented by RSBS.

Dr Fraser spent three weeks on Heron Island studying nervous system morphology and behaviour of crabs and crab larvae.

One of the events of the year was the Conference on Receptor Optics held at Darmstadt, Germany, with support from ANU, and from RSBS in particular. This meeting was held in Germany because the main audience and principal participants from ANU were already there. Six members, or past members, of Neurobiology were present, and four of our associates from Applied Maths. One day we worked from

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nine in the morning until 11.45 p.m. Intense interaction was the rule every day. The Conference volume soon to appear will convey advances in this field which have emerged from the interaction between Dr Snyder and his group with the work and experience on insect visual receptors in Neurobiology.

Simon Laughlin spent three months in Darmstadt, West Germany working as a research fellow in the Zoologische Institut of the Technische Hochschule at the invitation of Professor Randolf Menzel. He collaborated with Allan Snyder on theoretical studies of absorption in photoreceptor and gave a paper at the Receptor Optics Conference in Darmstadt. He gave seminars at major universities in West Germany and Great Britain and returned home, pausing to refresh himself in Mexico.

Dr Sandeman spent six months in the laboratory of Prof. Randolf Menzel in Darmstadt, Germany, at the invitation of the Deutsche Forschungsgemeinschaft. While there be collaborated with Drs Erber and Kien on a study of the optokinetic interneurons of the crab. During the six months absence from Canberra Dr Sandeman also visited a number of American,British and European Universities.

In preparation for the Alpha Helix expedition to Ambon and the Banda Sea in 1975, Professor Horridge spent some time in Jakarta in October visiting Bogor, Indonesian government departments and agencies related to marine sciences in Indonesia. He visited the Oceanology laboratory in Ambon and made a preliminary exploration of the island, the results of which are being reported to all members of the expedition.

Publications

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1. Member of the Department of Applied Mathematics, RSphyS.
2. Not a member of this University.
3. Visiting research worker.
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