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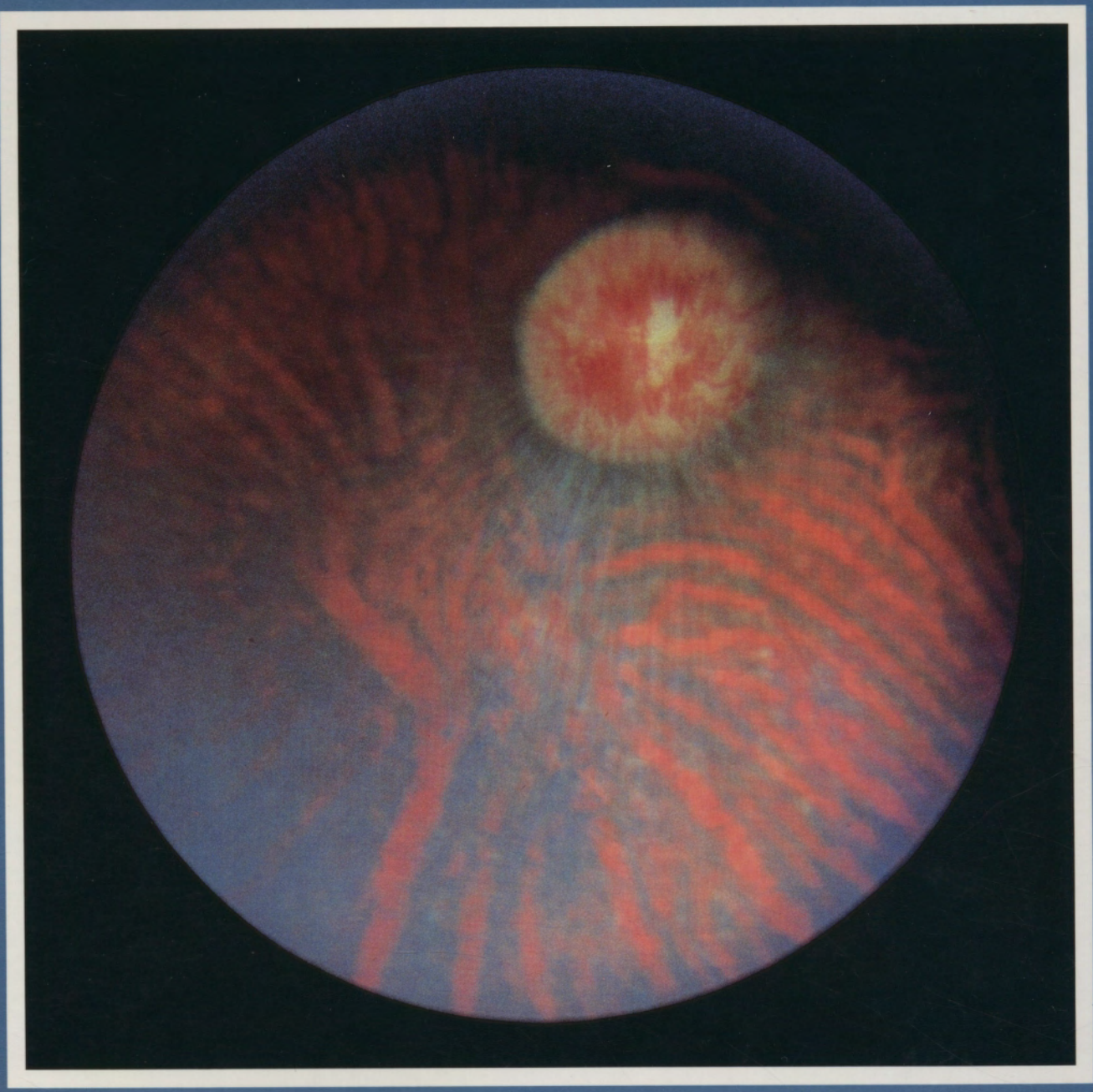
RESEARCH SCHOOL OF BIOLOGICAL SCIENCES

ANNUAL REPORT



1990

THE AUSTRALIAN NATIONAL UNIVERSITY

COVER STORY

This is a photograph of the living retina of the eye of a tammar wallaby. The pale disc with some small blood vessels over it is the beginning of the optic nerve. It is about one millimeter in diameter. White nerve fibres from the retinal nerve cells can be seen converging on it. Deep to these are red pigmented blood vessels and the blue background is the absorbtive pigment layer behind the retina. The neural retina comprising a layered network of nerve cells lies between the nerve fibres and the pigment layer and is quite transparent. The photograph was taken by Professor Richard Mark as part of a research project on the development of the marsupial visual system. Marsupials such as this wallaby *(Macropus eugenii)* are invaluable for development studies because the young are accessible for observation during the long period of pouch development. In most mammals and man comparable stages of development occur in the uterus.

THE AUSTRALIAN NATIONAL UNIVERSITY

RESEARCH SCHOOL OF BIOLOGICAL SCIENCES

ANNUAL REPORT 1990

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The photographs in this Report are, unless otherwise attributed, by Mrs Maureen Whittaker, Senior Technical Officer in the School's Photography and Illustration Unit.

SYMBOLS

In this report a number of symbols are used to indicate that named individuals are not members of the School's staff. These symbols are:

\# Visiting research worker
§ Former visiting research worker
\+ Not a member of the University
• Former member of the University
† Member of another part of the University

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DIRECTOR'S INTRODUCTION

B.E.S. Gunning
Acting Director

1990 was a year of intense activity in RSBS. Two very satisfactory outcomes deserve pride of place: the appointment of Professor C.B. Osmond FAA,FRS as the School's new Director, and the largely positive report of the Committee established to review the Institute of Advanced Studies, of which RSBS is a part. We add to these the opening of the ANU Electron Microscope Unit, now housed in its entirety in RSBS; the beginning of a major new research endeavour in the form of the Centre for Molecular Structure and Function; the preparation of two major bids for Cooperative Research Centres on Plant Sciences and Ecology of Biotic Resources; the expansion of the Ecosystem Dynamics Group by the appointment of two new tenured staff; advanced planning for 900m^2 of new laboratory and office space; and a very healthy list of research accomplishments.

The implications of these developments will extend far into the future and in retrospect 1990 will be seen much more as a time of change and progress than as the anticipated period of quiescence pending the arrival of a new Director. As Acting-Director I would like to thank all personnel in the School for their help and support throughout the year. Selected highlights were:

- Professor Charles Barry Osmond FAA, FRS will take up the Directorship of RSBS in May 1991. His appointment is especially welcome because he was a founding member of the School when it opened in 1967 and his many distinctions arise mostly from research carried out here in RSBS. In 1982 he became Executive Director of the Desert Research Institute in the University of Nevada and in 1988 he was appointed to a special Chair at Duke University, North Carolina, from which he will be rejoining us.
- The School is delighted to welcome Dr Jim Peacock FAA, FRS, Chief of the CSIRO Division of Plant Industry, as an Adjunct Professor. Dr Peacock has had many links to RSBS and its staff and this new appointment gives formal recognition to his important contributions, both in research collaboration and student supervision.
- The report of the Institute Review Committee, issued in November, contains recommendations which will affect RSBS specifically. Chief among these is a recommendation to affiliate parts of the John Curtin School of Medical Research with RSBS. We see much potential mutual benefit in this suggestion. A more general recommendation concerns collaboration with other parts of the Australian research system. This too is welcome. As detailed in the 1989 Annual Report, some 25% of our publications already have co-authors from researchers in Australia, outside RSBS.
- The School's successes in previous rounds of the Vice-Chancellor's Strategic Planning Competition, which reallocates a proportion of the Institute's budget, led to expansion of the Ecosystem Dynamics Group and the creation of an inter-School Centre for Molecular Structure and Function (CMSF). Important developments in these areas during 1990 were the appointments of Dr Peter Chesson and Dr Marilyn Ball to tenured posts in Ecosystem Dynamics, and inaugural appointments in the CMSF, in protein engineering, gene targeting and computational aspects of gene sequencing, including appointment of Dr Hugh Campbell to a tenured post.
- Enormous effort has gone into preparing two submissions for Cooperative Research Centres. These Centres are a federal government initiative which owes much to the vision of the Chief Scientist, Professor R.O. Slatyer, the School's previous Director. One of our submissions involves collaboration with the CSIRO Division of Plant Industry, the ANU School of Life Sciences and an industrial partner, Biocem Pacific Pty, and concerns strategic and applied research on Plant Science. The other involves collaboration with the School of Life Sciences and the

Centre for Resource and Environmental Studies in ANU and the CSIRO Divisions of Wildlife and Ecology, Plant Industry and Entomology, and focuses on the Ecology of Biotic Resources in Australia.

- For the first time, this Annual Report contains a section devoted to the ANU Electron Microscope Unit. This gives recognition to the consolidation of the University's previously dispersed EM facilities. The former scanning and transmission units are now combined under one roof in a new extension to the RSBS building. Professor Ian Ross, former Pro-Chancellor, performed an official opening ceremony in August 1990 to mark this event. The EM Unit which is a University-wide facility is now fully operational under a newly-appointed Facility Coordinator, Dr Sally Stowe.

- The School, in conjunction with the CSIRO Division of Plant Industry and Monash University , began its contribution to the International Program to obtain the complete genetic sequence of the flowering plant *Arabidopsis thaliana*. Our work, supported by a grant from the Department of Industry Trade and Commerce (International Science and Technology Program), will be a major part of Australia's component of this 10-year operation involving scientists from many countries. It will be the botanical counterpart of the better-known Human Genome Project, and will be as significant for plant science and agriculture as the latter will be to molecular biology and medicine.

- One of the academic highlights of the year was a set of three research seminars given in the School by the winners of the inaugural Australia Prize, presented in Parliament House by the Prime Minister on May 10th. The prizewinners, Professors J. Schell (Max Planck Institute, Köln), E. Nester (University of Washington) and A. Kerr (University of Adelaide) each described their work on the crown gall organism, *Agrobacterium*, showing how it had revolutionised plant molecular biology by providing a controllable means of producing genetically transformed plants for exploitation in research and agriculture.

- Members of the School continued their strong record of achievement in attracting prestigious awards. Wendy Lewis-Henderson was the second student in two years to become a Young Achiever of the Year. Drs Dean Price and Susanne von Caemmerer were awarded Queen Elizabeth II Fellowships in the 1990 round. Professor Gunning was appointed a Distinguished Research Associate of the CSIRO Division of Plant Industry.

- The School building was transformed for two days in September into a magnificent display of spring blossom, interspersed with scientific exhibits, as part of the ANU Open Days. More than 1500 members of the public visited. It was a thoroughly enjoyable occasion, at least for the hosts, and we hope also for the visitors.

- This Annual Report summarizes much of the excitement and progress in the School's current research. One item is singled out here because of its great topical interest. It is essential that legislators have solid scientific evidence on which to base regulations to control the release of genetically manipulated organisms into the environment. Professor Barry Rolfe, of the School's Plant-Microbe Interaction Group, and Dr John Brockwell, of the CSIRO Division of Plant Industry, have completed the first stage of collaboration designed to provide such evidence. Their work was approved and scrupulously monitored by the University's Recombinant DNA Monitoring Committee and the Government's Genetic Manipulation Advisory Committee and was carried out in the government Plant Quarantine Station in Weston Creek, ACT. *Rhizobium* soil bacteria into which a harmless "marker" gene had been inserted were released into small fenced plots. *Rhizobium* is an important test case because of the great opportunities it offers for genetic

engineering of strains with improved efficiency in nitrogen-fixation and tolerance of acidified soils. The research showed that the modified bacteria could survive and enter into the desired symbiotic association with legume plants, that there was no spread into neighbouring soil, that the altered gene was not passed on to other organisms and that complete removal of the altered *Rhizobium* from the treated soil had been achieved by the security measures used at the end of the investigation. Further work on this very important topic, vital for agricultural developments in the coming decades, is now planned.

RESEARCH SUBJECT AREAS

DEVELOPMENTAL NEUROBIOLOGY GROUP

Introduction

The Developmental Neurobiology Group studies the growth and maintenance of nervous systems at all levels from the ways in which whole nervous systems progressively organise the processing of sensory information as they develop, to studies of the properties of single ion channels.

Projects within the Group use the pouch young of wallabies as models of events which are inaccessible to experimenters in the uterine embryos of mammals; the auditory systems of birds and wallabies, and the photoreceptor cells of insects, spiders and crabs. A notable feature of our work during 1990 has been an increasing number of collaborations with laboratories in Australia (including the John Curtin School of Medical Research) and overseas.

CELL BIOLOGY

Photoreceptors

Investigators: David Blest, Sally Stowe, Julia Clausen, Stephen Trowell#, Margrit Carter*, Emer O'Gara, Y. Tsukitani+

Our long-term program on the mechanisms of the massive daily turnover of phototransductive membranes by arthropods is now focused on two aspects of the regulation of turnover:

(i) What pathways evoke the internalisation and degradation of membrane, and how is the synthesis of replacement membranes induced?

Turnover is well known to relate in part to states of illumination of photoreceptors. An economical hypothesis suggests that turnover events are subject, *inter alia*, to regulation by products of the phototransduction cascade. Recent precedents from other cellular systems suggest that diacyl-glycerols released concomitantly with the second messenger InsP3 during transduction events might activate protein kinase Cs. Phosphorylation of proteins mediated through kinases might (a) regulate the internalisation of transductive membrane by pinocytosis, and (b) trigger the transcription or translation of transductive membrane components.

We are testing these hypotheses in two ways: Firstly, we are challenging crab retinae cultured *in vitro* and in darkness with combinations of the protein phosphatase inhibitor, okadaic acid, and two protein kinase activators, phorbol 12,13-diacetate and SC-9. The effects of these drugs are complex: on the one hand, there is a relatively fast demolition of phototransductive microvilli, followed under some conditions by the synthesis of hypertrophied arrays of microvillar membrane (rhabdoms). Neither of the two kinase activators is more than minimally effective in the absence of okadaic acid, and okadaic acid has little effect when used alone.

We have also challenged dawn retinae *in vitro* with light in the presence of okadaic acid alone, and find that the combination triggers rapid internalisation of membranes, followed by the resynthesis and reassembly of hypertrophied but disorganised rhabdoms. A large proportion of cells has degenerated after two hours under modest illumination.

These findings suggested a comparison with the slow course of events exhibited by illuminated retinae of the *Drosophila* light-dependent retinal degeneration mutant, $rdgB^{KS222}$. It proves that the slow degeneration events in the mutant are ultrastructurally comparable to the fast induced sequence in crab. It is currently believed that *rdgB* mutants lack either a protein phosphatase or, more probably, an associated regulatory protein.

Taken together these various results support a hypothesis that turnover events are mediated through multiple protein kinases. We will attempt a pharmacological dissection of their roles in 1991.

We have shown that the putative protein phosphatase studied by Stephen Trowell in this laboratory is not inhibited by concentrations of okadaic acid an order of magnitude greater than the 1 μM applied to crab retinae. Various lines of evidence support a conclusion that the enzyme(s) is an invertebrate arrestin homologue.

(ii) A model for the mechanism of extracellular shedding of microvillar membrane in flies.

We showed in 1982 that in a tipulid fly much microvillar membrane is shed to extracellular space during turnover. The photoreceptors retrieve it by endocytosis. Membrane destined for disposal consists of microvillar tips from which all intracellular contents seem to be absent. How such 'empty' tubes of membrane are generated has remained enigmatic. Recent work in American laboratories implicates the *Drosophila ninaC* gene product as a putative mechano-enzyme which probably constitutes the side-arms linking an axial actin filament to the microvillar walls. Using data on the polarity of axial filaments published by two former associates, Drs K. Arikawa and D.S. Williams with J. Hicks we have proposed a model which allows a side-arm with a myosin-I-like head apposed to an axial filament to provide a 'motor' driving a tube of microvillar membrane distally to generate an empty shedding zone.

As a first step towards testing the model, we have used ultrastructural immunocytochemistry to examine the distribution of actin between basal regions and shedding zones of tipulid rhabdoms. The results confirm our earlier, less rigorous finding that shedding zones lack an axial cytoskeleton, as our model requires.

Ion Channels: Analysis of Single Channel Currents Using Digital Signal Processing Techniques

Investigators: Shin Ho Chung, Peter Gage†, John Moore†

Measurement of the elementary ionic currents flowing through single channels in the cell membrane has proved to be a powerful tool for studying living membranes. Accurate characterization of these currents will provide an insight into the molecular mechanisms underlying opening and closing of a receptor-channel complex. The magnitude of channel currents induced by neurotransmitters or their agonists, however, is often very small compared to background noise and therefore signals cannot easily be resolved. To obviate this problem, we have devised a digital signal processing technique for extracting and characterizing small signals obscured by measurement noise. This powerful new technique provides information about details of channel currents which are buried in the noise and which have hitherto been inaccessible. Using this method, we are currently analyzing small single channel currents activated by GABA, glutamate and some other intracellular messengers.

SENSORY CODING IN AUDITION

Analysis of Firing Rate and Fine Temporal Structure in Responses of Auditory Nerve Fibres in the Mammal

Investigators: Ken Hill, Alan Palmer+, Dan Geisler+

Following the discovery in the guinea pig of a previously unrecognized factor associated with two-tone suppression in rodent auditory nerve fibres, experiments were conducted to determine whether such a phenomenon occurs in the cat. The study would establish the generality of the phenomenon in the mammalian cochlea. The experiments were designed to further characterize this factor in two-tone suppression and to elucidate the underlying mechanisms. So far, the analysis of the results confirms the occurrence of the phenomenon in the cat. Further analysis of data will provide additional insight into two-tone suppression and the sensory mechanisms of the cochlea in general.

Application of a Cochlear Model to Temporal Properties of aAuditory Nerve Discharges

Investigator: Ken Hill

The development of the time-domain cochlear model continues. Hair cell function is mathematically-modelled with the incorporation of positive feedback to represent bidirectional transduction and the concept of a cochlear amplifier.

Responses of Pigeon Auditory Nerve Fibres to Impulsive Sounds

Investigators: Ken Hill, Tony Gummer, Jianwu Mo

When the vertebrate cochlea is stimulated with an intense, brief click, fibres conduct trains of spike potentials, in which spike timing is periodic and spike probability decays exponentially. We have conducted a detailed analysis of click-evoked spike trains in the auditory nerve of ketamine xylazine anaesthetized pigeons in order to clarify mechanisms of the sensory response. The periodicity in general corresponds with fibre best frequency and is attributable to the filter characteristic of the tuning mechanism. The minimum latency of the response and the phase

of the spike trains are not consistently attributable to a unipolar, compression/rarefaction mode of excitation of the fibre. These data will be modelled in terms of synaptic and hypothetical, extra-synaptic influences on generator potentials in fibres.

Neural Encoding in the Avian Auditory Periphery

Investigators: Tony Gummer, Ken Hill

The firing patterns of afferent neurones of the auditory nerve of birds exhibit two properties—quasiperiodic spontaneous activity and single-tone rate-suppression: they have important consequences for understanding mechanoelectric transduction and neural encoding in the auditory periphery of all animals. These properties have been investigated experimentally and theoretically. Spontaneous and tone-evoked single-unit activity was recorded from the cochlear ganglion of the anaesthetized pigeon, and the data analyzed in a way that allowed the physics of underlying mechanisms to be described. Neural activity was characterized by an exponential spike-generator function, where the underlying random process was either a nonhomogeneous Poisson process (46% of neurones) or a nonhomogeneous diffusion process in which the probability density function of the postsynaptic membrane potential was specified by the forward set of Kolmogorov difference equations. The Poissonian statistics of the former group of neurones are consistent with a classical excitatory mode of spike generation, whereas the non-Poissonian statistics of the latter group indicate inhibitory potentials at the afferent terminal.

DEVELOPMENT OF THE MARSUPIAL NERVOUS SYSTEM

It is because in placental mammals most of the growth and assembly of neuronal circuits takes place in the uterus, where experimental intervention is almost impossible, that so little is known of the early development of the mammalian brain. Consequently much of our understanding of mammalian and human brain development is by analogy with that of lower vertebrates, particularly those that lay eggs in which the embryo is accessible for observation and experiment.

Marsupials, in most respects typical mammals, differ importantly from the placental line only in matters of reproduction, the most obvious being a short intrauterine gestation followed by very protracted development in the pouch. The immature state of parts of the nervous system in the first few weeks of pouch life, particularly those concerned with vision, means that events may be followed from a very early stage, even before the eye makes connections with the brain.

To this end the RSBS maintains a colony of tammar wallabies (*Macropus eugenii*) for the express purpose of studying the early development of the mammalian nervous system.

Work is proceeding on three main lines: detailed study of the normal anatomy and physiology of the adult nervous system, experimental studies tracing the development of various brain structures and their interconnections; and experiments involving intervention at the time of important events and study of the effects on consequent development.

Development of Thalamocortical Connections in the Visual System

Investigators: Lauren Marotte, Xiao-Ming Sheng, Richard Mark

Connections between the cerebral cortex and the immediate subjacent structures on the visual pathways have previously only been studied by indirect tracing methods. Because of access to the marsupial pouch young it proved possible to inject these pathways with a tracer substance directly in the living young and to follow them in high detail in histological preparations. Sensory fibres were found to terminate through much of the full thickness of the developing cerebral cortex right from the beginning of innervation. This is not in accord with the results of experiments on other animals in which fibres have been described as accumulating beneath the developing cortex until relatively late in development and then innervating it only after a waiting period. Either marsupials are different, which seems unlikely, or our more sensitive procedure allows the display of fine nerve fibres in the developing cortex which were not

visible by other techniques. The results bear on the question of whether the early development of the cerebral cortex is largely autonomous or whether it is controlled by its sensory connections.

Effects of Visual Experience on the Formation of Retinotopically Organised Connections to the Midbrain

Investigators: Richard Mark, Xiao-Ming Sheng, Lauren Marotte

We had previously shown that if a developing eyecup is misaligned with the optic stalk by rotating it before it connects to the brain, the link is nevertheless established anatomically correctly according to embryological signals. In animals with such a rotational squint, electrophysiological mapping of the retinal projection to the superior colliculus showed that the physiological map was not always as would be expected from the amount of anatomical rotation. In many cases the projection was partially reorganized towards the normal orientation. This also happened in animals in which the rotation was performed later, at the time of eye opening but after the formation of neural connections was complete. It shows that the functional connections may be reorganized on the basis of visual experience in the face of anatomical misalignment of the eye. This is the first time such a compensatory remapping of the visual system has been described in mammals.

The Anatomy and Electrophysiology of the Lateral Geniculate Nucleus and the Visual Cortex

Investigators: Richard Mark, Geoff Henry[†], T.R. Vidyasagar[†], Judy Wye-Dvorak[•]

Single cell recordings have been made from the lateral geniculate nucleus to try and find correlations between the location of the cell bodies in each of the 9 eye specific laminae and the functional properties of their receptive fields. The only clear correlation is a segregation of sluggish responses to the B segment which suggests a functional streaming akin to that in placentals. The anatomical limits of the primary visual cortex were estimated autoradiographically. The projection of the visual field from the response of single cortical units is in agreement. Comparison of the magnification factors of the retinal ganglion cells of the retina and the cortex shows that the visual streak, the concentration of retinal ganglion cells along the horizon, does not appear on the cortex. Cortical cells within the binocular field have wide disparities suggesting a well-developed system of stereopsis.

The Development of the Representation of Whiskers in the Cerebral Cortex

Investigators: Lauren Marotte, Richard Mark, P.M.E. Waite[+]

By the use of evoked potentials the time of functional innervation of the cerebral cortex by sensory projections from the mystacial whiskers has been found and correlated with the histological appearance of accumulations of cortical cells stained by succinic dehydrogenase activity corresponding to each whisker (barrels). A study of the microscopic structure of the whiskers shows them to be innervated at birth. The synchronous maturation of the anatomical and functional connections to the cortex much later in development suggest that there is a separate trigger for the formation of cortical connections.

The Development of Innervation of Muscles Fibres and Muscle Spindles

Investigator: P.H. Harrison[•]

The hindlimb of wallaby pouch young at birth is extremely rudimentary. The timetable of maturation of the motor and sensory innervation is being established with a view to the study of the development of reflex pathways in the spinal cord, the early stages of which are as yet undescribed in mammals.

A Stereotaxic Atlas of the Developing Wallaby Brain

Investigators: Richard Mark, Shinji Hayashi[+]

Research into the wallaby brain has been hampered by the lack of a complete atlas for the adult and at various stages of development. This project was begun early this year and the histological and photographic work will be finished by its end.

The Development of Afferent and Efferent Connections to the Cochlea

Investigators: Tony Gummer, Stuart Cole[+]

By cochlear injection of the fluorescent retrograde neuronal tracers diamidino yellow (DY) and fast blue (FB), the organization of efferent projections from the brainstem to the cochlea in the 79-day pouch young was established. A lateral and a medial system of stained cell bodies of centrifugal olivo-cochlear neurones were found with the lateral system constituting 78% of the cell bodies on the ipsilateral side and 11% on the contralateral side. These results compare with those reported by Robertson and co-workers for neonatal rat at postnatal day 0, using the same labelling technique, and will serve as a time reference for further studies on the development of the auditory system of the tammar wallaby.

CENTRE FOR MOLECULAR STRUCTURE AND FUNCTION

In 1989 the University decided to support, through its strategic developments funding, a strategic plan for development of cross-campus molecular biological research. The plan was proposed by RSBS, the John Curtin School of Medical Research, the Research School of Chemistry and the Faculty of Science with the intention of focussing researchers in key areas on collaborative enterprises. This development parallels the international trend towards interdisciplinary research where converging objectives and shared skills transcend traditional discipline boundaries.

Professor Ian Young (left) from the John Curtin School of Medical Research and Dr George Miklos from RSBS have developed complementary research projects on gene targeting and manipulation which will be one of the cross-campus research programs in the new Centre for Molecular Structure and Function.

RSBS is a major partner in three of the Centre's programs:

- gene targeting and manipulation
- protein structure and design
- gene sequence/structure interface

In 1990, in the first of these projects, Dr Hugh Campbell was appointed to a Fellowship to provide a substantive working link between Dr George Miklos, Molecular Neurobiology Group, RSBS and Professor Ian Young in the JCSMR. The two laboratories are conducting experiments attempted nowhere else in Australia, working at the vertebrate/invertebrate interface, which is now, internationally, receiving increasing attention. Here, basic biological principles operating in lower organisms, which are found also in humans, can be assessed and evaluated in a lower organism. Homologous brain and neuromuscular development genes are present in the fruitfly and man. The detailed workings of these genes can be readily studied during insect embryogenesis. Unravelling the role of these genes may ultimately make a profound contribution to our understanding of, for example, neurodegenerative disorders.

The protein structure and design program links Dr John Andrews' studies of the key photosynthetic enzyme Rubisco in the Plant Environmental Biology Group with the Research School of Chemistry's expertise in protein x-ray crystallography. During the year Dr Matthew Morell was appointed to a Research Fellowship to experiment with site directed and random mutagenesis of Rubisco. Comparison of the structures of interesting mutants with the known structure of the wild-type enzyme will guide attempts to improve the efficiency of this enzyme which is a key determinant of the productive efficiency of plants.

Work on the gene sequence/structure interface being pursued by Dr Adrian Gibbs is enhancing the analysis of molecular sequences by improving university-wide information technology facilities and also, in the Molecular Evolution and Systematics Group, by improving methods of sequence analysis and comparison and, in particular, the methods for predicting the structure of proteins from their genetic sequences. During the year Dr George Weiller was appointed, with funding from the Centre for Information Science Research and Jack Palmer joined the Group to strengthen the programming capacity.

MOLECULAR NEUROBIOLOGY GROUP

Introduction
Humans, Flies and Locusts

Many structural and functional components of nervous systems are highly conserved from insects to humans. Nearly 40 percent of monoclonal antibodies raised to components of the fly brain cross react to components of the human brain. This neural conservatism, coupled with genetic manipulability, makes the fly eminently suitable for investigating neural structure, connectivity and function. The fly brain can now be dismantled into functional subsystems using neurogenetic techniques and the fly homolog of any gene can be rapidly cloned by microcloning or "enhancer trap" techniques. The molecular pathways in which these genes participate can be established by the use of appropriate mutants. Mutant phenotypes are then readily rescued using sophisticated genomic re-entry vectors and genome re-organization techniques which are unavailable in humans. The locust nervous system, on the other hand, is particularly attractive for other reasons. It yields access to large neurons and to well defined circuits that are individually recognizable in every preparation. Furthermore, when molecules such as fasciclins, which play a role in establishing axonal connections, are cloned in the locust, genomic and cDNA libraries can be screened from the fruit fly to open the use of genetic systems available in that organism. In the Molecular Neurobiology Group, and in our component of the Centre for Molecular Structure and Function, therefore, we are utilizing human, fly and locust systems to understand the control of neuronal fates in the central nervous system. We are also examining neuronal connectivity, cell adhesion and cell recognition phenomena during neuronal development and various aspects of behaviour.

The Invertebrate—Vertebrate Interface

Investigators: George Miklos, Jane Olsen, Ray Erikson[+], Sabine Ottilie[+], Graham Webb[+], H. Gert de Couet[+], Nesrin Ozsarac[+], Thorsten Schimansky[#], Hugh Campbell[†], Ian Young[†]

The finding by Miller and Benzer that a significant proportion of genes are common to human and fly brains opened up an exciting research avenue. Our group, in collaboration with groups in the University of New South Wales and the University of Melbourne and overseas colleagues, has been systematically evaluating this finding using a defined part of the fly genome. The genetic and molecular overlap between human and fly means that one can shuttle between the two organisms in order to uncover the biological principles involved in conserved processes. For example, it is not experimentally possible, nor desirable, to study the molecular events of very early embryogenesis in humans. However, fly embryos are particularly amenable to genetic and molecular analysis and the workings of the "human equivalent" genes can be easily studied in fly embryogenesis.

We have intensively studied a section of the fly X chromosome and have already found that at least six of the eleven fly transcription units either cross hybridize to, or have sequence similarity to, human or vertebrate genes. The power and bi-directionality of our approach is illustrated by the following two examples. Professor Ray Erikson's lab at Harvard University has isolated and extensively characterized a particular vertebrate protein kinase that is active in early development. Its function however, and its place in a defined developmental heirarchy is unknown, owing to the difficulty of manipulating vertebrate genomes. We have genetically mapped the fly equivalent of this human protein kinase gene to the vicinity of the *uncoordinated-like* gene in the fly. We have now focussed the extensive genetics of the fly system onto this gene and are evaluating its characteristics, prior to pursuing its function in humans.

In an analogous manner, but in the reverse direction, de Couet and Ozsarac, our collaborators at the University of NSW and at the University of Hawaii at Manoa, have shown that one of our extensively studied fly genes that causes muscle degeneration is in fact related to a family of human actin binding proteins. We are now in the position of being able to ask which human diseases are likely to occur when the human gene is mutated, since we now have an idea of the early embryological consequences that ensue when this gene is mutated in the fly.

Molecular Biology of the Fly Nervous System

Investigators: George Miklos, David Hayward, Stephen Delaney, Fiete Barleben[+], Karl Fischbach[+]

A major problem in neurobiology is to understand the mechanisms by which nerve cells form connections. In building a brain, a genome coordinates the construction of networks of neurons which determine the behavioural repertoires of organisms. How these final synaptic specificities are achieved in a molecular sense is unknown. Our approaches to this central problem are from the integrated avenues of recombinant DNA, genetics, and neuroanatomy. We have focussed all three approaches onto a selected subset of behavioural genes which we believe have a major involvement in events relating to neuronal connectivity and to the construction of various subsystems of the fly brain.

This year we continued to target the "brain" genes, termed *small optic lobes* and *sluggish*, each of which when mutated causes neurological lesions that perturb the behavioural repertoires of the fly. Mutations in the *small optic lobes* gene result in tissue autonomous cell degeneration in the *medulla cortex* of the brain and lead to the loss of many transmedullary neurons. These neuro-anatomical defects are reflected, for example, in abnormal figure-ground discrimination. Mutation of the adjacent *sluggish* complementation group does not result in detectable neuro-anatomical defects. However, *sluggish* flies not only exhibit defective phototaxis but show uncoordinated behaviour and motor debilitation in combination with certain chromosomal deficiencies.

We have cloned the DNA landscape containing the *small optic lobes* and *sluggish* genes and have totally sequenced three of the four transcripts in this area. Two of the transcription units have sequence similarity to human genes, one to a calcium activated neutral protease domain and another to a gene co-expressed with a human lymphocyte adhesion molecule. We have constructed transgenic flies carrying a normal copy of the *small optic lobes* gene and have thus rescued the mutant phenotype and restored it to normalcy. It should be noted that this means that mutant individuals which would have undergone massive brain degeneration, now have

normal, or near normal, brain circuitry. We have also constructed transgenic flies carrying various combinations of the three transcription units in the *sluggish* region, and we now know which construct rescues the mutant phenotype.

Genetics, Molecular and Cell Biology of a Defined Chromosome Segment

Investigators: James Cotsell, Ryszard Maleszka, Rich Binari[+], Andy Link[+], Norbert Perrimon[+], Jane Davies[•], Kevin O'Hare[•], Len Kelly[+], Ute Schuppler, George Miklos

Most "genome projects" at the present time are severely constrained because the production of large amounts of DNA sequence information cannot be coupled either to a transcriptional data base or to a genetic mutant data base. To overcome this enormous hurdle, we have examined a genetically saturated 2.5 million base pair region of the fly genome, out of a total of 165 million base pairs. This area contains 24 gene complexes that when mutated cause lethality of the organism. We have found however, that there are many more genes in this region which, when mutated, do not kill the fly, but instead disable it in various ways.

We are continuing to carry out long chromosomal walks in this region using *phage lambda* as well as *yeast artificial chromosome* (YAC) vectors. To date we have over 800,000 base pairs assembled into various contiguous DNA stretches, which are being aligned with the genetic and transcriptional maps. It is this correspondence that is allowing us to systematically examine the differential functions that emanate from this stretch of DNA.

Our major achievements this year have concerned:

(i) The finding that a significant number of our fly genes correspond in part, or in whole, to known human genes.

(ii) the completion of long chromosomal walks, which together with the use of yeast artificial chromosomes, have provided a DNA landscape of over 800,000 base pairs in which to characterize more fly genes and their human counterparts.

Neuroethology and the Evolution of Hearing in Insects

Investigators: George Boyan, Lez Williams[§], James Fullard[§], Eldon Ball

Our investigations of the cellular pathways underlying behaviour in insects over the past few years have focussed on (a) the role of the wind-sensitive cercal system in flight behaviour of the locust; and (b) the auditory input to central circuits involved in the avoidance response of noctuid moths to the echolocating calls of predatory bats. In each case we have been able to follow the path of information flow from the periphery through all the intervening stages to motor output to flight muscles.

The fact that we have been working on these two very different preparations in parallel has lead to an unexpected, and exciting, discovery with respect to the organization of central nervous pathways. Because we have been able to analyse cellular pathways in terms of individually identifiable cells, we have been able to compare the anatomical projections of auditory units in such phylogenetically divergent insect groups as locusts and moths. We found remarkable similarities in the organization of the auditory pathways of these insects. On extending our research to other insects and examining the literature it became apparent that if an insect possesses an ear, irrespective of where it is located on the body, then the afferents from that ear project into the same region of the central nervous system in each insect group, and contact first order interneurones that project in the same fibre tracts to other parts of the central nervous system. This means that the insect central nervous system is organized according to a common plan, which we have termed a "Bauplan". If an insect does not possess an ear, homologous mechanosensory afferents are present in the same place, and we are now ascertaining whether these afferents use the same set of central interneurons as the auditory afferents. Such knowledge can provide valuable insights into the evolutionary plasticity of nervous systems and the evolution of hearing in insects.

Molecular Biology of the Grasshopper Nervous and Neuromuscular Systems

Investigators: Eldon Ball, Nipam Patel[+], Jay Rehm[+], Corey Goodman[+]

There has been a change of emphasis in our grasshopper studies towards a more molecular approach. During several periods of Outside Studies in the laboratory of Professor Corey Goodman at the University of California, Berkeley, Eldon Ball has learned a number of new molecular techniques which are providing the basis for fresh approaches to nervous and neuromuscular systems. This collaborative research has already resulted in the cloning and sequencing of a grasshopper heteronuclear ribonucleoprotein gene, which is of interest in both an evolutionary and functional sense because comparison of this molecule to homologous molecules of vertebrates helps to determine what portions of the molecule are conserved and therefore likely to be of functional significance. In addition, the homeobox genes coding for two DNA-binding proteins expressed in the central nervous system of the fruitfly, grasshopper, and several mammals have been cloned and are presently being sequenced. These two genes, known as "even-skipped" and "Antennapedia", also play a pivotal role in the segmentation of the embryo during early development. We hope that by cloning them and examining their expression in the grasshopper we may learn more about their evolution and the role they play during their two periods of expression.

VISUAL SCIENCES GROUP

Introduction

In the early 80s we studied visual processing by the neurons of the insect optic lobe. The general concept that emerged was that these neurons are not interested in stationary images on the retina, but they see change. A whole series of projects have now demonstrated that vision of the 3-dimensional world in insects is based on self-motion.

Our approach has led us to study the importance of motion cues in unravelling the 3-dimensional structure of the visual world. This approach provides new insights into animal vision, since similar principles apply to vertebrate early vision, on which is super-imposed higher level cognitive processing. Our work therefore defines the cellular, physiological and computational strategies of early visual processing in both invertebrates and vertebrates. The principles derived from this work have particular application in building mobility devices for the visually impaired, robots, automatic vehicles and rockets.

We are reaping the benefits of a rich cross-fertilization of ideas from various fields, particularly through the combination of psychophysical, cell biological and computational approaches to those problems. Our involvement in the Centre for Visual Sciences and the Centre for Information Science Research fosters precisely the sort of interaction between specialists in different areas that is essential for our work.

Retinal Circuits, Neurotransmitters and Visual Processing

Investigators: Ian Morgan, Zhi-Kun Li, Patricia Miethke, Guang Yang, Roman Poznanski, Les Davies*

We attempt to explain how vertebrate retinas turn visual inputs registered in any eye by photoreceptors as rather stereotyped responses, into subtle, coded, meaningful messages transmitted by retinal ganglion cells to the brain. Our multidisciplinary research uses neuroanatomical, neurochemical and neurophysiological techniques. In parallel, we employ immunohistochemical techniques for ultrastructural characterization of retinal cells, pharmacological manipulation of inputs to identified cells, and electrophysiology. A key feature of our approach is the use of neurotoxins to specifically and permanently eliminate groups of neurons from retinal circuits, enabling analysis of their synaptic connections, and of physiological and even behavioural functions.

This year we have continued to focus on the cholinergic and GABAergic amacrine cells and the displaced directionally-selective ganglion cells. We have developed a technique which selectively stains the displaced directionally-selective ganglion cells based on cytochrome oxidase staining to reveal neurons which are particularly active metabolically. We are investigating whether the specific staining achieved will enable us to use ultrastructural

Dr Ian Morgan from the Visual Sciences Group demonstrates some of the latest techniques in neuroanatomical research to participants in the 1990 Neuroscience Workshop. Each year, the Neuroscience groups in RSBS, in conjunction with those in the John Curtin School of Medical Research, organise a three day workshop for students who are interested in a career in neuroscience research. In 1990, 16 students from universities and colleges from as far away as Perth, Hobart and Townsville attended. Most have gone on to higher studies at universities all over Australia in 1991.

histochemistry to define the dendrites of the displaced directionally-selective ganglion cells, since this might markedly simplify the analysis of their connections with the cholinergic and GABAergic cells.

Other aspects of the cytochrome oxidase staining pattern are also of considerable interest. The method delineates the centrifugal projection from the isthmo-optic nucleus to a population of either amacrine or displaced ganglion cells, a finding that may explain previous reports of heterogeneity amongst the displaced ganglion cells in the avian retina. The method also defines strongly stained classes of orthotopic ganglion cells. We have attempted to define their central properties by looking for strongly stained sites of retinal projection. Unfortunately the central sites of retinal projections are all strongly stained, and lesion and developmental studies suggest that the staining may be constitutive, and not subject to retinal regulation.

Studies on the distribution of immunohistochemically detectable $GABA_A$ receptors did not clearly define the distribution of $GABA_A$ receptors on amacrine or ganglion cells. We have now carried out biochemical studies on the GABA receptors of the retina, coupled with the specific cellular lesions we have developed over the past few years. These studies have shown that the retina contains almost trivial amounts of $GABA_B$ receptors. The $GABA_A$ receptors are found in the outer retina, apparently on both horizontal cells and photoreceptors, and in the inner retina on both amacrine and ganglion cells. Specific association of GABA receptors with cholinergic amacrine cells was confirmed, but there was no specific association of GABA receptors with serotoninergic or dopaminergic amacrine cells. Detailed biochemical and immunohistochemical studies of the distribution of GABA, glutamic acid decarboxylase and $GABA_A$ receptors have shown that the NMDA and kainic acid lesions selectively affect the inner retina, and leave the outer retina intact. This strengthens the conclusions we have drawn from previous physiological studies that amacrine cells are not involved in the generation of transience.

Neuropeptide Processing and Function

Investigators: Ian Morgan, Meewuis Boelen+, Mark Dowton+, Ian Chubb+

Our work on the regulation of enkephalin processing in the retina has been extended by analysing the levels of enkephalin-immunoreactive peptides in the retina during development. At around the time when the retina first becomes physiologically mature as the outer segments of the photoreceptors differentiate, there is a marked increase in the levels of the enkephalin-immunoreactive peptides, and a marked shift towards the enkephalin-pentapeptides. These changes are consistent with a marked change in the synthesis and processing of the enkephalins at around this time. There is a similar change in the levels of somatostatin immunoreactive peptides at around the same time, with a marked shift in the ratios of somatostatin 14 to somatostatin 28.

White-Noise Studies of the Insect Lamina

Investigators: Andrew James, Daniel Osorio

A study has just been completed, using white-noise stimuli to explore quantitatively the spatial and temporal properties of the large monopolar cells. These cells are the first "way stations" encountered by signals travelling from the photoreceptors to the brain in the insect visual pathway. This work provides a complete characterization of the response properties of these cells, in two dimensions of space and time. It also offers a new candidate for the hitherto elusive mechanism of lateral inhibition observed in these cells, and provides evidence for two parallel, excitatory input pathways from the receptor to the lamina.

Neurophysiology of Retinotopic Visual Processing in Insects

Investigator: Daniel Osorio

Each point in visual space, or 'pixel' in the retinal image is represented by a column of several dozen neurons in the brain. The object of this research is to learn about how different components of the image, say colour, form or motion, are divided amongst the 40 or so neurons in each column, and also to look at how the retinal signal is transformed to give the highly refined 'neural image' which is found in any particular class of cell. The properties of one major class of nonlinear edge-detecting cells has recently been outlined using simple stimuli. Together with with A.C. James, more sophisticated stimuli are now being developed to take this project to its next stage. In addition, a review has been made of the evolution of arthropod vision to argue that the visual processing beneath compound eyes was elaborated very early in the history of arthropods and the basic plan has remained substantially unchanged, with only minor variations needed to permit the adaptive radiation which has occurred since, e.g. the acquisition of flight by insects. This research is partly supported by the ANU Centre for Information Sciences.

Object Detection by Dragonflies

Investigator: David O'Carroll

Dragonflies possess the largest and best developed compound eyes of any insect, and most aspects of their behaviour are visually mediated. This project is investigating the electrophysiological properties of the object detection system, and its ethological implications. The dorsal eye region is used primarily for the detection of prey (mostly small flies and mosquitoes). Detection is mediated through several classes of 'target' interneurons in the third optic ganglion (lobula). The photoreceptors of this region have been found to be primarily sensitive to violet and ultra-violet light, precluding the use of commercially-available cathode-ray tubes commonly used to generate stimuli in vision research. Consequently, an electromechanical apparatus is used in combination with a xenon-arc light source to provide moving targets at UV wavelengths. Two anatomical classes of interneurons that respond selectively to the movement of small objects have been identified by intracellular recording and injection with lucifer yellow.

Inputs to Large-field Motion Detection in the Insect Visual System

Investigators: Michael Ibbotson, Ted Maddess, Roger Dubois

It is now generally agreed that the large-field direction selective motion-detecting neurons in the insect brain and ventral nerve cord mediate optomotor behaviour, and the responses of these neurons have been characterized quite comprehensively over the last 20 years. Yet, we know surprisingly little about the identity of the neurons that provide the inputs to this pathway at the level of the lamina and the medulla, and how the image captured by the receptor array is processed before movement is detected. Experiments using moving gratings displayed behind rectangular windows or slits, coupled with theoretical modelling now reveal

that lateral inhibition is an essential component of early visual processing in the movement-detecting pathway.

Experimental Tests of the Template Theory of Motion Detection

Investigators: Adrian Horridge, Ljerka Marčelja

Tests have been conducted on the motion-detecting neuron, H1, to evaluate the template theory of motion perception developed by Horridge over the past two years. Tests with jumping bars and edges, in which the polarity of the stimulus is either preserved or reversed, indicate that motion is computed by sensing the displacement of edges of similar, and not opposite polarity. These findings are in accord with the template theory developed recently in this laboratory (see 1989 RSBS Annual Report).

Mapping Motion Receptive Fields of Direction-Selective Visual Interneurons

Investigators: Mandyam Srinivasan, Zhe-Fei Jin, Gert Stange, Michael Ibbotson

There are very few instances in which the receptive fields of motion-sensitive neurons have been measured quantitatively and precisely. Such a characterization is essential if one wishes to ascertain a neuron's function (e.g. detection of horizontal or vertical motion, looming, roll, or motion parallax). A "vector white-noise" approach has been developed for mapping the sensitivities and preferred directions of motion at different locations within the receptive fields of direction-selective motion-detecting visual interneurons. The advantages of this technique over the conventional approach of probing the receptive field sequentially at each of the grid locations are that the highly parallel nature of the stimulus (i) yields quicker results, and (ii) is sensitive to nonlinear interactions (such as shunting inhibition or mutual facilitation) between different regions of the receptive field. The technique has been used to determine accurately the motion receptive fields of directional-selective motion-detecting neurons in the optic lobes of insects, and is potentially applicable to motion-sensitive neurons with highly structured receptive fields, such as those in the optic tectum of the pigeon or in area MT of the monkey.

Visual Discrimination of Orientation by Honeybees

Investigators: Mandyam Srinivasan, Hans van Hateren[#], Peter Wait[+], Kim Witney[*]

Despite the period of over a century that has elapsed since Helmholtz's classic treatise on Physiological Optics, the vocabulary of vision—that is, the collection of "tokens" by which the visual system represents and recognizes objects—remains largely a mystery. The honeybee is a promising subject in which to explore this question, as its visual system is turning out, in many respects, to be a "stripped down" version of that found in many higher vertebrates, including man. Experiments in which bees are trained to discriminate the orientation of spatially random gratings are demonstrating that, contrary to earlier notions, certain classes of patterns can be recognized and discriminated without storing their images in the form of a literal, or "photographic" representation. These experiments show that bees can generalize pattern orientation, and provide information on the number and tuning properties of the orientation or motion-sensitive channels that participate in this task.

Artificial Seeing Systems Based On Insect Vision

Investigators: Peter Sobey, Martin Nagle, Gert Stange, Robert Edwards, Jan Dalczynski, Adrian Horridge, Mandyam Srinivasan, Tony Heyes[+], Richard Brent[†]

We have been developing artificial "eyes" based on the visual cues used by flying insects, to overcome major problems which have hindered progress in the development of artificial vision systems based on present knowledge of human pattern perception. The goals of this research are twofold: (i) to assess, through the construction and testing of artificial vision devices, the extent to which we understand biological vision in simple systems, and (ii) to develop seeing aids for the blind, and artificial vision systems for robotics and industry.

Humans measure range by using cues derived from stereopsis, eye convergence, lens accommodation, perspective and what-obscures-what. Our research on visual behaviour of bees has shown that insects are unable to use these cues but rely instead on cues derived from apparent motion on the eye, whereby nearby objects appear to move faster (see 1988 and 1989 Annual Reports). By knowing its own speed and measuring the apparent velocity of the object, an insect can calculate an object's distance.

This year we have continued to develop and refine two devices which measure the ranges of objects in the environment by using principles derived from insect vision. One model, a hand-held scanning device designed and built by Martin Nagle, has an "eye" built from a

microscope lens and a light-sensitive electronic chip (charge-coupled device). This instrument indicates the distances of various edges in the scene by measuring their apparent velocities as the scene is scanned. Sobey and Nagle are now improving the performance of this device by replacing the scanning motion by "virtual motion", achieved by using a fixed eye in conjunction with a series of mirrors.

A second device, designed by Stange, Srinivasan and Dalczynski, is a hand-held, non-scanning device built from five photodetector elements. It uses angular and spatial gradients, detected by the five detector elements, to calculate an object's distance. It gives high resolution in a field of view of about two to three degrees over a range of one to five metres. Development of this device has been completed this year, and an international patent has been applied for.

Both devices have advantages over conventional ultrasonic sytems which resolve small objects poorly and are prone to erroneous range readings, because of specular reflection of the sound beam. The first device is able to give the user (or robot) a "panoramic" view , picking out a series of objects at different ranges. The other has a narrower field of view, detecting and ranging small objects in the direction in which it is pointed.

A third focus of effort has been the development of new and efficient algorithms for the computation of two dimensional optical flow from a sequence of images of moving scenes. The performance of the generalized-gradient algorithm for optical flow computation, developed last year (see 1989 Annual Report) has now been tested on real, moving images, using a video camera coupled to a computer-driven frame grabber. The results so far indicate that the algorithm is capable of measuring two-dimensional image velocity accurately, and with a computational effort that is low in comparision to that required by other schemes. The next step would be to adapt the scheme to measure the velocities of multiple moving objects.

Research in this area is being supported partly by the Centre for Information Sciences, ANU, by a GIRD grant from the Australian Department of Industry, Technology and Commerce, as well as by Fujitsu International, Japan.

Perception of "Non-Fourier" Image Motion, and its Application to the early detection of Glaucoma

Investigators: Ted Maddess, Lawrence Severt, Richard Mark, George Henry†

The performance of normally sighted subjects in detecting moving, reversing-contrast gratings has been studied, and related to the spatial sampling densities and temporal response properties of a specific class of retinal ganglion cells. The functional degeneration of these cells during the onset of glaucoma is now being examined by conducting psychophysical as well as optokinetic (eye-tracking) measurements on patients viewing non-fourier motion stimuli. Based on this research, a scheme for the early detection of glaucoma has been developed and patent applications have been filed. A licensing agreement has been obtained with a major biomedical company for the design and manufacture of a product based on this intellectual property. The company will provide funds to continue this research. The ANU Centre for Visual Sciences has acquired two sophisticated noninvasive eye and head tracking systems under a Boardman Grant, which it is anticipated will be used in studies relevant to glaucoma in humans (in collaboration with Dr T. Hine of the Research School of Physical Sciences) and on monkeys in collaboration with Dr Vidyasagar and Dr G.H. Henry of the John Curtin School of Medical Research.

MOLECULAR AND POPULATION GENETICS GROUP

Introduction

The research of the group is mainly concerned with the genetic analysis of variation in a variety of species some of which, such as yeast, *Drosophila* and the mouse, are traditional experimental organisms, whilst a number of native animals and plants, e.g. *Caledia* and *Acacia* sp. provide interesting biological problems which also serve to illuminate evolutionary phenomena.

Genetics of *Drosophila* Populations

Investigators: John Gibson, Jing Jiang Zhou, Jane Symonds, Darryl Reed, Anh Cao, Ann Wilks

Natural populations of animals and plants are segregating for substantial amounts of genetic variation at structural and regulatory gene loci. This variation is evidence of past mutational events and is the raw material for adaptive evolution. An important question concerns the relationships between the amount of this variation, its phenotypic effects and the pattern of evolution of specific proteins. Our research focusses on two gene enzyme systems—alcohol dehydrogenase and sn-glycerol-3-phosphate dehydrogenase—which have important roles in *Drosophila* metabolism.

(i) Molecular similarity of thermostable alleles

Investigators: John Gibson, Darryl Reed, Ann Wilks, Chengshan Jiang

Most natural populations of *Drosophila melanogaster* are polymorphic for two electrophoretically detectable alleles at the alcohol dehydrogenase locus. Within the ADH-F electrophoretic class, a third category of variant has been identified because the ADH encoded is thermostable. These thermostable ADH variants have been detected worldwide at low, but polymorphic, frequencies. We have previously shown that a thermostable allele, Fast Chateau Douglas, extracted from an Australian population, differs from ADH-F by the substitution of serine for proline at residue 214 and the relevant codon is changed to TCC.

We have amplified, by the polymerase chain reaction, a 367bp fragment from genomic DNA of *Adh* thermostable variants isolated from eleven populations on different continents. An allele specific oligonucleotide probe, based on the DNA sequence of Fast Chateau Douglas, was hybridised under stringent conditions to the amplified fragment from each of the thermostable alleles but not to a similar fragment from normal activity alleles. This showed that the thermostable alleles all contain the triplet TCC. The molecular similarity of *Adh* thermostable alleles suggests that they had a common origin and the mutation probably arose in Southern China, where relatively high frequencies of the alleles are now found.

(ii) Transcription in *Adh* null alleles

Investigators: Allan Freeth*, John Gibson, Ann Wilks

Alcohol dehydrogenase null alleles have been found in some Tasmanian populations at frequencies as high as 4%. The DNA sequence of one of these null alleles has eight extra nucleotides (in two groups of four) in the second intron, commencing six bases 3′ from the 5′ splice site. A stop codon was also found in exon 2 but it is likely that the mutation responsible arose later than the insertions. S1 nuclease protection experiments have shown that the insertions in intron 2 disrupt the correct splicing of intron 2. The increased size of the intron reduces the efficiency of splicing at the authentic splice sites and causes splicing to occur at three alternative 5′ splice sites and five alternative 3′ sites. The observed preferential use of some splice sites gives a range of transcript sizes between 1020 and 1413 bases, at least 100 bases longer than the normal mature adult transcript. The amount of the null allele transcript is about 10% of the normal level possibly due to a decrease in mRNA stability caused by the aberrant splicing.

(iii) Molecular structure of sn-glycerophosphate dehydrogenase variants

Investigators: Jane Symonds, Darryl Reed, John Gibson

sn-Glycerophosphate dehydrogenase is an important enzyme in providing energy for flight in Dipterans. There is evidence that the primary structure of GPDH has been conserved over long periods of evolutionary time. Yet within the species *D. melanogaster* there is a relatively high frequency of low activity variants at the *Gpdh* locus compared to other allozyme loci. These low activity variants are biochemically heterogeneous and to identify the molecular changes responsible for the alterations in properties we have cloned and sequenced a representative allele from each of four classes of low activity variant. We have shown that a duplication of the *Gpdh* locus, which is present in natural populations, is not the cause of the low activity.

The duplicated region is not transcribed and its DNA sequence shows that it lacks exon 1, intron 1 and all of exon 2. The duplicated region is contiguous with the normal gene except that a sequence of nine T's is present at the junction. We have used the polymerase chain reaction to amplify genomic DNA in the junction region from a number of duplicated alleles and shown that these all hybridise to an oligonucleotide probe specific to the DNA sequence of one of the variants. The evidence suggests that the duplicated alleles have a common origin and are identical by descent. The other categories of low activity variants have been shown by

DNA sequences to have either alterations to the structural gene giving rise to single amino acid substitutions, or they have changes in 5' control elements.

Molecular Genetics of Yeasts

(i) Mitochondrial genome structure, transmission and evolution

Investigators: Des Clark-Walker, Ryszard Maleszka, Anne Mathews, Patrick Skelly, Min-Xin Guan, Alexandra Plazinska, Erika Wimmer

Horizontal mobility of a group II mitochondrial DNA intron has been inferred from sequence analysis of the cytochrome oxidase subunit 1 gene from the long genome form of *Kluyveromyces lactis* mitochondrial DNA. This study has shown that the first intron has 96% base matching to the second intron of the *Saccharomyces cerevisiae* cox1 gene while flanking exons have only 87% base matching. High *in vivo* mobility of the *K. lactis* cox1.1 has also been shown in a cross between strains of *K. lactis* that have mitochondrial genomes differing in the presence or absence of this intervening sequence.

Rates of mtDNA base substitution, in comparison to nuclear DNA mutations, have also been examined in the yeasts *K. lactis, Candida (Torulopsis) glabrata* and *S. cerevisiae* by sequence analysis of mitochondrial and nuclear genes. Sequences have been obtained for the nuclear encoded small subunit ribosomal RNA and cytochrome c genes of *K. lactis* and *C. glabrata.* Comparison of mutation rates in these genes with those previously obtained show that mtDNAs in yeasts have a slow rate of base substitution relative to nuclear genes.

Investigations into the mechanism of mtDNA replication in yeasts have been undertaken by pulsed field gel electrophoresis. It has been found that the majority of mtDNA molecules recovered from gently lysed cells exist as linear molecules with lengths varying from one to three genome equivalents. mtDNA replication in bakers yeast is also being studied by the characterization of temperature sensitive mutants affected in their ability to maintain mtDNA at the restrictive temperature. Studies have also continued into the nature of recombinogenic sequences at deletion sites in mtDNA during petite mutant formation in *S. cerevisiae.*

(ii) Ribosomal DNA in yeasts

Investigators: Des Clark-Walker, Ryszard Maleszka

Repeated genes are necessary to meet cellular demand for certain transcripts. One such family of genes is represented by ribosomal RNA cistrons (rDNA) that occur in eukaryotes as tandemly repeated arrays, organized in a head-to-tail fashion. Although the structure and transcription of rDNA clusters have been studied in great detail in many organisms, there is a considerable gap in our knowledge concerning the mechanisms which control the number of rRNA genes and the impact of rDNA deficiency on cell physiology. Recent technical developments using yeasts as a model system have allowed us to:

(a) quantify rDNA copy number in various yeast strains by employing pulsed field gel electrophoresis.

(b) identify strains with decreased levels of rRNA genes.

(c) demonstrate that under certain conditions yeast mutants can compensate for the lack of sufficient rRNA cistrons.

(d) develop a screening procedure for selection of rDNA deficient mutants.

Cancer Cell Biology

Investigators: Hiroto Naora, Lun-Quan Sun, Felice Driver, Zheng-Zhou Xu, Helen Liszczynsky, David Buckle

During the year, the highlight of our work on cancer cell biology has been the observation of conversion of cells from a cancerous to a normal state. Conversion was achieved when activated oncogene activity was interfered with through a *cis-* acting gene-to-gene interaction. The principle of interference between gene activities through a *cis-* acting interaction occurring when two genes lie on the same DNA strand and have an intergenic distance shorter than a defined length, was derived from our previous work. Based on this observation, we constructed plasmids carrying a series of linked gene pairs comprising human mutated c-H-*ras* and *E. coli* guanine xanthine phosphoribosyltransferase *(gpt)* genes either on the same or on different DNA strands, and transformed mouse NIH/3T3 cells with these plasmids. Cell lines subsequently isolated showed that the cancerous state of a cell could be repeatedly converted to the normal state and vice-versa when a subtle interference in activated c-H- *ras* expression was produced by the neighbouring gene's activity. Further experiments showed that the manipulation of such an interaction, i.e. enforced expression of the neighbouring gene, enabled us to halt the rapid

growth of malignant tumours in nude mice, formed as a result of subcutaneous inoculation of the cell line. These experiments clearly show that the cancerous nature of a cell is no longer irreversible.

Due to the lack of an appropriate experimental system in the past, study of the events which take place in the process of conversion of cancer cells has not yet been pursued in detail. The cell lines we have established will provide us with a suitable experimental system in which the molecular events involved can be investigated and also a novel approach to cancer "chemotherapy" developed.

Work has progressed to examine the possibility that the above principle underlying manipulation of gene expression may be used to regulate c-*myc* oncogene expression in naturally occurring cancers. In previous work, we discovered a novel gene, closely linked to the c-*myc* oncogene. Isolation and characterization of cDNA clones are under way.

Genome Organization and Chromosomal Evolution in the Genus *Caledia*

Our investigations into the evolutionary significance of the structure and function of genome organization have focussed on three major areas:

(i) Molecular and cytological characterisation of the centromere

Investigators: Dave Shaw, Nelida Contreras

Following the discovery of a moderately repeated DNA sequence located adjacent to, or actually within the centromere, two further sequences that are attached to this moderate repeat have been isolated from a genomic library. It is hoped that these sequences will lead us into the region of the chromosome that is directly involved in spindle attachment and chromosome segregation. The involvement of the isolated DNA sequences in the latter process has been investigated by *in situ* hybridisation of the H 3-labelled sequence to meiotic chromosomes during anaphase. Initial results clearly show that the target sequence is intimately associated with the spindle attachment mechanism. It should now be possible to investigate this process in more detail using a combination of biotin labelled sequences and microtubular antibodies to determine the nature of the interaction between the sequence and spindle proteins.

(ii) Developmental and chromosomal profiles along a genomic gradient

Investigators: Fran Groeters, Dave Shaw

In relation to the biological function of chromosomal restructuring during evolution, we have made considerable progress in linking it to changes in the rates of embryonic development. In south east Australia, the entire genome of *Caledia captiva* shows a gradual but concerted change in its structure caused by the directional movement of the centromere along all chromosomes. Conventional genetic explanation of such a phenomenon is not meaningful and we have advocated a biophysical role for chromosome structure in modulating rates of cell division during development. Such an explanation has received support from a combined ecological and chromosomal study of developmental patterns along the genomic cline in south east Australia. The analysis has associated major changes in life history patterns and developmental profiles with changes to the organization of the genome. The underlying cellular and nuclear processes are currently being investigated by cell cycle analysis.

Host/Parasite Evolutionary Relationships in a Zone of Hybridisation

Investigators: Jenny Ninham, Dave Shaw

Zones of hybridisation between genetically differentiated taxa have been proposed to act as "evolutionary sinks" from which emerge genotypically novel pest species. It is hypothesised that the hybridisation between genetically differentiated hosts in natural hybrid zones may affect the evolution of host/parasite interactions. The generality of this hypothesis is currently being tested using the hybrid zone that exists between two genetically differentiated taxa of the grasshopper *Caledia captiva* and their enteric sporozoon parasite, *Gregarina* sp. Molecular techniques are being devised that will allow the genetic differentiation of the parasite to be compared with that of the hosts across the hybrid zone. Previous research has shown that genetic coadaptation within each of the hosts breaks down in the hybrid zone and we will assess if a similar breakdown occurs in the parasite. The hypothesis proposes that infestation rates will be highest in hybrid individuals due to the breakdown in host resistance and this

proposal is currently being tested by examining parasite infestation levels among individuals taken from within and outside the hybrid zone.

Evolutionary Studies of the *Acacia* Genus

Investigators: Julia Playford, Dave Shaw, Rudi Appels[+], Gavin Moran[+]

Acacia melanoxylon (Blackwood) is a commercially grown timber tree. Despite its high economic value, the population biology and taxonomic status of the species is virtually unknown.

The establishment of plantations of Blackwood has become a priority, as current logging practices in native forests are seen as no longer viable.

As a prelude to the establishment of plantations, the distribution of genetic resources of the species has been analysed. *Acacia melanoxylon* is distributed over the east coast of Australia from Atherton to Southern Tasmania. Allozyme analysis shows major differentiation between populations north of the Hunter River and those to the south, with a smaller difference between populations in northern Victoria and New South Wales compared to those in southern Victoria and Tasmania and South Australia. There is very little apparent differentiation between Tasmania's commercial trees and those on the mainland. This work will be used in the selection of the best genetic material for Blackwood plantations.

The taxonomic status of the genus *Acacia* is currently being reviewed by an international team of researchers. In this group variation in the 5SrDNA is being studied. Species from Africa, South America, Australia and the Pacific Islands are being analysed by sequencing the non-transcribed spacer region of the 5SrRNA gene. DNA restriction fragment analysis of the same region of DNA is being used to study variation within the Australian species of *Acacia* and *Acacia melanoxylon.*

MOLECULAR EVOLUTION AND SYSTEMATICS GROUP

Molecular Systematics of Plant Photosynthetic Pathways

(i) Use of DNA sequence data in grass systematics

Investigators: Nancy Dengler[#], Ron Dengler[#], Paul Hattersley, Graham Hudson, Janette Lenz, Les Watson

A project was commenced to assess the evolutionary relationships of C_3 and C_4 grasses using genomic sequence data. Oligonucleotide primers were synthesised complementary to segments of the gene encoding the large subunit of rubisco of *Neurachne munroi* (C_4). These were used in a polymerase chain reaction to replicate selectively sequences from a sample of C_3, C_4 and C_3-C_4 grasses for sampling.

(ii) Mesophyll architecture of grasses in relation to photosynthetic pathways

Investigators: Nancy Dengler[#], Ron Dengler[#], Paul Hattersley, Graham Hudson, Janette Lenz, Les Watson

Leaf material of over 120 species has been prepared for detailed, comparative and quantitative analysis of mesophyll tissue and its relations with the bundle sheath. The aim is to identify suites of anatomical features which correlate with photosynthetic and phytogeographical differences, so that structural features of (eco)physiological significance can be pinpointed. All major taxonomic groups and photosynthetic pathway variants known within the Poaceae were sampled.

(iii) *In situ* mRNA labelling of rubisco activase in C_3 and C_4 plant leaves

Investigators: Nancy Dengler#, Ron Dengler#, Paul Hattersley, Graham Hudson, Janette Lenz, Les Watson

Ribulose-1,5-bisphosphate carboxylase/oxygenase (rubisco) activase activates rubisco in light, but it is unknown whether it is cellularly compartmented in the leaves of C_4 plants (as rubisco itself is). Using the sequence of the activase gene of spinach, sense and antisense single-stranded RNA probes were prepared by partial alkaline hydrolysis of RNA transcribed from linearised plasmid template DNA. Probes were radiolabelled with 35 S or 32 P, and biotinylated probes were prepared. Probes were also prepared for the small subunit of rubisco (using the maize rubisco sequence).

Leaf tissue of *Atriplex rosea* (C_4), *A. patula* (C_3), *Spinacia oleracea* (C_3), and *Zea mays* (C_4) was fixed, prepared and sectioned in various ways. The best ways for successfully labelling mRNA were not resolved for all species; however, antisense probes for both rubisco small subunit and rubisco activase showed that mRNA is confined to the bundle sheath tissue of *Atriplex rosea.*

COMPUTERISED DATABASES

Grasses, Sedges, Legumes and Families of Flowering Plants

Investigators: Les Watson, Jeremy Bruhl, Mike Dallwitz+, Murray Henwood, Janette Lenz, Carolyn Mihaich, Elizabeth Gibbs-Russell+

This group continues to contribute to the development of methods for automating taxonomic descriptions, and to prepare operational databases for important assemblages of plants. In a project commenced in 1970, we have developed a computerised data bank of morphological, anatomical, physiological, cytological and geographical information on grasses. This bank now incorporates data on nearly 500 characters for all 776 (narrowly defined) genera. The data are encoded in a format that permits uses ranging from information retrieval and correlation-seeking, to classification, automated generation of printed keys and descriptions, and interactive identification. The system is linked directly with automatic typsetting and microfiche generation, and most operations (notably interactive identification) can now be done on microcomputers. In 1990 we continued updating and improving the data; reorganized our automated identification/information retrieval package, 'Grass Genera of the World', to include the full generic descriptions, classification, references etc. on floppy disks in a form accessible for screen display (obviating the need for microfiches). We published a book, 'Grasses of Southern Africa', which involved integrating our generic descriptions with locally prepared species-level data (including data and maps generated automatically via the PRECIS specimen database) and which is available accompanied by floppy disks carrying the full descriptive data in interactive form; and we are organizing illustrations in readiness for their large scale incorporation in the interactive world generic set. Work has continued on an automated species level treatment of the Australian Poaceae Pooideae (commenced 1988) with completion this year of the Triticeae; and we have continued to append physiological and leaf-anatomical data to the these floristic descriptions, and to those of the Poaceae-Paniceae (prepared here some years ago).

Considerable progress was made this year with automated descriptions of Angiosperm families. All the families have now been entered, with comprehensive information on geographical distributions, numbers of genera and species, etc., plus comprehensive data on photosynthetic pathways and assignments to the alternative classifications of Dahlgren *et al.*; Cronquist and Takhtajan for nearly 300 families (including all of the 259 represented in Australia) now have sufficient information to allow interactive identification. A complete, operational database of the 177 genera of Leguminosae-Caesalpinioideae continues to be maintained; and in one database all the 130 genera of Cyperaceae (resembling the grass generic database in contents) is almost ready for publication as another package for automated identification/information retrieval.

Virus Identification Data Exchange Project

Investigators: Adrian Gibbs, Alan Brunt+, Karen Crabtree, Mike Dallwitz+, Les Watson

Work has continued on the plant virus taxonomic databank project. A book 'Viruses of Tropical Plants' has been published during the year. It records information on about 500 characters of all 550 recorded viruses of tropical plants. Data collection involved the help of 160 virologists worldwide. It is planned that by the end of 1991 we will have collated up-to-date information on all 1000 or so recorded plant viruses for publication in various forms.

Dr Adrian Gibbs, Molecular Evoluation and Systematics Group, presents the first copy of "Viruses of Tropical Plants" to Dr George Rothschild, Director of the Australian Centre for International Agricultural Research, in the presence of Dr Peter Smith (left) and Paul Ferrar (right), who are the Research Programme Co-ordinators for Crop Sciences at ACIAR.

The book has been produced by the VIDE (Virus Indentification Data Exchange) project which is funded by ACIAR, and was published by CAB International, UK. It contains details of up to 570 characters of all 700 known viruses (and 42 virus groups) of tropical plants, and was collected by an international team of over 150 virologists including most of those in Australia. The editorial team was Dr Alan Brunt (Horticulture Research International, UK), Ms Karen Crabtee (formerly of RSBS, now at CAB International, UK) and Dr Adrian Gibbs (project leader).

Virus Studies

Investigators: Adrian Gibbs, Shou-wei Ding, Anne Mackenzie, Mary Skotnicki, Pattana Srifah, Marjo Torronen

Work to produce full length cDNA clones of tymovirus genomes has continued. So far, full length clones of the Blue Lake and Club Lake isolates of turnip yellow mosaic (TYMV), ononis yellow mosaic, erysimum latent and eggplant mosaic tymoviruses have been obtained, and the first three of these have been shown to produce infectious RNA transcripts. The clones will be used to analyse viral functions and genomic evolution, especially the molecular basis of host preferences, and this will be done by preparing recombinants and mutagenizing selected nucleotides. Various recombinants have been produced which are being tested.

A project has started to assess the amount and causes of genetic variability in natural populations of TYMV. Populations of the virus in swards of *Cardamine lilacina* growing in the cirques of Blue Lake and Club Lake of the Kosciusko Alpine area have been sampled. Their genomic variation is being assessed using cRNA probes transcribed from parts of the genomic clone of TYMV-Blue Lake; the labelled probes are hybridized to the viral genomic populations and mismatches caused by mutational differences revealed by ribonuclease hydrolysis and electrophoresis.

The program to select *Arabidopsis* mutants with altered responses to tymovirus infection has continued. Several mutants resulting from EMS treatment resist the lethal effects of TYMV-Blue Lake infection. These have been back-crossed with genetically tagged *Arabidopsis* strains so that the mutant TYMV-tolerating genes can be mapped, separated from genes with irrelevant mutations, tested for dominance and, when combined in pairs, tested for synergy.

Agrobacterium transposon mutagenesis is being used in a major project to produce a 'library' of *Arabidopsis* mutants with genes tagged with kanamycin resistance. Work on the genetic transformation and regeneration of plants of *Arabidopsis* and *Cardamine* has also started.

Molecular Sequence Analysis and Structure Prediction

Investigators: Adrian Gibbs, Georg Weiller, Jack Palmer, Gillian Air+, Jan Blok+

The Molecular Evolution and Systematics Group, with the support and collaboration of the Centre for Molecular Structure and Function, the Protein/DNA Facility and the Centre for Information Science Research, has strengthened work on the analysis of molecular sequences in two ways. Firstly we aim to improve University-wide on-line facilities and consultation for sequence analysis and database searches, and have started a regular programme of seminars and workshops. The second objective is to improve methods of sequence analysis and comparison, and, in particular, the methods for predicting the structure of proteins from their sequences, concentrating initially on data from tymoviruses and retroviruses.

Methods for detecting changes in the rate of evolution are being developed. Sequence changes in the haemagglutinin and neuraminidase genes of influenza A and B orthomyxoviruses have been analysed; the origin and date of collection of each isolate are known. It was found that the influenza B genes have evolved at one third to one fifth of the rate of influenza A genes, and the encoded proteins even more slowly. Only about 30% of the changes in the influenza B genes have resulted in amino acid changes (close to that expected had the mutations been random). By contrast about half of the nucleotide changes in the influenza A genes resulted in changes to the proteins. This indicates that either there has been less selection for change or less tolerance to change in the influenza B proteins; influenza A evolution seems to have been dominated by antibody selection of the virion surface antigens.

A classification deduced from the nucleotide sequences of the NS1 genes of 5 Thai and 3 Sri Lankan isolates of dengue 2 flavivirus was found to correlate closely with a classification deduced from their envelope genes. Parts of these sequences were combined with published data from another 40 isolates to prepare a general classification. Most of the isolates fell into three groups, and the year in which they were isolated was clearly correlated with their relatedness; extrapolations indicate that these groups started to diverge around 1940. By contrast a group of West African isolates (all obtained from mosquitoes) showed no such correlations and had a significantly different ratio in the number of transition and tranversion nucleotide differences between isolates. The result of the analysis of influenza and dengue sequences are of great interest as they illustrate how ecological factors can influence selection pressures and hence evolutionary rates.

Studies of Fungi

Investigators: Peter Anderson, Tony Pryor+, Adrian Gibbs

A system has been developed for the application of restriction fragment length polymorphic (RFLP) markers to study sexual and somatic genetic systems in rust fungi. Molecular probes were selected from cDNA libraries made from poly A +RNA of germinated spores of three major rusts, *Puccinia sorghi* (maize rust), *P. graminis tritici* (wheat stem rust) and *Melampsora lini* (flax rust). One RFLP in *P. sorghi* was found to be caused by the insertion of a 498bp sequence. The sequence is highly repeated throughout the genome and showed no homology to genomic DNA from *M. lini* and *P. graminis*. Structural features such as two 64bp direct repeats suggest that this sequence may have originated from a transposable element. It is also known that the direct repeats exist as inverted repeats in the genome. The mobility of this and related sequences is being investigated.

PLANT CELL BIOLOGY GROUP

Introduction

Today the most significant advances in our knowledge of plant development arise from studies at the cellular level. To investigate effectively a range of key aspects of plant cell

biology, the Group has developed a multidisciplinary approach involving diverse techniques ranging from microscopy and immunocytology, through recombinant DNA technology, to advanced biochemical methods. In much of our work use is made of mutants of the miniature flowering plant *Arabidopsis*.

Because plant cells are encased in walls and are therefore unable to move appreciably, plants have developed very precise mechanisms for controlling the geometry of cell division and cell enlargement to permit development of functional tissues. These mechanisms are based on the cytoskeleton, a structural framework which controls intracellular dispositions and orientations. Studies of the plant cytoskeleton continue to be a major component of our research. A second node of activity focuses on the mechanisms responsible for the induction and cessation of cell division in plant tissues with emphasis on genetic controls, regulatory proteins and hormones which trigger division. A third research area focuses on the plant cell surface, components of which interact with the cytoskeleton to control developmental events, and are also vital in the interaction between plant cells and microorganisms. In the latter area, emphasis is given to the infection of plant roots by the dieback fungus *Phytophthora*, a serious plant pathogen in Australia. The fourth area of study concerns plant hormones, particularly cytokinins and auxins, which are chemical messengers that control cellular events ranging from induction of cell division and cell differentiation to onset of senescence. Major advances in all four areas were made during the year as outlined below.

Studies of Plant Cytoskeleton

(i) Genetic analysis of cytoskeleton control proteins

Investigators: Peter John, Liping Wu, Brian Gunning

We have successfully established a method of genetic analysis to study proteins that are involved in major rearrangement of the cytoskeleton during the transition from interphase to mitosis. Although the main structural proteins in microtubules are becoming well known the proteins that catalyse their disassembly and reassembly elsewhere in the cell in different configurations, remain unknown. It has not been clear, for example, whether regulatory proteins operate continuously, with slight shifts in the balance of their activities brnging about net changes in the cytoskeleton. From our studies last year we now know that this is not always so and that at least one control element intervenes decisively at a particular time. By screening large populations of mutagenised cells of the unicellular plant *Chlamydomonas* we have selected a temperature conditional mutation in a gene that controls changes in the cytoskeleton. The faulty gene product has no adverse effects throughout interphase as the cell grows and the cytoskeleton extends. Up to the end of interphase cells transferred back to the permissive temperature, which allows normal function of the cytoskeleton control protein, can continue normally through the cell cycle. However in late G2 phase, when the cytoskeleton must be changed in preparation for mitosis, the mutated protein suddenly begins to cause abnormal changes to the cytoskeleton which cannot be retrieved later even if the cells are transferred to the permissive temperature. In the absence of the functional gene product the interphase cytoskeleton cannot be disassembled to be replaced by the mitotic spindle. This intervention of a cytoskeleton control protein acting on the cytoplasmic cytoskeleton at a particular time in the cell cycle was not previously suspected.

(ii) Cytoskeletal preparations for cell division

Investigators: Brian Gunning, Janet Gorst, Margaret Sammut, Cathy Busby, Larry Fowke#

The placement of new cell walls at the time of cell division is an important stage in plant development. Regulating exactly where new cell walls are inserted determines the three-dimensional arrangements, and hence functions, of cells in tissues and organs. We know from previous work that the higher plant cells make a "preprophase band" (PPB) of microtubules at the position where the new wall will be placed after completion of mitosis. Work completed in 1990 determined the time course of PPB development by means of a double-immunolabelling procedure following identification of cells which were duplicating their DNA. It turns out that as soon as the cell's DNA has been duplicated, some time before mitosis, the microtubule rearrangements of PPB formation begin. PPB development is a long and slow process throughout the G2 period of the cell division cycle and it culminates in a short-lived mature PPB which very precisely marks where the cell will divide.

In other projects we are examining PPBs in plant tissue cultures and in callus formation induced by plant growth regulators and by infection with the tumour-producing bacterium *Agrobacterium tumefaciens*. The evolution of the PPB system is being examined in a range of taxa from mosses to cycads.

(iii) Cytoskeletal and morphological mutants of *Arabidopsis thaliana*

Investigators: Richard Williamson, Tobias Baskin, Andreas Betzner[#], Ann Docherty, Janet Elliott

We are studying the molecular genetics of cell shape determination in the root of *Arabidopsis thaliana*, and in particular identifying genes that are involved in the alignment of cortical microtubules. Microtubules in the wild-type root are transverse throughout the elongation zone—as expected when elongation exceeds increase in girth—and oblique in older regions. We have identified three recessive mutations involved in determining cell shape, two of which cause major changes to this arrangement of microtubules. The *bre1* mutation causes bulging of root epidermal cells, the *rdw1* mutation severely inhibits root elongation and the *rsw1* mutation causes root swelling in the sub apical region. Microtubules in roots carrying the *rdw1* and *rsw1* mutations are severely misaligned. Using these and other mutants, we will investigate the postulated relationship between microtubules, cellulose alignment and cell shape, and conduct a "chromosome walk" to clone the genes involved.

(iv) Construction of a physical map of a region of chromosome 1 of *Arabidopsis thaliana*

Investigators: Jacek Plazinski, Ursula Hurley, Liz Dennis[+], Richard Williamson

The multinational *Arabidopsis* genome project aims to identify all of the genes and sequence the entire genome of the flowering plant, *Arabidopsis thaliana*. We are contributing to the generation of a physical map of the *Arabidopsis* genome that will facilitate the cloning of genes identified only by their map position from mutants. Restriction fragment length polymorphisms mapping to a region of chromosome 1 are being assigned to large fragments of *Arabidopsis* DNA that have been cloned as yeast artificial chromosomes. A contig of overlapping clones will be constructed.

(v) The cytoskeleton in cell shape determination and cytoplasmic streaming and its regulation by Ca^{2+}

Investigators: Richard Williamson, David Collings, Janet Elliott, Ruth Hagan[†], Alice Harmon[+], Peter Jablonsky, Lin Qiao, David McCurdy, Geoffrey Wasteneys

We are investigating the movement of plant organelles by the proteins actin and myosin and the determination of cell shape by microtubules. Monoclonal antibodies prepared to a putative myosin heavy chain from mung beans show similar properties to antibodies prepared to mammalian myosins. They react with the same high molecular weight polypeptides in several plant species and show similar labelling of the fibres that contain actin filaments and the motile endoplasmic organelles in giant cells of *Chara*. While microtubules are not required to drive cytoplasmic streaming, they do exist in the endoplasm as well as forming the prominent arrays of microtubules present in the cortical cytoplasm. Some microtubules are apparently associated with the actin cables and we have evidence that they may affect the extent of actin assembly. The alignment of cortical microtubules correlates with the acid/alkali banding properties that probably reflect the local properties of the plasma membrane.
Microtubule-associated proteins are being sought through anti-idiotypic antibodies raised to a peptide identified in animal cells as the region of tubulin to which many such proteins bind.

Ca^{2+} regulates cytoplasmic streaming and Ca^{2+}-dependent phosphorylation of proteins has been demonstrated in perfused cells of *Chara*. Antibodies to a Ca^{2+}-dependent protein kinase first purified in soybeans show that its distribution parallels that of myosin in *Chara*. The antibodies inhibit ATP-dependent cytoplasmic streaming in perfused cells, presumably because their binding to the motile organelles and the actin bundles impedes the movements of the organelles over the actin cables. A second calcium-binding protein, calmodulin, is not a component of the actin bundles but is widespread in the endoplasm. Perfused cells retain the Ca^{2+}-dependent protein kinase but calmodulin is extracted. Elevated Ca^{2+} irreversibly inhibits ATP-dependent cytoplasmic streaming in such cells consistent with the activated Ca^{2+}-dependent protein kinase inhibiting streaming and a calmodulin-dependent protein phosphatase reactivating it.

(vi) The regulation of cortical microtubule orientation by membrane properties

Investigators: Geoffrey Wasteneys, Richard Williamson

The orientation of cortical microtubules in characean internodal cells changes from transverse to random when growth is complete. In *Chara corallina*, this transition may be divided into three stages: when microtubules are (1) predominantly transverse, (2) locally parallel but with shifts in orientation from transverse to oblique to longitudinal and (3) random. These cells develop alternating acid and alkaline bands along their lengths which correspond to localized regions of proton influx and efflux. In older, slowly-growing cells, the microtubule orientation patterns alternate between stage 2 to stage 3 in strict accordance with the pH bands. We now hope to investigate how these bands influence microtubule orientation.

(vii) Development of flower components

Investigators: Mary Webb, Arthur Davis, Brian Gunning

Despite their importance for plant reproduction and agriculture, remarkably little is known about cellular aspects of megaspore and embryo sac development. We have adapted several techniques for examining the cytoskeleton of plant cells to look at these female reproductive structures, focussing on *Arabidopsis thaliana*. All stages of megasporogenesis, embryo sac formation and early embryogenesis have been monitored with respect to changes in the disposition of actin and microtubules. Features of interest that have emerged include a complete reorganization of cytoplasmic microtubules at the onset of megasporogenesis. From then on until the embryo starts to grow there are no preprophase bands. Microtubules do, however, assume very specific conformations and probably play a hitherto unrecognized role in fertilization.

Floral nectaries are plant glands that secrete sugar solutions attractive to a wide variety of animals. Nectar-gatherers utilize these secretions as a food source, and in the case of honey bees, nectar is ripened into a product of commercial significance. Pollination may be effected by these animals during their visits to flowers. Current research on nectar secretion involves the investigation of structural and physiological aspects of the cells which constitute these floral glands, so that the secretory process can be better understood. The projects being undertaken include the development and functional role of stomata on the nectary surface, the contribution of nectary starch to total nectar-sugar production, changes in nectar-sugar composition throughout flowering, and the influence of pollination, pollen-tube growth and fertilization on the secretory activity of floral nectaries important to Australian apiarists.

Control of Cell Division

Plant growth requires a supply of new cells. To understand the division process by which they are formed we have pursued three objectives. One is to identify the key proteins that initiate the phases of the cell cycle and so drive progress to division. Our laboratory was the first to discover that the key protein $p34^{cdc2}$ has this function in plant cells. The second objective is to understand the interactions between different processes within the division cycle, which ensure that each occurs in the right sequence and in the right place to allow successful division. We have investigated this by using mutation to disrupt single events, such as changes to the cytoskeleton, so that we can study the effects on other processes in division. The third objective is to reveal the mechanism by which cells cease division and develop specialised structural and metabolic functions. This cessation of division allows formation of tissues with particular contributions to plant growth, such as functions of support, photosynthesis and storage. We have discovered that big changes in the level of key proteins that drive progress through the cell cycle are used to switch cells from division to specialised functions.

(i) Conserved control molecules

Investigators: Peter John, Swati Baindur, Frank Sek, Kerong Zhang, Janet Elliott

This year we made two important advances in our understanding of how the cell cycle control protein $p34^{cdc2}$ regulates division in plants. One discovery showed that plant $p34^{cdc2}$ is a calcium and cyclic AMP-independent protein kinase which binds to a regulatory subunit $p13^{suc1}$. The subunit has been shown by genetic analysis to be necessary for completion of mitosis and restoration of the interphase cytoskeleton; therefore the association of these two plant proteins is probably an important element in plant nuclear division. The second

discovery illuminates the way in which the orderly initiation of mitosis requires the appropriate phosphorylation of key proteins such as $p34^{cdc2}$, which is only active when certain of its amino acids are phosphorylated and others are not. We have found that a specific inhibitor of phosphatase activity blocks higher plant cell division at the earliest stage of mitosis. High concentrations of the inhibitor induce the premature hypercondensation of chromosomes.

(ii) Division control by cAMP

Investigators: Suchirat Sakuanrungsirikul, Charles Hocart, Bill Parker, Peter John

For the first time in plant cells we have identified mutations that inactivate adenyl cyclase, the enzyme responsible for synthesis of cyclic AMP (cAMP). We have demonstrated that in the *Chlamydomonas* cells carrying the mutations there is a greatly lowered level of cAMP. This is the first time that a low cAMP level has been imposed on any plant cell and it allows investigation of what the function of cAMP may be. This situation is particularly significant because in the presence of a second mutation cell division is prevented unless cAMP is provided. The cells lacking cAMP arrest just prior to DNA replication and the mutation that makes them sensitive to lack of cAMP at this point is being investigated. It has been known for many years that plants contain the enzymes for cAMP synthesis and breakdown but, because they maintain optimum levels of this signal molecule, its functions could not be pinpointed. Now it is clear that at least one function is to promote an early event in the cell division sequence.

(iii) Proliferation or differentiation control

Investigators: Peter John, Swati Baindur, Frank Sek, Janet Gorst, Kerong Zhang and Ann Docherty

We now understand part of an important molecular switch that changes the behaviour of cells that leave the cell division regions of plants. They must cease cell division and take on the specialised shapes and functions required in plant tissues. By studying the seedling wheat leaf we have discovered that division ceases after a more than fifteenfold decline in the level of the cell cycle control protein $p34^{cdc2}$ which ensures that cells are committed to differentiate and not to divide. Another phenomenon that can be accounted for by loss of this key division protein is the declining responsiveness of mature cells of grass leaves to division-inducing phytohormones when they are excised. No mechanism for changing hormone responsiveness has previously been determined. In other circumstances changing responsiveness may be due to changing numbers of hormone receptors but in this instance loss of the key division protein provides a simple explanation.

The genetically induced interruption of division in *Arabidopsis* roots has been shown on reversal to promote a burst of mitotic activity and the induction of lateral roots. The basis of this effect is being investigated.

The Infection of Plants by the Dieback Fungus

Investigators: Adrienne Hardham, Larry Lehnen, Frank Gubler, Jadwiga Duniec, Geoff Hyde, John Dearnaley, Janet Elliott

The dieback fungus, *Phytophthora cinnamomi*, is a destructive plant pathogen that causes widespread damage in Australia. Both native forest and heathland species are susceptible, as are a number of important crops. The fungus spreads rapidly and infects new plants by producing large numbers of motile spores which swim through the soil and attach to potential hosts. The main aim of our research is to identify and elucidate the function of key molecules involved in the infection process. Because spore motility and the early interaction with the host are fundamental aspects of infection, we have focussed our attention on components of the motility apparatus and on surface molecules involved in recognition of and attachment to the host.

The central feature of our work is the use of monoclonal antibodies directed against specific spore components. These antibodies have allowed us to greatly extend our understanding of the ultrastucture of the fungal spores and of the function of selected spore components. This year we have used one antibody to identify the sites of storage of glycoproteins needed during the initial growth of the fungus after it has attached to the plant surface. Using another antibody,

raised by Dr Peter Jablonsky, we have also discovered that there is a high concentration of the Ca^{2+}-binding protein, calmodulin, in a specialised structure at the base of one of the two flagella, the organelles responsible for spore motility. This suggests that the two flagella are likely to respond differently to changes in Ca^{2+} levels. This differential response may be an important part of the regulation of spore motility.

We have also used the monoclonal antibodies to isolate genes that code for components in the flagella apparatus, on the cell surface and involved in infection. A cDNA library containing messages necessary for the production of the fungal spores was generated from mRNA isolated during spore formation. The monoclonal antibodies were used to identify and isolate clones with inserts coding for epitopes recognised by selected antigens. Gene products targeted include: tubulin, the putative adhesive molecule, the storage glycoprotein and a number of cell surface proteins including one involved in triggering loss of motility at the host surface. In future work we hope to learn how these genes are regulated and to elucidate their role in the infection process.

Another highlight of our research this year has been the use of the High Pressure Freezing Apparatus at the University of Massachusetts in Amherst. This machine produces high quality freeze-fixation of large cells and has given us new insights into the mechanism of cytoplasmic partitioning during fungal spore formation.

Hormonal Control of Development

(i) Cytokinins—hormonal regulators of development and senescence

Investigators: Stuart Letham, Charles Hocart, Sue McKinney, Elizabeth Taverner, William Parker, David Willcocks, Jian Wang, Xue-Dong Zhang

Studies of cytokinin metabolism in relation to plant development were continued during the year and particular attention was devoted to the following areas: (1) development of new and highly sensitive mass spectrometric methods for quantifying cytokinin bases; (2) purification of cytokinin binding proteins from plant nuclei; (3) the control of leaf and flower senescence; (4) cytokinin translocation in the xylem; (5) cytokinin production by *Rhizobium* bacteria; (6) development of plants in which chimeric cytokinin biosynthesis genes are expressed; and (7) cytokinin gradients in roots in relation to lateral root initiation. Aspects of work concerning (1), (4), (5) and (6) are summarized below.

The sensitivity and reliability of gas chromatography-mass spectrometry (GC-MS) methods for cytokinin quantification would be improved by a more rational approach to derivatization methods. In developing improved derivatization procedures for cytokinins, consideration should be given to the desirability of the following: (1) use of chemical reactions which exhibit selectivity for cytokinins by recognising their distinctive structural features; (2) preparation of derivatives which are stable to permit further purification by liquid chromatography; (3) preparation of derivatives with "electron-capturing" groups in the molecule. In response to these considerations, we have developed stable derivatives containing fluorine atoms for GC-MS analysis of cytokinin bases such as zeatin and dihydrozeatin. Use of these derivatives in conjunction with deuterium-labelled internal standards and negative ion mass spectrometry has greatly facilitated cytokinin quantification in plant tissues and bacterial culture supernatants.

Rhizobium-produced cytokinins are implicated in nodule development and we have found that nodules contain much higher levels of cytokinins than root tissue, but to date no *Rhizobium* genes or genetic loci directly involved in cytokinin biosynthesis have been identified. Reports of cytokinins in *Rhizobium* culture media are contradictory. Some workers have detected low levels of zeatin-like compounds in media by bioassay; others have failed to detect such cytokinins. To resolve these differences we have examined culture supernatants of a normal *Rhizobium* strain for cytokinins by mass spectrometry using the new derivatization procedure mentioned above and by radioimmunossay. Eight cytokinins were identified and quantified and these are the first unambiguous identifications of cytokinins in a *Rhizobium* culture medium. Nodulation of pigeon pea plants with an unusual species of *Rhizobium* induces certain modifications in shoot development similar to those caused by exogenous cytokinin. By mass spectrometry, this bacterium was shown to be an overproducer of cytokinin in culture and to elevate cytokinin levels markedly in xylem sap of inoculated plants. Genetic

studies by coworkers have led to the characterisation of the bacterial genetic locus involved in elevation of xylem cytokinin levels. The genes present differ from the genes in *Agrobacterium* and *Pseudomonas* which encode cytokinin biosynthetic enzymes and are therefore of particular interest. Their further characterisation is in progress. Pigeonpea plants inoculated with the unusual *Rhizobium* strain provide a novel system to study the role of endogenous xylem cytokinins in aspects of shoot development, especially lateral shoot development and hyponasty.

It is generally accepted that root-produced cytokinin moves in the xylem to control aspects of shoot development. In previous studies we have established the basic features of the distribution and metabolism of xylem translocated cytokinin using lupin plants. However, an important question remained unanswered: do xylem cytokinins accumulate in developing seed and could such accumulation account for the high endogenous cytokinin content in seed? In the studies now reported, cytokinins of high specific radioactivity were specially synthesized by a new method and were introduced into the xylem of pod-bearing lateral stems of intact lupin plants. A small proportion of xylem supplied cytokinin was found to be conserved in the seed as compounds with cytokinin activity but this would only account for less than 1% of the observed cytokinin content. The seed coats of legume seeds appear to shield the embryos from the low proportion of xylem cytokinins which reach the seed. The developing embryos may be completely autonomous with respect to cytokinins due to adequate biosynthetic capacity. This would seem logical for plant survival as it is not desirable for the seed to be dependent on a hormonal supply (the xylem) which is subject to marked fluctuations caused by changes in the environment of the root. It has often been proposed that xylem cytokinins move preferentially to developing seeds and that such movement is associated with induction of leaf senescence in monocarpic plants. The results reported above invalidate these proposals.

The cytokinins appear to play an important role in regulating plant growth and differentiation. Evidence for this comes from both correlative studies, which attempt to relate endogenous hormone concentrations to specific physiological processes, and from effects of externally applied hormones. However, both lines of evidence are open to criticism e.g. correlative studies are frequently unable to distinguish between cause and effect. Some of these difficulties would be eliminated by development of mechanisms for directing *in vivo* production of hormones. One approach is to devise chimeric cytokinin biosynthesis genes and transfer them to plants to give controlled hormone production. In conjunction with CSIRO and Calgene Pacific we have developed several plant systems for physiological study by such gene transfer. Studies of tobacco plants with a chimeric cytokinin biosynthesis gene (*ipt* gene from *Agrobacterium* with constitutive promoter replaced by chalcone synthase promoter from antirrhinum petals) show that endogenous cytokinins suppress root initiation, inhibit lateral root formation, reduce the ratio of root to shoot, induce lateral shoot development, increase stem diameter by stimulating both cell division and cell enlargement in the pith tissue, increase node and leaf number per plant, control leaf shape, and retard sequential leaf senescence, and prolong the vegetative period of plant development.

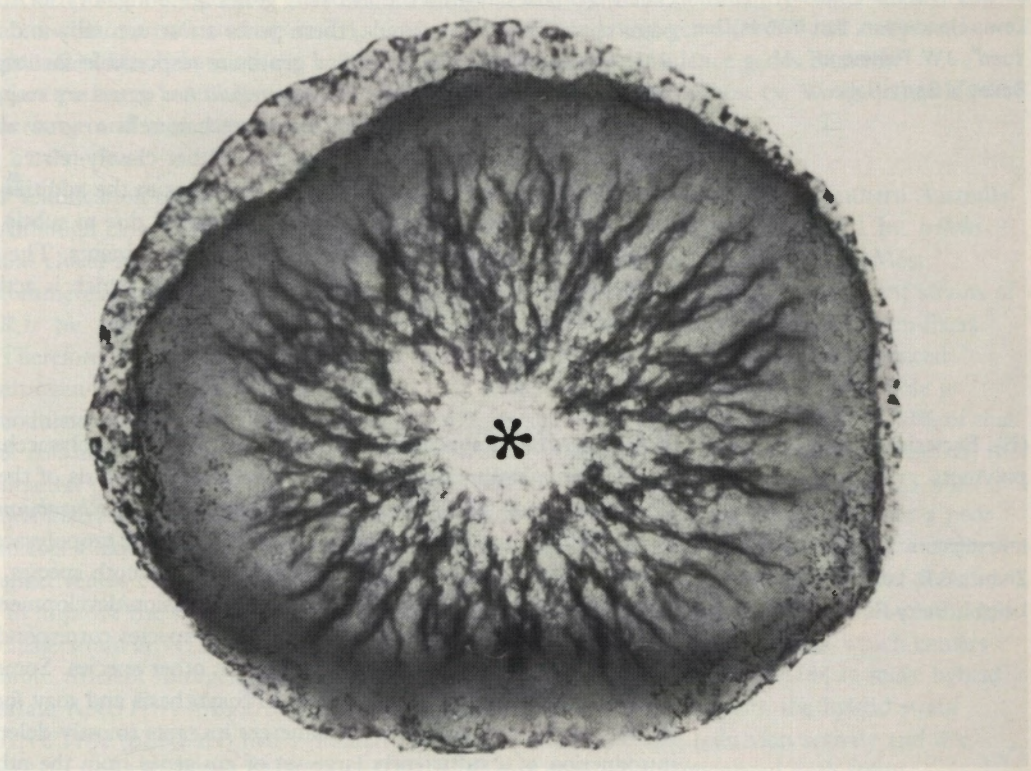
(ii) Pattern determination in vascular tissues and cells

Investigators: Pamela Warren Wilson[#], John Warren Wilson[†]

We have devised a simple system for experimental studies of the control of vascular patterns. A thin slice of lettuce pith parenchyma, devoid of vascularisation, is explanted under sterile conditions on to an agar culture medium which lacks the auxin that is required for xylem differentiation. An ion-exchange bead loaded with auxin (indoleacetic acid: IAA) is then placed on the surface of the explant. On incubation, xylem strands develop in a characteristic radiating pattern centred on the IAA-loaded bead. Similar patterns arise in thin explants of begonia pith and of storage tissue of carrot and sweet potato. We suggest that the patterns of xylem strands are generated by (1) radial diffusion of IAA from the bead, as shown by [^{14}C] IAA studies, (2) flux-dependent increase in conductivity resulting in canalisation of IAA flow along pathways, and (3) xylem strand differentiation being induced along these pathways.

The tracheary elements constituting such xylem strands tend to be oriented with their long axes parallel to the strand and their secondary wall banding perpendicular to the strand. The orientations of cell wall elongation and of secondary wall banding are known to be determined

by cortical microtubule orientation. Accordingly, we suggest that these microtubules undergo alignment perpendicular to the flow of auxin, perhaps mediated by the associated transcellular acid flux.



This explant, initially 7 mm in diameter, was cultured in the dark at 25°C on a nutrient agar medium lacking auxin. An IAA-loaded bead was placed centrally (*) on the upper surface. After 11 days the explant measured 9.5 mm in diameter and a pad of callus covered most of the surface. The explant was then cleared and treated with safranin. This has stained the tracheary strands radiating in the callus away from the bead site, and was also retained by suberin, particularly at the edge of the callus pad. This novel technique has potential for the elucidation of the processes of pattern formation at both cell and tissue levels.

PLANT MICROBE INTERACTION GROUP

Introduction

Microbes and plants often interact together through the exchange of chemical signals. In the case of plant pathogens this signal exchange can lead to invasion and disease of the plant tissues. The soil bacterium, *Rhizobium*, responds to the excretion of flavonoid compounds from the roots of leguminous plants by colonizing the roots and infecting the emerging root hair cells without inducing the plant's defence systems. The outcome of this invasion can result in a mutually beneficial relationship between the two organisms and fixation of atmospheric nitrogen into a form which the plant can use for growth. This symbiosis occurs in plant root outgrowths called nodules which the rhizobia colonize. Thus, the *Rhizobium*-legume interaction is a valuable one for the study of symbiosis, and plant recognition, resistance and defence systems.

Rhizobium Bacteria and the Infection of Leguminous Plants

(i) Recognition responses in the *Rhizobium*-legume interaction

Investigators: Michael Djordjevic, Jeremy Weinman, Wendy Lewis-Henderson, Jan McIver, D. Yuan[#], J.W. Redmond[+], M. Batley[+], Barry Rolfe

Rhizobia are soil bacteria capable of inducing nitrogen fixing nodules on the roots of specific legumes. Specificity can be seen at all levels of the interaction: a class of plant-generated signal molecules (flavonoids) is recognised by rhizobia and this results in the generation of a highly-specific signal from the bacterium to the plant. We have focused on the interaction of *Rhizobium leguminosarum* biovar *trifolii* with clover (*Trifolium*) plants. Rhizobia are chemotactic towards flavonoid molecules released from the plant's roots (at 10nM–1mM concentrations) which also serve to induce transcription of several plasmid-borne operons in the bacterium. In conjunction with the regulatory protein, NodD, flavonoids induce the operons *nodABCIJT, nodFERL* and *nodMNX* which are co-ordinately regulated via conserved promoter elements called *nod*-boxes. While the *nodABC* genes are obligatory for the production of the secreted plant specific signal molecule, these genes are structurally and functionally conserved in several *Rhizobium* species. The other *nod* genes are responsible for imparting host species specificity. Together, the products of the *R.l.* bv. *trifolii nod* genes are responsible for the elaboration of a clover signal molecule, which induces root hair cells to grow aberrantly and cortical cells to undergo altered developmental responses. Other closely-related plant genera (e.g. *Vicia* or *Medicago*) show weak or no detectable responses to the addition of this molecule. In some cases, cultivar specific interactions are recognised due to subtle *nod* gene differences between *R.l.* bv. *trifolii* isolates and single host gene determinants. The clover signal molecule is a low molecular weight, heat stable, non-polar molecule which is active at low (10^{-8}-10^{-11}M) concentrations.

(ii) Bacterial surface polymers

Investigators: James Gray, H. Zhan[+], S.B. Levery[+], J.A. Leigh[+], Barry Rolfe

Work on the biosynthesis of the complex acidic exopolysaccharides (EPS) of the cell surface of *Rhizobium* strains has focussed on the genetic analysis of the genes controlling this process. *R. meliloti* strain SU47 (alfalfa which nodulates) and *Rhizobium* sp. strain NGR234 (broad host range *Rhizobium* which nodulate *Leucaena*) produce exopolysaccharides (EPS) that are structurally distinct despite partial similarities. In both species, clusters of genes are required both for EPS synthesis *exo* and for nodule invasion/development on the respective hosts, alfalfa and *Leucaena*. Most of the *exo* genes in each species corresponded by hybridization and functional complementation to genes in the other species. Some of these genes are responsible for post-transcriptional regulation of EPS synthesis and may form part of a membrane-bound catalytic/regulatory complex. In some *exo* mutants (mostly deletions) from each species, the introduction of a sufficiently large set of *exo* genes from the other species resulted in the production of the EPS of the other species. These constructs have enabled us to demonstrate that (1) all of the genes necessary for the determination of specific EPS structures are within the known *exo* cluster of each species, and (2) in each case the heterologous EPS is not sufficient for nodule invasion/development even when produced in the root environment by the bacterial species that normally nodulates the host.

(iii) *Rhizobium* a host specific nodulation genes and a clover nodule morphogenesis

Investigators: Jan McIver, S.S. Huang , Michael Djordjevic, Jeremy Weinman, Barry Rolfe

Nodule formation appears to be a perturbation of an existing plant program of cellular development. All of the types of cell changes seen in nodule formation can be seen during root growth and lateral root development in uninoculated plants. However, in the process of the nodule formation there is a difference in the way these cellular changes are organized and regulated. This study shows the development of structures in uninoculated controls which appear analogous to the early cellular changes observed in nodule formation in white clover. We compare at various stages of nodulation the structures induced by (a) the wild type *R.l.* bv. *trifolii* strain ANU843; (b) *R.l.* bv. *viceae* strain 300, a strain which normally infects peas and rarely nodulates white clover; and (c) *R.l.* bv. *viceae* strain 300 containing different combinations of strain ANU843 host specific nodulation genes. The presence of particular strain ANU843 *hsn* genes in strain 300 increases the frequency at which more advanced nodule structures are observed.

(iv) Cultivar specific nodulation of subterranean clover by a *Rhizobium*

Investigators: Michael Djordjevic, Wendy Lewis-Henderson, Jan McIver, Jeremy Weinman, S.S. Huang , Barry Rolfe

Gene-for-gene interactions have been demonstrated in many plant-pathogen relationships involving bacteria, fungi, viruses, insects and nematodes. Several *Rhizobium nod* genes (e.g. *R. leguminosarum nodE* and *R. meliloti nodQ* and *nodH*) have been shown to function pleiotropically, conferring virulence on homologous hosts and "avirulence" on non-homologous hosts. In contrast, cultivar-specific avirulence is rarely seen in the *Rhizobium*-legume symbiosis. We have investigated the molecular genetics of a cultivar-specific interaction between *Rhizobium leguminosarum* biovar *trifolii* and *Trifolium subterraneum* (subterranean clover). There is clear evidence for a gene-for-gene-pathway interaction in this relationship which involves a complex interplay between positively and negatively-acting nodulation genes in the bacteria, and a single host gene. The *nodT* gene was shown to dominantly confer nodulation on nodulation-restricted strain TA1, and two negatively-acting genes (*nodM* and *csn1*) were identified which have all the hallmarks of cultivar-specific avirulence genes found in plant-pathogen interactions. The cultivar specificity seen with the host cv. Woogenellup is heritable and segregates in a Mendelian manner.

(v) Construction of acid tolerant, nitrogen-fixing strains of *Rhizobium trifolii*

Investigators: Hancai Chen, Elena Gartner, Barry Rolfe

Acidification of soils beneath clover-based pastures is a serious problem in southern Australia. Although clover plants themselves are moderately tolerant of acid conditions, *R.l.* bv. *trifolii* and clover nodulation are sensitive to low pH and associated acid soil factors (1). Most commercial inoculant strains of *R.l.* bv. *trifolii* are acid sensitive strains. Acid-tolerant strains of *R.l.* bv. *trifolii* nodulate clover plants at low pH, but most of them are poor nitrogen-fixers. Therefore, we are seeking to construct acid tolerant *R.l.* bv. *trifolii* strains with enhanced nitrogen-fixing capacity. Strain ANU1173 is an acid-tolerant *R.l.* bv. *trifolii* strain able to nodulate clover plants at pH 4.4. At pH 6.5, its symbiotic effectiveness was about 80% of that of commercial inoculant strains of *R.l.* bv. *trifolii*. Strain ANU1173 contains four plasmids, the smallest plasmid being the Sym plasmid. When the Sym plasmid of strain ANU1173 was mobilized into a non-nodulating (Nod-) strain of *R.l.* bv. *viciae*, it continued to confer a poor nitrogen-fixing phenotype on clovers. These results suggested that the low symbiotic effectiveness of strain ANU1173 was due to the poor efficiency of genes on the Sym plasmid. To improve the symbiotic effectiveness of strain ANU1173, it was cured of its Sym-plasmid to create strain ANU1184. Then another *R.l.* bv. *trifolii* Sym plasmid, pBRIAN which confers more efficient nitrogen fixation on clovers was transferred to strain ANU1184 to make hybrid strain ANU1184 (pBRIAN). Subterranean clover plants inoculated with the hybrid strain ANU1184 (pBRIAN) had a dramatic increase in both acetylene reduction activity and dry weight when grown at pH6.5 or pH4.4 compared with plants inoculated with strain ANU1173 and grown under the same pH conditions.

(vi) Detection of plant signals in wheat seedlings using a specific *Rhizobium* strains

Investigators: Kathryn Le Strange, Gregory Bender*, Michael Djordjevic, Barry Rolfe, John Redmond+

Extensive studies have shown that the nodulation (*nod*) gene *nodD* is a crucial gene involved in the earliest stages of host recognition between various rhizobia and legumes. The product of *nodD* is believed to be a transcriptional activator protein that binds to the promoters of inducible *nod* genes. Plant-synthesized compounds, in concert with the *nodD* gene product, activate inducible *nod* genes, which then initiate the early processes involved in nodulating a plant host.

Rhizobium strain NGR234 is a broad host range *Rhizobium* and is one of the few *Rhizobium* a strains capable of forming nodules with a nonlegume host, the woody tree *Parasponia* from the Ulmaceae family. Despite the high level of molecular conservation with other *nodD* alleles, the *nodD1* gene of strain NGR234 is less specific in host recognition than the *nodD* genes from more widely characterized, narrow host range rhizobia. Because of this less stringent host range of the strain NGR234 *nodD* gene product, a range of plant extracts from various plants can be examined for transcriptional activation factors.

Vanillin and isovanillin are present in extracts of wheat seedlings and interact with the nodulation (*nod*) gene *nodD1* from *Rhizobium* strain NGR234 to induce expression of *R. leguminosarum* bv. *trifolii nod* genes. Seven varieties of Australian wheat were examined. Vanillin, isovanillin, or both were present in five of the varieties tested. Assays of a wide range

of authentic flavonoid and other phenolic compounds for transcriptional induction of the same *nodA:lacZ* fusion revealed that a hydroxyl group para to a electron-withdrawing group and/or the presence of a cluster of oxygen functions are the prime structural requisites for transcriptional activation of NodD1-activated *nod* genes.

Formation of Nodule-like Structures on the Roots of the Non-alegumes Rice and Wheat

Investigators: Barry Rolfe, Lynette Preston, Dominique Barnard, Greg Bender*

Specific *Rhizobium* strains have been shown to cause root hair curling on rice. Research on the genetic basis of *Rhizobium* nodulation of *Parasponia* led to the engineering of a *Rhizobium* strain that occasionally forms nodules on rice. Currently, nodulation is infrequent (about 0.25% of inoculated plants) and unpredictable, but the internal structure of nodules closely resembles that found in legumes. When nodules do form on rice roots, *Rhizobium* bacteria can enter and be "packaged" within membranes, as found in legume nodules, although there is no evidence of infection thread formation, normally seen in legume root nodules. These structures have vascular bundles.

Addition of the synthetic auxin 2,4-D to wheat seedlings resulted in the formation of nodule-like structures, which are probably modified lateral roots. Within a narrow concentration range, 2,4-D induced the formation of structures on wheat roots which resembled nodules formed on legumes. Furthermore, there appears to be a narrow concentration window of 2,4-D addition that induces these structures on wheat roots without apparently interfering with adequate lateral root growth and good shoot growth. Seedlings with 1×10^{-6} M auxin form both lateral roots and nodule-like structures and have normal top growth. Plants exposed to 5×10^{-6} M 2,4-D and above form nodules, have few to no lateral roots and have yellowing and reduction of top growth. Different strains of *Rhizobium*, *Azospirillum*, *Agrobacterium* and *E. coli* have been added separately with auxin to wheat roots. The various bacteria do not behave in the same manner; some strains added with 2,4-D at 5×10^{-6} M caused a marked stunting of the roots and killing of the seedlings. Other strains have a negligible effect or show a slight decrease in the level of added auxin required to induce nodule structures, lateral roots and good shoot growth. The nodules on wheat roots do not have substantial levels of internal bacteria present and the nodule structure is not highly organized like that occurring in legumes. To date, no evidence of nitrogen fixation has ever been found with any of these induced nodule-like structures on either rice or wheat.

The Use of *Trifolium subterraneum* for the Investigation of Plant-microbe Interactions

Investigators: Jeremy Weinman, Michael Djordjevic, Paul Howles, Tony Arioli, Marie Oakes, Bill Creaser, Kath Britt, Barry Rolfe

We have been developing *Trifolium repens* and *Trifolium subterraneum* for the study of both symbiotic and pathogenic interactions between plants and bacteria.

The diploid, self-fertile *T. subterranean* clover, a small seeded legume with a small genome, is proving to have a number of advantages for studying the molecular basis of plant-microbe interactions. A genomic library constructed from cv. Karridale has provided clones for a number of chalcone synthase genes and for the early nodulins, ENOD2 and ENOD12. The characterization of these clones is currently being undertaken. Furthermore, a large series of biological probes consisting of viruses, *Rhizobium* and *Pseudomonas* strains, and *Phytophthora* are available to examine signals triggering plant defense responses.

Plant Defence Mechanisms

(i) Isolation of cinnamyl alcohol dehydrogenase from *T. subterraneum*

Investigators: Bill Creaser, Kath Britt

We are interested in the biosynthesis of lignin in clover, especially in relation to its control by environmental parameters and as a defence mechanism. Therefore we are studying an essential enzyme in the pathway, cinnamyl alcohol dehydrogenase (CAD). It was found that roots were the richest sources of CAD enzymes. Root extracts subjected to gel electrophoresis and stained for dehydrogenase enzyme activity show that there are up to about ten cinnamyl dehydrogenase bands present which have differential specificities for the three alcohols tested. Wounding and elicitation causes increase in CAD activity in clovers. Experiments showed that the largest molecular weight CAD protein is the inducible defence protein.

(ii) Location of the victorin binding protein

Investigators: David Loschke, Dean Gabriel[+], Barry Rolfe

An important prospect for the future of plant genetic engineering will be the introduction of natural and synthetic disease resistance genes into selected crop plants. Oats containing the dominant *Vb* allele are susceptible to the fungal toxin victorin. The *Vb* allele is either the same as, or very closely linked to, the *Pc-2* gene, a dominant rust resistant gene. The identification of a specific binding protein for victorin in oat leaf slices has been reported by Wolpert and Macko. By using radioactively labeled purified victorin, we have found a victorin binding protein in oat protoplasts. Further studies have shown that the detected protein is located in the plasma membrane of oats as determined by binding to the protein in plasma membranes purified by aqueous two-phase partitioning.

PLANT ENVIRONMENTAL BIOLOGY GROUP

Introduction

Research in the Plant Environmental Biology Group is focussed on examining how plants and other photosynthetic organisms acquire inorganic carbon from the external environment and use it for efficient growth processes. In the case of higher plants, particular emphasis is placed on how this is achieved with optimal use of water and on the effect of environmental factors. These studies are being conducted at levels ranging from the ecophysiological and agronomic to the genetic and molecular bases of processes and responses, with a long term goal of being able to identify genetic elements which might be incorporated into commercially important agricultural species to improve their performance.

MOLECULAR ANALYSIS OF PHOTOSYNTHESIS

The aim of this program is to investigate the molecular basis of key photosynthetic processes in both agricultural and native species, for identification of ways in which the photosynthetic process might be manipulated to improve the performance of agricultural plant species.

Rubisco

Investigators: Matthew Morell, Kalanethee Paul, Heather Kane, Peter Thygesen, Juta Viil[§], John Andrews

The photosynthetic carboxylating enzyme, Rubisco, is interesting, not only because it catalyzes the only significant reaction by which the biosphere has access to inorganic carbon, but also because it appears to perform the task most inefficiently. Perhaps Rubisco's evolutionary refinement has been retarded by mechanistic constraints (but no sign of such constraints is presently obvious) or by complexities associated with the genes for its two constituent subunits being encoded in different cellular compartments in eukaryotes (the chloroplast and the nucleus) and its requirement for accessory proteins to aid in assembly and catalysis. Since major improvements in the efficiency with which plants use water, light and nutrients would be possible if this catalyst could be artificially improved, the sub-programme is aimed at assessing such prospects.

Last year, we became aware that there was another dimension to Rubisco's apparent inefficiency which had not previously been recognised. The catalytic reaction is prone to abortive side reactions, one of which produces the strong inhibitor, D-xylulose-1,5-bisphosphate, by stereochemically incorrect protonation of one of the intermediates of the reaction, the enediol of the substrate, D-ribulose-1,5-bisphosphate. This year, the list of by-products has been extended. A subsequent reaction intermediate, the C-2 carbanion of the product, 3-phospho-D-glycerate, decays by elimination of a phosphate ion to give rise to substantial quantities of pyruvate. These abortive reactions confirm the existence of the intermediates which give rise to them and provide insight into the catalytic mechanism.

Work on Rubisco's subunit interactions has continued using the *Escherichia coli* system for the separate expression of the cyanobacterial *rbc*L and *rbc* S genes developed previously. Mutations of the small subunit were made at two conserved residues, threonine-14 and tyrosine-17, on the N-terminal arm of the small subunit. These interact with highly conserved large subunit residues. Threonine-14 was replaced by either alanine, valine, glycine or aspartic

acid and cysteine by cysteine. Analyses showed that all five mutants were able to bind to large subunits and form active enzymes. However, the glycine-14, aspartic acid-14 and tyrosine-17 mutant small subunits bound less tightly to large subunits and induced 2- to 3-fold lower k_{cat} values than the wild-type small subunits. With the exception of the glycine-14 mutant enzyme, which had increased substrate affinities, all other mutant enzymes had similar substrate affinities to the wild type enzyme. To investigate the role of the N-terminal arm of the small subunit further, mutants with deletions in this region have been constructed and are being analyzed.

Previous studies indicated that a consistent difference in amino acid sequence, methionine or isoleucine at position 309, correlates with changes in CO_2 affinity of the Rubiscos from C_3 and C_4 plants, respectively. Crystallographic structural studies indicate that position 309 lies in a hydrophobic pocket between the N-terminal and $\alpha\beta$ barrel domains of the large subunit. Last year, a project was initiated to examine the effect of mutations at position 309 of the model Rubisco from the cyanobacterium, *Synechococcus* PCC6301. No change in CO_2 affinity was detected when isoleucine 309 was replaced by methionine. This year a range of further amino acid substitutions has been made at this position. Leucine was tolerated at position 309, but the highly conservative substitution of valine for isoleucine completely eliminated the ability of the enzyme to assemble into holoenzyme. Further substitutions with glycine, tryptophan and arginine were also unable to assemble.

A major impediment to study of the structure and function of Rubisco has been the lack of an efficient system for selecting Rubisco mutants with altered properties under defined conditions. Photosynthetic organisms such as plants, algae, cyanobacteria and bacteria all have limitations as selection hosts for a variety of reasons, including long generation times, complex genetic systems, poor transformability and the presence of CO_2 concentrating mechanisms. In order to overcome these limitations, a project was initiated this year which aims to construct an *E. coli* strain which will depend on two photosynthetic enzymes, phosphoribulokinase and Rubisco, for growth. A mutation which blocks glycolysis has been introduced into the *E. coli* chromosome and the phosphoribulokinase and Rubisco genes have been engineered for co-expression in *E. coli*.

Rubisco's relative specificity for CO_2, as opposed to O_2, controls the relative levels of the mutually antagonistic processes of photosynthetic CO_2 assimilation and photorespiration. The relative specificities of Rubiscos of bacterial, cyanobacterial, algal and higher-plant origins vary over an order of magnitude but the values for the higher-plant enzymes, which are the highest, cluster closely. Since this crucial property must be constantly under strong selection for increase, the progressive evolutionary refinement of Rubisco should leave its signature on this parameter. However, existing methods for measuring the relative specificity are not precise enough to reveal variation in relative specificity among the higher-plant enzymes. A new method has been developed this year which is based on the HPLC separation of the dephosphorylated reaction products. The method has the requisite repeatability (better than 1% under routine conditions) and avoids several sources of uncertainty which have bedevilled previous methods. The new method will be used to survey higher-plant Rubiscos for variability in the relative specificity in order to study its mechanistic basis and to determine whether specificity correlates with carbon isotope discrimination.

Genetic Manipulation of Photosynthesis

Investigators: John Andrews, Murray Badger, Graham Hudson, Dean Price, Matthew Morell, Prue Kell, Yvonne Arvidsson, Anne Gallagher, Wayne Gerlach+

Research into the photosynthetic process has advanced to the stage where genes are now available for many of the key enzymes and proteins. We have initiated a program that is aimed at specifically manipulating the activity and intrinsic catalytic properties of targeted proteins within the leaf. Our goal is to identify the nature of the rate limitations and regulatory processes which operate to determine how photosynthesis contributes to growth under various conditions.

The proteins have been chosen because of the controlling influence which they exert over photosynthesis. In the stromal reactions of photosynthesis, Rubisco and its associated proteins have been chosen, together with enzymatic steps which are directly upstream and downstream

of this reaction (phosphoribulokinase and glyceraldehydephosphate (GAP) dehydrogenase). In addition, carbonic anhydrase is also of interest because of its possible role in a CO_2 concentrating mechanism similar to that in cyanobacteria.

(i) Antisense RNA

The expression of antisense RNA in higher plants has provided the opportunity for reducing the level of individual proteins, thus producing plants with a range of activities of a specific protein within an otherwise isogenic background. The controlling influence of individual enzymes can, therefore, be directly tested *in vivo*.

Tobacco has been selected as a convenient model species for the introduction of antisense RNA constructs. However, this system has a limitation for work on photosynthesis in that relatively few genes or cDNAs for photosynthetic proteins have been cloned from this species. As an attempt to circumvent this problem, antisense constructs derived from spinach cDNA sequences were introduced into tobacco based on the hope that sufficient homology might exist with tobacco mRNA to allow effective inhibition of protein expression. Unfortunately, screening of constructs made against phosphoribulokinase, Rubisco activase and carbonic anhydrase showed that very little reduction in the activity of these proteins could be achieved by the use of heterologous antisense. By contrast, transgenic plants expressing antisense RNA to message for native tobacco Rubisco small subunit and subunit A from GAP dehydrogenase showed up to 90% suppression of gene expression. In view of this, tobacco DNAs for a number of the selected proteins are being isolated. Both the antisense Rubisco and GAP dehydrogenase plants are being analysed for changes in biochemistry, physiology and growth.

(ii) Engineering of phosphoribulokinase (PRK)

A spinach PRK cDNA was isolated by the polymerase chain reaction method and cloned into an expression vector under the control of the *lac* promoter. Induction of this promoter leads to the appearance of high levels of PRK protein in *E. coli*, and this induction was inhibitory to growth of the bacterium due to the production of high intracellular levels of ribulose bisphosphate. Site-directed mutagenesis of one of the regulatory cysteine residues (Cys-55) has been used to produce mutant enzymes with activities of 7% (Ser-55) and 0.8% (Gly-55) of the wild type enzyme as assayed in crude extracts. Purification and analysis of these mutant proteins will determine whether these mutations affect the stability or the catalytic properties of the enzyme. Expression of mutant PRKs with altered or defective regulatory properties in transgenic plants will be used to probe photosynthetic regulation.

Regulation of Gene Expression in C_4 Plants

Investigators: Graham Hudson, Yvonne Arvidsson, Paul Hattersley*, Nancy Dengler§, Ron Dengler§, Geoff McFadden+

The spatial distribution of specific mRNAs in the leaves of the dicots *Atriplex patula* and *Atriplex rosea*, two closely related C_3 and C_4 species, was investigated by *in situ* hybridization using ^{32}P-labelled RNA probes complementary to the mRNAs. The distribution of mRNA for the Rubisco activase protein closely followed that of the Rubisco small subunit mRNA. Both were found only in the bundle sheath cells of the C h4 plant leaf. This suggests that the activase is found only in conjunction with Rubisco, and therefore has no other target proteins. Attempts to use biotinylated RNA probes for *in situ* hybridization have so far been unsuccessful.

The CO_2 Concentrating Mechanism in Cyanobacteria and Green Algae

Investigators: Murray Badger, Dean Price, Jian Wei Yu, Kikki Palmqvist#, Karin Harrison

Aquatic phototrophs face special problems in obtaining CO_2 from the surrounding liquid environment. As an adaptation, many of them have developed mechanisms for actively acquiring both CO_2 and HCO_3-and are able to use this inorganic carbon to elevate their internal CO_2. This allows their primary photosynthetic carboxylase, Rubisco, to operate more efficiently. Our studies have involved the detailed examination of this mechanism in cyanobacteria as well as understanding how other more complex eukaryotic organisms may compare.

Study of the role of carboxysomes in cyanobacteria as the site of CO_2 elevation has continued. The DNA region which is immediately adjacent to the 5' end of the Rubisco large subunit gene has been cloned and sequencing is proceeding to determine the number of open

reading frames which may exist here and be involved in the assembly of a functional carboxysome. Antibodies are being made to both synthetic epitopes and expressed protein for selected ORFs in order to test whether these putative proteins may be involved in either the composition of the carboxysome coat itself, or perhaps are involved as coat assembly proteins.

A DNA region has been isolated which complements our previously isolated type II mutants. These mutants appear defective in carboxysome function but the lesion is in a region different to the 5' region of the Rubisco large subunit gene. Sequencing and analysis is proceeding to determine the function of this genetic region.

A concentrated effort is being made to isolate new mutants that are defective in either inorganic carbon transport or internal carbonic anhydrase which plays a presumptive role in CO_2 and HCO_3-interconversion. These mutants will be required to make further progress in understanding the molecular basis of the CO_2 concentrating mechanism (CCM).

In an attempt to compare the CCM in cyanobacteria and green algae, studies have been started with *Chlamydomonas* and *Scenedesmus* species. A mass spectrometric technique has been developed for quantifying the exchange of both HCO_3-and CO_2 between the cells and the external medium as well as both internal and external carbonic anhydrase. This is being used to examine the changes which occur in response to adaptation for growth at low inorganic carbon and the properties of various mutants which have already been isolated.

PHOTOSYNTHESIS, WATER-USE EFFICIENCY AND GROWTH

In higher plants the supply of CO_2 to Rubisco is via stomatal pores in the leaf epidermis. This inevitably allows the egress of water by evaporation, which brings with it the possibility of desiccation. Thus, the compromise between carbon gain and water loss is a fundamental one, even for C_4 plants with CO_2 concentrating mechanisms. The aim of the following programmes is to understand the control of carbon gain and water loss at scales increasing from the leaf to the paddock.

Biochemical and Physiological Studies of Photosynthesis aand Stomatal Conductance

Investigators: Susanne von Caemmerer, Ian Cowan, John Evans, Graham Farquhar, Sally Henderson, O.L. Lange+, T.G.A. Green+, Jon Lloyd§, Jim Syvertsen§

The rate of CO_2 assimilation of leaves can, over a wide range of conditions, be described by simple equations which summarise the underlying biochemical processes. Key components are the kinetic properties of Rubisco, the capacity for ribulose bisphosphate (RuP_2) regeneration, the concentrations of the substrates CO_2 and O_2, and the irradiance. A precise quantitative link between the rate of CO_2 assimilation, as measured by gas exchange and these biochemical components, requires that the CO_2 pressure at sites of carboxylation in chloroplasts be known.

Simultaneous measurements of gas exchange and short term carbon isotope discrimination were used to estimate a CO_2 transfer conductance from the intercellular airspaces to chloroplasts. Photosynthetic capacity was shown to correlate with the CO_2 transfer conductance and the average ratio of chloroplastic to intercellular CO_2 pressure was 0.7. This means that, in general, under high irradiance the ratio of chloroplastic to ambient CO_2 pressure is about 0.5. We showed that in wheat the CO_2 transfer conductance could be correlated with the chloroplast surface area appressing intercellular airspaces.

Conductances to CO_2 transfer have also been investigated in lichens. We have made progress towards a better understanding of sources and sinks, and diffusion pathways in the moist thallus by measuring net assimilation rate as a function of ambient partial pressure of CO_2 in air, and in helox (79% He, 21% O_2), in which CO_2 diffuses 2.3 times faster than in air. This has been done with nine species, with one of them, *Ramalina maciformis*, at a number of light intensities and thallus water contents. The results have enabled us to determine physical resistances to diffusion through the thallus and thus to characterise assimilation rate in the phycobiont as a function of local partial pressure of CO_2. As expected, the resistances are large and increase with increasing water contents, to the extent that the local pressure of CO_2 experienced by the algae in moistened lichens is generally about one-half that in ambient air. Our work now concentrates on relating diffusion resistances to the structure of thalli,

comparing assimilation characteristics in different phycobionts, and reinterpreting ecophysiological investigations of lichen function in the field.

The rate of assimilation that can be achieved with a given canopy investment in protein for photosynthesis depends on how this is invested in relation to light absorption. A lucerne canopy grown in a glasshouse was used to examine acclimation to natural shading and redistribution of nitrogen within and between leaves. Gradients in leaf properties were observed down through the canopy including photosynthetic capacity, leaf nitrogen content and chlorophyll a/b ratio. The gradient in photosynthetic capacity was due to a combination of remobilization of nitrogen out of lower leaves and photosynthetic acclimation to shade. The benefits of these changes were calculated using the measured daily course of irradiance. The lucerne canopy achieved 88% of the maximum potential daily photosynthesis through the combination of removing nitrogen from leaves low in the canopy and redeploying it at the top, as well as the change in nitrogen partitioning within the leaf due to photosynthetic acclimation. For the observed nitrogen profile through the canopy, photosynthetic acclimation improved potential daily photosynthesis by about 2%, close to the maximum possible. By contrast, nitrogen redistribution between leaves improved potential daily photosynthesis by 8% above that for a uniform distribution of nitrogen between the leaves. This was well below the 21% possible. It is intriguing that photosynthetic acclimation should occur when greater potential benefits could accrue by remobilising more leaf nitrogen from the older leaves deep in the canopy to the upper leaves.

The C_4 photosynthetic pathway serves to concentrate CO_2 in the bundle-sheath cells around the enzyme Rubisco. The efficiency of operation of this concentrating mechanism depends upon the fraction of CO_2 initially released into the bundle-sheath cells which leaks back out into the mesophyll cells or intercellular airspaces. At present little is known about the extent of this leakage. Our modelling of carbon isotope fractionation processes occurring during C_4 photosynthesis has related leakiness (the fraction of CO_2 fixed by PEP carboxylase which is subsequently lost by leakage from the bundle-sheath) to carbon isotope discrimination by the leaf. We have measured carbon isotope discrimination while the leaf is photosynthesising to estimate leakiness in *Sorghum bicolor* L. Moench. We estimated that leakiness is approximately 20% and that it does not vary in the short-term with changes in irradiance. *Sorghum bicolor* was also grown at several levels of nitrogen nutrition. Once again there was very little variation in leakiness between treatments. The estimates of leakiness made during short-term measurements of carbon isotope discrimination agree well with the estimates of leakiness made from whole plant measurements of transpiration efficiency and leaf dry matter carbon isotope composition described in a previous report.

Cassava is a staple source of carbohydrate in much of the third world. Others have reported that the plant is a C_3-C_4 intermediate. If so, this would complicate the task of recognising water-use efficient lines from measurements of carbon isotope discrimination (see next section). Gas exchange measurements were, therefore, made on leaves of Cassava to determine the CO_2 compensation point at different ambient O_2 pressures. The CO_2 compensation point is that CO_2 pressure at which the CO_2 uptake rate of leaves balances the CO_2 efflux rate. Cassava has a compensation point of 50 μbar CO_2 at 25°C and the compensation point increases linearly with oxygen concentration. These results clearly identify Cassava as possessing the C_3 photosynthetic pathway and as, therefore, being amenable to our normal carbon isotope analyses.

An important advance was made this year with the development of an explanation of the response of stomata to external evaporative conditions. Stomata sometimes close so much when ambient humidity is decreased that rate of transpiration is also decreased. This has generally been accepted as evidence that stomata sense external evaporative conditions directly, rather than indirectly through the leaf-internal consequences of vapour loss through the stomatal pores. However, an analysis has now shown that the response can be explained by a non-linear feedback mechanism. It is based on three assumptions: that, with partially open stomata, the

hydraulic pressure in the guard cell decreases as guard cell volume and stomatal aperture increase (i.e. the elastic modulus of the volume is negative, as it is in a partially inflated rubber balloon); that the metabolic processes influencing the amounts of solutes in the guard cell conspire to maintain osmotic pressure, (rather than osmotic content), constant at any given light intensity; and that water potential in the region of the guard cell is affected by efflux of vapour through the pore. There is some evidence for the truth of each of these assumptions. The first two assumptions provide a basis for the observation that stomatal apertures in a leaf are often highly heterogeneous, as they imply that guard cells can exist in either of two states at a given water potential.

Growth, Water-Use and Carbon Isotope Discrimination in Plants

Investigators: Graham Farquhar, Ian Cowan, Chin Wong, Susanne von Caemmerer, Candido Lopez-Castaneda, Helena Gomez-Macpherson, Kerry Hubick*, Josette Masle, Jim Virgona, David de Pury, Peter Groeneveld, Win Coupland, Derek Millar, Andy Mower, Sue Wood, Mary Grealy, Tony Condon*, Richard Richards+, Frank Dunin+, Tom Denmeand+, Ray Leuning+, Ian White+, Michael Dingkuhn+, S.K. de Datta+, John O'Toole+, Graeme Wright+, Alan Cruickshank+, Tony Hall+, R.G. Mutters+

We previously reported that the ratio of carbon gain by photosynthesis to water loss by leaves (transpiration efficiency) is negatively related to the discrimination against the naturally occurring, stable isotope ^{13}C during CO_2 fixation by C_3 leaves. This has been confirmed at the leaf level in field measurements of gas exchange by upland rice varieties.

The relationship between transpiration efficiency and crop growth and yield is potentially complex, even in regions normally thought to be semi-arid. With increasing scale, we have verified that wheat crops modify their microclimate. Further, the stomatal compromise between carbon gain and water loss, which ends up being expressed as transpiration efficiency, is so fundamental to the plant that it is inevitably associated with other aspects of plant functioning. For example, we have observed a tendency large transpiration efficiency to be associated with greater plant mass per unit leaf area, when measured at a given age of the plants. This tendency, by itself, would reduce relative growth rate in efficient lines. Despite these potential obstacles, it was a highlight of the year when analysis of large-scale experiments on two paddocks of wheat, of cultivars with contrasting carbon isotope discrimination, revealed that greater transpiration efficiency occurred in the cultivar with least discrimination. The experiments have been repeated this year, with more detailed studies of advection, and especially of soil water loss. The low discrimination line, because of its carbon partitioning, tends to show slower earlier growth, thereby allowing more soil water loss.

The observations have given impetus to studies of early growth in wheats and barleys. These reveal that faster germination in barley is associated with a greater embryo size in seeds of the same weight.

The large-scale experiment has also been of interest in the context of global atmospheric change, as the variety with least discrimination has the stomatal conductance that we expect the other variety would have if atmospheric CO_2 levels were doubled.

Effects of Increased CO_2 Concentration on the Growth of Plants

Investigators: Chin Wong, Graham Farquhar, Paul Kriedemann#, Ying Ping Wang , Roger Gifford+

In an attempt to predict some future effects of global atmospheric change on growth of wheat canopies, we have extended our models of CO_2 assimilation to include partitioning of carbon, respiratory losses, light absorption within canopies and some simple aspects of development. The model was tested against field data at ambient CO_2 levels and glasshouse data at double the ambient level. It was predicted that the direct beneficial effect of elevated concentration on growth will counterbalance the more rapid development caused by a three degree rise in temperature.

Climate change in future decades will be associated with a steady increase in atmospheric CO_2 concentration. Present levels of about 350 ppm are expected to double in the next 50 years. Plant growth will be affected, but the nature and scale of that response is likely to vary between species, and between provenances within a species. In order to predict vegetation response to this aspect of climate change, process-based models require data on CO_2-driven growth responses as inputs. Our experiments with Australian tree species address that need.

Accordingly, three provenances of *Acacia melanoxylon* and four species of eucalypt which contrast in form and habitat and inherent vigour were raised as seedlings under either normal ambient (350 ppm) or CO_2-enriched (700 ppm) conditions on either of two levels of nitrogen

supply (provided as a soil supplement of nutrient solution containing either 1.2 or 6.0 mM nitrate). This 2 x 2 factorial combination was applied to both Acacia and eucalypt.

Three provenances of *A. melanoxylon* were used in the study: (1) Burnie, Tasmania; (2) Tallaganda, NSW; and (3) Atherton Tableland, Queensland. They responded differently to nutrient levels and CO_2 enrichment. The Atherton Tableland provenance responded positively (3X) to high nutrient levels at both atmospheric CO_2 concentrations, while in Tallaganda and Burnie provenances, nutrient level had no effect on growth at 350 ppm CO_2. At 700 ppm CO_2, high nutrient level caused a three-to five-fold increase in dry matter yield.

At low nutrient level, doubling CO_2 concentration had no effect on dry matter accumulation of Burnie and Tallaganda provenances; there was a 1.5-fold increase in dry matter in Atherton Tableland provenance. At high nutrient level, there was an eight-fold increase in dry matter yield in Burnie provenance and two-and three-fold increase in dry matter yield in the Tallaganda and Atherton Tableland provenances.

In *Eucalyptus camaldulensis, E. cypellocarpa, E. pauciflora* and *E. pulverulenta*, analysis of growth over 12 weeks has revealed positive growth responses to elevated CO_2 in all species, with a highly significant CO_2 by nitrogen nutrient interaction, varying according to species and stage of growth but not necessarily correlating with inherent "vigour" or size of mature trees. Moreover, biomass response to high nitrogen nutrition, and especially in combination with elevated CO_2, was accompanied by a change in plant form from a single stem, virtually free of axillary growth to branched and even multiple stemmed seedlings.

Genetic Analysis of Growth and Water Use

Investigators: Graham Farquhar, Josette Masle, Jeong-Sheop Shin*, Jim Virgona, Kate Clark, Jenny Read+

When plants grow in dry soil, their roots experience difficulty in penetrating it. We showed previously that plants grow more slowly and transpire less in soil with high mechanical resistance (dry or compact soils). Our earlier work had shown that these effects are primarily induced by a message produced in the roots when they sense adverse conditions. This year, genetic variation in the nature and amplitude of the response was investigated. We found large variation in both wheat and barley, the amplitude of which seems to be dependent on the radiation level (smaller response at low light -200μE m^{-2} s^{-1} vs 600), and more homogeneous among barley genotypes). Two of the 21 genotypes studied were largely unaffected in their stomatal conductance, whereas growth was significantly reduced, indicating that either production or perception of the signals mediating the two responses are at least partially different. We plan to use the extreme genotypes to see if high soil mechanical resistance affects growth via an effect on gene expression.

At a more detailed level, the analysis, started last year, of DNA polymorphisms associated with variation in carbon isotope discrimination (i.e. water-use efficiency) was continued. Two *Arabidopsis* ecotypes, having extreme values of carbon isotope discrimination (Δ) and showing several DNA polymorphisms were selected and crossed to produce F1 and F2 progeny. F3 families are now being grown for further analysis of the correlation between Δ and the identified DNA polymorphisms.

The ratio of total plant carbon to leaf area, ϱ, is an important parameter determining the early growth of plants. A negative association between ϱ and Δ (and water-use efficiency) has now been observed in sunflower, peanut, wheat, barley (and a wild relative). Some of the genotypic differences in ϱ disappear when ϱ is compared at a given biomass, suggesting that the underlying relationship may be more one between development and Δ. We noted previously that a variety of Chico, which has a rapid approach to the reproductive stage, is a plant with large Δ. This general pattern has now been observed elsewhere among annual plants.

A most interesting pattern was found among (perennial) *Nothofagus* species. This genus is found over a wide range of what was once Gondwanaland. When seeds or cuttings of species from different habitats were grown in a common, controlled environment, large variation in Δ was observed which showed a negative relationship with the amount of rainfall that those

species (or ecotypes) would normally receive in their native habitats during the driest months of the year. It appears that the trees native to the driest places are opportunistically reacting the most to the availability of water. Apart from its ecophysiological interest, this finding has implications for the plant collector seeking material relevant to breeding programs on water-use efficiency.

Stomatal Development

Investigator: D. Carr #

During 1990 the cuticles of the central Australian bloodwoods were studied, continuing similar work on Western Australian and Queensland bloodwoods published in *Eucalyptus II* (Phytoglyph Press, Canberra 1988). The eleven species were shown to have characteristic features of leaf cuticles, and the cuticles of nectaries and stamens which enable them to be distinguished using herbarium material. The differences are both qualitative and quantitative. An important addition to previous descriptions is a table of the frequency spectra of subsidiary cells of the leaf stomata. The spectra are constant within narrow limits for a species, different for the two sides of the leaf and different for different species.

In addition, studies were made of the development of the stomatal complexes in different groups of eucalypts, and in species of *Angophora*. In all eucalypts and angophoras, the cotyledons have stomata which develop following one or two divisions of a single cell, a type known as unilabrate or dolabrate. By the fourth seedling leaf the adult type of stomatal development is achieved, which then persists throughout life. Three types of adult development are found. In the bloodwoods and the *Clavigerae* (paper bloodwoods), the adult stomata develop after three divisions of a single initial, cutting off a central guard mother cell (anisocytic). One group of eucalypts (*Monocalyptus sensu* Carr and Carr, 1959) previously thought to be related on grounds of comparative morphology, especially of the flower, were found to have stomatal complexes conforming to a type, rare among angiosperms, known as staurocytic. They develop from anisocytic initials, but the orientation of the guard mother cell division and readjustments of shape of the subsidiary cells yields an end result different from that of other eucalypts. The third group, including all other eucalypts maintain the uni/dolabrate development of the cotyledons throughout life. The existence of three main types of origin of stomata characteristic of three large groups of eucalypts is of interest in the taxonomy of the genus.

ECOSYSTEM DYNAMICS GROUP

Introduction

Australia's terrestrial ecosystems are an irreplaceable natural resource vital to the maintenance of reasonable living standards. Our biotic resources are coming under increasing threat from human activities such as clearing, logging, fire and global change. Their successful management depends on our ability to understand and predict the ensuing changes in plant communities. Our goal is to improve these abilities by combining experimental and field studies of the structure and functioning of native plant communities with the development of ecological theory, and models and software to assist land managers.

Global Change

Investigators: M. Austin#, M. Ball, J. Landsberg, I. Noble, D. Moore*, M. Stafford Smith*, P. Werner+, J. Williams

Many of the Group's studies are related to the impact that global atmospheric and climatic change will have on our terrestrial ecosystems. Some studies are field based, others are in the laboratory and glasshouse, while others emphasise the use of computer models to improve our understanding of the changes that face us.

Mangrove communities will be particularly sensitive to changes in sea level, climate and CO_2. They are providing us with insights into the impacts we might expect in other communities. Dr Ball has shown that the distribution of species within mangrove forests is strongly influenced by interspecific differences in water use characteristics in association with

differences in salt tolerance. She is now mapping forest properties across the wet-dry gradient from Cape York to Western Australia where regional variation in climatic factors reduce water use efficiency with little change in coastal temperature regimes. These data, along with glasshouse experiments designed to determine how interspecific differences in water use and water use efficiency relate to differences in growth, carbon partitioning and salt balance under different climatic conditions, will be used to establish quantitative models of the responses of mangrove vegetation to changes associated with the "greenhouse" effect.

Similar studies have begun in the eucalypt forests of south-eastern Australia. Drs Ball, Austin and Williams are surveying strategies of carbon gain in relation to water use in selected eucalypt species of commercial and ecological importance. They wish to determine whether interspecific differences in the rate and efficiency of water use are associated with differences in growth, carbon partitioning and foliage architecture, and whether differences in water use characteristics are correlated with the differential distribution of species along environmental gradients of rainfall and temperature.

Drs Landsberg and Stafford Smith are concentrating on the impacts of both climate change and management actions on insect populations associated with dieback of eucalypts. They have developed a deterministic model of the dynamics of the insects and trees based on Dr Landsberg's detailed field studies over the past 10 years. Increased dieback has resulted from increased nitrogen concentrations in the soil due to current agriculture practices, and will be exacerbated by higher temperatures or wetter summers due to global change.

This is only one of several models relevant to climate change being developed in the Group. Dr Noble used 60 years of data from an arid zone field station maintained by the University of Adelaide to show that the frequency and composition of the flushes of pasture growth are very sensitive to even small changes in the winter temperatures and rainfalls. Savannas support 30% of the world's population and are particularly susceptible to global change. Their unique structure of scattered trees over a grassy understorey is determined by a delicate balance of several processes including competition for water and the impact of fires. They can be easily changed by small pertubations to dense shrub thickets or sparse grasslands. Dr Noble has developed several models of savannas. One is being incorporated in a Decision Support System for land-owners in western New South Wales (RESTORELAND—a joint project with CSIRO and the NSW Soil Conservation Service). With Dr Werner he is analysing the response of tropical savanna communities to different fire regimes and applying the data to a model designed to assist in managing fires in the Kakadu area. David Moore and Dr Noble are developing expert systems to assist managers to set up and run these models. In a multi-continent collaboration they are developing a model of the tree-grass interactions that might be applied to a wide range of savanna situations, world wide.

Process Studies

Investigators: Marilyn Ball, Joe Connell[#], David Gillieson[+], Mike Hodda, Chris Holly[†], Alan House[#], Susan House, Heather Keith, Jill Landsberg, Greg Laughlin[†], Ian Noble, Jann Williams, Scott Wilson, Charlie Zammit

Global Circulation Models predict that the impact of "greenhouse" processes will lead to environmental conditions not previously experienced. Thus we will be increasingly dependent on the theoretical basis of our physiological and ecological sciences to predict ecological change. Most of the Group's effort is directed to improving this theoretical basis by seeking to understand basic ecological processes so that we will be in a better position to anticipate change.

Light is usually regarded as a resource, but it can also be a major source of stress. Photoinhibition is light-dependent loss of photosynthetic capacity that occurs when leaves are exposed to both high irradiance and environmental stresses, such as freezing temperatures or drought. In a collaborative study Mr Holly, Dr Laughlin (Geography Department, ANU), and Dr Ball found that the growth of *Eucalyptus polyanthemos* saplings was enhanced by protecting plants from exposure to high light intensities during winter. These results have implications for improving the success of tree establishment in cold areas. Drs Ball and Williams are extending these studies to the interactive effects of light and low temperature in eucalypt forests.

Dr Marilyn Ball (left) and Karl Grigulis preparing *Eucalyptus pauciflora* seedlings for field planting in ecological experiments. Dr Ball has indentified interactions between light and cold which strongly influence the successful regeneration of species. Her findings have major implications for replanting strategies used by commercial foresters and other concerns, such as 'Greening Australia'.

The dynamics of savanna communities are affected by the pathways of nutrient usage. Termites consume substantial quantities of plant material but fire is another 'competitor' for this material. Mike Hodda has been examining the impact of termites on tropical woodlands in relation to buffalo grazing, water availability, vegetation and fire regimes. Buffalo and water availability are the major influences that determine the distribution of termite communities; fire affects their dynamics. In the absence of fire many nutrients are used for colony metabolism and expansion. By contrast, on frequently burnt sites colonies become smaller and most effort is devoted to reproduction.

The long-term consequences of different fire regimes are central to Heather Keith's work in south-eastern eucalypt forests. Repeated low-intensity prescribed burning reduces both the soil mineral-N level and the rate of mineralization and thus the availability of N for plant uptake. Trees respond to changes in nutrient supply differently in the growth of the trunk and foliage. The main effect of changed nutrition is in the growth of leaf area but not in leaf level assimilation rates.

Nutrient availability not only affects the growth of trees but also the growth and impact of leaf eating insects. In a collaborative study by Dr Landsberg with Dr Gillieson (Australian Defence Force Academy), the influences of climate and soil nutrition on soil, development, tree growth and insect herbivory have been investigated in natural eucalypt communities at sites located along a climatic gradient ranging from the cool humid foothills of the Victorian Alps to the warm arid mallee woodlands of western NSW. Insect damage peaks at climates similar to that of Canberra. Measurements in native oak woodlands growing along a similar climatic gradient in Arizona confirm the Australian results.

Much of the work in the Group is conducted along environmental gradients so that we can test the generality of the conclusions reached. Dr Wilson has conducted a series of field experiments to show that relative importance of above- and below- ground competition varies inversely along environmental gradients.

Dr Zammit is investigating the factors influencing seed survival and seedling establishment in unburnt *Eucalyptus* forest. The project is divided into two experiments using eight representative forest species from three matched dry forest sites and three matched wet

forest sites. The first experiment evaluates the impact of seed predators and seed fungal pathogens on seed survival, while the second experiment examines the importance of herbivory and competition on seedling establishment.

Professor Connell with Dr Noble and collaborators from the Universities of New England, Griffith and the World Heritage Commission, DASETT are studying the community ecology of tropical and subtropical rain forests. The main question being addressed is "what are the mechanisms that control the species diversity"?. Another question of interest is: "how do recruitment, growth and mortality vary in space and time among the different species of trees in rain forests"? Long-term records (27 years) of recruitment, growth and mortality have been kept for two rain forests in north and south Queensland, and a shorter term record (6 years) for a rainforest in lowland New Guinea.

In another rainforest study Dr Alan House is asking why the ecotone between rainforests and open eucalypt forests in north Queensland is so dynamic. In the absence of fires, rainforest taxa establish rapidly and a semi permanent shift in repetition distributions can result. The determinants of the rates of these changes are being investigated, in particular, the spatial organization of species, and the viability in soil nutrients in eucalypt forests in relation to patterns of rainforest establishment. Rates of vegetation change over the past c.10,000 years are also being measured by quantifying and ageing charcoal present in rainforest soils.

Dr Susan House argues that differential reproductive capacities of trees may be one process operating in the formation of natural ecotones in eucalypt forest systems and in fragmented environments. Is pollen flow to outliers restricted, resulting in reduced genetic variation and fewer, viable seed in their seed crops compared with trees growing in higher densities? Outcrossing rates (using allozyme electrophoresis), seed number and viability are being compared between seed crops of isolated and aggregated trees in eight populations of *Eucalyptus stellulata*. The responses of the pollinating fauna to the changes in density of the floral resource in space and time are also being monitored.

Ecological Theory

Investigators: Peter Chesson, Habiba Gitay, Hugh Possingham, Ian Noble, David Stockwell

Some of the activities of the Group are related to fundamental research that seeks a theoretical basis for the stability of the complexity of ecosystems. Dr Possingham and Dr Chesson are studying the theory of plant life-history adaptations and behaviour in the context of a variable environment. Dr Possingham is focussing on optimal water use strategies, leaf adaptations to light, and resource allocation during growth. He is using a technique called stochastic dynamic programming to predict plant behaviour. These analyses may lead to a classification of plant species on the basis of their ecological characteristics, i.e. functional groups, and insights into the structure of ecosystems. Dr Noble has tentatively identified two functional groups of eucalypt species and he and Dr Gitay are examining the basis of the classification via field experiments.

Population viability analysis is a theory that can predict whether a species will persist in a fragmented environment. Drs Possingham and Noble are being supported by the Resources Assessment Commission inquiry into forestry to develop models of the viability of populations partially isolated by fragmented environments to help them assess the conservation potential of spatially complex forests.

Artificial Intelligence is finding wide application in natural resources management. Members of the group are involved in research on decision support systems, geographic information systems, and modelling animal a plant interactions with the environment. David Stockwell is combining machine learning with biological modelling to provide tools for building applications of artificial intelligence in ecology. Some advantages of automating model development with machine learning are greater predictive accuracy, speed of model development and meaningfulness of the resulting models to users. His work has led him to a formal description of scientific explanation and an analysis of the preferences of scientists and lay-people for particular types of explanation. His results may lead to better communication both between computer-based advisory systems and between scientists and their audience.

JOINT RESEARCH PROJECTS UNDERTAKEN WITH OTHER UNIVERSITIES AND CSIRO

DEVELOPMENTAL NEUROBIOLOGY GROUP

The regulation of phototransductive membrane turnover in arthropods via protein phosphorylations by Drs A.D. Blest and S. Stowe with Dr Y. Tsukitani, Fujisawa Pharmaceutical Co. Ltd, Tokyo.

The role of putative mechanoenzymes represented by the *ninaC* gene products of *Drosophila* in the extracellular membrane shedding of phototransductive microvilli by Drs A.D. Blest, S. Stowe and J.A. Clausen with Dr D.S. Williams and J.L. Hicks, School of Optometry, University of Indiana at Bloomington, USA.

The roles of cysteine proteases specific to the photoreceptors of *Drosophila* by Drs A.D. Blest, J.A. Clausen and S. Stowe* with Dr L. Kelly, Department of Genetics, Melbourne University.

Pharmacological dissection of the roles of different categories of protein kinases in the regulation of arthropod phototransductive membrane turnover by Drs A.D. Blest and S. Stowe* with Dr P.D. Davis, Roche Products Ltd., UK.

Effects of molecular genetic manipulation of the phosphorylation sites of a *Drosophila* rhodopsin on photoreceptor membrane turnover by Drs A.D. Blest and S. Stowe with Dr S. Britt and Professor C. Zuker, Howard Hughes Institute for Medical Research, University of California at San Diego, USA.

Role of protein phosphorylations in the biochemical defects of the *Drosophila* light-dependent retinal degeneration mutant $rdgB^{KS222}$ by Drs A.D. Blest, J. Clausen and S. Stowe* with Professors B. Minke and Z. Selinger, the Hadassah Medical School, University of Jerusalem, Israel.

Regulation of phototransductive membrane synthesis in higher Diptera by Drs A.D. Blest, J. Clausen and S. Stowe with Dr J. Schwemer, Ruhr Universitat, Bochum, FRG and Dr H.G. de Couet, University of Hawaii, USA.

Time course of rate responses to two-tone stimuli in auditory nerve fibres in the guinea pig by Dr K.G. Hill with Dr A. Palmer, MRC Institute for Hearing Research, University of Nottingham, England.

Fine-temporal analysis of spike responses to two-tone stimuli in auditory nerve fibres in the cat, by Dr K.G. Hill with Professor C.D. Geisler, Department of Neurophysiology, Madison, Wisconsin, USA.

Development of cortical barrels in somatosensory cortex of the wallaby by Dr L.R. Marotte, Professor R.F. Mark and Ms M. Porter with Dr P. Waite, School of Anatomy, University of NSW.

Sensory innervation of the mystacial vibrissae in the wallaby by Dr L.R. Marotte and Professor R.F. Mark with Professor F. Rice, Department of Anatomy, Albany Medical College of Union University, Albany, New York, USA and Dr P. Waite, School of Anatomy, University of NSW.

Development of axonal arborizations from retinal ganglion cells in the superior colliculus of the wallaby by Professor R.F. Mark and Dr L.R. Marotte with Professor G.E. Schneider, Dr S. Jhaveri and Dr R. Erzurumlu, Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology.

Innervation of the superior colliculus by retinal fibres by Dr L.R. Marotte and Professor R.F. Mark with Drs G.E. Schneider and S. Jhaveri, Massachusetts Institute of Technology, Department of Brain and Cognitive Sciences, USA.

Development of auditory pathways in the brainstem and ultrastructure of the cochlea by Drs A.W. Gummer and L.R. Marotte and Professor R.F. Mark with Dr C. Hackney, Department of Communication and Neuroscience, University of Keele, UK.

Auditory efferent projections in the pouch young and adult Tammar wallaby, established with fluorescent retrograde neuronal tracers by Dr A.W. Gummer, Dr L.R. Marotte and Professor R.F. Mark with Dr D. Robertson and Mr K.S. Cole, Department of Physiology, University of WA.

Temporal response patterns of auditory nerve fibres to current injection into scala media of the pigeon by Dr A.W. Gummer with Drs L. Schermuly and T. Vossieck and Professor R. Klinke, Klinikum der J.W. Goethe-Universität, Zentrum der Physiologie, Frankfurt am Main, Germany.

MOLECULAR NEUROBIOLOGY GROUP

Characterization of molecules important in early neuromuscular development in the grasshopper by Dr E.E. Ball with Dr M.J. Bastiani, University of Utah, Salt Lake City, USA.

Cloning and characterization of grasshopper homeobox genes by Dr E.E. Ball with E.J. Rehm, Dr N.H. Patel, and Dr C.S. Goodman, Univ. of California, Berkeley, USA.

Development and evolution of giant neurones in the orthopteroid insects by Dr E.E. Ball with Dr G.S. Boyan*, Univ. of Basle, Basle, Switzerland

Neuromuscular development in embryonic insects by Dr E.E. Ball with Dr P. Whitington, University of New England, Armidale.

Neural circuitry in the auditory systems of moths underlying avoidance responses to predatory bats by Dr G.S. Boyan with Dr L.A. Miller, Biology Institute, University of Odense, Denmark.

Common neural pathways in tympanate and atympanate moths by Dr G.S. Boyan with Dr J.H. Fullard, University of Toronto, Canada.

Isolation of large *Drosophila* DNA molecules from the base of the X-chromosome in yeast artificial chromosome (YAC) vectors by Dr G.L.G. Miklos with Professor N. Perrimon, Mr R. Binari and Mr A. Link, Howard Hughes Medical Institute, Harvard University, Boston, Massachusetts, USA.

Molecular neuroanatomy of the *small optic lobes locus* by Dr G.L.G. Miklos with Professor K.F. Fischbach, University of Freiburg, Freiburg, FRG.

Cloning and characterization of the neuromuscular gene, *flightless*, by Dr G.L.G. Miklos with Dr H.G. de Couet and Ms N. Ozsarac, University of NSW and University of Hawaii, USA.

Molecular characterization of DNA sequences in divisions 19 and 20 by Dr G.L.G. Miklos and Mr J. Cotsell, with Dr K. O'Hare, Imperial College of Science and Technology, London, UK.

Molecular cloning of the neurological *stoned* gene complex by Dr G.L.G. Miklos with Dr L. Kelly, University of Melbourne.

Molecular characterization of the *Drosophila* homologue of the human S6 kinase gene by Dr G.L.G. Miklos with Professor R. Erikson and Ms S. Ottilie, The Biological Laboratories, Harvard University, Cambridge, Massachusetts, USA.

Molecular analyses of cephalopod nervous systems by Dr G.L.G. Miklos, with Drs C.C. Lu and L. Christidis, Museum of Victoria, Melbourne and Professor J.H. Choat, James Cook University, Townsville.

Molecular analysis of the human homologues of the *Drosophila shaking* gene complex by Dr G.L.G. Miklos with Dr J. Davies, University of Glasgow, Scotland, UK.

VISUAL SCIENCES GROUP

Depth perception in insects by Dr M.V. Srinivasan with Dr M. Lehrer, Zoologisches Institut, University of Zurich.

Electrophysiology of honeybee vision by Dr M.V. Srinivasan and Dr M. Ibbotson with Dr T. Labhart, Zoologisches Institut, University of Zurich, Switzerland.

Expression of peptoenkephalin mRNA in avian retina by Dr I. G. Morgan with Dr M. Dowton, Max-Planck-Institut für Experimentelle Medizin, Göttingen.

Lateral inhibition in visual systems by Dr M.V. Srinivasan with Professor R.B. Pinter, University of Washington, Seattle, USA.

Localization of GABA receptors in avian retina by Dr I.G. Morgan with Professor A. de Blas, Department of Molecular Biology and Biochemistry, University of Kansas.

Localization and function of calretinin in retinal neurones by Dr I.G. Morgan with Dr Z.H. Rogers, Physiological Laboratories, Cambridge.

Modelling of directionally selective neurons by Dr I.G. Morgan and Mr R. Poznanski with Dr D. Vaney, National Vision, Hearing and Touch Centre, University of Queensland.

Non-Fourier motion detection in insects by Dr M.V. Srinivasan and Dr P. Sobey with Professor C. Thomas, Case Western Reserve University, Cleveland, Ohio, USA.

Orientation discrimination in honeybees by Dr M.V. Srinivasan with Mr P. Wait, University of Adelaide.

Pattern recognition in honeybees by Dr M.V. Srinivasan with Dr H. van Hateren, Department of Biophysics, University of Gröningen, The Netherlands.

Peptidase activities in the vertebrate retina by Dr I. G. Morgan with Dr M.K. Boela, Bendigo College of Advanced Education.

Responses to excitotoxins of retinal neurons by Dr I. G. Morgan with Dr D. Ehrlich, Department of Anatomy, Monash University.

Neuropeptides in the retina by Dr I.G. Morgan with Professor I.W. Chubb, Division of Biochemistry and Molecular Biology, Faculty of Science.

Virtual-motion illusions by Dr M.V. Srinivasan with Professor K.G. Goetz, Max-Planck Institut für biologische Kybernetik, Tubingen, Germany.

Localization of Thy1 and related proteins in avian retina by Dr I.G. Morgan with Dr P. Jeffrey, Children's Medical Research Foundation, University of Sydney.

MOLECULAR AND POPULATION GENETICS GROUP

Population genetics of *Acacia melanoxylon* (Blackwood) by Ms J. Playford with Dr G.F. Moran, CSIRO Division of Forestry and Forest Products and Dr R. Appels, CSIRO Division of Plant Industry.

Studies on the differential expression of the oncogenes in human gastric cancers by Drs H. Naora and L.-Q. Sun with Professor C.-Z Su, the Fourth Military Medical University, Xi'an, PRC.

Molecular and morphological studies of specific functions of platypuses by Dr H. Naora with Dr T. Tsujii, Shigei Medical Research Institute, Okayama, Japan.

Evolution of genes and genomes by Dr H. Naora with Professor R.N. Curnow, University of Reading, Reading, UK.

Reversible conversion of cells between cancerous and normal states by Dr H. Naora and Mr Z.-Z. Xu with Professor S. Seno, Shigei Medical Research Institute, Okayama, Japan.

The population genetics and taxonomic status of *Acacia melanoxylon* by Ms J. Playford with Dr R. Appels and Dr G. Moran, CSIRO Divisions of Plant Industry and Forestry, respectively.

Evolution of the Australian avifauna by Dr D. D. Shaw and Mrs S. Maynes with Dr L. Christidis, Museum of Victoria, Melbourne.

Establishment of cell cultures from grasshopper embryos by Dr D.D. Shaw with Dr P. Christian and Ms C. Fernon, CSIRO Division of Entomology.

MOLECULAR EVOLUTION AND SYSTEMATICS GROUP

Comparative anatomy and physiology of grasses by Dr P. Hattersley with Professor R.H. Brown, College of Agriculture, University of Georgia, USA; Dr R.E. Dengler, Life Sciences Division, University of Toronto, Canada; Professor N. Dengler, Department of Botany, University of Toronto and Dr J.R. Wilson, CSIRO Division of Tropical Pastures, Brisbane.

Preparation of automated descriptions, provision of interactive identification and information retrieval facilities, research into grass classification and preparation of floristic treatments by Dr L. W. and Mrs J. Lenz with Dr M.J. Dallwitz, CSIRO Division of Entomology, Canberra, Mr M. Lazarides, Australian National Herbarium and Dr G.E. Gibbs Russell, National Botanical Institute, Pretoria, South Africa.

Biosystematics and phylogeny of the endemic Australian wheatgrasses (Australopyrum) by M.J. Henwood with Dr R. Appels and Dr J.G. West (CSIRO Division of Plant Industry, Canberra).

Photosynthetic pathway variation in *Alloteropsis* Presl (Poaceae) by Dr P. Hattersley with Ms C. Long, Faculty of Science, Northern Territory University, Darwin, NT.

Compilation of a database (the VIDE project) of diagnostic information on plant viruses by Dr A. Gibbs with Ms Karen Crabtree, now of CAB International, Wallingford, UK and Dr A. Brunt of Horticulture International, Littlehampton, UK and about 200 plant virologists worldwide. Collation of a database of diagnostic information on the plant viruses of India by Dr A. Gibbs with Professor A. Varma and Mr S. Viswanath of the Indian Agricultural Research Institute, New Delhi.

Establishment of a network of plant virologists in the Asia Pacific region, and a bank of reference antisera for plant virus identification with staff of the Department of Agriculture, Bangkok, Thailand by Dr A. Gibbs. Compilation of a database of diagnostic information on plant viruses of Thailand, and testing of methods of data handling by Dr A. Gibbs and Mr D. Southwell with Ms U. Dilokunanant of Kasetsart University, Bangkok.

Potyvirus taxonomy by Dr A. Gibbs with Dr D. Shukla and Dr C. Ward of the CSIRO Division of Biomolecular Engineering, Melbourne.

Taxonomy and transposition mechanisms of the GC clusters of yeast mitochondrial DNA by Dr G. Weiller with Dr R.J.Schweyen, Vienna and Dr R.A. Butow, UTSW, Dallas, USA.

Studies on taxonomic significance of leaf epicuticular waxes in the Epacridaceae by Dr Carolyn Mihaich with Dr R.K. Crowden, University of Tasmania and Dr J.M. Powell, National Herbarium of NSW.

PLANT CELL BIOLOGY GROUP

Actin proteins: presence and involvement in division of *Chlamydomonas* by Dr D.W. McCurdy and Dr P.C.L. John with Dr J.D.I. Harper* and Dr J. Salisbury, Mayo Clinic, Minnesota, USA.

Calcium-dependent protein kinase and cytoplasmic streaming in plants by Dr D.W. McCurdy with Dr A.C. Harmon, University of Florida, Gainesville, USA.

Cell cycle control proteins and lateral root development by Dr P.C.L. John and Professor F. Wightman, Carleton University, Ottawa, Canada.

Cloning of cell cycle genes by Dr P.C.L. John with Dr M. Lee, Glaxo Group Research Ltd., UK.

Conserved cell cycle control proteins by Dr P.C.L. John with Dr J. Hayles and Professor P. Nurse, Oxford University, UK.

Construction of a physical map of *Arabidopsis thaliana* by Drs J. Plazinski and R.E. Williamson with Dr E. Dennis, CSIRO Division of Plant Industry, Canberra, Dr D. Smythe, Monash University, Dr C. Deane, John Innes Centre, Norwich, UK and other overseas groups.

Control of cytoskeletal changes during plant cell division by Mrs Liping Wu, Dr P.C.L. John and Professor B.E.S. Gunning with Professor J. Pickett-Heaps, University of Melbourne.

Expression of cell cycle control genes in suspension culture cells by Dr P.C.L. John with Dr T.J. Higgins, CSIRO Division of Plant Industry, Canberra.

Hormonal control of lateral root development by Dr D.S. Letham with Professor F. Wightman, Carleton University, Ottawa, Canada.

Hormonal control of leaf senescence by Dr D.S. Letham with Professor L.D. Noodén, University of Michigan, USA.

Hormonal control of bulb dormancy by Dr D.S. Letham with Dr N.G. Smith, University of New England, Armidale, NSW.

IAA conjugates and differentiation patterns by Dr P.M. Warren Wilson with Dr P.J. Hall, Hiram College, Hiram, Ohio, USA.

Molecular characterization of symbiotic genes in *Anabaena-azollae* strains by Dr J.Plazinski with Dr W. Shaw, Northern Territory University, Darwin.

Monoclonal antibodies for diagnosis of *Phytophthora* disease by Dr A.R. Hardham with Dr R. Wills, Department of Conservation and Land Management, Dwellingup, WA.

Phosphorylated proteins and microtubule organizing proteins in plants by Dr P.C.L. John with Dr P.N. Rao, University of Texas, USA.

The dieback fungus *Phytophthora cinnamomi*: development of the infective agent by Dr A.R. Hardham and G. Hyde with Professor P. K. Hepler, University of Massachusetts, Amherst, USA.

The infection of plants by the dieback fungus *Phytophthora cinnamomi* by Dr A.R. Hardham with Professor K. Mendgen, University of Konstanz, FRG.

The role of the cytoskeleton in embryo sac development, fertilization and early embryogenesis in *Arabidopsis* by Professor B. Gunning with M. Webb and Professor R.B Knox, School of Botany, University of Melbourne.

Transfer of hormone genes to plants by Dr D.S. Letham with Dr E. Cornish, Calgene Pacific, Melbourne.

Transfer of hormone genes to plants by Dr D.S. Letham with Dr T.J. Higgins, CSIRO Division of Plant Industry, Canberra.

Use of monoclonal antibodies for rapid diagnosis of the dieback fungus *Phytophthora cinnamomi* by Dr A.R. Hardham with Dr E. Scott, Waite Institute, SA.

PLANT MICROBE INTERACTION GROUP

Analysis and characterization of acid tolerant *R. trifolii* strains by Professor B.G. Rolfe and Dr M. Djordjevic with Dr R. Roughley, Department of NSW Agriculture, Gosford, NSW.

Analysis of bacterial oligosaccharides and acid exopolysaccharides by Professor B.G. Rolfe and Dr S. Djordjevic with Professor J. Redmond and Dr M. Batley, Macquarie University, North Ryde, NSW.

Analysis of plant resistance genes by Professor B.G. Rolfe and Dr D. Loschke with Dr D. Gabriel, University of Florida, Gainesville, Florida, USA.

Analysis of the *Rhizobium trifolii* nodulation genes by Drs M.A. Djordjevic and J.J. Weinman with Dr H.P. Spaink of University of Leiden, The Netherlands.

Controlled field testing of genetically engineered microorganisms (GEMS) which are acid tolerant and nitrogen-fixing on subterranean clovers by Professor B.G. Rolfe with Dr J. Brockwell, CSIRO Division of Plant Industry, Canberra.

Genetic and molecular analysis of the phenylpropanoid pathway in the pasture lcgume, subterranean clover by Drs M.A. Djordjevic and J.J. Weinman with Drs P. Larkin and G. Tanner, CSIRO Division of Plant Industry, Canberra.

Lectin trifoliin A binding and analysis of *nod* gene function by Professor B.G. Rolfe and Dr M.A. Djordjevic with Professor F.B. Dazzo, Michigan State University, East Lansing, Michigan, USA.

Regulation and functional analysis of *R. trifolii* nodulation (*nod*) genes by Professor B.G. Rolfe, Drs J.J. Weinman and M.A. Djordjevic with Dr C.A. Wijffelman, University of Leiden, The Netherlands.

PLANT ENVIRONMENTAL BIOLOGY GROUP

Evaluation of photosynthetic efficiency in relation to growth and water-use efficiency in native C_4-grasses by Dr S. von Caemmerer and Professor G.D. Farquhar with Mr W. Johnston, NSW Soil Conservation Service, Wagga Wagga.

Measurements of variation in water-use efficiency/radiation use efficiency and growth in the field of diverse sorghum genotypes by Ms S. Henderson, Drs S. von Caemmerer, K.T. Hubick, Professor G.D. Farquhar with Drs G.L. Hammer and L.J. Wade, Queensland Department of Primary Industries.

Use of antisense RNA and ribozyme techniques for selectively reducing gene expression to study the regulation of photosynthesis by G.S. Hudson, T.J. Andrews and M.R. Badger with Dr W. Gerlach, CSIRO Division of Plant Industry.

Use of *in situ* RNA hybridization to study the regulation of gene expression in C h4 plants by G.S. Hudson with P. Hattersley, Bureau of Flora and Fauna, ACT, Nancy Dengler, Department of Botany, University of Toronto, Ron Dengler, Life Sciences Division, University of Toronto, and Geoff McFadden, Department of Botany, University of Melbourne.

Analysis of the CO_2 concentrating mechanism in cyanobacteria by Drs M.R. Badger and G.D. Price with Dr T. Ogawa, Riken Institute of Physical and Chemical Research, Tokyo, Japan.

Analysis and manipulation of the algal CO_2 mechanism by Dr M.R. Badger, G.D. Price and J-W. Yu, with Dr M. Spalding, Department of Botany, Iowa State University, USA.

Transgenic expression of carbonic anhydrase in C_4 and C_3/C_4 *Flaveria* species by Drs M.R. Badger and G.D. Price with Drs W.C. Taylor, M.D. Hatch and R.T. Furbank, CSIRO Division of Plant Industry, Canberra, ACT.

Molecular analysis of plant respiration by Drs M.R. Badger and G.D. Price with Dr D.A. Day, Department of Botany, ANU and Dr J.T. Wiskich, Department of Botany, University of Adelaide.

CSIRO land and water care project on management of cereal stubble at Harden by Mr D. de Pury with Drs J. Angus, M. Roper and J. Kirkeguard, CSIRO Division of Plant Industry.

Water-use efficiency of peanut cultivars by Professor G.D. Farquhar and Dr K.T. Hubick, with G. Wright and A. Cruickshank, Queensland Department of Primary Industries.

Analysis of the effects of scale on water-use efficiency of contrasting cultivars of wheat by Professors G.D. Farquhar and I.R. Cowan, Dr S.C. Wong and Messrs D. de Pury, P. Groeneveld, W. Coupland with Dr A. Condon, Mr. F. Dunin, Dr. R. Richards, CSIRO Plant Industry, Drs. O.T. Denmead, I. White and R. Leuning, CSIRO Environmental Mechanics and Dr H. Cleugh of Macquarie University.

Water-use efficiency of upland rice varieties by Professor G.D. Farquhar with Drs M. Dingkuhn and S. de Datta, International Rice Research Institute, Philippines, and Dr J. O'Toole, Rockefeller Center, USA.

Water-use efficiency of cowpea varieties by Professor G.D. Farquhar with Professor A. Hall and Dr R. Mutters, University of California, Riverside, USA.

Water-use efficiency of Australian native tree species by Professor G.D. Farquhar and Dr S.C. Wong with Dr P.E. Kriedemann, CSIRO Division of Forestry and Forest Products.

Effects of elevated CO_2 concentration of Australian native tree species by Dr S.C. Wong and Professor G.D. Farquhar with Dr P.E. Kriedemann, CSIRO Division of Forestry and Forest Products.

Analysis of carbon assimilation in lichens in relation to thallus water-content and environment by Professor I.R. Cowan with Professor O.L. Lange, Botany Institute, University of Würzburg, and Dr T.G.A. Green, Department of Biological Sciences, University of Waikato.

ECOSYSTEM DYNAMICS GROUP

Environmental determinants of vegetation patterns in mangrove forests of the humid tropics by Dr M.C. Ball with Dr B. Clough, Australian Institute of Marine Sciences, and Professor J. Chappell, Research School of Pacific Studies, ANU.

Growth in relation to water use and salt balance in the mangroves, *Rhizophora apiculata* and *R. stylosa*, with variation in factors affecting uptake of water at the roots (salinity) and loss of water from leaves (atmospheric concentrations of water vapour and carbon dioxide) by Dr M.C. Ball, Ms M. Cottam and Mr K. Grigulis with Dr H. Rawson, CSIRO Division of Plant Industry, Canberra.

Patterns of herbivory by insects in mangrove forests along natural salinity gradients by Professor P.A. Morrow, University of Minnesota, USA, with Dr M.C. Ball.

Identification of key ecophysiological attributes and morphological traits associated with differences in distribution and relative performance of eucalypt species along climatic gradients of temperature and rainfall in southeastern Australia by Dr M.C. Ball, Ms M. Cottam, and Dr I.R. Noble with Dr M.P. Austin, CSIRO Division of Wildlife and Ecology, Canberra.

Vulnerability of juvenile *Eucalyptus maculata* and *Elaeocarpus reticulatus* grown under natural understorey conditions to photoinhibition following forest clearfelling by Mr M. von Zedlitz and Dr M.C. Ball with Dr A.M. Gill, CSIRO Division of Plant Industry, Canberra.

Cold-induced photoinhibition and the optimal design of shelters for establishment of juvenile *Eucalyptus polyanthemos* by Mr C. Holly and Dr G.P. Laughlin, Geography Department, ANU, with Dr M.C. Ball.

Theoretical and empirical studies of communities in stochastic environments by Dr P.L. Chesson with Dr N. Huntly, Idaho State University, USA.

Radiocarbon ages fo charcoal from rainforest soils in tropical North Queensland by Dr A.P.N. House with Mr J. Head, Radiocarbon Dating Research Laboratory, Research School of Pacific Studies, ANU.

Seedling establishment by rainforest taxa in eucalypt forest in relation to spatial variation in soil nitrogen availability by Dr A.P.N. House with Mr R. Robson, Australian Defence Force Academy, Canberra.

Essential oils in leaves of primitive angiosperms from North Queensland rainforests by Dr A.P.N. House with Mr D.J. Boland, CSIRO Division of Forestry and Forest Products, Canberra and Dr J.J. Brophy, University of New South Wales.

Vegetation of the Lake Barrine volcanic crater, North Queensland by Dr A.P.N. House with Professor D. Walker, Radiocarbon Dating Research Laboratory, RSPacs and Mr J.G. Tracey, DASETT, Atherton.

The population ecology and genetic structure of *Idiospermum australiense*, a rare tree species in North-East Queensland rainforest by Dr S.M. House with Dr G. Harrington and Mr A. Irvine, CSIRO Tropical Forest Research Centre, Atherton.

Genetic determinants of dominance in regeneration stands of *Eucalyptus regans* in Victoria by Dr S.M. House with Dr A.R. Griffin and Dr G. Moran, CSIRO Division of Forestry and Forest Products, Canberra.

Phenology, insect and bird communities in low elevation mixed forests, East Gippsland, Vic. by Dr S.M. House with Dr J. Landsberg, Dr. H.P. Possingham, Mr P.M. Cochrane, and Mr D. Driscoll and The Victorian Department of Conservation and Environment.

Effects of fire and fertilization on nitrogen cycling and tree growth in a snow gum forest by Miss H. Keith with Dr R.J. Raison, CSIRO Division of Forestry and Forest Products.

A comparison of soil development, tree nutrition and insect herbivory along gradients in climate and soil nutrition, in plant communities dominated by *Eucalyptus* species in Australia and by *Quercus* species in North America by Dr J. Landsberg with Dr D.S. Gillieson, Australian Defence Force Academy University of NSW.

Modelling populations of a common leaf-eating beetle and its impact on rural dieback, in response to changes in soil nutrition and climate by Dr J. Landsberg with Dr D.M. Stafford Smith, CSIRO Division of Wildlife and Ecology.

A functional classification of insects found in eucalypt forests and woodlands by Dr J. Landsberg and Ms S. Berry with Mr P. Berrie, Macintosh Consultant, Canberra.

RESTORELAND: a decision support system for land management in western NSW by Dr I.R. Noble with staff from CSIRO Division of Wildlife and Ecology and the NSW Soil Conservation Service.

Long-term population biology of rainforest communities by Dr I.R. Noble with Professor J.H. Connell, University of California, USA.

Models of the population dynamics of savanna woodlands by Dr I.R. Noble with Dr P. Werner, National Science Foundation, Washington DC, and Dr A.D. Moore, CSIRO Division of Plant Industry.

Issues in landscape ecology by Dr I.R. Noble and Professor R.O. Slatyer with Professor J.H. Connell, University of California, USA.

EESTRU: A collaborative project on the ecologically and economically sustainable use of tropical rainforests by Dr I.R. Noble with Dr G. Harrington, CSIRO Division of Wildlife and Ecology, Atherton and other CSIRO and PNG scientists.

The Australian vegetation in relation to the current environment by Dr I.R. Noble with Dr J. West, CSIRO, Division of Plant Industry.

Spatial population dynamics of intertidal sessile organisms by Dr H.P. Possingham with Professor J. Roughgarden, Stanford University, USA.

Variation in competition intensity measured using *Poa pratensis* by Dr S.D. Wilson and Mr K.A. Grigulis with Dr R. Reeder, University of Guelph, Canada, Dr J.B. Grace, Louisiana State University, USA, Dr J. Gurevitch, State University of New York, USA, Professor D. Tilman, University of Minnesota, USA, Dr P.A. Keddy, University of Ottawa, Canada, Dr B. Shipley, McGill University, Canada, Dr R. van Hulst, Bishop's University, Canada, Dr C. Nilsson, Umea University, Sweden, Dr H. Olff, Groningen, Netherlands, Dr R. Turkington, University of British Columbia, Canada, and Dr C. Morris, University of New South Wales.

Plant diseases data bank in Thailand by Dr A.J. Gibbs, Plant Molecular Biology, with Ms U. Dilokkunanant of Kasetsart University and Mr D.R.B. Stockwell, Ecosystem Dynamics.

Interactive effects of fertility and disturbance on components of plant competition by Dr S.D. Wilson and Professor D. Tilman, University of Minnesota, USA.

Impact of forest fragmentation on soil seed banks by Dr C.A. Zammit with Dr C. Margules, Dr M.P. Austin and Dr N. Nicolls, CSIRO Division of Wildlife and Ecology.

Regeneration of *Eucalyptus maculata* following clearfelling by Dr C.A. Zammit with Mr P.M. Cochrane and Dr M. Gill, CSIRO Division of Plant Industry.

CONFERENCES

DEVELOPMENTAL NEUROBIOLOGY GROUP

Local

Chung, S.H., Gage, P.W.†, Moore, J.B.†, Krishnamurthy, V.† and Premkumar, L.S.† Adaptive digital signal processing methods based on hidden Markov Models for extracting small single channel currents from noise. Australian Physiological and Pharmacological Society, Sydney, September.

Gage, P.W.†, Milburn, T.†, Moore, J.B.†, Xia, L.† and Chung, S.H. Techniques of extracting small ion currents from noise. Australian Physiological and Pharmacological Society, Sydney, September.

Gage, P.W.†, Premkumar, L.S.† and Chung, S.H. Oligomeric potassium channel activated in neurons by GABA. Australian Physiological and Pharmacological Society, Sydney, September.

Milburn, T.†, Gage, P.W.† and Chung, S.H. Single channel currents activated by GABA and pentabarbitone in mammalian hippocampal neurons. Australian Physiological and Pharmacological Society, Sydney, September.

Premkumar, L.S.†, Gage, P.W.† and Chung, S.H. Potassium channels with multiple conductance states activated in neuronal membrane by arachidonic acid. Australian Physiological and Pharmacological Society, Sydney.

Hill, K.G. Interpreting cochlear mechanisms from response properties in auditory nerve fibres. Australian Neuroscience Society, Brisbane, April.

Hill, K.G. and Palmer, A.R.* Excitation and suppression of discharge rate by two tone stimuli in auditory nerve fibres in the guinea pig. Australian Neuroscience Society, Brisbane, April.

Mark, R.F. and Chung, S.-H. Field potential analysis in the wallaby superior colliculus during development. Australian Neuroscience Society, Brisbane, April.

Mark, R.F., Hoffmann, K.-P.,* Henry, G.H.† and Marotte, L.R. Electrophysiological analysis of the consequences of very early eye rotation in the wallaby (*Macropus eugenii*). Australian Neuroscience Society, Brisbane, April.

Marotte, L.R., Waite, P.M.E.* and Mark, R.F. Development of vibrissal representation in the cortex of the wallaby (*Macropus eugenii*). Australian Neuroscience Society, Brisbane, April.

International

Blest, A.D., Carter, M.• Clausen, J.A., Stowe, S.′, Trowell, S.C.′ and Tsukitani, Y.* The implications of protein phosphorylations in the regulation of arthropod phototransductive membrane turnover. *Festschrift* for Professor B.B. Boycott FRS, Harvard University, Cambridge Mass., USA, June.

Gummer, A.W. Neural encoding in the avian auditory periphery. Sonderforschungsbereich 45, Frankfurt, Germany, June.

Gummer, A.W. Temporal properties of spontaneous activity recorded extracellularly from the spiral ganglion of the pigeon. 27th Workshop on Inner Ear Biology, Stockholm, Sweden, June.

Gummer, A.W. Symposium of the International Group for Ear Research, Sweden, June.

Gummer A.W. Spontaneous activity of auditory afferent neurones in the spiral ganglion of the pigeon. 1990 Conference on the Mechanics and Biophysics of Hearing, Madison, USA, June.

Hill, K.G. and Palmer, A.R.* Time course of rate response to two-tone stimuli in auditory nerve fibres in the guinea pig. 27th Workshop on Inner Ear Biology, Stockholm, Sweden, June.

Hill, K.G. and Palmer, A.R.* Two-tone rate suppression in auditory nerve fibres: Time course of suppression and excitation in peri-stimulus time histograms. International Meeting on Cochlear Mechanics, Madison, Wisconsin, USA, June.

MOLECULAR NEUROBIOLOGY GROUP

Local

Ball, E.E. Target recognition by grasshopper motor neurons, grasshopper homeobox genes and research in the Goodman laboratory. Australian Fly Meeting, Corowa, September.

de Couet, G.H.•, Bonsing, J.*, Ozsarac, N.* and Miklos, G.L.G. Molecular characterization of the flightless locus in *Drosophila melanogaster*. ANZ Society for Cell Biology Meeting, Sydney, February.

Delaney, S., Hayward, D. and Miklos, G.L.G. Structural brain mutants: a transcript in the small optic lobes region shows similarity to vertebrate calpains. 15th Annual Lorne conference on protein structure and function, February.

Miklos, G.L.G. 9th Annual Meeting. Structural brain mutants: a transcript in the *small optic lobes* region shows similarity to vertebrate calpains. ANZ Society for Cell Biology, Sydney, February.

Myers, C.M.•, Whitington, P.M.′, Ball, E.E. Embryonic development of the innervation of the locust extensor tibiae muscle by identified neurons: formation and elimination of inappropriate axon branches. ANZ Society for Cell Biology, Sydney, February.

International

Boyan, G.S. Integration of auditory information for avoidance flight in the grasshopper and noctuid moth. 18th Göttingen Neurobiology Conference, Göttingen, FRG, May.

Hennig, R.M. Neuronal switching between stridulation and flight in the cricket, *Teleogryllus commodus*. 18th Göttingen Neurobiology Conference, Göttingen, FRG, May.

Hennig, R.M. Burst patterns of stridulatory interneurons in the cricket *Teleogryllus commodus*. 7th International Meeting on Insect Sound and Vibration. Piran, Jugoslavia, September.

Miklos, G.L.G. The 55th Cold Spring Harbor Symposium on Quantitative Biology "The Brain", May/June.

Miklos, G.L.G. The evolution of genomes and nervous system. Fundacion Juan March Conference "The Reference Points in Evolution", Madrid, Spain, September.

VISUAL SCIENCES GROUP

Local

Li, Z.-K. and Morgan, I.G. Localization of GABA and glycine receptors in the chicken retina. Australian Neuroscience Society, Brisbane, April.

Boelen, M.K.*, Dowton, M.+, Chubb, I.W+ and Morgan, I.G. Dopaminergic control of leu-enkephalin levels in chicken retina. Australian Neuroscience Society, Brisbane, April.

Morgan, I.G. and Li, Z-K. Are there GABA receptors on cholinergic amacrine cells? Australian Neuroscience Society, Brisbane, April.

Reymond, E.* and Morgan, I.G. Destruction of cholinergic amacrine cells in the retina abolishes opto-motor responses in the chicken. Australian Neuroscience Society, Brisbane, April.

Poznanski, R.R. Analysis of a postsynaptic scheme for directional selectivity. Australian Neuroscience Society, Brisbane, April.

Srinivasan, M.V., van Hateren,* H. and Wait, P*. Bees do not require eidetic visual memory to learn pattern orientation. Australian Neuroscience Society, Brisbane, April.

Srinivasan, M.V. Motion computation in the visual system of the honeybee. First Australian Conference on Neural Networks, Sydney, January.

Srinivasan, M.V. Edge detection in honeybee vision. 17th Experimental Psychology Conference, Canberra, July.

Yang, G. and Morgan, I.G. Destruction of cholinergic amacrine cells in the retina silences directionally selective units in the nucleus of the basal optic root of the chicken. Australian Neuroscience Society, Brisbane, April.

Zhu, H.†, Yang, G. and Morgan, I.G. Motion sensitivity of chicken retinal ganglion cells. Australian Neuroscience Society, Brisbane, April.

International

Horridge, G.A. The mechanisms of vision in insects and how to use them for new technology. Symposium on Vision, Cochin, India, November.

Jin Z.-F. and Srinivasan, M.V. Physiologically realistic gradient models for the measurement of image velocity. 13th European Conference on Visual Perception, Paris, September.

Maddess, T. and Henry, G.H†. Density of nonlinear visual units and glaucoma. Association for Research in Vision and Ophthalmology. Sarasota, Florida, May.

Sobey, P.J. Automated optical grading of timber. SPIE Conference, Boston, USA November.

Sobey, P.J. Determining range information from self motion—the template model. SPIE Conference, Boston, November.

van Hateren, J.H.* Srinivasan, M.V. and Wait, P.* Discrimination of pattern orientation in bees. 13th European Conference on Visual Perception, Paris, September.

MOLECULAR AND POPULATION GENETICS GROUP

International

Clark-Walker, G.D. Application of mitochondrial and nuclear DNA sequence analysis to yeast systematics. The 14th International Specialized Symposium on Yeast, Smolenice, Czechoslovakia, September.

Gibson, J.B. Genetic variation and gene regulation in natural populations of *Drosophila melanogaster* . Eucaryotic Gene Regulation and Expression, Institute of Molecular Biology and Biotechnology, Crete, Greece, May.

Naora, H., Xu, Z.-Z., Sun, L.-Q., Liszczynsky, H. and Seno, S.+ A novel regulatory mechanism of oncogene expression: an attempt to normalise the cancerous nature of cells by *cis*-acting gene-to-gene interaction. The First Congress of the Asian and Pacific Organization for Cell Biology, Shanghai, PRC, November.

Shaw, D.D. The genomic and environmental determinants of a narrow hybrid zone: cause or coincidence? International Congress on Systematics and Evolutionary Biology. University of Maryland, USA, July.

MOLECULAR EVOLUTION AND SYSTEMATICS GROUP

Local

Hattersley, P.W. and Long, C.+ Systematics, biogeography and photosynthetic pathway variation in Indo-Malayan/African *Alloteropsis* Presl (Poaceae). ASBS Symposium, Canberra, August.

Watson, L. and Dallwitz, M.J.[+] Introduction to the DELTA system, and workshop, ASBS Symposium, Canberra, August.

International

Ding, S.-W. The tymobox, a molecular tool in studies of tymoviruses. 'Genetic Interactions of Plant Viruses', an International Workshop at the Fundacion Juan March, Madrid, July.

Gibbs, A.J. Evolution of the tymoviruses. 4th International Congress of Systematics and Evolutionary Biology, Washington, July.

Gibbs, A.J. Rates of virus evolution. 'The Reference Points in Evolution', an International Workshop at the Fundacion Juan March, Madrid, September.

Hattersley, P.W. Intra-C h4 photosynthetic pathway variation in grasses: does it have ecophysiological significance? Jornadas Argentinas de Botanica Cordoba, Argentina, November, 1989

PLANT CELL BIOLOGY GROUP

Local

Collings, D.A., Overall, R.L.[+] and White, R.G.[+] Measurements of extracellular ionic currents around corn *(Zea mays* L.) roots. Australian Society for Biophysics, 14th Scientific Meeting, Melbourne, December.

Collings, D.A., Overall, R.L.[+] and White, R.G.[+] Gravity-induced ionic current changes about roots of *Zea mays*. Australian Society of Plant Physiology, Sydney, September.

Gorst, J.R., Sek, F.J. and John, P.C.L. Induction of $p34^{cdc2}$ homologue by auxin mediates stimulation of cell division in excised carrot cotyledons. 12th Annual Conference on the Organization and Expression of the Genome, Lorne, February.

Gorst, J.R., John, P.C.L. and Sek, F.J. 2,4-D stimulation of dedifferentiation in explants is accompanied by induction of a $p34^{cdc2}$ homologue. Australian Society of Plant Physiologists, University of NSW, September.

Gunning, B.E.S. Pre-prophase and development. Australia and New Zealand Society for Cell Biology, Macquarie University, February.

Gunning, B.E.S., Sammut, M. and McCurdy, D. Kinetics of pre-prophase band development in plant cell division. Australia and New Zealand Society for Cell Biology, Macquarie University, February.

Hardham, A.R. Immunological studies of the infection of plants by the dieback fungus, *Phytophthora cinnamomi*. 11th Australian Conference on Electron Microscopy, Melbourne, February.

Hardham, A.R. and Gubler, F. Cell surface properties of infective cells of pathogenic fungi. Australia and New Zealand Cell Biology Society, 9th Annual General Meeting, Sydney, February.

Hocart, C.H., Letham, D.S., Parker, C.W., Upadhyaya, M.N.[•] and Dart, P.J.[•] Cytokinin metabolism and plant development. 34th Annual Conference of the Australian Biochemical Society, Sydney, September.

Hyde, G.J., Gubler, F. and Hardham, A.R. Compartmentalisation of a multinucleate system: an immunogold-assisted study of *Phytophthora cinnamomi*. 11th Australian Conference on Electron Microscopy, Melbourne, February.

John, P.C.L., Sek, F.J., Carmichael, J.P and McCurdy, D.W. A homologue of the cell cycle control protein $p34^{cdc2}$ in wheat leaf; levels correlate with regions of cell division, hormone response and differentiation. 12th Annual Conference on the Organization and Expression of the Genome, Lorne, February.

Williamson, R.E. Cortical microtubules in plant cells. Australia and New Zealand Cell Biology Society, 9th Annual General Meeting, Sydney, February.

International

Davis, A.R. and Gunning, B.E.S. The modified stomata of the floral nectary of *Vicia faba* L. 2. Stomatal number and distribution as selection for breeding for high nectar sugar production. 6th International Symposium for Pollination, Tilburg, The Netherlands, August.

Gunning, B. Spatial regulation of cell division in plants. International Workshop on Plant Development, University of California, Berkeley, January.

Gunning, B., McCurdy, D. and Sammut, M. Video-immunofluorescence microscopy of developing preprophase bands and associated actin in wheat root tip cells. International Workshop in Plant Development, University of California, Berkeley, January.

Gorst, J.R. and Gunning, B.E.S. The preprophase band of microtubules: a possible link with organizational potential *in vitro*. 7th International Congress on Plant Tissue and Cell Culture, Amsterdam, June.

Hardham A.R. Infection of plant roots by *Phytophthora cinnamomi*. 4th International Mycological Congress, Regensberg, FRG, August.

Hardham, A.R. and Gubler, F. Polar attachment of zoospores of *Phytophthora cinnamomi* pre-aligns germ tube emergence. 5th International Symposium on the Molecular Genetics of Plant-Microbe Interactions, Interlaken, Switzerland, September.

Hyde, G., Gubler, F. and Hardham, A.R. Ultrastructure of zoosporogenesis of *Phytophthora cinnamomi*. 4th International Mycological Congress, FRG, August.

Jablonsky, P.P., Hagan, R.P.[†], Grolig, F. and Williamson, R.E. Organelle movements in Calcium in Plant Growth and Development, 13th Annual Symposium on Plant Physiology, Riverside, California, January.

Webb, M.C. and Gunning, B.E.S. Megasporogenesis in *Arabidopsis thaliana*, including the microtubular cytoskeleton. 11th International Symposium "Embryology and Seed Reproduction", Leningrad, USSR, July.

Webb, M.C. and Gunning, B.E.S. The cytoskeleton during megametogenesis and fertilization in *Arabidopsis thaliana*. 11th International Symposium "Embryology and Seed Reproduction", Leningrad, USSR, July.

Williamson, R.E., Baskin, T.I., Docherty, A. and Elliott, J. Microtubules and cell shape determination in mutant and wild type roots. 4th International Symposium on *Arabidopsis* Research, Vienna, June.

PLANT MICROBE INTERACTION GROUP

Local

Djordjevic, M.A., Weinman, J.J., Lewis-Henderson, W.R., McIver, J., Yuan, D., Redmond, J.R.[+], Batley, M.[+] and Rolfe, B.G. Recognition responses in the *Rhizobium*—legume interaction. The Australian Society of Plant Physiologists 13th Annual Conference, The University of NSW, September.

International

Arioli, T., Howles, P., Oakes, M., Weinman, J.J., Djordjevic, M.A., Rolfe, B.G., Chin, S.F.[+], Tanner, G.[+] and Larkin, P.[+] The use of *Trifolium subterraneum* for the investigation of Plant-Microbe Interactions. 5th International Symposium on the Molecular Genetics of Plant-Microbe Interactions, Interlaken, Switzerland, September.

Bender, G.L., Preston, L., Barnard, D. and Rolfe, B.G. Formation of nodule-like structures on the roots of the non legumes rice and wheat. 8th International Congress on Nitrogen Fixation, Knoxville, Tennessee, USA, May.

Chen, H., Gartner, E. and Rolfe, B.G. Construction of acid tolerant, nitrogen-fixing strains of *Rhizobium leguminosarum* bv. *trifolii*. 8th International Congress on Nitrogen Fixation, Knoxville, Tennessee, USA, May.

Dazzo, F.[+], Olen, T.[+], Squartini, A.[+], Chapman, K.[+], Phillip-Hollingsworth, S.[+], Orgambide, G.[+], Barker, D.[+], Cargill, L.[+], Wright, S.[+], Djordjevic, M. and Rolfe B. Alterations in surface components of *nodE*: Tn*5* a mutant of *Rhizobium* a *trifolii* ANU843. 5th International Symposium on the Molecular Genetics of Plant-Microbe Interactions, Interlaken, Switzerland, September.

Djordjevic, M.A., McIver, J., Lewis-Henderson, W., Huang, S.S.[*], Weinman, J.J. and Rolfe, B.G. *Rhizobium* host range genes involved in triggering cortical cell division and cultivar specific interactions in clover. 5th International Symposium on the Molecular Genetics of Plant-Microbe Interactions, Interlaken, Switzerland, September.

Gray, J.X., Zhan, H.[+], Levery, S.B.[+], Rolfe, B.G. and Leigh, J.A.[+] Heterologous exopolysaccharide production by chimeric *Rhizobium* sp. strain NGR234 and *R. meliloti* and demonstration of host-symbiont specificity in promotion of nodule development and invasion by exopolysaccharide. 5th International Symposium on the Molecular Genetics of Plant-Microbe Interactions, Interlaken, Switzerland, September.

Loschke, D., Gabriel, D.[+] and Rolfe, B.G. Evidence for the location of the victorin binding protein in the oat plasma membrane. 5th International Symposium on the Molecular Genetics of Plant-Microbe Interactions, Interlaken, Switzerland, September.

McIver, J., Huang, S.S.[*], Djordjevic, M.A., Weinman, J.J. and Rolfe, B.G. The effect on clover nodule morphogenesis of *Rhizobium leguminosarum* bv. *trifolii* host specific nodulation genes. 5th International Symposium on the Molecular Genetics of Plant-Microbe Interactions, Interlaken, Switzerland, September.

Rolfe, B.G. and Bender, G.L. Evolving a *Rhizobium* for non-legume nodulation. 8th International Congress on Nitrogen Fixation, Knoxville, Tennessee, USA, May.

Weinman, J.J., Djordjevic, M.A., Howles, P.A., Arioli, T., Lewis-Henderson, W., McIver, J., Oakes, M., Creaser, E.H. and Rolfe, B.G. The use of the genus *Trifolium* for the study of plant-microbe interactions. 5th International Symposium on the Molecular Genetics of Plant-Microbe Interactions, Interlaken, Switzerland, September.

PLANT ENVIRONMENTAL BIOLOGY GROUP

Local

Andrews, T.J. Mechanisms in Rubisco function. Swedish Australian Scientific Symposium on Plant Gene Regulation and Productivity, Melbourne, March.

Andrews, T.J. Structure, mechanism and manipulation of Rubisco. 30th Annual General Meeting of the Australian Society of Plant Physiologists, Sydney, September.

Badger, M.R. Carbon dioxide concentration mechanisms in aquatic phototrophs. Swedish-Australian Scientific Symposium on Plant Gene Regulation and Productivity, Melbourne, March.

De Pury, D.G.G. A comparison of leaf and crop gas exchange. Degradation of Vegetation in Semi-Arid Regions: Climate Impact and Implications, Macquarie University, Sydney, January.

Evans, J.R. Ultraviolet-B radiation impacts. Fenner Environment Conference, Australian Academy of Science, Canberra, September

Farquhar, G.D. Stomatal behaviour and its representation by models at different spatial scales. Degradation of Vegetation in Semi-Arid Regions: Climate Impact and Implications, Macquarie University, Sydney, January.

Farquhar, G.D. Stomata to big leaf: Big swamp to real landscape. Mathematical and Statistical Modelling of Global Change Processes, IGBP Workshop, ANU, Canberra, April.

Gomez-Macpherson, H. and Richards, R.A.[+] Why does early sowing of wheat result in poor yield? 5th Australian Agronomy Conference, Perth, February.

Gomez-Macpherson, H. and Richards, R.A.[+] Yield limitations in winter wheat: are there breeding solutions? Sixth Assembly of the Wheat Breeding Society of Australia, Tamworth, September.

Gomez-Macpherson, H. and Richards, R.A.[+] Does ear-stem competition limit the yield of winter wheats? 30th Annual General Meeting of the Australian Society of Plant Physiologists, Sydney, September.

Hudson, G.S., Mahon, J.D.[+], Anderson, P.A.[+], Gibbs, M.J.[+], Badger, M.R., Andrews, T.J. and Whitfeld, P.R.[+] Comparisons of *rbc* L genes for the large subunit of ribulose bisphosphate carboxylase from closely related C h3 and C h4 plant species. Swedish-Australian Scientific Symposium on Plant Gene Regulation and Productivity, Melbourne, March.

Hudson, G.S., Morell, M.K., Arvidsson, Y., Kane, H.J. and Andrews, T.J. Expression of spinach phosphoribulokinase in *Escherichia coli*. 30th Annual General Meeting of the Australian Society of Plant Physiologists, Sydney, September.

Lopez-Castaneda, C. and Richards, R.A.[+] Traits to increase the early vigour of wheat: learning from barley. Sixth Assembly of the Wheat Breeding Society of Australia, Tamworth, September.

Lopez-Castaneda, C., Richards, R.A.[+], Hubick, K.T.[•] and Farquhar, G.D. Why does barley grow faster than wheat? 30th Annual General Meeting of the Australian Society of Plant Physiologists, Sydney, September.

Morell, M.K., Hudson, G.S., Kane, H.J. and Andrews, T.J. Role of residue 309 in Rubisco structure and catalysis. Swedish-Australian Scientific Symposium on Plant Gene Regulation and Productivity, Melbourne, March.

Morell, M.K. Site directed mutagenesis of Rubisco. 30th Annual General Meeting of the Australian Society of Plant Physiologists, Sydney, September.

Paul, K. Morell, M.K. and Andrews, T.J. Site-directed mutagenesis of *Synechococcus* Rubisco small subunit. Swedish-Australian Scientific Symposium on Plant Gene Regulation and Productivity, Melbourne, March.

Paul, K., Morell, M.K. and Andrews, T.J. Mutant small subunits of *Synechococcus* PCC6301 Rubisco. Annual Meeting of the Australian Society of Plant Physiologists, Sydney, September.

Price, G.D. and Badger, M.R. The role of genes 5' to the Rubisco large subunit in the structure and function of carboxysomes and the CO h2 concentrating mechanism in *Synechococcus* PCC7492. 30th Annual General Meeting of the Australian Society of Plant Physiologists, Sydney, September.

Virgona, J., Farquhar, G.D. and Hubick, K.T.[•] Improving the transpiration efficiency of sunflower using carbon isotope discrimination. 8th Australian Sunflower Workshop, Kooralbyn, March.

Yu, J.W. and Woo, K.C.[•] The effect of light on the activity of glycerate/glycolate translocator in isolated plastids. 30th Annual General Meeting of the Australian Society of Plant Physiologists, Sydney, September.

International

Andrews, T.J. and Kane, H.J. Pyruvate is a by-product of Rubisco catalysis. Gordon Research Conference on CO_2 fixation in green plants. New London, New Hampshire, USA, July.

Andrews, T.J. and Kane, H.J. Pyruvate is a by-product of Rubisco catalysis. Annual Meeting of the American Society of Plant Physiologists, Indianapolis, USA, July.

Badger, M.R. Molecular approaches to understanding the central role of the carboyxsome in the cyanobacterial CO_2 concentrating mechanism. Gordon Research Conference on CO_2 fixation in green plants. New London, New Hampshire, USA, July.

Badger, M.R. Selection and analysis of mutants of the CO_2 concentrating mechanism in Cyanobacteria. Second International Symposium on Inorganic Carbon Utilization by Aquatic Photosynthetic Organisms, Kingston, Canada, August.

Caemmerer S. von, Determination of the CO_2 pressure in chloroplasts from leaves of several C_3 plants. Gordon Research Conference on CO_2 fixation in green plants, New London, New Hampshire, USA, July.

Evans, J.R. Determination of the CO_2 pressure in chloroplasts from leaves of several C_3 plants. Gordon Research Conference on CO_2 fixation in green plants, New London, New Hampshire, USA, July.

Farquhar, G.D. Integration of plant form and function in the face of water stress. Water and Life: Comparative Analysis of Water Relationships at the Organismic, Cellular and Molecular Levels. Crans-sur-Sierre, Switzerland, September.

Farquhar, G.D. and Masle, J.M. Photosynthesis, environment and plant productivity. Trends in Photosynthetic Research, Palma de Mallorca, Spain, September.

Farquhar, G.D. Use of stable isotopes in evaluating plant water-use efficiency. FAO/IAEA International Symposium on the Use of Stable Isotopes in Plant Nutrition, Soil Fertility and Environmental Studies, Vienna, October.

Morell, M.K., Kane, H.J. and Andrews, T.J. Role of residue 309 in Rubisco structure and catalysis. Annual Meeting of the American Society of Plant Physiologists, Indianapolis, USA, July.

Price, G.D. and Badger, M.R. The role of genes 5' to the Rubisco large subunit in the structure and function of carboxysomes and the CO h2 concentrating mechanism in *Synechococcus* PCC7492. Annual Meeting of the American Society of Plant Physiologists, Indianapolis, USA, July.

Price, G.D. and Badger, M.R. Evidence for the role of carboxysomes in the cyanobacterial CO_2 concentrating mechanism. Second International Symposium on Inorganic Carbon Utilization by Aquatic Photosynthetic Organisms, Kingston, Canada, August.

ECOSYSTEM DYNAMICS GROUP

Local

Berry, S.L. and Zammit, C.A. The effect of ants and fungi on seed survivorship in mixed eucalypt forests. Ecological Society of Australia, Melbourne, September.

Hodda, M.E. Responses of termites to changes in food supply in savanna woodland. Australian Entomological Society, Canberra, July.

Hodda, M.E. Fire, termites and Australian savanna vegetation. Ecological Society of Australia, Melbourne, September.

Hodda, M.E. Variation in space and time of nematodes in Australian estuaries. Ecological Society of Australia, Melbourne, September.

House, S.M. and Moritz, C.[+] The impact of rainforest fragmentation on flora and fauna. Institute of Tropical Rainforest Studies workshop on Research Needs for Rainforest, James Cook University, Townsville, May.

House, S.M. Tree density and patterns of pollen dispersal in a population of dioecious rainforest trees. Australasian Pollination Ecology Society, Bendigo, September.

House, S.M. Variation in seed production and quality in eucalypts. Ecological Society of Australia, Melbourne, September.

House, S.M. Implications of habitat fragmentation for forest trees. University of New England Ecosystem Management Department workshop on Forest Fragmentation and Seed Dispersal Ecology, Armidale, October.

Landsberg, J. and Stafford Smith, M.[+] Implications of climatic change for insect-related rural dieback. 59th ANZAAS Congress, Hobart, February.

Noble, I.R. Impact of global change on arid ecosystems. Change in arid lands. Macquarie University, February.

Possingham, H.P. A lifetime fitness perspective for plant behaviour in a stochastic environment. Ecological Society of Australia, Melbourne, September.

Possingham, H.P. Habitat selection by two species of bee. Australian Pollination Ecology Society, Bendigo, September.

International

Chesson, P. Community dynamics in a variable environment: the role of within-population heterogeneity. Royal Society, Discussion Meeting, London, May.

Chesson, P. The changing role of equilibrium in ecological theory. Ecological Society of America, Annual Meeting, Utah, USA, July.

Chesson, P., Huntly, N.[+]: Tackling environmental variability in community ecology. Workshop as part of "Bridging the Gap between Theoretical and Empirical Ecology", an independent international meeting, Texas, USA, November.

Noble, I.R. Linking simulation models and geographic information systems. SCOPE Open Executive Meeting Workshop on the Sustainable Use of Land in Latin America, Santiago, Chile, July.

Noble, I.R. Approaches to modelling tropical savannas. IUBS Decade of the Tropics Meeting: Modelling savanna ecosystems, Harvard, USA, October.

SYMPOSIA, VISITORS AND SEMINARS

MOLECULAR NEUROBIOLOGY GROUP

Andrew Hawken, Zoology Department, University of New England (summer student).

Ms N. Ozsarac, Biological Sciences, University of NSW.

Thorsten Schimansky, Dip. Biol (Freiburg)

Professor D. Sherratt, Genetics Department, University of Glasgow, Glasgow, Scotland, UK.

Dr P. Ingham, Molecular Embryology Laboratory, Developmental Biology Unit, Zoology Department, University of Oxford, UK: "Segment Polarity Genes and Cellular Communication in Embryogenesis".

VISUAL SCIENCES GROUP

Dr J. R. Riley, Overseas Pest Control Centre, UK: Insect orientation and navigation.

Dr T. Kaneko, NTT Human Interface Laboratories, Autonomous Robot Systems Laboratory, Take, Yokosuka-shi, Japan: Trinocular stereovision by computer.

Dr T. Toriu, Pattern Information Processing Lab, Fujitsu Laboratories Ltd, Japan.

Mr P. Wait, University of Adelaide.

Dr H. van Hateren, Department Biophysics, University of Groningen, The Netherlands: Studies on bee vision.

Dr D. Nilsson, Department of Zoology, University of Lund: Retinas of butterflies and mayflies.

Dr L. Labhart, Zoologisches Institut, Universität Zurich, Switzerland: Electrophysiology of bee optic lobes.

Dr M. Lehrer, Zoologisches Institut, Univesität Zurich, Switzerland: Spatial vision in honeybees.

Professor C.W. Thomas, Biomedical Engineering Department, Case Western Reserve University, Cleveland, Ohio, USA: Image synthesis.

Dr J. Zeil, Lehrstuhl für Biokybernetik, Universität Tubingen, FRG: How flying insects exploit optical flow.

Ms L. Muir, Queensland Institute of Medical Research: Electrophysiology of mosquito eye.

Dr P. McKerrow, University of Wollongong.

MOLECULAR AND POPULATION GENETICS GROUP

Dr T. Takahashi, Japan Science Council, Tokyo, Japan.

Dr A. Georges, University of Canberra.

Dr C. Moritz, University of Queensland, Brisbane.

Dr. L. Christidis, Museum of Victoria, Melbourne.

MOLECULAR EVOLUTION AND SYSTEMATICS GROUP

Dr J. Bruhl, Missouri Botanical Gardens, USA.

Professor T. Clifford, Botany Department, University of Queensland.

Professor N. Dengler, Department of Botany, University of Toronto, Canada.

Dr R. Dengler, Life Sciences Division, University of Toronto, Canada.

Ms S. Kiratiya-Angul, Department of Agriculture, Bangkok.

Dr M. Mayo, Scottish Crops Research Institute, Dundee, Scotland.

Professor N. Symonds, University of Sussex, UK: Directed mutagenesis: fact or fiction?

PLANT CELL BIOLOGY GROUP

Dr Andreas Betzner, Max-Planck Institute für Entwicklungsbiologie, FGR: The bacterial cell wall—its implication for human sleep.

Professor L.C. Fowke, Department of Biology, University of Saskatchewan, Canada: Tissue cultures for studies of plant cells.

Dr John Hamill, Developmental Biology, Monash University, Melbourne: Transformed plant organ cultures: production of secondary metabolites for biotechnology.

Professor Hans Hohl, Institut für Pflanzenbiologie Cytologie, University of Zürich, Switzerland: Surface-related host pathogen interactions in the *Phytophthora* soybean system.

Professor L.D. Noodén, Biology Department, University of Michigan, Ann Arbor, USA.

Professor W. Silk, Department of Land, Air and Water Resources, University of California, USA: How *Zea* copes with stress.

Mr Tao Guo-qing, Institute of Botany, Academia Sinica, PRC.

PLANT MICROBE INTERACTION GROUP

Dr Tapan Chakrabarty, Institute of Microbial Technology, Chandigarh, India.

Dr Herman Spaink of Leiden University, The Netherlands: Host range genes in *Rhizobium*.

PLANT ENVIRONMENTAL BIOLOGY GROUP

Dr Preston K. Andrews, Massey University, New Zealand: The continuing debate over the role of root-synthesised biochemical messengers in plant response to water deficits—research on the periphery.

Professor C.-I. Branden, Swedish University of Agricultural Sciences, Uppsala: The structure of Rubisco.

Dr John Coleman, Department of Botany, University of Toronto.

Dr Barrie Entsch, Department of Biochemistry and Nutrition, University of New England: Site-directed mutagenesis—a precise probe of protein function requires precise measurements to yield greater understanding.

Dr Manfred Küppers and Ms Barbara Küppers, Institut für Botanik, Darmstadt, FRG.

Dr Richard Leegood, Robert Hill Institute, University of Sheffield, UK: Effects of temperature on photosynthesis and metabolism.

Dr Jon Lloyd, NSW Department of Agriculture, Alstonville,NSW.

Dr Erling Ogren, Department of Plant Physiology, University of Umeä, Sweden: Photoinhibition of photosynthesis in response to environmental variation.

Professor Gunnar Oquist, Plant Physiology Department, University of Umea, Sweden: Photoinhibition at low temperatures.

Ms Kristin Palmqvist, Department of Plant Physiology, University of Umeä, Sweden: The physiology of inorganic carbon accumulation in the green algae *Chlamydomonas reinhardtii*, and its interaction with photosynthesis.

Dr Catherine Potvin, Department of Biology, McGill University, Montreal, Canada.

Dr Jim Siedow, Botany Department, Duke University, Durham, NC, USA: Characterisation of a pore forming protein from cytoplasmic male sterile maize mitochondria, expressed in *E. coli*.

Dr James Syvertsen, University of Florida, USA: Factors limiting photosynthesis in woody horticultural crops.

Dr Juta Viil, Estonian Academy of Sciences: Photosynthetic carbon metabolism and environment (studies in Estonia).

ECOSYSTEM DYNAMICS GROUP

Professor J.H. Connell, School of Biological Sciences, University of California, Santa Barbara, USA: Maintenance of diversity among organisms that compete for space.

Dr R.M. Cowling, Department of Botany, University of Cape Town, South Africa: Coexistence in fynbos—local and regional—level patterns and processes.

Dr Yrjo Haila, Zoological Laboratory, University of Helsinki, Finland: Scaling population and community processes in the southern Finnish taiga.

Dr Robert Howe, Department of Natural and Applied Sciences, University of Wisconsin, USA: The biological conservation of metapopulations.

Dr Manfred Küppers and Ms Barbara Küppers, Institute für Botanik, Technische Hochschule Darmstadt, FRG: Linking leaf gas exchange with plant growth: the significance of allocation and architecture; Leaf ecophysiology of montane eucalypts, *E. pauciflora* and *E. delegatensis*; Leaf ecophysiology of a mistletoe (*Amyema miquelli*) and its mallee host, *E. behriana*.

Dr R. Leemans, Global Change Department, National Institute of Public Health and Environmental Protection, The Netherlands: A system analysis of the global boreal forest.

Professor P.A. Morrow, Department of Ecology, Evolution and Behaviour, University of Minnesota, USA: Insect host plant location: lost in the prairies.

Mr T. Sisk, Department of Biological Sciences, Stanford University, Stanford, USA: Conservation implications of edge effects in bird communities.

Dr Dan Shoen, McGill University, Canada: The evolution of plant reproductive systems.

EXTERNAL SUPPORT RECEIVED

DEVELOPMENTAL NEUROBIOLOGY GROUP

Dr A.D. Blest is indebted to the Taisho Pharmaceutical Co. Ltd., Tokyo and Dr K. Hanada for generously supplying novel inhibitors of cysteine proteases since 1982.

VISUAL SCIENCES GROUP

Funding of US$179,000 over 2 years, from Welch Allyn (USA) to Dr T. Maddess to further research into the early detection of glaucoma.

Funding of $20,000 (for 1991) a to Dr T. Maddess from the Ophthalmology Research Institute of Australia to further research into the early detection of glaucoma.

Funding of $90,000 over a period of 3 years, from the Centre of Information Sciences Research (CISR) to Dr Srinivasan to support a PDF/RF position in the area of visual electrophysiology. Dr Osorio was appointed to this post.

Dr I.G. Morgan secured an Australian Research Council National Research Fellowship for work on the cellular basis of directional computation (appointee Dr Z.-K. Li) ($35,000).

Dr I.G. Morgan received an NH&MRC-funded joint grant for $39,000 annually for three years with Professor I.W. Chubb, Higher Education Council, DEET, for work on the peptidergic cells of the retina.

The Fujitsu Corporation continues to support work on insect vision and its application to robotic vision.

Generic Research and Development Grant, No. GIRD 16009 is funded by DITAC for the development of seeing-eye devices based on principles of insect vision. Three three-year PDF/RF positions plus equipment (1989–92) are funded (appointees Dr Backhaus and Dr Sobey). Funding is $335,000 over a period of three years.

MOLECULAR AND POPULATION GENETICS GROUP

Dr. Clark-Walker continued to receive funds from Mauri Foods for the project 'genetically marking yeasts' until the end of August ($42,600).

Dr H. Naora received a grant from The Toyota Foundation to attend The First Congress of Asian and Pacific Organization for Cell Biology ($5,094).

Ms. J. Playford received support from ACIAR (Australian Centre for International Agricultural Research) for the collection of *Acacia melanoxylon* seed.

MOLECULAR EVOLUTION AND SYSTEMATICS GROUP

Dr M.J. Henwood in collaboration with Dr R. Appels and Dr J.G. West (CSIRO Division of Plant Industry) received a joint ANU/CSIRO Research Award of $15,500 to study the biosystematics and phylogeny of the Australian wheatgrasses (*Australopyrum*).

Dr L. Watson continued to receive funds from the Australian Bureau of Flora and Fauna, principally to support a postdoctoral fellowship concerned with preparing automated floristic description of Australian grasses ($36,000).

Dr A.J. Gibbs continued to receive support from the Australian Centre for International Agricultural Research for the VIDE project in Australia, Thailand, UK and India ($104,700), and a final grant from Betatene Pty Ltd for work on retrovirogene evolution ($21,500).

PLANT CELL BIOLOGY GROUP

Dr F. Gubler continued to receive a Queen Elizabeth Fellowship to support work on subcellular localization of sites of protein synthesis and secretion in fungal and plant cells ($5,500).

Professor B.G. Gunning continued to receive a National Research Fellowship to support the research of Dr J. Gorst into the plant cytoskeleton and cell division ($35,000).

Dr A. R. Hardham continued to receive an Australian Research Council National Research Fellowship for work on antibodies as tools for understanding how the dieback fungus, *Phytophthora cinnamomi*, infects plants (appointee Dr L. Lehnen) ($35,000).

Dr A.R. Hardham received a grant from the International Science and Technology Program to use high pressure freezing to study the infection of plants by the dieback fungus, *Phytophthora cinnamomi* ($3,500).

Mr G. Hyde received a grant from the Department of Industry, Technology and Commerce for work on the dieback fungus, *Phytophthora cinnamomi*: development of the infective agent ($3,700).

Dr P.C.L. John was awarded a National Research Fellowship for study of plant cell cycle genes. Dr S. Baindur occupies the Fellowship ($35,000).

Dr D.S. Letham continued to receive a grant from the Industry Research and Development Board for expression of hormone biosynthesis genes in plants ($58,000).

Dr D.S. Letham continued to receive a National Research Fellowship for molecular studies of hormonal control of leaf senescence. Dr C.H. Hocart occupies this Fellowship ($35,000).

Dr D.W. McCurdy continued to receive a Queen Elizabeth II Fellowship to support his research into the actin cytoskeleton ($40,000).

Dr J.Plazinski and Dr.W.Shaw, Northern Territory University, Darwin received a three-year grant from the Australian Research Council to study symbiotic genes in *Anabaena azollae* strains ($132,000).

Dr P.M. Warren Wilson and Professor J. Warren Wilson, received a grant from the Australian Research Council for further work on 'Positional control of tracheary elements and strands' ($25,000).

Dr P.M. Warren Wilson and Professor J. Warren Wilson received a grant from the Australian Research Council for further work on 'Induced abscission in plants: positional control, differentiation and partitioning mechanisms' ($25,000).

Dr R.E. Williamson and Dr E. Dennis, CSIRO Division of Plant Industry received a grant from the International Science and Technology Program of the Department of Industry Trade and Commerce to contribute to the Multinational *Arabidopsis* Genome Project ($210,000).

Dr R.E. Williamson continued to receive a National Research Fellowship to support the research of Dr G.O. Wasteneys into the cytoskeleton of characean algae ($35,000).

PLANT MICROBE INTERACTION GROUP

Professor B.G. Rolfe received a one year grant from the Australian Wheat Board for a feasibility study to investigate the possibility of nodulating wheat ($70,000).

Professor B.G. Rolfe received a grant from the Rice Research Committee to study nodulation of rice by *Rhizobium* bacteria ($7,000).

Professor B.G. Rolfe continues to receive an Australian Postdoctoral Research Fellowship for the investigation of *Rhizobium* competitiveness (Dr J.J. Weinman) ($35,000), and a shared Australian Postdoctoral Research Fellowship with Dr K.F. Scott on the nodulation of non-legumes.

Professor B.G. Rolfe received a grant from the Australian Wool Research and Development Council, for the analysis and field testing of acid tolerance in the clover bacteria *Rhizobium* a *trifolii* ($49,000).

Professor B.G. Rolfe received a grant from Dylway, a bioremediation company ($24,000).

Dr M.A. Djordjevic and Dr J.J. Weinman continued to receive a CSIRO/ANU Collaborative Research Project Grant for work on the genetic and molecular analysis of the phenylpropanoid pathway in the pasture legume, subterranean clover ($15,000).

Dr M.A. Djordjevic and Dr J.J. Weinman continued to receive a joint grant from the Australian Wool Corporation to investigate clover disease resistance mechanisms in subterranean clover ($162,000 over 3 years).

PLANT ENVIRONMENTAL BIOLOGY GROUP

Dr T.J. Andrews continued receipt of a National Research Fellowship for 1987–1990 for study of "Improvement of photosynthesis and crop yields by genetic modification of the primary carboxylation enzyme, ribulose bisphosphate carboxylase (Rubisco)". Dr M.K. Morell is the occupant of this Fellowship (until May). ($35,000)

Dr T.J. Andrews continued receipt of a National Research Fellowship for 1989–1991 for "Investigation and manipulation of the expression of natural and foreign genes within plant chloroplasts". Dr G.S. Hudson is the occupant of this Fellowship. ($35,000)

Dr M.R. Badger received a grant from the Bilateral Science and Technology Collaboration Program (DITAC) for a collaborative project with Dr M. Spalding of the University of Iowa studying "Manipulation and analysis of the algal CO_2 concentrating mechanism". ($10,740)

Dr M.R. Badger was awarded an ANU CSIRO research award in collaboration with Drs W.C. Taylor, M.D. Hatch and R.T. Furbank for "Transgenic expression of carbonic anhydrase in C_4 and C_3/C_4 species of *Flaveria*". ($10,000)

Dr M.R. Badger was awarded a National Research Fellowship for "Molecular analysis of a novel CO_2 concentrating mechanism in cyanobacteria, eukaryotic algae, and higher plant chloroplasts" (Dr Jian-Wei Yu is the occupant of this Fellowship). ($35,000)

Dr M.R. Badger was awarded an ARC Research Grant in collaboration with Dr D.A. Day (Department of Botany, ANU) and Dr J.T. Wiskitch (Department of Botany, University of Adelaide) for "Molecular analysis of plant respiration". ($105,500)

Mr D.G.G. de Pury continued to receive a CSIRO INRE Project Award with Dr. O.T. Denmead (CSIRO Centre of Environmental Mechanics). ($6,000)

Dr G.D. Price was awarded a Queen Elizabeth II Fellowship for "Molecular biology of inorganic carbon transport in cyanobacteria and micro-algae". ($50,000)

Drs G.S. Hudson, T.J. Andrews and M.R. Badger were awarded a continuation of an ANU/CSIRO collaborative research award in collaboration with Dr W. Gerlach of CSIRO, Division of Plant Industry, for the use of antisense RNA and ribozyme techniques for selectively reducing gene expression to study the regulation of photosynthesis. ($14,000)

Dr S. von Caemmerer was awarded a Queen Elizabeth II Fellowship and an Australian Research Council grant for "The analysis of C h4 photosynthetic carbon dioxide fixation by mutant selection" which she will take up in 1991. (total $75,000)

Professor G.D. Farquhar continued receipt of a National Research Fellowship for "Identification of genes contributing to water-use efficiency of plant growth". (Dr J. Masle occupies this Fellowship). ($35,000)

Professor G.D. Farquhar received a grant from the International Centre for Tropical Agriculture (CIAT) for studies on cassava and beans. ($66,000 for 1990)

Professor G.D. Farquhar received a grant from the Oilseeds Research Council for "Selection of sunflower genotypes for improved water-use efficiency". ($36,485 for 1990/91)

Professor G.D. Farquhar and Dr J. Masle were awarded an ANU/CSIRO research grant to work with Dr D. Sheriff, CSIRO Forestry, on "Transpiration efficiency of *Pinus radiata* by measurement of the ratio of ^{13}C to ^{12}C in plant dry matter as affected by degradation of soil structure". ($7,000 for 1990/91)

Dr S.C. Wong and Professor G.D. Farquhar received a grant from CSIRO/INRE for work on wheat crops. ($26,000)

Professor G.D. Farquhar and Dr S.C. Wong, together with Professor B.G. Rolfe (Plant Microbe Interaction), Dr A.J. Gibbs (Plant Molecular Biology), Drs R.M. Gifford and H. Rawson (CSIRO) and Dr D. Eamus (Northern Territory University) received a grant from the National Greenhouse Advisory Committee for "Carbon dioxide and vegetation: Introducing carbon dioxide into climate change,

impact models and mitigation strategies involving vegetation" ($275,000 for 1990/91)

Professor G.D. Farquhar received a grant from the Wheat Research Council for "Managing nitrogen to maximise the grain yield of wheat" ($20,800 for 1990/91)

ECOSYSTEM DYNAMICS GROUP

Dr M.C. Ball continued receipt of a National Research Fellowship to work on predicting changes in mangrove vegetation in response to changes in sea level and climate induced by increasing concentrations of atmospheric carbon dioxide ($35,000).

Mr P.M. Cochrane, Drs S.M. House, J. Landsberg and H.P. Possingham accepted a consultancy from the Department of Conservation and the Environment, Silvicultural Systems Project, to characterise field sites for a flora and fauna study in East Gippsland ($10,000). Mr D. Driscoll was employed for three months to complete the task.

Dr J. Landsberg and Mr P. Berrie of MacVisions received a grant from Apple Australia for the development of a database to facilitate the classification of insects collected from the forests of southeastern Australia ($500).

Mr R. Sinclair was based in the School for 6 months with the support of the National Soil Conservation Programme to work on the RESTORELAND project with CSIRO Division of Wildlife and Ecology .

Drs H.P. Possingham and I.R. Noble accepted a consultancy from the Resource Assessment Commission to evaluate population viability analysis (PVA) for assessing the risk of species extinction ($10,000).

Dr H.P. Possingham received a Queen Elizabeth II Fellowship to continue his studies in theoretical population biology ($40,000).

OTHER ACTIVITIES OF STAFF

DEVELOPMENTAL NEUROBIOLOGY GROUP

Dr A.D. Blest visited and gave seminars at the Department of Experimental Pathology, Charing Cross Hospital Medical School, London; the Department of Zoology, Cambridge University, and the Department of Biology, University of California at San Diego. He also visited the School of Biological Sciences, Sussex University; the British Museum (Natural History); the Neurosciences Division, University of Arizona at Tucson. He is an Associate Editor of Cell and Tissue Research, and of the International Journal of Insect Morphology and Embryology. He serves as a Member of the Scientific Advisory Committee for the International Conference on the Neurobiology of Sensory Systems (ICONOSS) to be held in Goa in 1991. He was a member of the RSBS Academic Promotions Committee for 1990, and served on the Board of the Institute of Advanced Studies until August 1990.

Dr K.G. Hill visited Dr A.R. Palmer at the MRC Institute for Hearing Research, University of Nottingham, UK in June. From July to October, Dr Hill worked on a collaborative project with Professor C.D. Geisler in the Department of Neurophysiology at the University of Wisconsin, Madison. In October, Dr Hill lectured on auditory perception to third year psychology students at ANU.

MOLECULAR NEUROBIOLOGY GROUP

Dr E.E. Ball completed his term as the Secretary of the Australia New Zealand Society for Cell Biology in February. He organized the neuroscience contribution to the National Summer Science School and served on the organizing committee for the RSBS Open Day. He spent a three month Outside Studies Program in the laboratories of Dr C.S. Goodman (Department of Molecular and Cell Biology, University of California, Berkeley) and Dr M.J. Bastiani (Department of Biology, University of Utah, Salt Lake City).

Dr G.S. Boyan was elected a Fellow of the Royal Entomological Society (FRES) of London. He continues to serve on the Editorial Boards of the Journal of Insect Physiology, and of Life Sciences (Advances).

Dr G.L.G. Miklos gave lectures in the unit Biochemistry CO_2, in the Faculties, ANU, on the Evolution of Information Storage Systems. He was also a PhD Advisor to Ms N. Ozsarac, Biological and Behavioral Sciences, University of New South Wales. He gave a lecture at The Childrens Medical Research Foundation, The Childrens Hospital, Camperdown, Sydney.

VISUAL SCIENCE

Professor Horridge gave seminars in the Physiology Department, Cambridge, at the Indian Academy of Science, Bangalore, at the TATA Institute of Medical Research, Bombay and at the Centre for Ecological Sciences, Indian Academy of Science, Bangalore.

Dr T. Maddess' glaucoma project was chosen as one of the ANU's research programs to be exhibited both at the National Science Centre and Parliament House. Dr Maddess also represented the ANU and ANUTECH with negotiations at WestMed International in Auckland, New Zealand, over funding of further glaucoma research.

Dr I.G. Morgan is a member of the Editorial Board of Neuroscience. He was a member of the Deputy Vice Chancellor's Advisory Group on Large Equipment. He was a consultant Drug Evaluator for the Commonwealth Department of Health. Dr Morgan lectured in the Neuroscience Honours/Diploma course, and was a member of its Management Committee. He also gave a course entitled "Neuroscience: A Biochemical Perspective" to third-year biochemistry students at the ANU. Dr Morgan is coordinator of the proposed Graduate Program in Neuroscience. He gave seminars at the JCSMR, The Department of Biochemistry, The Faculties, and the Faculty of Medicine, University of Newcastle.

Dr D. Osorio attended the European Conference on Visual Perception in Paris and visited the Universities of Cambridge and Manchester in the UK to present talks and papers on arthropod vision.

Dr P.J. Sobey attended the First European Conference on Computer Vision at Antibes and visited computer vision laboratories in Grenoble, France and Genova, Italy. He met representatives of Fujitsu in Japan to discuss joint projects in computer vision and to visit their supercomputer manufacturing facility at Numazu and computer vision projects at their Kawasaki laboratories.

Dr Srinivasan gave a lecture to the Colour Society of Australia, NSW Branch, Sydney, July. He is a member of the IEEE Steering Committee for Biological Cybernetics, USA, for 1990–91.

MOLECULAR AND POPULATION GENETICS GROUP

Dr J.B. Gibson visited laboratories in the UK including the Department of Pure and Applied Biology at Imperial College, London. He also attended a workshop organized by the International Center for Genetic Engineering and Biotechnology in Crete. He gave a research seminar in the Biochemistry Department, The Faculties and continued to serve on the Editorial Board of the Annals of Human Biology (UK).

Dr H. Naora served as Vice-President of The Asian and Pacific Organization for Cell Biology.

Dr D.D. Shaw, member, the Committee on Public Affairs and Continuing Education (COPACE). He is also Chair of Toad Hall and Convener of the Graduate Program in Evolution and Systematics. Dr Shaw acted as RSBS organiser for ANU Open Days.

MOLECULAR AND EVOLUTION SYSTEMATICS GROUP

Mr P. Anderson visited the USA in June. He gave seminars and had discussions at Cornell

University, New York; Du Pont, Wilmington and the University of California, Davis.

Dr A. Gibbs visited laboratories in Thailand, India, USA and UK in July and September. He lectured on viruses and on molecular evolution in undergraduate courses at ANU and Canberra University. He continued to serve on Editorial Boards and panels of the Review of Plant Pathology, Indian Phytopathology and Archives of Virology. He joined the Editorial Advisory Board of the 'Encyclopedia of Virology', and was elected Member of the Executive Committee and Chairman of the Code and Data Subcommittee of the International Committee of Taxonomy of Viruses. He served on panels of the Australian Wheat Research Council, the Australian Research Council and the National Genome Information Committee of DITAC.

Dr M. Skotnicki attended the 4th International Conference on *Arabidopsis* Research, Vienna.

Dr G. Weiller visited the Martinsreid Institute for Protein Sequences (MIPS), Germany and Genbank in Los Alamos, New Mexico and Mountain View, California to discuss novel techniques in sequence database uses and to plan collaborative projects.

PLANT CELL BIOLOGY GROUP

Mr Davis wrote and circulated a newsletter for the Nectar Working Group of the International Commission for Plant-Bee Relationships. He attended the General Assembly of the International Commission for Plant-Bee Relationships, Tilburg, The Netherlands and the conference on Recent Research in Honey Bee Pathology, Ghent, Belgium. He visited the following laboratories: Institüt Bienenkunde, Frankfurt; Institut für Botanik, Darmstadt and Zellenlehre, Heidelberg.

Professor Gunning continued to serve as Deputy Chairman of the Australian Research Council Biological Science Advisory Panels and as a member of the ARC Research Grants Committee. 1990 was his third and final year in the ARC grants system. He was a member of the Australian Academy of Science "Biology for the 1990s" committee and the Academy's selection committee for Endeavour Fellowships. He also assisted with selection processes for the International Science and Technology Advisory Committee of the Department of Industry, Trade and Commerce. As Acting-Director of RSBS, he sat on the Management Committees for the Centre for Molecular Structure and Function and the Centre for Visual Sciences. He also became Chairman of the ANU Electron Microscope Unit Management Committee. He continued to serve as Editor of Protoplasma and a member of the Editorial Board of the Journal of Cell Science and joined the Editorial Panel of Planta. He gave a research seminar in the Department of Biological Science, Newcastle University and visited the School of Botany, Melbourne University to assist in establishing an image-processing facility. He gave invited lectures at an international workshop on Plant Developmental Biology in Berkeley, California, and at a conference in Macquarie University.

Dr L.C. Fowke gave a presentation at the Australian Society for Plant Physiology Meeting in Sydney and seminars at the University of Newcastle and at RSBS.

Dr J. Gorst gave a series of lectures in the Botany BO2 unit in the Faculty of Science, ANU and to two courses on Techniques in Plant Tissue Culture at the ACT Institute of TAFE (Weston campus). She gave a seminar at the Jodrell Laboratory, Royal Botanic Gardens, Kew; a seminar in the Department of Plant Sciences, University of Tasmania; an invited lecture in the Faculty of Horticulture, University of Western Sydney and contributed to the Electron Microscopy II course at the ACT Institute of TAFE (Bruce Campus). She was also a contributor to Biology: The Common Threads, a high school text published by the Australian Academy of Science.

Dr A.R. Hardham was a member of the Barley Research Council Review Committee and the University Electron Microscope Unit Management Committee. Dr Hardham coordinated RSBS involvement in the ANU National Science Summer School. Dr Hardham and J. Dearnaley ran a 2 day laboratory and tutorial course in plant cell biology for a class of third year students from the School of Biological Sciences, University of Sydney. Dr A.R. Hardham presented seminars at the Max Planck-Institute for Plant Breeding at Kövln, FRG; the Max Planck-Institute for Cell Biology, Ladenburg, FRG; the University of Konstanz, FRG; the Electron Microscopy Centre, University of WA; the School of Botany, University of Melbourne and at the CSIRO Division of Plant Industry. She also gave talks on the dieback fungus *Phytophthora cinnamomi* at the Canberra branch of the Society for Growing Australian Plants and at the Western Australian branch of the Australian Society of Plant Pathologists in Perth.

Mr G. Hyde gave a research seminar at the University of Massachusetts, Amherst.

Drs P.C.L. John, R.E. Williamson, G.O. Wasteneys and M.C. Webb and J. Elliott contributed lectures and practical demonstrations in the Botany Department third year unit in Plant Cell Biology.

Dr J. Plazinski gave research seminars at the 2nd International Azolla Research Workshop, Fujian Academy of Science, Fuzhou, PRC, in June and attended the Australasian Gene Mapping Workshop, Macquarie University, Sydney.

Dr G. Wasteneys gave research seminars at the University of California at Berkeley and at Davis, the University of Minnesota at St Paul and the University of Massachusetts at Amherst. He also visited laboratories at the University of Colorado at Boulder in June/July. He also taught a course on techniques in plant biology and contributed to the electron microscopy course at the Bruce TAFE college.

Ms M. Webb gave research seminars in the Department of Environmental Biology, University of Siena, Siena, Italy, and in the Department of Cytology and Morphology, Agricultural University, Wageningen, The Netherlands.

Dr R.E. Williamson continued to serve on the editorial board of Cell Biology International Reports and completed his term on the editorial board of European Journal of Cell Biology.

PLANT MICROBE INTERACTION GROUP

Mr T. Arioli, Ms W. Lewis-Henderson, Drs J. Gray, J. Weinman, M. Djordjevic and Professor B. Rolfe attended the 5th International Symposium on the Molecular Genetics of Plant-Microbe Interactions, Interlaken, Switzerland in September. Dr M. Djordjevic visited Leiden University, Leiden, Holland to discuss future collaborations and then visited the Max-Planck Institute für Molecular Genetik, Berlin and discussed research results with Drs G. Felix, M. Vazuez and L. Segovia. Dr J. Weinman held discussions with collaborators from Leiden University. Mr J. Gray visited Professor A. Pühler at the University of Bielefeld, Professor K. Hahlbrock at the Max-Planck Institute in Kövln, Professor J. Déinarié and Dr N. Grimsley at the INRA laboratories in Toulouse and Professor J. Tempé and Dr A. Kotoujanski in Paris and Professors P. Albersheim and A. Darvill at the University of Georgia, where he presented seminars and discussed research results.

Dr H. Chen attended the 8th International congress on Nitrogen Fixation at Knoxville, Tennessee, USA in May and also attended the Australian Acid Soil Research Workshop at Coonawarra, SA.

Dr M. Djordjevic co-ordinated glasshouse space allocation in RSBS from January to March. He also gave an invited talk at JCSMR in October and at CSIRO Division of Plant Industry. He spent five months at Macquarie University in the Research School of Chemistry in the laboratory of Associate Professor J. Redmond isolating bioactive molecules from *Rhizobium leguminosarum* biovar *trifolii* strain ANU843 and supervising a PhD student.

Following her year as president of the Council of the Australian Postgraduate Association in 1989, Ms K. Le Strange completed her responsibilities on the Review of Australian Graduate Studies and Higher Degrees and an NBEET grant project, 'Postgraduate Coursework Database' as signatory and member of the Steering Committee. Ms Le Strange also finished 2 years as postgraduate representative on the Board of the Institute of Advanced Studies and presented a seminar in the ANU's Research School of Biological Sciences series "Development, Change and Upheaval in Higher Education 1987–1990" on Postgraduate Input to Policy Determination.

Ms W. Lewis-Henderson was chosen as the winner in the Rural Development Section of the Channel Ten Young Achiever Awards, NSW. She was also awarded a Queen Elizabeth II Silver Jubilee Trust for Young Australians Grant.

Professor B. Rolfe variously visited, engaged in consultations and presented seminars at: the Botany Department, UCLA, Los Angeles, USA; the Department of Microbiology, University of Washington, Seattle, USA and the University of Tennessee at Knoxville, USA where he chaired the 8th International Congress on Nitrogen Fixation. Later in the year, he visited the Botany Department, University of Nottingham, UK. Professor Rolfe chaired the 5th International Symposium on the Molecular Genetics of Plant-Microbe Interactions, Interlaken, Switzerland, and visited the Institute Pasteur, Paris, France. He is a consultant to the USA Environmental Protection Agency, Washington in the context of release of micro-organisms into the environment. He serves on the International Boards and Review Panels for the International Congress on Nitrogen Fixation, and the International Symposium on the Molecular Genetics of Plant-Microbe Interactions.

Locally, Professor Rolfe is a member of a Workshop on the Future of Science and the Direction of Australian Society, he made a Submission to both Senators and Members of the Australian House of Representatives; he also helped to promote a selection of the work of the Australian National University at an Exhibition, "Commitment to Discovery" presented to the public, media representatives and Members of Parliament. Following a submission, he appeared before the Australian House of Representatives Standing Committee on Industry, Science and Technology in the context of an "Inquiry into Genetically Modified Organisms". Within the Australian National University, he prepared a position paper on the Staff Performance Evaluation and Development Program, and represented the Institute of Advanced Studies on a Working Party which developed a Report on Performance Appraisal and Development. As a member of BIAS, he was appointed as the Representative of the Institute of Advanced Studies on the Liaison Committee responsive to a Committee appointed by the Vice-Chancellor to review the Central Administration of the University. He lectured on "Plant-microbe Interactions" and on "What is the possible future for Australia in the 21st Century?" to undergraduate students in the ANU and gave television presentations for the "Quantum" Science Series (ABC TV), "Beyond 2000" and "Australia 2020" (Channel 7) and interviews for ABC and commercial radio that focussed on Australia's Commitment to Science.

PLANT ENVIRONMENTAL BIOLOGY GROUP

Dr M.R. Badger attended the 1990 Annual meeting of the Australian Society of Plant Physiologists, University of NSW.

Drs S. von Caemmerer and J.R. Evans gave a two-day course on gas exchange techniques to Plant Physiology students from the University of Sydney.

Professor G.D. Farquhar was appointed Chairman of the Advisory Committee for the Australian Journal of Plant Physiology and continued as a member of the Editorial Boards of Planta and Functional Ecology (British Ecological Society), and of the Review Board of Plant, Cell and Environment. He was a member of the Australian Committee for International Geosphere-Biosphere Programme, of the International Coordinating Panel on Biospheric Aspects of the Hydrological Cycle (IGBP) and of the International Photosynthesis Committee.

Dr M.K. Morell presented a course of three lectures on plant molecular biology at the Department of Agricultural Chemistry, University of Sydney.

Dr G.D. Price gave research seminars on "The role of carboxysomes in the cyanobacterial CO_2 concentrating mechanism" at the Riken Institute of Physical and Chemical Research, Tokyo, Japan and at CSIRO Plant Industry, Canberra. He attended the Gordon Research Conference on CO_2 fixation in green plants, New London, New Hampshire, USA.

Dr J.W. Yu attended the Second International Symposium on Inorganic Carbon Utilization by Aquatic Photosynthetic Organisms, Kingston, Canada.

ECOSYSTEM DYNAMICS GROUP

Dr M.C. Ball served as a judge in the Biology Division of the BHP National School Science Awards.

Dr P.L. Chesson served as an editor of *Theoretical Population Biology* and as an associate editor of *The American Naturalist*. He was also a member of the Advisory Panel on Population Biology and Physiological Ecology for the National Science Foundation (USA).

Mr M.E. Hodda assisted in teaching first year Botany and Zoology units in the Faculty of Science.

Dr A.P.N. House spent 6 months at CSIRO Division of Forestry and Forest Products, Canberra, co-editing a book on essential oils of *Eucalyptus*.

Dr S.M. House gave a seminar on density dependent breeding success of forest trees in the Ecosystem Management Department, University of New England in October. Dr House is the ACT coordinator for TROPINET, the international newsletter of the Organization for Tropical Studies.

Dr J. Landsberg spent three months in the USA, from March to June. During this time she gave seminars at Arizona State University, University of Northern Arizona and the Mountain Research Station of the University of Colorado, and held informal meetings with researchers from the University of Hawaii, the University of Arizona and the University of Illinois; she also conducted a joint field project in northern Arizona with Dr D.S. Gillieson (Australian Defence Force Academy) and Dr S. Faeth (Arizona State University). She has several times been consulted by Greening Australia and the Bureau of Rural Resources about the potential impacts of insects on plantings of farm trees and in October she gave an invited talk on this topic to a workshop organized by Greening Australia. She also contributed a 15 page chapter on Ecosystems for an Australian undergraduate textbook on biology.

Mr. D. Moore gave seminars at the University of New England and the University of Tasmania.

Dr I.R. Noble was appointed to the International Geosphere Biosphere Programme Scientific Steering Committee for the "Global Change and Terrestrial Ecosystems" Core Project. This is a panel of c. 12 scientists set up to plan a scientific program to predict the impacts of global change on terrestrial ecosystems. Dr Noble took part in a meeting of the panel in Boston and in two National IGBP Workshops on Past Climates and on Hydrology. He visited China for two weeks as a reviewer of the UNESCO Cooperatiive Ecological Research Programme between the Chinese Academy of Science and the West German Government. He is a member of Australian National Committee for Man and the Biosphere (MAB) and a member of the SCOPE Scientific Advisory Committee for "Application of Information Technology to Sustainable Development". He was invited to take part in the SCOPE Executive Meeting in Santiago, Chile, in July. He continued to serve on the Editorial Boards of Ecological Modelling and the UNESCO/MAB Book Series. Dr Noble was appointed to the Federal Government's Sustainable Development Working Group on Forestry to help formulate development strategies to integrate environmental considerations into government decision making. Dr Noble was a consultant with Kestel Research to advise on modelling and expert systems requirements for the DASETT Environmental Resource Information Network (ERIN). He was elected as President of the Ecological Society of Australia for a term starting January 1991.

Dr H.P. Possingham gave six lectures in the third year course, Advanced Ecology in the Zoology Department, ANU, and two lectures on Biomathematics in the Mathematics Department, ANU. He contributed a 15 page chapter on Population Ecology for an Australian undergraduate textbook on biology. He spoke on "Earthworm" (ABC Radio) on three occasions regarding forest conservation and biodiversity. He made a presentation on National Estate Forests and Reserves in the South-East of NSW and East Gippsland at a Parliamentary Library Seminar. He presented a seminar at the University of Adelaide and gave talks to a variety of community groups about birds, conservation and theoretical ecology.

Dr S. Wilson spent two weeks at Cedar Creek Natural History Area of the University of Minnesota, USA, in April.

Dr C.A. Zammit participated in an IGBP Workshop on the Utilization of Renewable Biological Resources organized by Dr R. Gifford, CSIRO Division of Plant Industry from 3rd to 5th October. Proceedings are to be published by DPIE.

PUBLICATIONS

SYMBOLS

In this section symbols are used to indicate affiliations of authors of publications. The Symbols are:

Visiting research worker
§ Former visiting research worker
+ Not a member of the University
• Former member of the University
† Member of another part of the University

DEVELOPMENTAL NEUROBIOLOGY GROUP

Published

Blest, A.D. and O'Carroll, D. The evolution of the tiered principal retinae of jumping spiders (Araneae, Salticidae). In: *Neurobiology of Sensory Systems*, pp.155–170. (eds. N. Singh and N.J. Strausfeld). Plenum, New York.

Blest, A.D. and Stowe, S.# Dynamic microvillar cytoskeletons in arthropod and squid photoreceptors. Cell. Motil. Cytoskel. 17, 1–5.

Blest, A.D., O'Carroll, D.C. and Carter, M. Comparative ultrastructure of Layer-I receptor mosaics in principal eyes of jumping spiders: the evolution of regular arrays of light guides. Cell Tissue Res. 262, 445–460.

Chung, S.H., Moore, J.B.†, Xia, L.†, Premkumar, L.S.† and Gage, P.W.† Characterization of single channel currents using digital signal processing techniques based on Hidden Markov Models. Phil. Trans. R. Soc. Lond. B. 329, 265–285.

Cole, K.S.# and Gummer, A.W. A double-label study of efferent projections to the cochlea of the chicken *Gallus domesticus*. Exp. Brain Research 82, 585–588.

Gage, P.W.†, Chung, S.H., Moore, J.B.† and Premkumar, L.S.† Detection and interpretation of multiple conductance levels in ion channels in membranes. In: *Exocrine Secretion II*. pp. 53–56 (eds. P.Y.D. Wong and J.A. Young). ISES.

Gummer, A.W. Spontaneous activity of auditory afferent neurons in the spiral ganglion of the pigeon. In: *Mechanics and Biophysics of Hearing*. pp. 103–110 (eds. P. Dallos, C.D. Geisler, J.W. Mathews, M. Ruggero and C.R. Steele). Springer-Verlag, Heidelberg.

Harrison, P.H.# Effects of an ectopic hindlimb on the brachial motoneurons in *Xenopus*. Dev. Brain Res. 39, 134–139.

Harrison, P.H.# Induction of locomotion in spinal tadpoles by excitatory amino acids and their agonists. J. Exp. Zool. 254, 13–17.

Hill, K.G. and A.R. Palmer+ Two-tone rate suppression in auditory nerve fibres: time course of suppression and excitation in peri-stimulus time histograms. In: *Mechanics and Biophysics of Hearing*. pp. 111–117 (eds. P. Dallos, C.D. Geisler, J.W. Mathews, M. Ruggero and C.R. Steele). Springer-Verlag, Heidelberg.

Hill, K.G. Comparative aspects of cochlear function: avian mechanisms. In: *Information Processing in Mammalian Auditory and Tactile Systems*. pp. 73–79. (eds. M. Rowe and L. Aitkin) Alan R. Liss, Inc.

Marotte, L.R. Development of retinotopy in projections from the eye to the dorsal lateral geniculate nucleus and superior colliculus of the wallaby (*Macropus eugenii*). J. Comp. Neurol. 293, 524–539.

Premkumar, L.S.†, Chung, S.H. and Gage, P.W.† GABA-induced potassisum channels in cultured neurons. Proc. R. Soc. Lond. B 241, 153–158.

Premkumar, L.S.†, Gage, P.W.† and Chung, S.H. Coupled potassium channels induced by arachidonic acid in cultured neurons. Proc. R. Soc. Lond. B. 242, 17–22.

Stowe, S.# and Davis, D. Anti-actin immunoreactivity is retained in rhabdoms of *Drosophila ninaC* photoreceptors, Cell Tiss. Res. 260, 431–434.

Stowe, S.#, de Couet•, H.G. and Davis, D.T.• Turnover of photoreceptor membrane in the crayfish *Cherax* studied by anti-rhodopsin immunocytochemistry. Cell Tiss. Res. 262, 483–499.

In Press

Blest, A.D., Stowe, S.#, Clausen, J.A. and Carter, M.• The distribution of actin immunoreactivity in rhabdomeres of tipulid flies in relation to extracellular membrane shedding. Cell Tiss. Res.

Blest, A.D., Carter, M.,• Clausen, J.A., Stowe, S.,# Trowell, S.C.# and Tsukitani, Y.+ Induction of retinal degeneration in a crab by light and okadaic acid *in vitro*: comparison with the *Drosophila* light-dependent retinal degeneration mutant $rdgB^{KS222}$. Vis. Neurosci.

Harrison, P.H. Development of behaviour in the hindlimb of the frog *Crinia signifera*. Developmental Psychobiology.

Krishnamurthy, V.†, Moore, J.B.† and Chung, S.H. On hidden fractal model signal processing. Signal Proc.

Sheng, X.-M., Marotte, L.R. and Mark, R.F. Development of connections to and from the visual cortex in the wallaby (*Macropus eugenii*). J. Comp. Neurol.

Sheng, X.-M., Marotte, L.R. and Mark, R.F. Development of the laminar distribution of thalamocortical axons and corticothalamic cell bodies in the visual cortex of the wallaby. J. Comp. Neurol.

Waite, P.M.E.+, Marotte, L.R. and Mark, R.F. Development of whisker representation in the cortex of the tammar wallaby *Macropus eugenii*.Devel. Brain. Res.

MOLECULAR NEUROBIOLOGY GROUP

Publications:

Ball, E.E., Oldfield, B.P.*, and Rudolph, K.M.+ Auditory organ structure, development and function. In: *Cricket Behavior and Neurobiology*. pp. 391–422. (eds. F. Huber, T.E. Moore and W. Loher). Cornell University Press, Ithaca.

Boyan, G.S. Integration of auditory information for avoidance flight in the grasshopper and noctuid moth. In: *Brain-Perception-Cognition. Proceedings of the 18th Gottingen Neurobiology Conference* . p. 72. (eds. N. Elsner and G. Roth). Georg Thieme, Stuttgart, New York.

Boyan, G.S. and Ball, E.E. Neuronal organization and information processing in the wind-sensitive cercal receptor/giant interneurone system of the locust and other orthopteroid insects. Progress in Neurobiology 35, 217–243.

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Sally Jane Stowe, MSc(Hons) (Auckland), PhD (until March)

Postdoctoral Fellows
Julia Ann Clausen, BA(Hons)(Newcastle), MEngSt and PhD(Queensland) (from January)
Sheng, Xiao-Ming, BSc(Shanghai), PhD (until November)

Visiting Fellows
Mr K.S. Cole, Department of Physiology, University of Western Australia.
Dr P. Harrison, Mitchell College of Advanced Education.
Dr Sally Jane Stowe, ANU Electron Microscope Unit (from March).
Dr Stephen Charles Trowell, Entomology Divison, CSIRO

Research Officers
Lauren Marotte, MSc (Monash), PhD
Gert Stange, Dr rer nat (Göttingen) (jointly with Visual Sciences)

Research Students
John Andrew Bell (Melbourne)
Ian John Faulks (UNSW)
Jianwu Mo, BSc (Beijing)

Head Technical Officer
Margaret Canney (jointly with Molecular Neurobiology and Visual Sciences)

Programmer
Robert Edwards (jointly with Visual Sciences)

Technical Officer
Margrit Carter, BSc(Hons) (Adel)(until July)
Emer O'Gara, BA,GradDipApplSc (from July)
Margaret Porter, BSc

Laboratory Technician
Amanda Devlin

Group Secretary
Margaret Donohue

MOLECULAR NEUROBIOLOGY GROUP

Senior Fellow and Group Leader
George Leslie Gabor Miklos, BSc, PhD (Syd)

Fellow
Eldon Edward Ball, AB (Stan), PhD (Calif)

Research Fellow
George Stephen Boyan, BSc (LaTrobe), PhD (Until April)

Postdoctoral Fellows
Stephen John Delaney, BSc (Leeds), PhD (London)
David Charles Hayward, BSc, PhD (London)

Visiting Fellows
Dr Heinz Gert de Couet, Dip. Biol, Dr rer nat (TH Darmstadt)
Dr Nipam H. Patel, BA (Princeton), PhD (Stanford)
Dr Paul Whitington, BSc (Flinders), PhD

Research Students
Matthias Hennig, Dip. Biol (Erlangen-Nurnberg), (until April)
Ute Schuppler, Dip. Biol (Karlsruhe)

Technical Staff
James Cotsell, BSc
Fiona Hall, Dip. App. Sci. (Canberra), (until April)
Martin Jones, BSc (Adel), (from October)
Jane Olsen, BSc

Group Secretary
Elaine Marion Napper (part-time) (jointly with Ecosystem Dynamics)

VISUAL SCIENCES GROUP

Professor and Group Leader
George Adrian Horridge, MA, PhD, ScD (Camb), FAA, FRS

Fellows
Ian George Morgan, BSc (Melb), PhD (Monash)
Mandyam Veerambudi Srinivasan, BE (Bangalore), PhD (Yale)

Research Fellow
Werner Backhaus, PhD (Berlin), Ing.(grad) (Dieburg) (until September)
Daniel Osorio, MA (Camb), PhD (funded by Centre for Information Science Research, from October)

Postdoctoral Fellows
Michael Robert Ibbotson, BSc, PhD (Lond)
Andrew James, BSc (Adel), PhD (ANU)
Zhi-Kun Li, MD (Zhangchan Medical University, PRC)
Ted Maddess, BSc (UBD), PhD
David Charles O'Carroll, BSc, PhD (Flinders)
Daniel Osorio (until October)
Peter Sobey, BEng, PhD (Adel)

Visiting Fellows
Dr Les Philip Davies, Dept of Community Services & Health, ACT
Dr Miriam Lehrer, Zoologisches Institut, Zurich (from November)
Dr Pedro-Clemente Marijuan, DPTO Genetica Molecular CSIC, Barcelona (until September)
Dr Peter McIntyre, Australian Defence Force Academy, ACT
Dr Sulochana D. Moro, NZ (from October)
Prof. Cecil Thomas Case, Western Reserve University, Cleveland, Ohio (until July)

Research Students
Zoran Aleksic, MSc (Belgrade)
Jan Dalczynski, MSc (Tech Univ Warsaw)
Roger Dubois, BSc (Adel)
Yang En-Cheng, BSc National Chung Hsing Uni. Taiwan
Marc Golcich, BSc (Adel), Grad. Dip. Sci.
Mats Holmqvist, BSc University of Lund, Sweden
Andrew Charles James, BSc (Adel)
Zhe Fei Jin, BSc (Univ Sci & Tech, Heifei, PRC)
Roman Poznanski, BAppSc (RMIT), MSc (Monash)

Jian Shi, BSc (Univ Sci & Tech, PRC)
Qi Jian Sun, BSc (Inst Biophysics, Beijing, PRC)
Eric James Warrant, BSc (NSW)
Guang Yang, BSc (Univ Sci & Tech, Hefei, PRC)

American Rotary Association Student
Lawrence Severt, BA (Princeton University, NJ)

Research Officer
Gert Stange, PhD (Gott), Grad. Dipl. (CCAE) (jointly with Developmental Neurobiology)

Research Assistant
Ljerka Marčelja, BSc (Zagreb)
Jenny Vaughan, Assoc. Dip. Graphic Design, ACT (from April)
Kim Witney, BSc (ANU) (until May)

Head Technical Officer
Margaret Canney (jointly with Developmental Neurobiology and Molecular Neurobiology)

Senior Technical Officers
Patricia Miethke, BSc (Adel)
Martin Nagle, BSc (UCD), Grad. Dip. Elec. (NIHE)
Mark Snowball, E & C

Technical Officer
Geno Ewyk

Laboratory Technician
Philip Drury

Group Secretary
Elizabeth Watson

MOLECULAR AND POPULATION GENETICS GROUP

Professorial Fellow and Group Leader
John Bryan Gibson, BSc, PhD (Sheff), MA (Camb)

Professorial Fellow
Hiroto Naora, BSc (Tokyo Univ. of Literature and Science), DSc (Tokyo)

Senior Fellow
George Desmond Clark-Walker, MSc (WAust), DPhil (Oxon)

Fellow
David Dobson Shaw, BSc (Durh), MSc (Birm), PhD (S'ton), M.I.Biol

Research Fellow
Ryszard Maleszka, MSc, PhD (Warsaw)

Postdoctoral Fellows
Francis Richard Groeters, BA (Williams College), MS (Iowa), PhD (Calif. at Davis)
Adam Douglas Marchant, BSc, M.I.Biol. PhD (until May)
Anne Mathews, BSc (Agric), MSc (Agric)(Bangalore), PhD (until August)
Patrick Skelly, BSc, MSc (Dublin), PhD (until April)
Lun-Quan Sun, BSc (Anhui Univ.) MSc, PhD (The Fourth Military University, PRC) (until October)
Jing-Jiang Zhou, (Peking University, PRC) PhD (London) (from June)

Visiting Fellows
Dr Arthur Georges, University of Canberra (until June)
Professor P. Hebert, University of Guelph (until March)
Dr Patrick Skelly, Dublin (from April to October)
Dr Scott Fraser, Imperial College, London, UK (November to December)

Research Students
Bryan Clarke, BSc (part time with CSIRO) (until June)
Felice Driver, BSc
Jennifer Fisk, BSc (part time with CSIRO)
Min-Xin Guan, BSc (Hangzhou University, PRC)
Chris Hardy, BSc (until January)
Kyoko Koishi, BPharmSc, MPharmSc (Karnazawa)
Chengshan Jiang, MSc (Fudan) (until January)
Jennifer Ninham, BSc (from February)
Julia Playford, BSc (UWA)
Darryl Reed, BSc (from February)
Stephen Sarre, BAppSc (CCAE) MAppSc (CCAE) (from February)
Jane Elizabeth Symonds, BSc (Newcastle, UK)
Zheng-Zhou Xu, MMSc (Fourth Medical Military University, PRC)
Duan Yu, BAgric (NE For.Instit., PRC), Grad. Dip. Sci.

Research Assistants
David Willoughby Buckle, BSc (Melb), MSc (Auck)
Susan Maynes, Dip Animal Care (NSWIT)

Senior Technical Officers
Patricia Wilkinson, BAppSc (CCAE) (jointly with Plant Cell Biology)
Ann Verona Wilks, BSc, MSc (Melb)

Technical Officers
Nelida Contreras, BSc (Chile)
Helen Liszczynsky, BSc (Adel)
Alexandra Plazinska, MSc (Cracov) (until July)
Erika Wimmer

Laboratory Technicians
Ahn Thi Huiynh Cao, BLet (Saigon) (until August)

Group Secretaries
Catherine Condon (until February)
Catherine Stewart-Moore (from March)

Office Assistant
Vivienne Potter (until August)

MOLECULAR AND EVOLUTION SYSTEMATICS GROUP

Senior Fellow and Group Leader
Adrian John Gibbs, ARCS, PhD (Lond)

Senior Fellow
Leslie Watson, MSc (Manch), DSc

Research Fellows
Paul Hattersley, BSc (Lond), MSc(Liv), PhD (until March)
Mary Louise Skotnicki, BSc (Reading), PhD (National Research Fellow)
Georg Weiller, BSc, PhD (Munich) (from September)

Postdoctoral Fellows
Shou-wei Ding, BSc, MSc (PRC), PhD (until October)
Sue Faragher, BSc, PhD (until March)
Murray Henwood, BSc (Vic. Uni. Wellington), PhD (until July)
Carolyn Mihaich, BSc, PhD (Tasmania) (from September)

Visiting Fellows
Dr Denis Anderson, BSc (Hons), PhD
Dr Nancy Dengler, BA (Santa B), PhD (UCA) (until August)
Dr Ronald Dengler, BA (Davis), PhD (UCA) (until August)
Dr Wayne Gerlach, BSc (Hons), PhD (Adel)
Dr Paul Hattersly, BSc (Lond), MSc(Liv), PhD (from November)
Dr Paul Konrad Keese, PhD (Adel)
Dr Gabrielle Persley, PhD (Qld)
Dr Peter Smith, BAgrSc, MAgrSc, PhD (Melb) (from April)

Computer Programmers
John Armstrong BSc,(Manchester) MSc (from November)
Jack Palmer BSc (Hons) (Scotland)

Research Students
Peter Anderson, BSc
Areelak Kashemsanta, BSc, MSc (Mahidol)

Yuguang Shi, BSc (PRC) MSc (UNE)
Pattana Srifah, BSc (Kasetsert), MS (Thai)

Research Assistants
Karen Jane Crabtree, BSc (Loughborough) (until June)
Janette Rosemarie Lenz, BA

Head Technical Officer
Neal Gowen, (BRTC) (jointly with Plant Microbe Interaction Group)

Senior Technical Officer
Anne Maree Mackenzie, BSc (Melbourne)

Technical Officer
Marjolein Torronen (BRTC)

Laboratory Technician
Julie Glover

Group Secretaries
Louise Booth (Jointly with Plant Microbe Interaction Group)
Valerie Rawlings (Jointly with Plant Microbe Interaction Group)

PLANT CELL BIOLOGY GROUP

Professorial Fellow and Group Leader
David Stuart Letham, MSc (NZ), PhD (Birm), FAA

Professor
Brian Edgar Scourse Gunning, MSc, PhD (Belf), DSc, FAA, FRS

Senior Fellows
Peter Crook Lloyd John, BSc, PhD (Lond)
Richard Edward Williamson, MA, PhD (Camb)

Fellow
Adrienne Ruth Hardham, BSc (Monash) PhD

Research Fellows
Tobias Baskin, BSc (Yale), PhD (Stanford) (from April)
Peter Paul Jablonsky, BSc, PhD (La Trobe) (until September)
Jacek Plazinski, MSc, PHD (Krakow)

Queen Elizabeth II Fellows
Frank Gubler, BSc, PhD (NSW) (until May)
David McCurdy, BSc, PhD (La Trobe)

Postdoctoral Fellows
Swati Baindur, BSc, PhD (Essex) (National Research Fellow)
Janet Gorst, BScAg, MSc (NE), PhD (National Research Fellow)
Charles Hocart, MSc (WA) PhD, MRACI (National Research Fellow)
Larry Lehnen, BS, MS (Eastern Illinois), PhD (Miami Univ) (National Research Fellow)
Geoffrey Wasteneys, BSc (Car) PhD, (National Research Fellow)

Visiting Fellows
Dr Barbara Jane Badenoch-Jones, BRurSc (NE) PhD (Nott)
Dr Andreas Betzner, Max-Planck Institute für Entwicklungsbiologie, Tubingen, FGR
Dr Larry Fowke, Department of Biology, University of Saskatchewan, Saskatoon, Canada (from August)
Dr Peter Paul Jablonsky (from September)
Professor Larry Noodén, Biology Department, University of Michigan (from May)
Professor Wendy Silk, Department of Land, Air and Water Resources, University of California, USA
Mr Tao Guo-qing, Institute of Botany, Academia Sinica, PRC (from September)
Professor F. Wightman, Biology Department, Carleton University, Ottawa, Canada (until February)
Dr Pamela Warren Wilson
Kerong Zhang, Department of Biochemistry, Fudan University, Shanghai, PRC (until May).

Research Students
Jeremy Carmichael, BSc (Belfast) (until February)
Mark Clements, BSc, MSc
David Collings, BSc (Sydney)
Arthur Davis, BSc, MSc (Guelph)
John Dearnaley, BSc (Monash)
Geoffrey Hyde, BSc (Sydney)
Qiao Lin, BSc (Schichuan)
Suchirat Sakuranrungsirikul, BSc (Bangkok)
Jian Wang, BS (Hebvei)
Mary Webb, BSc (Melb)
Liping Wu, BSc (Hunan), MSc (Wuhan)
Kerong Zhang, BSc (Shanghai), MSc (Shanghai) (from May)
Xue-Dong Zhang, BSc (Nankai)

Research Assistants
Janet Elliott, BAppSc (QIT)
Elizabeth Taverner, MAgrSc (Melb), DipEd (NE)

Senior Technical Officers
Patricia Wilkinson, BAppSc (CCAE) (jointly with Molecular and Population Genetics)
Charles W. Parker, MSc, MRACI (until April)
Frank Sek, BAppSc (CCAE)

Technical Officers
Cathy Busby, BSc (Monash), MSc
Jadwiga Duniec, MSc (Warsaw)
Ursula Hurley, BSc (Natal)
David Willcocks, DipAppSci (Biol) (CCAE)

Laboratory Technicians
Ann Docherty
Susan McKinney, Assoc Dip Tech Path (Bruce TAFE)
Margaret Sammut

Group Secretary
Margaret Wigney

PLANT MICROBE INTERACTION GROUP

Professor and Group Leader
Barry G. Rolfe, BAgrSc, PhD (Melb)

Senior Fellow
Ernest H. Creaser MA, PhD (Camb)

Research Fellow
Michael Anthony Djordjevic BSc (Qld), PhD

Postdoctoral Fellows
Hancai Chen, BSc, PhD
David Loschke, BA, PhD (WSU)
Jeremy John Weinman, BSc, PhD a (National Research Fellow)

Visiting Fellows
Dr John Ferguson, BSc, PhD, DSc (Sth Africa) (DYLWAY Ltd.)

Research Students
Tony Arioli, BSc
Tracey Cross, BSc (Hons) (Melb)
James Gray, BSc (Syd)
Paul Howles, BSc (Adel)
Kate Le Strange, BSc (NSW)
Wendy Lewis-Henderson, BSc

Head Technical Officer
Neal Gowen, BRTC (jointly with Molecular Evolution and Systematics)

Technical Officers
Kathleen Britt, BSc, AAIMLT (Melb)
Elena Gartner, BA
Jan McIver, BSc (Melb)
Marie Oakes, BSc
Lynette Preston, BSc (until October)

Laboratory Technicians
Dominique Barnard, BA (Syd)
Kate Clark, BSc (until June)
Jane Lewis-Male, BSc (until March)
Anne Moten, BSc (Adel), BA

Group Secretaries
Val Rawlings (jointly with Molecular Evolution and Systematics Group)
Louise Booth (Jointly with Molecular Evolution and Systematics Group)

PLANT ENVIRONMENTAL BIOLOGY GROUP

Senior Fellow and Group Leader
Murray Ronald Badger, BScAgr (Syd), PhD

Professors
Ian Roy Cowan, MSc (Lond), PhD (Nott), FAA
Graham Douglas Farquhar, BSc (Qld), BSc, PhD, FAA

Senior Fellow
Thomas John Andrews, BSc, PhD (Qld)

Research Fellows
Susanne von Caemmerer, BA, PhD
John Richard Evans, BSc, PhD (QEII Fellow)
Kerry Trent Hubick, BSc, PhD (Calgary) (until August)
Graham Stanley Hudson, BSc, PhD (Melb) (National Research Fellow)
Josette Masle, DrIng (INA Paris)
Matthew Kennedy Morell, BAgrSc, PhD (Syd) (National Research Fellow until May—RF from May)
Graeme Dean Price, MSc, PhD
Suan Chin Wong, MSc (Nanyang), PhD

Postdoctoral Fellows
Jeong Sheop Shin, MS (Korea), PhD (Mont. St.) (National Research Fellow) (until January)
Jian Wei Yu, PhD (from May)

Visiting Fellows
Dr Stuart Boag (January to December)
Emeritus Professor Denis J. Carr, BSc, PhD (Manc), MSc (Melb)
Dr John Coleman, University of Toronto, Canada (from December)
Dr Barrie Entsch, University of Michigan (September to December)
Dr Kerry Hubick Department of Industry, Technology and Commerce (August to December)
Dr Paul Kriedemann, CSIRO Forestry & Forest Products (August to December)
Dr Manfred Küppers, Institut für Botanik, Darmstadt, FRG (September to October)
Ms Barbara Küppers, Institut für Botanik, Darmstadt, FRG (September to October)
Dr Richard Leegood, University of Sheffield, UK (September)
Dr Jon Lloyd, NSW Department of Agriculture, Alstonville (April to June)
Dr Erling Ögren, University of Umeå, Sweden (September to December)
Ms Kristin Palmqvist, University of Umeå, Sweden (September to December)
Dr Catherine Potvin, McGill University, Montreal, Canada (November to December)
Dr James Syvertsen, University of Florida, USA (May to June)
Dr Juta Viil, Institute of Experimental Biology, Estonia, USSR (June to September)

Visiting Scholar
Lin-Ke Huang, MSc (until June)

Research Students
David de Pury, BAgrSc(Hons) (Melb)
Helena Asteria Gomez-Macpherson
Sally Henderson, BAgrSc(Hons) (Melb)
M.S. Candido Lopez-Castaneda, BScAgr, MSCAgr (Chapingo)
Kalanethee Paul, MSc (Singapore)
James Virgona, MSc (Macquarie)

Research Assistant
Andy Mower, BSc(Hons) (Adel) (until December 1989)(from July)

Head Technical Officer
Charles William Parker, MSc ARACI (from April)

Senior Technical Officers
Win S. Coupland
Anne Gallagher, BRTC
Heather Jean Kane, BSc PhD
Derek Millar (until August)

Technical Officers
Yvonne Barbro Carina Arvidsson, BSc (Göteborg)
Peter Groeneveld, BSc (For)
Karin Harrison, AssDip ApplSci
Prue Kell, BRTC
Sue K. Wood

Laboratory Technicians
Kate Clark (from July)
Mary Greenaway
Anthony van Herwaarden (from November)
Wesley Keys (until March)
Peter Thygesen, BSc (part-time)

Temporary Assistants
Megan Griffith (from November)
Jian-Wei Yu (January to May)

Group Secretary
Leonie Hoorweg

ECOSYSTEM DYNAMICS GROUP

Senior Fellow and Group Leader
Ian Roy Noble, BSc (Adel), PhD (Adel)

Senior Fellow
Peter Leith Chesson, BSc (Adel), PhD (Adel), (from December)

Fellow
Marilyn Crowl Ball, MSc (Miami), PhD (from July)

Senior Research Fellow
David Geoffrey Green, MSc (Monash), PhD (Dal) (until July)

Research Fellows
Marilyn Crowl Ball, MSc (Miami), PhD (National Research Fellow) (until July)
Jennifer Jill Landsberg, BPharm, DipEd, BSc (Qld), PhD, (until July)
Scott Douglas Wilson, BSc (Trent), PhD (Ottawa) (until August)
Charles Anthony Zammit, BSc (Murd), PhD (Macq) (until July)

Queen Elizabeth II Fellows
Hugh Phillip Possingham BSc (Adel), D.Phil (Oxford)

Postdoctoral Fellows
Habiba Gitay, BSc, PhD (Wales), (from November)
Susan Margaret House, MSc (Lond), PhD
Jann Elizabeth Williams, BSc (Hons) (Melb), PhD, (from November)

Visiting Fellows
Dr Michael Phillip Austin, BSc, PhD (Lond), CSIRO Division of Wildlife and Ecology
Professor Joseph Hurd Connell, BSc (Chicago), MA (Calif), PhD (Glasgow), University of California, Santa Barbara (from September until December)
Dr Alan Pennock Newton House, BSc (S'ton), PhD, Australian Defence Force Academy, Canberra
Professor Ralph Owen Slatyer, AO, DSc (Agric) (WAust), HonDSc (WAust and Duke), FAA, FRS
Dr Alan Bruce Wellington, BSc (Monash), PhD
Dr Yingping Wang, BSc (Central South Forestry Univ), PhD (Edin), CSIRO Division of Atmospheric Research (from February until August)

Research Students
Honours
Don Anthony Driscoll, BSc (Melb) (visiting student from Department of Botany) (from July)

Matthias von Zedlitz (visiting student from University of Bielefeld) (from November until July)

Doctor of Philosophy
Damian Joseph Barrett, BSc (Hons) (Adel) (jointly with Department of Botany, ANU)
Michael Edward Hodda, MSc
Heather Keith, BSc (NSW)
Michael Harvey Kottek, BSc (Melb)
David Russell Bancroft Stockwell, BSc

Head Technical Officers
Peter Michael Cochrane, BSc, MPubPol (until August)
Charles William Parker, MSc, ARACI (jointly with Plant Environmental Biology) (from April)

Technical Officers
Sandra Lee Berry, Assoc. Dip. Lab. Tech. (Darling Downs), BSc(Hons)(Macq)
John James Egerton, BSc(For), BSc

Laboratory Technicians
Michelle Jane Cottam, BSc
Graham Carl Doering
Don Anthony Driscoll, BSc (Melb) (from March until July)
Karl Alfred Grigulis, BSc (from June)
Ian Alan Stirling (until December)
Colin Yates, BSc(Hons) (from November until May)

Programmers
Ian David Davies BA, Grad.Dip.Comp. (U. Canberra) (from May)
Timothy John Montgomery BSc (until February)
David Mitchell Moore BSc (Hons)

Group Secretary
Elaine Marion Napper (part-time) (jointly with Molecular Neurobiology)

CENTRAL SERVICES

SCHOOL SERVICE STAFF

Administration
Business and Technical Manager
Peter Firth

Assistant Business Manager
Alexander McDonald

Assistant to Business Manager (Purchasing)
Carol Barmin

Purchasing Assistants
Carole Jensen
Karen Adernson
Olivia Mitchell

Budget Assistant
Monika Jones

Budget Clerk
Susie Hearder

Administrative Officer
Brit Helgeby

Computer Unit
Programmer
David Sandilands, DA (Muresk), BSc

Assistant Programmer
Barbara Schmeltzer

Laboratory Preparation
Laboratory Attendants
Elizabeth Cipe
Leticia Aaronsen

Gas Chromatograph/Mass Spectrometer
Senior Technical Officer
Charles William Parker, MSc, ARACI

Visual Communication
Technical Officer
Maureen Whittaker

Technical Officer
Garry Stephen Hanson

Laboratory Technician
Jeffrey Wilson

Illustrator
James Whitehead (from August)

Laboratory Technician
James Whitehead (until July)

Plant and Animal Culture
Senior Technical Officer
Paul Thomas Puttifoot

Technical Officers
Peter Hank Fokker
Russell Cameron

Laboratory Technicians
Arthuro Samcam
Chris Boehm

Safety Officer
Robert Jackson

Security and Cleaning
Head Watchman/Janitor
Terence James Durrant

Leading Hand
Alexander King Kyle

Watchmen/Janitors
Stanley Kelly
William Kyle
John Nelson
Robert Payne

Cleaners (part-time)
Cveta Bodrozic
Romone Casio
Alexander Estrellado (from July)
Peter Kent
Edelisa Locus
Louise Mirande
Marica Peric
Maria Santosousso

Store
Senior Store Supervisor
Robin George Mark Hassall

Store Supervisor
Eric Ward (until September)
Ray Thomas (from September)

Clerk
Annemarie Thaller

Senior Storeman
Kevin Scholz (from September)

Tea Assistant
Guisela Queck

Workshop
Head Technical Officer
William Moffat (from September)

Electronics Workshop
Senior Technical Officers
Doug Crawford
Kerry Richens

Technical Officers
Albert Pool (from January)

Laboratory Technicians
Andrew Cooper (from February)
Denis Vukoja
George Parson

Mechanical Workshop
Senior Technical Officer
Paul Larsen

Senior Laboratory Craftsmen
Godfried Aschenberger
Michael Gerstenbuehler
Greg Jackson
Malcolm Andrew Lamond
Alfred Lee
Jan Reyn
Frank Valeri
Edgar Weiss

Apprentice Carpenter
Benjamin Tuohy (apprentice elect)

THE ANU ELECTRON MICROSCOPE UNIT

Facility Coordinator
Margaret Canney (until March)
Sally Stowe, MSc (Hons) (Auck) PhD (from March)

Senior Technical Officers
Roger Heady, BAppSc, Grad. Dip. Elec., Grad. Dip. Res. Man. (CCAE)
David Llewellyn, Dip. Eng. (Bruce TAFE)
David Vowles, Dip. Appl. Phys. (WAIT)

Technical Officers
Jennifer Brown, Ass. Dip. Appl. Sci. (Footscray IT)

Laboratory Technicians
Michael Ciszewski, B. Tech (Brunel)
Alan Lee (BSc (Griffith), Dip. Ed. (Qld) (from April)

The Director of RSBS, together with a Management Committee drawn from the IAS and the Faculties, has overall responsibility for the ANU Electron Microscope Unit. With a staff of seven, the Unit is sited in RSBS and receives much valued help from the School's administrative section, store and workshop.

The EM Unit has had an eventful year. In March, a Coordinator, Dr Sally Stowe, was appointed to head it. In June an extension of RSBS to house it was completed. It included additional microscope rooms and a greatly improved preparation area with two new fume hoods. Of the two scanning electron microscopes formerly housed in the Forestry Department, The Faculties, the older was transferred to the Research School of Earth Sciences to be used as a dedicated instrument for energy-dispersive X-ray analysis, and the newer Cambridge S360 was moved, with only one week down-time, to the facility in RSBS. A new JEOL 6400 scanning electron microscope was also installed mid-year, giving the integrated Unit two scanning and four transmission electron microscopes, with a range of ancillary equipment. Badly needed improvements were made to the ventilation system serving the Unit's photographic darkrooms.

In spite of the disruptions caused by construction and the movement of equipment into the expanded facility, usage increased dramatically during the course of 1990.

STUDENT THESES SUBMITTED AND EXAMINED DURING 1990

MOLECULAR NEUROBIOLOGY GROUP

Doctor of Philosophy

Hennig, R.M.
Thesis: The neuronal organization of stridulation and flight in the cricket.

VISUAL SCIENCES GROUP

Doctor of Philosophy

Aleksic, Z.
Thesis: Applications of nonlinear dynamics to information processing.

James, A.
Thesis: White-noise studies in the fly lamina.

Warrant, E.J.
Thesis: Resolution and sensitivity in the arthropod superposition eye.

Yang, G.
Thesis: Information processing in the inner plexiform layer of the chicken retina.

MOLECULAR AND POPULATION GENETICS GROUP

Doctor of Philosophy

Jiang, Chengshan,
Thesis: A study of genetic variation in natural populations of *Drosophila melanogaster*.

Koishi, K.
Thesis: The rat C-Mos: its expression and structure.

Master of Science

Clarke, B.C.
Thesis: A molecular analysis of the *Nor* locus in *Australopyrum retrofractum*.

Cell Biology Honours

Reed, D.S.
Thesis: Molecular analysis of a low activity of sn-glycerol-3-phosphate dehydrogenase allele in *Drosophila melanogaster*.

MOLECULAR EVOLUTION AND SYSTEMATICS GROUP

Doctor of Philosophy

Bruhl, J.
Thesis: Taxonomic relationships and photosynthetic pathways in Cyperaceae.

Moody, S.
Thesis: Interaction between peanuts and fungi of the *Aspergillus* section *flavi*.

PLANT CELL BIOLOGY GROUP

Doctor of Philosophy

Carmichael, J.
Thesis: Strategies for cloning cell division cycle genes in plants.

PLANT MICROBE INTERACTION GROUP

Doctor of Philosophy

Gray, James
Thesis: Molecular analysis of exopolysaccharide genes of *Rhizobium* sp. strain NGR234.

PLANT ENVIRONMENTAL BIOLOGY GROUP

Master of Science

Huang, Lin-Ke
Thesis: Effects of low temperature on the photosynthesis and productivity of rice plants.

Doctor of Philosophy

Bagnall, David
Thesis: Environmental regulation of processes controlling yield in peanut (*Arachis hypogaea*)

Yu, Jian-Wei
Thesis: Metabolite transport and photorespiratory NH h3 assimilation in plastids of higher plants.